CHINA'S STRATEGIES

TO BECOME AN INNOVATION JUGGERNAUT

China's strategies to become an innovation juggernaut

DROEGE & COMP. SINGAPORE PTE LTD
International Management Consultants

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Zu dieser Studie

Die Volksrepublik China ist dabei, eine neue Wirtschaftspolitik umzusetzen. Statt quantitatives steht nunmehr qualitatives Wachstum im Mittelpunkt des 11. Fünfjahresplans. Die Begrenztheit der Ressourcen, der Schutz der Umwelt und die Bewältigung der sozialen Probleme erfordern nach Aussagen der politisch Verantwortlichen eine neue Innovationsstrategie des Landes.

Der Anteil der Aufwendungen für Forschung und Entwicklung am Bruttoinlandsprodukt soll bis 2020 auf 2,5 Prozent gesteigert werden, was eine Vervierfachung gegenüber 1995 bedeutet. Zugleich verfolgt China das Ziel, die Abhängigkeit von ausländischer Technologie zu verringern. Es sollen unabhängige Innovationskapazitäten aufgebaut und das sogenannte „Nationale Innovationssystem“ gestärkt werden. Dabei profitiert China sehr stark vom Technologietransfer nach China durch die auslandsinvestierten Unternehmen und von aus dem Ausland zurückkehrenden Studierenden.

Wie sieht das innovationsgesteuerte Wachstumsmodell Chinas aus? Welche Strategien wendet die chinesische Regierung an, damit das Wachstum der chinesischen Wirtschaft mehr auf Innovationen basiert? Wie werden diese Strategien umgesetzt? Antworten auf diese Fragen sind von elementarer Bedeutung für die Unternehmen des deutschen Maschinen- und Anlagenbaus. Das innovationsgesteuerte Wachstumsmodell könnte deutsche Ausfuhren nach China und Positionen im internationalen Markt gefährden. Deshalb hat die IMPULS-Stiftung Droege & Comp. Singapore Pte Ltd. beauftragt, das Innovationssystem Chinas und die veränderten Strategien im Bereich Maschinen- und Anlagenbau zu analysieren.

Die Studie untersucht dabei in umfassender Weise die Wissensbasis Chinas einschließlich der F&E-Programme und -Institutionen, des Hochschul- und Bildungssystems, die Innovationsstrategien der Unternehmen und die mögliche weitere Entwicklung der Forschungseinrichtungen. In Interviews mit Vertretern von staatlichen und wissenschaftlichen Einrichtungen sowie von deutschen Tochtergesellschaften in China wurde auch der Frage nachgegangen, wie stark der Einfluss der zentralen Lenkung in China ist und wie ernst er genommen wird.

Mit der vorliegenden Studie wollen wir den Unternehmen des deutschen Maschinen- und Anlagenbaus Hinweise geben, welche Implikationen die neue Wachstumspolitik für das Treffen eigener strategischer Entscheidungen haben kann.

Begleitet wurde die Studie von einem Steering Committee, das Fragen formuliert und die möglichen Konsequenzen des innovationsbasierten chinesischen Wachstumsmodells diskutiert hat. Unser Dank gilt insbesondere den Herren Otto Schafhauser, ZF Friedrichshafen AG, Ralf-Peter Tinkl, Bosch Rexroth AG und Oliver Wack, Außenwirtschaftsabteilung des VDMA, den Vertretern deutscher Unternehmen in China und den Mitarbeitern von Droege & Company.

Frankfurt, im November 2007

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Abbreviations and acronyms

AEP	The Association of Educational Publishers
ASEAN	Association of Southeast Asian Nations
BRIC	Brazil, Russia, India, China
CAD	Computer Aided Design
CAGR	Compound annual growth rate
CAM	Computer Aided Manufacturing
CAS	Chinese Academy of Science
CD-ROM	Compact Disc Read-Only Memory
CEO	Chief Executive Officer
CIMS	Computer Integrated Manufacturing Systems
CIPA	Investment Promotion Agency of Ministry of Commerce
CNC	Computerized Numerical Control
Corp.	Corporation
Dept.	Department
Dr.	Doctor
e.g.	exempli gratia = for example
EPO	European Patent Office
EPO	European Patent Office
ERAWATCH	Joint Research centre in collaboration with CORDIS, (Community Research and Development Information Service of the EU)
etc.	et cetera
EU	European Union
FDI	Foreign Direct Investments
FIE	Foreign Invested Enterprises
GATT	General Agreement on Tariffs and Trade
GDP	Gross Domestic Product
GNP	Gross Net Product
h	Hours [unit]
HR	Human Resources
HS codes	Harmonized Commodity Description and Coding System (HS) of tariff nomenclature, internationally standardised system of names and numbers for classifying traded products (by World Customs Organization).
i.e.	id est = that is
ICT	Information and communication technology
IES	Institute of Education Statistics – US Department of Education
IPR	Intellectual property rights
ISO	International Standardization Organization
JPO	Japanese Patent Office
JV	Joint Venture
Ltd.	Limited
m	Million
M&A	Mergers & Acquisitions
MNC	Multinational company

NA	Not applicable; in interview context often: not answered
NBS	National Bureau of Statistics of China
NBS	National Bureau of Statistics of PR China
NC	Numerically controlled
NESO	Netherlands Education Support Office
No.	Number
OECD	Organisation for Economic Cooperation and Development
OEM	Original Equipment Manufacturer
p.a.	per annum
PhD	Philosophiæ Doctor, Latin term for tertiary education degree "Doctor of Philosophy"
POE	Privately-owned enterprises
PPP	Purchasing Power Parity
PRB	Population Reference Bureau
R&D	Research and development
RMB	Renminbi (Chinese Currency) [unit]
	The currency exchange rate applied in this study is fixed to the average interbank exchange rate of January to June 2007, i.e. US$ 1 equivalent to RMB 7.73, unless indicated otherwise.
SIPO	State Intellectual Property Office, China
SME	Small/medium-size enterprises
SME	Small and medium sized enterprises
SOE	State-owned enterprise
TBP	Technology Balance of Payments
TFP	Total Factor Productivity
TPF	Triadic Patent Families
UK	United Kingdom of Great Britain and Northern Ireland
US	United States of America
USA	United States of America
USD	United States dollar [unit]
USPTO	US Patent Office
VAT	Value added tax
VDMA	Verband Deutscher Maschinen- und Anlagenbau e.V., Frankfurt, Germany
VP	Vice President
WFOE	Wholly foreign-owned enterprise
WIPO	World Intellectual Property Organization
WTO	World Trade Organization
YOY	Year on year

Executive summary

Executive summary (deutsch)

China ist zunehmend in die Weltwirtschaft integriert. Jahrzehnte stabilen Wachstums halfen, das Pro-Kopf Einkommen auf mehr als USD 1.900 (PPP) im Jahr 2006 zu heben, eine spürbare Verbesserung des Lebensstandards.[1] Das im derzeitigen 11. Fünfjahresplan (2006-2010) angestrebte Wachstumsziel der chinesischen Wirtschaft von 7,5% pro Jahr ist nicht minder beeindruckend, allerdings ist es deutlich niedriger als zuvor. Dies ist das Ergebnis einer wichtigen wirtschaftspolitischen Richtungsänderung. Chinas politische Führung ist zur Überzeugung gelangt, dass das derzeitige Wachstumsmodel mit einem exzessiven Ressourcenverbrauch und hohen Investitionsquoten in Industrien mit geringem Wertschöpfungsanteil in China nicht nachhaltig beibehalten werden kann. Der chinesischen Öffentlichkeit wird zunehmend bewusst, dass die Kluft zwischen Arm und Reich tiefer wird, dass ausländische Firmen mittlerweile große Bereiche der chinesischen Industrie dominieren und dass die Umweltschäden dramatischer werden. China möchte auch weiterhin wachsen, aber anders und langsamer – wenn das der Preis dafür ist, ein paar dieser dringlichen Probleme in den Griff zu bekommen.

In seiner Rede vor dem Nationalkongress am 15. Oktober 2007, fasste Präsident Hu Jintao die Richtung für Chinas zukünftiges Wachstum zusammen: „… ein starkes Wirtschaftswachstum bei gleichzeitigem verringerten Ressourcenverbrauch und mehr Anstrengungen im Bereich Umweltschutz“ sowie einer „Reform des Systems der Einkommensverteilung um den Trend wachsender Einkommensunterschiede umzukehren.“[2] Um diese Ziele zu erreichen, muss China eigene, innovative Lösungen entwickeln, da es weltweit keine entsprechenden Vorbilder gibt.

„Eigenständige Innovationen“ zum Erreichen von nachhaltigem, harmonischem Wachstum: Die Regierung hat sich zum Ziel gesetzt, China zu einem innovativen Staat zu machen und insbesondere zu einem, der sich auf die heimische Innovationskraft verlassen kann. „Eigenständige Innovationen“ sollen es chinesischen Unternehmen ermöglichen, ihre Ressourcen besser und effizienter zu nutzen, um sich von der Produktion mit geringer lokaler Wertschöpfung (Billigproduktion) zu lösen. Ein größerer Anteil an einheimischer Innovation – und damit ist normalerweise der technologische und wissenschaftliche Fortschritt gemeint – soll auch das lokale Einkommen stärken, die Abhängigkeit von Technologieimporten mindern und helfen, die vielen Kritiker am chinesischen Rechtsrahmen zum Schutz geistigen Eigentums zum Schweigen zu bringen. Dies, so die Erwartung, würde Chinas Wachstum “harmonischer” gestalten und so die soziale sowie politische Stabilität sichern.

Angesichts Chinas unbedingtem Willen, in punkto Technologie und Innovation zur Weltmacht zu werden, beginnen sich die reicheren Länder des Westens und Ostens zu fragen, ob dies nicht den Kern ihres eigenen

[1] Pro-Kopf Bruttoinlandsprodukt als Näherungswert.

[2] http://english.cpcnews.cn/92243/6283199.html und http://english.cpcnews.cn/92243/6283146.html

Wettbewerbsvorteils berühren wird. Werden wir in naher Zukunft Hochtechnologieprodukte mit dem Label "Invented and Designed in China" statt nur "Made in China" kaufen?

Die vorliegende Studie erkundet Chinas derzeitige und zukünftige Innovationsfähigkeiten, deren beeinflussende Faktoren sowie die Ziele und Strategien der chinesischen Regierung, um die Wertschöpfung der heimischen Wirtschaft zu erhöhen. Diese Studie basiert vor allem auf den Einsichten aus ca. 200 Expertengesprächen, u. a. mit chinesischen Politikern, mit Vertretern von Behörden, Hochschulen, *Think Tanks* und Niederlassungen deutscher Maschinenbauunternehmen in China.

Der Status Quo: Beitrag von Technologie und Innovation zu Wachstum steigend, allerdings ausgehend von niedrigem Niveau

Chinas nationale Forschungs- und Entwicklungsausgaben wachsen rasant: Mit USD 136 Milliarden, gerechnet in lokaler Kaufkraftparität, hat China im vergangenen Jahr Japan in der Rangliste der größten F&E Investoren überholt, und rangiert nun auf Platz zwei nach den USA in punkto Forschungsausgaben.[3]

F&E Intensität steigend, aber noch unter dem Niveau entwickelter Volkswirtschaften: Chinas Forschungsausgaben relativ zur Gesamtwirtschaft (Bruttoinlandsprodukt, BIP) haben sich seit 1995 mehr als verdoppelt auf 1,4% (2006). Nichtsdestotrotz ist dieser Anteil in entwickelten Ländern höher: In Deutschland, den USA und Japan zum Beispiel liegt er bei 2,5% und mehr - dies ist im Übrigen auch das Ziel, welches China sich bis 2020 gesetzt hat.

Weiterhin starke Abhängigkeit von ausländischen Technologien: Chinas Technologieimporte wachsen stetig, (USD 14,8 Milliarden für 2006), während entsprechende Exporte noch rar sind.[4] Die OECD schätzt darüber hinaus, dass zur Zeit ein Anteil von 25-30% der Unternehmensausgaben für F&E in China von ausländischen Unternehmen oder deren Beteiligungen erbracht wird.[5] Auslandsbeteiligungen dominieren auch Chinas Exportgeschäft: 2005 kamen 58% von Chinas Gesamtexporten, 90% der Hochtechnologie und 46% der Maschinenbauexporte von solchen Unternehmen. Für einheimische Unternehmen heißt dies vor allem eines: Mehr Wettbewerbsdruck. Aber die Präsenz von Technologieführern schafft auch mehr Anreize und Gelegenheiten, technologisch aufzuholen.

Unternehmen werden zur F&E-Triebkraft: In den vergangenen drei Jahrzehnten verschob sich das Innovationsgewicht in Chinas Wirtschaft weg von öffentlichen Forschungsinstituten vor allem hin zum Unternehmenssektor, aber auch zu Universitäten. Der Unternehmensanteil an den gesamten F&E Ausgaben

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[3] Bruttoinlandsausgaben für F&E: Summe der F&E Ausgaben von Unternehmen, der öffentlichen Hand und privaten gemeinnützigen Organisationen, Zahlen in aktuellen USD-Werten, gewichtet mit der lokalen Kaufkraftparität.

[4] Hier sind Technologien an sich gemeint, also nicht solche die in Form von Produkten geliefert werden, das heißt z.B. Lizenzen, Patente, Know-how sowie Forschungs- und Technologiedienstleistungen.

[5] OECD (2007), p. 32.

Chinas wuchs von 30% im Jahre 1994 auf 67% 2005, im Übrigen der gleiche Beitrag, den Unternehmen in Deutschland an den nationalen F&E-Aufwendungen ausmachen. Setzt man die F&E Ausgaben der Wirtschaft jedoch ins Verhältnis zum starken Umsatzwachstum chinesischer Unternehmen, ist der durchschnittliche Anteil bei 0,6% eher mager. Etwas besser ist er bei größeren Unternehmen mit 2,2%. Im Vergleich dazu stellen deutsche Maschinenbauunternehmen 2005 mehr Geld für F&E bereit, etwa 5,2% ihres Umsatzes. Viele chinesische Maschinenbauer betrachten Forschungs- und Entwicklungsleistungen zudem als teuer und riskant und scheuen sich daher, mehr Ressourcen dafür einzusetzen, wenn der Umsatz ohnehin steigt.

Chinesische Unternehmen haben Schwierigkeiten, interne Innovationsressourcen zu aktivieren und bedienen sich daher externer Ressourcen: Gut ausgebildete Mitarbeiter, insbesondere Techniker, Manager und erfahrene Entwickler sind eher rar in Chinas Arbeitsmarkt. Auch deshalb zögern chinesische Maschinenbauer, mehr für F&E auszugeben, denn Geld ist nicht der wichtigste Engpass. Die Situation wird noch verschärft durch das mangelnde Training in den Firmen selbst, aber auch durch das chinesische Bildungssystem, welches wenig Wert auf praxisnahe Ausbildung und kreative Fähigkeiten legt. Vor diesem Hintergrund wenden sich chinesische Unternehmen häufiger externen Wissensquellen zu als in entwickelten Ländern üblich. Insbesondere Geschäftspartner, Wettbewerber und Wissenschaftler werden vermehrt zu Rate gezogen, wenn es um Ideen für Innovationen geht.

Institutioneller Rahmen vorhanden, Umsetzung gestaltet sich schwierig: Die Rahmenbedingungen für den Schutz geistigen Eigentums und die Regelung des operativen Geschäfts von Unternehmen, müssen noch ausreifen. Während dessen untergraben sie den privaten Anreiz, echte Innovationen zu schaffen, denn Wissen wird schnell absorbiert – unabhängig von eventuellen Eigentumsrechten. Dies wird sich als ernsthaftes Hindernis zur Erreichung des Regierungsziels, eine unabhängige Innovationskultur zu schaffen erweisen.

Spezifisches Innovationsmuster chinesischer Unternehmen: Fehlende Ressourcen, Fähigkeiten und institutionelle Rahmenbedingungen lässt Unternehmen geringfügige Produkt- und Prozessverbesserungen gegenüber größeren bevorzugen, sowie externe Ideenquellen gegenüber internen und darüber hinaus gut vorstrukturierte Problemstellungen von Kunden gegenüber solchen, in denen die Lösung nicht offensichtlich ist. Daraus resultiert eine Innovationsstrategie, die üblicherweise „fast follower" oder im Duktus der chinesischen Regierung „Re-Innovation" genannt wird, d.h. Innovation, die vor allem aus dem Anpassen ausländischer Technologien und Produkte bestehen.

Innovative und weltweit erfolgreiche chinesischen Unternehmen werden zu Vorbildern: Unter den vier großen Entwicklungsnationen, die unter dem Kürzel „BRIC" geführt werden (Brasilien, Russland, Indien, China), schafften es dieses Jahr 24 chinesische Unternehmen in die Liste der 500 größten Unternehmen weltweit, in die *Fortune Global 500*, weitaus mehr als die anderen drei Länder. Chinas Regierung und die nationale Presse tun ihr Übriges, um ihre „nationalen Champions" weiter zu fördern.

Technologieorientierte kleine und mittelständische Unternehmen (KMUs) werden aktiv: In entwickelten Industrienationen bilden KMUs die Basis für die wirtschaftliche Innovationsfähigkeit des Landes. Dank der zunehmenden Anzahl von Wissenschaftsparks und Firmenausgründungen aus Universitäten wuchs der Technologie-KMU-Sektor in den 5 Jahren bis 2004 um 52%, dessen Patentanmeldungen für Erfindungen, die komplexeste Kategorie des chinesischen Patentsystems, hat sich im selben Zeitraum verdreifacht.

Innovationspläne der Regierung sind öffentlich und werden pragmatisch implementiert

Innovationsziele bis 2020 klar definiert: Die meisten Länder haben erkannt, dass sie am meisten von globalen Innovationsnetzwerken profitieren, wenn sie ihre eigenen Innovationsfähigkeiten aufpolieren. In diesem Sinne hat auch China einen langfristigen Plan zur Entwicklung von Wissenschaft und Technologie und Förderung von Innovationen verabschiedet. Ziel ist es, die Wirtschaft bis 2020 auf ein solides Fundament in punkto Innovation, Wissenschaft und Technologie zu stellen. Eine Reihe von Indikatoren sollen als Prüfmarken dienen, u. a.:

- F&E Ausgaben in Prozent des BIP sollen von derzeit 1,4% (2006) auf 2,5% bis 2020 steigen.
- Abhängigkeit von ausländischen Technologien soll bis 2020 von 50% (2005) auf 30% sinken.[6]
- Beitrag von Wissenschaft und Technologie zu Chinas Wirtschaftswachstum soll von 39% auf 60% wachsen, und würde damit Wachstumscharakteristiken einer entwickelten Industrienation annehmen.
- Proportion von High-Tech-Produkten an der industriellen Wertschöpfung soll sich von derzeit 14% auf 28% erhöhen.
- Verbesserung von Personalqualität und -quantität als kritischer Faktor für das Erreichen der Innovationsziele.

Zwei Innovationsstrategien – Vor allem „Aufholen" und einige Quantensprünge:

Als Entwicklungsland verfolgt China, was seine Innovationskraft anbelangt, eine Nachzüglerstrategie. Das bedeutet vor allem, dass es mit Hilfe von Imitation auf den Technologiestand hochentwickelter Staaten gelangen möchte. In zur Zeit 16 ausgewählten und prestigeträchtigen Feldern, wie zum Beispiel im Bereich von CNC-Maschinen, sind die Ziele ehrgeiziger: „Überspringen" ist die Devise, man fühlt sich an den ostdeutschen Slogan „Überholen ohne Einzuholen" der späten 1950er erinnert.

Innovationsstrategien und Maßnahmen im Maschinenbau: Im Maschinenbau wurden 10 Produkttypen ausgewählt, die vorerst den besonderen Schwerpunkt

[6] Im Vergleich zu den meisten OECD-Ländern ist China's Abhängigkeit von ausländischen Technologien recht hoch (OECD Durchschnitt liegt unter 30%). Indikator bezeichnet den Anteil der Technologieimporte ausgedrückt als Prozentsatz von den nationalen F&E Ausgaben plus Technologiehandelüberschuss. In anderen Worten: Wie viel von der in China gebrauchten Technologieleistungen müssen importiert werden.

bilden für die Entwicklung eigenständiger Innovationsfähigkeiten.[7] Eine solche Positivliste zeigt, dass in diesen Bereichen ein Fortschritt als am dringlichsten notwendig empfunden wird. Hier gibt es wahrscheinlich die besten Bedingungen für ausländische Unternehmen, die an eine Zusammenarbeit mit chinesischen Betrieben denken. Auf der anderen Seite gibt eine solche Liste Investoren auch einen Ausblick darauf, dass ihr Wissen wahrscheinlich schnell von chinesischen Wettbewerbern aufgenommen wird. Weitere Mittel, um den lokalen Anteil an Innovationen im Maschinenbau und anderen Industrien zu erhöhen, sind die Förderung des Wettbewerbs, Steueranreize für F&E, Bevorzugung in staatlichen Beschaffungsprojekten, die Unterstützung von internationalen Kooperationen und die anhaltenden Reformen des öffentlichen Forschungssystems.

Der Ausblick: Zuerst mehr Produkte, dann mehr Innovationen

Wird China ein Innovationsschwergewicht bis 2020? China hat seit dem Ende der 1970er Jahre eine Reihe von tiefgreifenden Veränderungen mit Hilfe von pragmatischen Maßnahmen gemeistert. Auch um das Innovationsziel zu erreichen, gibt es entsprechende Maßnahmenkataloge, die derzeit implementiert werden. Jedoch erschweren das atemberaubende Wirtschaftswachstum und eine Geschichte voller fundamentaler Änderungen Voraussagen über zukünftige Entwicklungen in China. Während einige Schätzungen Chinas Fähigkeiten im Wissenschafts- und Technologiebereich bereits in 10 Jahren neben denen entwickelter Industrienationen sehen, bleiben viele skeptisch – zumindest für das ganze Land, ganze Industrien und den kurzen Zeitraum von etwas mehr als einem Jahrzehnt.

Entwicklung eines starken nationalen Innovationssystems braucht Zeit: Innovationen können nicht per Regierungsdekret verordnet werden. Sie entstehen aus dem Zusammenwirken von Innovationsressourcen und -fähigkeiten sowie Eigenmotivation von Individuen und Organisationen. Zwar können Ressourcen (F&E Investitionen, Mitarbeiter etc.) in das System gepumpt werden und die Fähigkeiten sich langsam verbessern, aber die Ergebnisse werden sich erst dann entsprechend zeigen, wenn die Frage der Motivation ebenfalls angegangen wird.

Stolpersteine: Damit China seine Innovationsziele bis 2020 erreicht, ist es auf Privatinitiative angewiesen. Chinas heimische Unternehmen – vor allem die privaten – sind aber vorerst damit beschäftigt, ihr eigenes Wachstum operativ in den Griff zu bekommen. Organisationen beginnen gerade ihre F&E-Funktionen in größerem Maße zu formalisieren, aber sie verwenden noch nicht viel Geld darauf. Zudem, hat das chinesische Bildungssystem Schwierigkeiten, der Wirtschaft eine ausreichende Anzahl gut ausgebildeter Leute zuzuführen, die Probleme mit Eigeninitiative und Selbständigkeit lösen. Um dies zu ändern,

[7] Große, leistungsstarke Generatoren, elektrische Ausrüstungen/Umspannungsanlangen ausgelegt für Hochspannung, Großanlagen für die Ethylenproduktion, große/effiziente Kohlekraftwerke und metallurgische Ausrüstung, Bergbau-, Marine- und Schienentransportausrüstung, Umwelttechnologie und CNC-Maschinen.

müsste die Regierung das System reformieren und vor allem mehr Mittel bereitstellen – eine massive Aufgabe bei 230 Millionen Menschen, die zur Zeit an chinesischen Bildungsinstituten eingeschrieben sind.

Derzeit noch wenig Innovationsanreize für Individuen und Organisationen: Individuen und Organisationen sind nur dann motiviert, Mittel und Arbeit in Innovationen zu investieren, wenn die institutionellen Rahmenbedingungen, zum Beispiel Eigentumsrechte – sicher und berechenbar sind. Dies könnte sich als einer der Hauptstörfaktoren für Chinas Innovationssystem erweisen. So lange Investoren nicht genügend von ihren eigenen Innovationen profitieren, sollten wir nicht viele innovative Unternehmen auf Weltniveau in China antreffen – im Moment eine kaum zu verleugnende Realität. Das Land ist zur Zeit eher mit dem Aufholen (Re-Innovation) als dem Überholen und „eigenständigen Innovationen“ beschäftigt. Lange war Quantität alles und Qualität wenig – sowohl für die Regierung als auch für chinesische Unternehmen. Der Richtungswechsel in der Politik hin zur Förderung von “eigenständigen Innovationen“ ist vielleicht auch als Mahnung zu betrachten – zumindest an regierungsnahe Organisationen und Betriebe – dass Wissen und Innovationen in Zukunft einen größeren Beitrag zum Wachstum leisten haben.

Chinas industrielle Produktion wird die anderer Wirtschaftsmächte übertreffen: Um das Wirtschaftswachstum beizubehalten, wird China die Faktoren ersetzen müssen, von denen erwartet wird, dass sie ihr derzeit hohes Niveau verlassen werden, so wie Kapitalinvestitionen aber auch ausländische Direktinvestitionen. Der unbedingte Wille der Kommunistischen Partei Chinas, alles daranzusetzen, um dieses Ziel zu erreichen, kann für bare Münze genommen werden, denn es könnte um die eigene Existenzberechtigung bzw. um das eigene Führungsanrecht gehen.

Wenn China einen weiteren „Großen Sprung nach vorn“[8] macht, dieses Mal allerdings – ähnlich wie andere asiatische Nationen vorher – in die Richtung von Wachstum und Wissen, werden die Auswirkungen auf die Weltwirtschaft enorm sein. Aber selbst wenn das riesige Land mit seinen 1,3 Milliarden Menschen nur ein paar Schritte in die Richtung eines Innovations-schwergewichts macht bis 2020, wird der steigende Marktdruck die Industrielandschaften des Westens grundlegend verändern.

Marktdruck von Wettbewerbern steigt: Einige der deutschen Maschinenbauer in China befinden sich in einer relativ komfortablen Position, während andere mehr Druck von chinesischen Wettbewerbern zu spüren bekommen. Maschinenbauer mit einem hohen Exportanteil, einer anspruchsvollen Produktpalette, Produkte für verschiedene Kundenindustrien, kurzen time-to-market Innovationszyklen fühlen sich meist wenig von der chinesischen Konkurrenz bedroht. Während Produkte und deren Designs oft recht einfach nachzuahmen sind, sind es Produktionsprozesse hingegen nicht, da sie häufig

[8] “The Great Leap Forward”/ „Der große Sprung nach vorn“ meint die Entwicklungen während des 2. Fünfjahresplans (1958-1963) der Volksrepublik China. Ziel war die schnelle Umwandlung Chinas in eine industrialisierte kommunistische Nation, weg von der Landwirtschaft als dominierendem Sektor. Dieser Sozial- und Wirtschaftsplan wurde nur 2 Jahre angewandt, hatte aber in Kombination mit Misswirtschaft und Ernteausfällen verheerende Konsequenzen für Chinas ländliche Bevölkerung.

auf wenig kodifiziertem Erfahrungswissen beruhen. Deutsche Unternehmen, die einen zwei- bis dreijährigen Technologievorsprung wahren können, sind relativ sicher vor „schnellen Nachahmern". Stark spezialisierte Nischenanbieter werden zudem weniger nachgeahmt, da chinesische Unternehmen wenig Anreiz haben, Ressourcen, Leute und Forschungskapazitäten auf ein Produkt mit geringer Nachfrage zu verwenden. Ist die Technologie wichtig für den Fortschritt des Landes, ist die Übernahme eines technologisch überlegeneren Unternehmens im Ausland eine Alternative.

Deutsche Hersteller die Massenmärkte bedienen, die Standardprodukte mit langen Produktionsläufen, scheinbar komfortablen Margen und einer Technologie, die nicht auf dem neuesten Stand sein muss, haben Grund zur Sorge. Chinesische Maschinenproduzenten mögen technologisch einige Jahre zurückliegen, aber das muss nicht so bleiben.

In China beginnt eine förderliche Innovationsumgebung zu entstehen, in der ein entsprechendes Regelwerk den Rahmen vorgibt, die Regierung Innovationen durch Programme und Anreize fördert, in der chinesische Unternehmen ihr geistiges Eigentum geschützt sehen wollen und wo der internationale Druck auf chinesische Firmen diese dazu bewegt, sich internationalen Gepflogenheiten anzupassen. In einer Kultur, in der das Konzept des „Gesicht-Wahrens" einen solch hohen Stellenwert hat, ist es jedenfalls kaum akzeptabel, wenn Anwälte Ausstellungsstände auf internationalen Messen schließen, denn natürlich wollen chinesische Unternehmer keinen zweifelhaften internationalen Ruf erwerben. China ist bisher immer noch durch Integration gewachsen, Zeiten der Konfrontation waren eher rar und kurz. Es wird im Interesse chinesischer Firmen sein, als integraler Bestandteil der internationalen Gemeinschaft zu wachsen und nicht ständiger Anlass zur öffentlichen harschen Kritik an China zu sein.

Rechtliche Schritte einzuleiten gegen illegale Formen der Innovation ist der richtige Weg, in China und weltweit. Chinesische Unternehmen dazu zu bewegen, sich internationalen Regeln zu fügen, sobald sie international agieren, ist ebenso richtig. Es wäre allerdings für internationale Unternehmen ratsam, nicht nur den konfrontativen Ansatz mit chinesischen Wettbewerbern zu wählen, sondern auch Hilfestellungen in deren Lernprozess zu geben.

China wird zur großen Exportmacht – aber nicht unbedingt zur großen Gefahr: China hat die Welt der Innovationen jahrhundertelang beherrscht. Noch während der Ming-Dynastie, war China dem Westen weit voraus. Wirtschaftlich trugen China und Indien damals jeweils etwa 30% der weltweiten Wertschöpfung bei. Europa, Amerika und Afrika zusammen kamen auf ca. 40%. In den folgenden 500 Jahren isolierte sich das Reich der Mitte und wurde zunehmend schwächer. Auch zur Zeit des Kommunismus war China nach innen gewandt und erst unter Deng Xiaoping begannen die Reformen und die „Öffnung nach Westen". In den vergangenen 25 Jahren bestand diese Öffnung hauptsächlich darin, dass Chinesen die Türen öffneten und der Westen hereinkam, also vor allem die Öffnung gegenüber ausländischen Unternehmen, die in China Geschäfte machen wollten.

Nach Chinas Aufnahme in die WTO und mit anhaltender Globalisierung, wagen sich chinesische Unternehmen erstmalig seit 500 Jahren selbst wieder auf das internationale Parkett. Sie kennen die Regeln noch nicht, aber es wird ihnen peinlich klar gemacht, dass die chinesische Art des Geschäfts international nicht akzeptiert oder geduldet wird. Die Last der Geschichte abzuschütteln ist für kein Land einfach, aber wenn eines mit einer konfuzianischen Tradition, einer kommunistischen Vergangenheit, einer marktwirtschaftlichen Realität und 1,3 Milliarden Einwohnern dies in relativ kurzer Zeit unternimmt, geht diese massive Bewegung nicht ohne Verschiebungsgeräusche vonstatten.

Deutsche Maschinenhersteller wissen im internationalen Wettbewerb zu bestehen. Technologische Kompetenz, Qualität und die daraus resultierende Marke „Made in Germany“ sind wesentliche Bestandteile der Wettbewerbsstrategie. Deutsche Firmen sind es gewohnt nach internationalen Regeln zu spielen. Sobald chinesische Maschinenbauer internationale Standards befolgen, werden sie zu Wettbewerbern wie andere vor ihnen – beeindruckend, aber nicht einschüchternd.

Executive summary (English)

China has achieved a visible integration into the world economy. Decades of solid economic growth helped to lift the per capita GDP to more than USD 1,700 in 2005, thus substantially raising the living standard of her people. The GDP growth target of 7.5% per year adopted for the current 11th five year plan period (2006-10) is no less impressive, but lower than before. This is the result of a major change in economic policy, since China's political leaders have adopted the view that the current national growth pattern is not sustainable. The country employed ever more resources and invested heavily in order to maintain high growth rates. This however caused discontent among the Chinese people because it resulted in social inequality, dominance of foreign companies and brought vast ecological degradation. China still wants to grow, but differently and perhaps slower – if that is the price to pay for fixing some of these pressing problems.

In his speech at the National Congress on 15 October 2007, China's President Hu Jintao clearly gave directions for China's future growth: "… rapid growth will be under the condition of reduced consumption of resources and greater efforts in environmental protection"[9] as well as a "reform of the income distribution system to reverse the growing income disparity."[10] To achieve all that, China has to develop her own innovative solutions as there is no more role model to follow in the world.

New strategy to achieve sustainable and "harmonic" growth is "independent innovation". The government set the strategic goal to transform the Peoples' Republic into an innovative state in general and specifically into one, which relies more on domestic or home-grown innovation. Independent innovation shall enable domestic firms to use their resources better and more efficiently, thus moving away from low value added manufacturing. A larger domestic share of innovation – usually referring to local science and technology (S&T) progress – should also increase the income of the Chinese people, lower China's dependency on foreign technology and help to quieten foreign critics of China's intellectual property rights protection system. This will lead to a more "harmonious" development, helping to maintain political stability.

With China setting her mind on catching up with the world's rich nations in terms of innovation and technology, those countries begin to wonder if their competitive advantages will be threatened by China's aspirations to become an "innovation juggernaut" in its own right. Will we soon see "Invented and Designed in China" instead of simply "Made in China" on higher value added goods?

This study explores China's current and future innovation capabilities, its influencing factors as well as the Chinese government's strategies to move the

[9] http://english.cpcnews.cn/92243/6283199.html

[10] http://english.cpcnews.cn/92243/6283146.html

economy up the value chain. To carry out the study we examined the externally available material, but mainly relied on more than 200 in-depth interviews with politicians, representatives from authorities, academia, government think tanks and subsidiaries of German machinery companies in China.

The status quo: Contribution of technology and innovation to economic growth in China increasing, albeit starting from low level

China's total national R&D expenditure rising fast: At USD 136 billion in 2006, weighted with the respective purchasing power, China replaced Japan as the second largest R&D investor worldwide after the US.[11]

R&D as share of GDP still below western level, but growing: China's R&D expenditure relative to its Gross Domestic Product has more than doubled since 1995 to reach 1.4% in 2006. However, this indicator for China's national commitment to R&D is still much lower than that of more developed countries: In Germany, US and Japan the respective figure is 2.5% and higher, which is also the planned figure for China in 2020.

Dependence on foreign technology remains high: So far, Chinese technology imports are high (USD 14.8 billion in 2006), while technology exports are still relatively few.[12] Furthermore, OECD estimates that currently foreign R&D accounts for 25-30% of total business R&D in China.[13] Foreign companies also dominate Chinese exports – they accounted for 58% of China's total exports, 90% of high-tech and 46% of machinery exports in 2005. For local companies the presence of more advanced competitors increases the market pressure for sure, but it also gives more incentives as well as opportunities to catch up technologically.

Business becomes the engine for R&D: In the past three decades the innovation weight in the Chinese economy shifted from public research labs to enterprises, and – to an extend – to universities. Business share of total national R&D expenditure stepped up from 30% in 1994 to 67% in 2005, reaching Germany's business share. However, taking the high sales growth of Chinese companies into account, the percentage of R&D expenditures over sales of Chinese businesses are low, hovering around 0.6%. For large and medium sized enterprises, the figure was somewhat higher at about 2.2%. By comparison, Germany's machinery companies spent on average 5.2% of their sales value on R&D in 2005. Many Chinese machinery enterprises consider R&D as high-cost and high risk and currently shy away from such commitment if their sales are growing anyway.

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[11] Gross domestic expenditure on R&D (GERD) is the sum of R&D undertaken by businesses, the government, higher education institutions and private non-profit organisations, representing the total amount of R&D undertaken in an economy, figures measured in current USD weighed according to respective country's Purchasing Power Parity.

[12] Refers to traded disembodied technology, i.e. production ready technology, including licenses, patents, know-how and research and technical assistance services.

[13] OECD (2007), p. 32.

Lack of internal R&D infrastructure drives business to seek outside inspiration: Companies in China lack sufficient numbers of skilled employees, especially technical experts, management and experienced researchers. Thus, they are reluctant to employ more funds for R&D. Inadequate people training by businesses and the educational system exacerbates the situation. Instead, companies use external knowledge resources more extensively than their global peers, including business partners, competitors and academia.

Regulatory framework exists, but implementation is difficult: The Chinese framework securing property rights and regulating company operations and investment is still immature, thereby eroding the incentive to innovate in the first place. This poses a serious threat to the Chinese government's "independent innovation" goal.

Specific pattern of Chinese business innovation: The lack of resources, capabilities and frameworks makes businesses favour incremental improvements over major, resource intense innovations; external sources of ideas over internal ones and in general well structured problems over ill-structured problems to solve in order to create a value added to their customers. This innovation strategy is often labelled "fast follower" or in new Chinese government speak "re-innovation", referring to innovation based on learning and absorbing technologies from foreign firms.

Chinese companies emerging as "role models" of innovative and globally successful companies: Among the BRIC countries (Brazil, Russia, India, China), China is the most successful in producing sufficiently innovative companies that entered the Fortune Global 500 companies, listing 24 Chinese companies among the 500 largest companies worldwide in 2007. The Chinese government and the national press further promote these "national champions".

Technology SME[14] sector becoming more active: In developed countries, SMEs are crucial for national innovative capabilities. Thanks to the number of science parks and university spin-offs, the number of technology SMEs in China has increased by 52% and their patent applications for inventions more than tripled between 2000 and 2004.[15]

Government's innovation plans are broadly communicated and pragmatically implemented

Government innovation goals until 2020 clearly defined: Most economies realise that in order to benefit from global innovation networks, they need to strengthen their domestic innovation capabilities. China also adopted a long-term strategic plan to develop S&T and foster innovation. The goal is to become a major innovation economy by 2020. A number of S&T indicators to be achieved by 2020 are put forward in this respect, among others:

[14] SME - small and medium enterprise

[15] OECD (2007), p. 32.

- R&D expenditure as percentage of GDP to be raised from 1.4% in 2006 to 2.5% of GDP by 2020.
- Dependence on foreign technology to decrease from 50% in 2005 to 30% in 2020.[16]
- S&T contribution to economic growth to increase from 39% to 60%, thus taking on growth characteristics of a developed country.
- Proportion of high-tech manufacturing in manufacturing value added to be increased from currently 14% to 28% by 2010.
- Improvement of human resources as a critical component to enable China to achieve its goals.

Government innovation strategies involve mostly catching up, some "leap-frogging": As a developing country, China has adopted a latecomer strategy for its development of domestic innovative capabilities. This involves catching up with advanced countries by means of imitation, but China is also striving to surpass them in selected fields (often labelled as "leapfrog development"). For the more prestigious leap-frogging, 16 special industrial projects were selected, in which domestic companies are to compete and potentially surpass developed countries peers eventually, among them high-end CNC machines.

Innovation strategies and measures for the machinery industry: In the machinery industry 10 products types were chosen as the focus for independent innovation.[17] Such "most wanted" list on one hand shows that there are significant technology gaps for the certain machinery sectors and thus, opportunities of collaboration between foreign and Chinese firms. On the other hand, it gives foreign investors the outlook that their knowledge is likely to be quickly disseminated among Chinese competitors. Increased market competition, tax exemptions for R&D, preferred government purchasing, fostering international collaborations and further reforming public sector research are further measures to achieve a larger share of domestic innovation – for the machinery sector and for other industries.

Outlook: China is gradually moving from products to ideas

Will China be able to succeed to become an innovation juggernaut by 2020? With the help of pragmatic measures China has been going through a series of successful reforms since the late 1970s. In order to reach the innovation goal, there are also a number of well-publicised plans, that are currently implemented. However, the fast economic growth as well as a history of fundamental changes and reforms make exact predictions about future developments in China difficult. While some estimates place China's S&T capabilities among that of western

[16] Compared to most OECD countries, China's dependence on foreign technology remains high (OECD average is below 30%).

[17] Large-scale high performance clean generators, high voltage transmission/transformation equipment, large-scale ethylene production equipment, large-scale coal chemical plants, large-scale metallurgy equipment, mining/excavating, large-scale naval and rail transportation equipment, environmental technology and CNC machines.

nations in as little as 10 years, sceptics have their doubts because of the enormity of the challenge to transform an entire country and entire industries within the short time frame of little more than a decade.

A strong national innovation system needs time to develop: Innovation cannot be ordered by government decree. It needs to arise from the available resources, capabilities and motivation of individuals and organisations. Resources (such as R&D expenditure, people etc.) can be poured into the system and capabilities upgraded but the innovation outcome will only grow correspondingly if the motivational issue is tackled simultaneously.

Enterprises drive innovation, but R&D structure is yet to evolve. Reaching the proclaimed innovation goals heavily relies on private initiative. Chinese domestic companies however are currently at the stage of operationally mastering their own growth. R&D is just formalising on a larger scale but remains under-funded. On top of that, the Chinese educational system does not provide the economy with sufficient numbers of skilled people that can solve problems and show initiative. In order to change that, the government will need to reform and – above all – fund the educational system better – a massive task on its own considering some 230 million people are currently enrolled in Chinese education facilities.

Motivation for individuals and organisations to innovate needs to change: This will only happen if the institutional frameworks – especially property rights – are secure and predictable. This is where we see the major fault line in China's National Innovation System. As long as inventors cannot appropriate the profits of their innovation, we should not see many innovative companies in China – and in reality, we do not. At this moment, China is at the stage of knowledge absorption more than "independent" knowledge creation. For a long time, output growth was put ahead everything else by the government and businesses alike. The shift in government policy to promote "independent innovation" could therefore be seen more as a "reminder" or guideline – at least for government-affiliated organisations – to change their focus from resource intensive to a more knowledge intensive production.

China's economy will overtake other major world economies in terms of output: In order for the economy to keep growing, China must replace the input factors that are expected to decline from their high level in the coming decade, such as capital input, but also foreign direct investment. The strong political will of the Chinese Communist Party to do its best in order to achieve this, can be taken at face value since it may be a question of proving one's right to exist or to rule for that matter.

When China makes another "Great Leap Forward"[18] – this time in a growth and knowledge direction – similar to other Asian nations, the impact on the world economy and ecology must be tremendous. But even if China only makes a few

[18] "The Great Leap Forward" refers to the 2nd Five Year Plan for 1958-1963 by the People's Republic of China. Its goal was the country's rapid transformation towards an industrialised communist nation, away from the dominance of the primary sector. This social and economic plan was applied from 1958 to 1960 and in combination with mismanagement and bad harvests proved disastrous for China's rural population.

steps toward becoming an innovation juggernaut by 2020, the economic impact and market pressure coming from this Asian giant will still change the industrial landscapes of the west.

Competitive pressure rising: Some of the German machinery companies are in a relatively comfortable competitive position in China, while others face more pressure from their Chinese competitors. German machinery manufacturers with a large share of exports, with a sophisticated product range, short product cycles, products that meld various industries, short time-to-market innovation cycles, mostly do not fear the Chinese (or any other) competitor. Usually, products and their designs are relatively easy to emulate, manufacturing processes are not, since they bear a lot of tacit knowledge that cannot be copied by taking a product apart and emulating the design. A German manufacturer, who is able to maintain a 2-3 year technology lead, is relatively safe from fast followers. Furthermore, German producers operating in a technology niche or catering to a relatively small segment of the global market are also less targeted because Chinese companies do not think it worthwhile to invest resources, manpower and research capacity into a niche product. If the technology is really deemed important for the progress of the country, a takeover of a technologically more advanced company may be an alternative.

German manufacturers with mass-market appeal, standard products with long production runs and high volume, apparently comfortable profit margins and a technology that does not need to be state-of-the-art, need to worry. Chinese machinery producers may be some years behind, but that does not mean it will stay that way forever.

An innovation environment is gradually emerging in China, where respective rules and regulations provide a good framework, where the Chinese government encourages innovation through programmes and incentives, where Chinese companies realise the value of intellectual property and where the external pressures from the global community force Chinese firms to comply with the international rules. However, in a culture that highly values the concept of "keeping face", it is not seen as acceptable, if foreign lawyers close booths at international exhibitions and the Chinese entrepreneur will want to avoid a repetition. Chinese companies want to integrate themselves into global business and do not want to have a doubtful reputation worldwide. China has always grown through integration, and the rare occasions of confrontation have always been of a temporary nature. It will also be the desire of the future global Chinese companies to grow as an integral part of the international community and not be the subject of continued public "China bashing".

Taking actions against illegal forms of innovating is the right thing to do, in China and globally. Forcing Chinese companies to play by international rules when they emerge on the global theatre is certainly correct too. However, for Western companies it would also be advisable not only to choose the confrontational approach with Chinese competitors but also to provide a helping hand when they learn how to apply the rules.

China will be a major force in global trade, and they are there to stay: China has dominated the world of innovation for centuries. During the Ming dynasty, China was way ahead of the west. China and India also provided each about 30% of world GDP with the remaining 40% coming from Europe, America and Africa combined. For 500 years thereafter, the "Middle Kingdom" isolated herself from the world, became inward looking and gradually weakened. Deng Xiaoping is widely credited for the reforms that opened China's doors to the world. But for the past 25 years "Opening to the West" meant for the Chinese to open their doors and let foreigners come in. After China's accession to the WTO and with increased globalisation, for the first time in 500 years, China gets up, steps out of its door and re-emerges on the global stage. Shaking off the burden of history is not easy for any country, but for one with a Confucian tradition, a communist past, a capitalist reality and some 1.3 billion people, this is a process that is bound to cause some rumbles worldwide.

German companies know how to compete in the world. They compete on technical competence, on quality and on the resulting brand of "Made in Germany". Germans compete internationally within a framework of global rules and the Chinese have to learn to play by these rules. Once Chinese machinery manufacturers abide by international standards, they become competitors like others – impressive but not intimidating.

1 Introduction:

China wants to become an innovation juggernaut

Knowledge is power.
(Ipsa Scientia Potestas Est)
Sir Francis Bacon, 1597

1 Introduction: China wants to become an innovation juggernaut

China has achieved a visible integration into the world economy by increasing its productive capabilities while opening its doors for trade and investment. Bringing its huge and low-cost labour force to bear, China developed into an attractive location for labour-intensive manufacturing. Thus, in a short period, it has surpassed Japan and France to become the world's third largest exporter after Germany and the US, accounting for nearly 8% of global exports in 2006. Current trends prevailing, China's exports are forecasted to overtake the exports of the two leading economies by 2010.[19]

China needs economic growth in order to lift the standard of living of its people. Currently some 17% of the population still live on less than USD 1 a day. In order to achieve growth, one must either "work harder" or "work smarter". China's recent growth was mainly achieved by "working harder", i.e. the country employed more labour, land, capital and resources to produce more goods and services. The low costs of these input factors in China had attracted significant investment into its capital stock from both within and outside the country. However, being a low-cost manufacturing location alone is unlikely to be a long-term sustainable advantage in China's favour. Wage and property price levels in the Eastern economic hotspots such as Shanghai or Guangzhou are already reaching all-time highs. While China's factories churn out larger quantities of low value added products every year, there is a whiff of change in the air.

Recently, "innovation" seems to be one of the favourite buzzwords in the sphere of high-ranking Chinese government officials. In both its 11th Five-Year Plan for the period from 2006 to 2010 as well as in its "Mid-term and Long-term Science and Technology Development Programme," the Chinese government emphasises the importance of "independent innovation capabilities" and the strengthening of China's so-called National Innovation System (see Box 1). This represents a significant shift in China's growth policy as previous economic growth has been based on investments into low-value added mass production of goods that the world came to associate with "made in China". Apple's iPod is exemplary for China's current contribution to the global value chain: "Designed by Apple in California - Assembled in China".

While China already represents a direct competitor for other low-cost countries specialising in labour-intensive manufactures, technologically more advanced countries begin to wonder if their competitive advantages will be threatened by China's aspirations to become an innovation juggernaut in its own right. Will we soon see "Invented and Designed in China" instead of simply "Made in China" on higher value added goods?

[19] OECD (16 September 2005) and CIA World Factbook (2007 data).

As a country develops and a sufficient capital stock is established, "working smarter" becomes ever more important – in other words becoming more innovative. In this context, innovation is defined as "the production, diffusion and use of new, and economically useful, knowledge"[20] in order to create value added. Put more simply: "Innovation is the successful exploitation of new ideas. New ideas can take the form of new technologies, often embodied in capital equipment, new products or new corporate structures and ways of working."[21] When defining innovation as the introduction of something new, one important addition is that the innovation has to be new only to the adopting agent or country. When the ancient methods of Traditional Chinese Medicine including acupuncture found their way to Europe, locally they were an innovation. So many innovations may not be a global novelty but transferred to a different context they may be turned into an economically valuable innovation. For a technologically less advanced country like China, this is an important distinction, since even catching up with global standards is innovative in this sense.

There are already some indications that China is improving its national innovation system. According to the OECD, in 2006, the country invested twice as much into Research and Development as Germany did, i.e. USD 136 billion.[22] This is a remarkable change as in 2001, China and Germany were still on par in terms of public and private R&D spending. In 2006, China replaced Japan as the second largest R&D investor worldwide after the US.[23] Today, China employs some 926,000 staff in R&D functions, about twice as many as Germany does.

Nevertheless, in terms of advanced technologies, China still relies heavily on technology brought into the country by foreign companies. Thus, foreign affiliates came to dominate the Chinese export machine: They accounted for 58% of China's total exports in 2005.[24] This share is even higher for technology-intense product categories. Foreign-invested companies (including Joint Ventures) have seen their part in Chinese high-tech exports surging from 75% in 1998 to more than 90% in 2005.[25] For single high-tech goods, the dominance is even higher: For instance 97% of computers and telecommunications 92% of electronic components exported from China where manufactured by foreign-invested companies.[26] In the machinery industry however, China's foreign-

[20] Lundvall (1992) in OECD.

[21] DTI (2006).

[22] Measured in PPP dollars, i.e. adjusted for local purchasing power.

[23] OECD (2006-2) and various other OECD publications, figures measured in current USD weighed according to respective country's Purchasing Power Parity.

[24] MOFCOM figures: In 2005, foreign-funded companies accounted for USD 444 billion and SOE's for USD 169 billion of China's total export value of USD 762 billion.

[25] China High-tech Industry Data Book 2006, Ministry of Science and Technology 2006. Computer and telecommunications, as well as electronic components accounted for more than 92% of total high-tech exports in 2005.

[26] Sachwald (2006). Figure from 2003.

invested companies have a smaller share, but still accounting for 46% of machinery exports.[27]

Neither the government nor the Chinese media or public for that matter considers this a "harmonious" development. This might explain the new political emphasis on "*independent innovation capabilities*". Independent innovation is a new term put forth by the Chinese government. It became the central policy of the country as detailed in its 11th Five-Year-Plan. The addition "independent" differentiates innovations according to the degree of domestic ownership (see Figure 1). As intellectual property (IP) is a tangible way to quantify the quality/volume of innovation, the Chinese government set owning Chinese-controlled IPRs as the ultimate goal of the independent innovation movement. Given the different approaches for acquiring knowledge and IP, the government has categorized independent innovation into three types:

- *Original innovation:* This term refers to basic or fundamental innovations, such as technological inventions/scientific discoveries in crucial areas. One of the examples could be TD-SCDMA, a 3G standard mainly developed by Da Tang Telecom Technology.
- *Integrated innovation:* This pertains to a more market-oriented type of innovation that links various existing technologies into a new combination or form to fulfil certain customer needs on the market. One of the examples would be Chery QQ, an economic car model introduced by Chery, which integrates several existing technologies to satisfy low-end customer demands in the automotive market.[28]
- *Re-innovation:* Re-innovation refers to a special type of innovation that is based on learning and absorbing technologies from foreign firms, and further modifying them into a different form in new applications. One of the examples is the Three Gorges project, one of the biggest hydropower-complex projects in the world, which has attracted many of the world's leading firms as suppliers. Some of their existing technologies were transferred to China as part of the government purchasing agreements.

In short, independent innovation is a slogan put forward by the Chinese government for identifying the domestic share of innovations while assessing their overall market novelty.

[27] China Chamber of Commerce for Import and Export Machinery and Electronic Products (2006). p. 195.

[28] It has to be noted that these distinctions are somewhat artificial, since for instance GM, the owner of Daewoo, claims the Chery QQ bears a lot of (not accidental) resemblance to the Daewoo model Matiz.

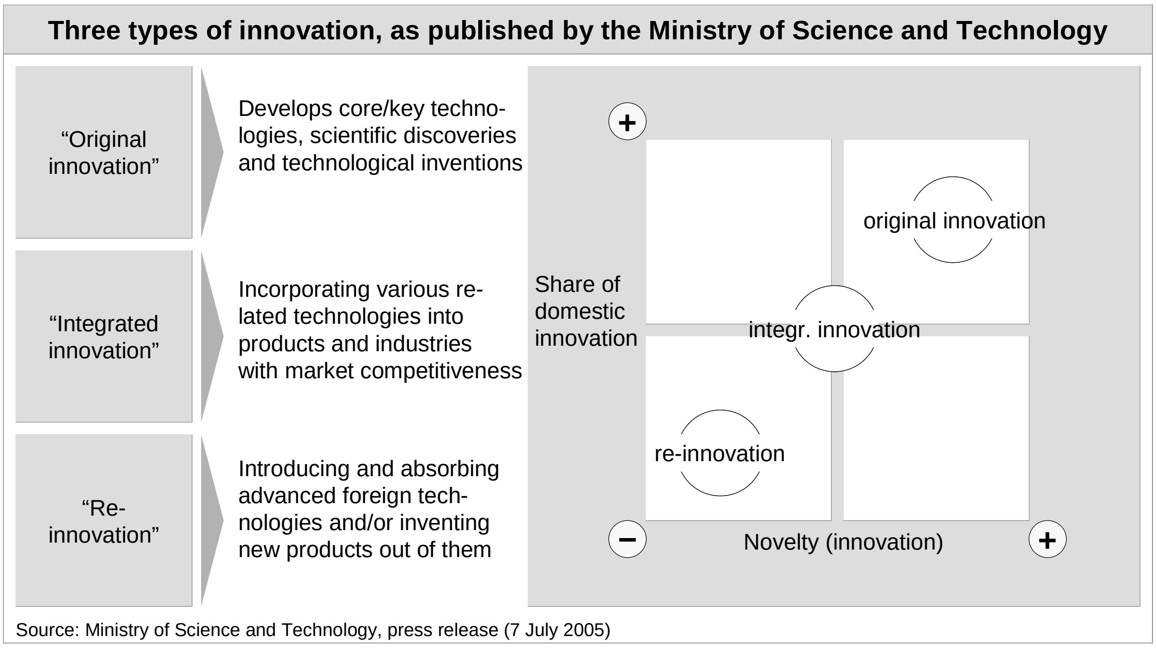

Figure 1: Three types of innovation, as published by the Ministry of Science and Technology.

This study explores China's current and future innovation capabilities, its influencing factors as well as the mid- and long-term strategies involved to move the economy up the value chain. In the course of the investigation, the role of the Chinese government in establishing a favourable institutional framework for innovation will be of particular interest. To avoid the research into the vast area of China's innovation capabilities from getting out of hand, the focus of the study is set on the machinery industry.[29] Machinery qualifies as a higher value added industry.[30] At the same time, it contributes significantly to exports of advanced economies like Germany, Japan and the US. The strengthening of the Chinese machinery sector will be a good indicator of China's own competencies in creating higher value adds.

To gain an insight into China's innovation system, both primary (interviews) and secondary (desktop research) information are collected. While desktop research is essential to get a comprehensive picture at the macro-level, interviews will fill the data with life. Interviews give a better feel for the direction, strengths and weaknesses of the system as seen by the people affected by and involved in it.

The study incorporates views and insights from foreign and Chinese sources. Hence, interviews were carried out with a variety of people: Representatives of German machinery companies with subsidiaries in China, politicians, officials working in administrative bodies as well as experts from academia or think tanks. The first group of interviewees helped to establish a snapshot of German

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[29] Machinery refers to mechanical machinery only, *excluding* electric equipment, office and household appliances as well as transport equipment.

[30] Although machinery in our definition is usually not covered by high-tech statistics. OECD labels machinery higher medium-tech.

machinery companies' R&D activities in China. Additionally it is assumed that these companies are aware of their local Chinese competitors' R&D conditions. The second group offered insights and interpretations of the status quo of the innovation system. In the face of notoriously vague Chinese policy documents, Chinese interview partners were crucial to develop an understanding of the policy strategies involved in upgrading the national innovation system, so that in the future, we might indeed see products labelled "Invented and Designed in China".

2 China's innovation system:
Current status and trends

心有余而力不足

xin you yu er li bu zu

The spirit is willing but the flesh is weak

2 The status quo: China's innovation system

For a developing country, shifting economic activity away from agriculture into industry and services is the only effective strategy for raising the income of its people to achieve a higher standard of living. In this respect, China has done remarkably well. Since engaging people in industrial rather than agricultural production yields higher value added, a massive number of people escaped poverty. As recent as 1981, some 634 million Chinese lived below the poverty line of less than a dollar a day, in 2001 this number had fallen to 212 million, but still equivalent to 17% of the population.[31]

Today, China is a highly industrialised country: The secondary sector contributed 47.5% to China's Gross Domestic Product (GDP), while the primary and tertiary sectors accounted for 12.6% and 39.9% in 2005. As a comparison, Germany's secondary sector contributed 29.1% to GDP. There is, however one peculiarity. Despite having declined sharply since 1978 when Deng Xiaoping initiated economic reform and opened the country to international trade, the share of agriculture in employment remains relatively high accounting for 45% of the labour force in 2005.[32]

As the share of the secondary sector in China's value added is very high, yet the share of it in employment hovers around a rather low 24%, scholars argue that China's long-term extraordinary growth rates are a result of high rates of fixed capital accumulation accompanied by extensive growth in labour productivity.[33]

While outside analysts seem to be mesmerised by this growth experience, the Chinese domestic debate has already moved on. China's political leaders seem to have adopted the view that the current growth pattern is not sustainable. An increasing share of the Chinese elite – not only conservatives but also some liberals – seems to feel a degree of unease about the current development pattern.[34] Some of their concerns include the rising pressure on the job market, a growing discontent with social inequality, the high shares of foreign ownership in industrial enterprises, the risk of external trade conflicts, high-energy consumption per unit of output and vast ecological degradation. The sentiment appears to be, that China still wants to grow, but differently and perhaps slower – if that is the price to pay for fixing a few of these pressing problems.[35]

[31] World Bank (2006).

[32] National Bureau of Statistics China (2006). Secondary industry includes construction. The share of agriculture in employment was 70% in 1978.

[33] Gu and Lundvall (2006).

[34] Zheng et al (2006), p. iii.

[35] In his report to the National People's Congress (NPC), China's Parliament, Chinese Premier Wen Jiaobao predicted an average annual economic growth of 7.5% during the 11th Five-Year Period, which

The new mantra for sustainable economic growth – and hence by implication social and political stability – is "independent innovation" as one mean to achieve "harmonious development", implying that the country's previous development pattern was somewhat "inharmonious". These two concepts are stressed in the current 11th Five-Year Plan (2006-2010). The government set the strategic goal to transform the Peoples' Republic into an "innovative state" in general (*chuangxin xing guojia* 创新型国家) and specifically into one, which relies more on domestic innovation.[36]

As said earlier, this report focuses on China's current innovation capabilities as well as on the strategies involved in upgrading them – with a particular focus on the machinery industry. To understand the challenges and direction of China's future innovation capabilities, the condition of China's current innovation system needs to be explored. This chapter will therefore shed light on the condition of two major elements of an innovation system: The first is business innovation. For an economy to be innovative, it is critical that companies create and absorb knowledge in order to generate economic value. The second element of China's innovation system that this chapter examines is the public sector science and engineering base for innovation, comprising of the research and the educational aspect of public entities. The public R&D sector mainly provides research services to the public, the government or to companies. The education sector shapes the basic and advanced skills of future entrepreneurs and employees.

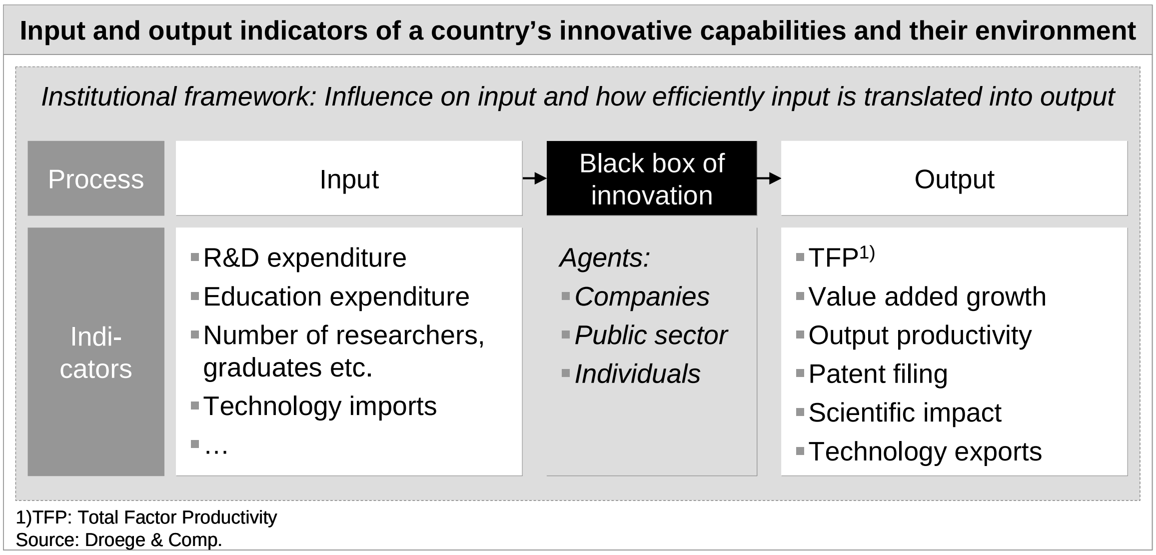


Figure 2: Input and output indicators of a country's innovative capabilities and their institutional environment.

To assess China's innovative capabilities, we need measures. Unfortunately, innovative capabilities are like a black box – which can only be estimated by a variety of indicators for what goes into this black box and what comes out of it

would be two percentage points lower than the average growth during the 10th Five-Year Period (2001-2005). See Zheng et al (2006), p. ii.

36 Zheng et al (2006), p. 5.

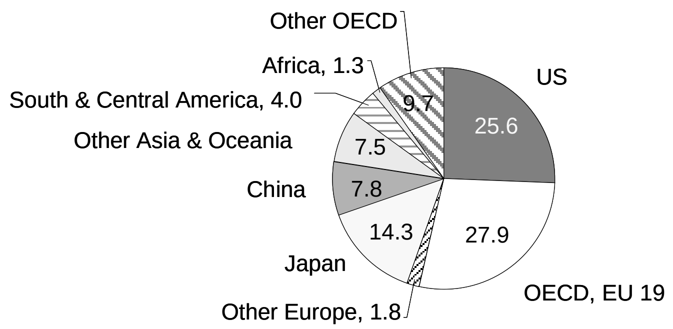
while the capabilities themselves remain largely obscure. By comparing those indicators to other countries, China’s innovation capabilities can be benchmarked. Figure 2 gives an overview of common indicators at hand to measure a country’s innovative capabilities, which will be examined later in this chapter.

2.1 Innovation and knowledge increase in China: National-level evidence

Is China turning into an innovation heavyweight? If it has not always been a heavyweight, it is certainly growing to be one – economically and hence politically as well as militarily. It is uncertain however if China is turning into an *innovative* force to reckon with in the near future. Let us look at the evidence.

China had seen a significant rise in its world share of manufacturing value added from about 1.5% in 1980 to reach nearly 8% in 2002. The latter is comparable to Germany's share in that year. China is the only Non-OECD country among the top 10 manufacturing nations in the world, ranking 3rd after the US and Japan, followed by Germany and France (see Figure 3).[37]

Share in world manufacturing value added (in %, 2002)



Note: Data are converted at exchange rates
Source: Pilat et al. (2006) based on data from OECD, STAN database and UN Statistics Division.

Figure 3: Share in world manufacturing value added, selected countries (2002).

Contribution of technology and innovation to economic growth in China increasing

From a very high-level perspective, three factors contribute to economic growth: Growth in the two main input factors labour and capital as well as a third factor, related to productivity, i.e., how well the input factors labour and capital are used.

Economists argue about whether the main driver for China's undoubtedly impressive economic output growth was due to capital accumulation or labour productivity growth. Combined however, they explain most of the growth in China.[38] These two production input factors have rather little to do with innovation. Capital accumulation refers to growth in fixed capital assets such as factories, machinery, equipment, and buildings, of which China saw plenty. Labour and labour productivity growth in China was largely due to a shift in the country's labour force from agriculture to manufacturing jobs; a pair of hands

[37] Pilat et al. (2006), p. 15, based on OECD data. Among the other BRIC economies Brazil is the 12th, India the 14th and the Russian Federation 15th largest manufacturer in the world.

[38] See overview in Shiu, Heshmati (2006).

tends to produce more value if employed in a factory rather than working on a field.

Aside from capital and labour, there is the third factor influencing output growth, as mentioned above. This factor is referred to as Total Factor Productivity (TFP). Total factor productivity (TFP) growth is the residual that remains after the contribution of labour and capital inputs are already subtracted from total output growth. TFP growth results from either an increase of efficiency or growth due to technological changes. An improved efficiency or better technology level can be interpreted as the result of innovative activities. Hence, we term it – somewhat simplistically – the "innovation/technology component of growth".[39]

Obviously, it would be misleading to compare the share of this innovation component in the growth of a highly developed country like Germany or Japan with that of a developing country's like China simply because the average Chinese is so much poorer in capital than the average German and therefore needs to catch up in terms of capital accumulation.

Country	Period	Output	Capital (%)	Labour (%)	TFP, "innovation/ technology component" (%)
Italy	1950-1973	5.0	32	4	64
France	1950-1973	5.0	32	6	62
W. Germany	1950-1973	6.0	37	8	55
Japan	1950-1973	9.2	34	27	39
Hong Kong	1960-1994	7.3	38	29	33
Taiwan	1960-1994	8.5	48	28	24
China	1960-1994	7.5	41	36	23
Singapore	1960-1994	8.1	54	27	19
South Korea	1960-1994	8.3	52	30	18

Table 1: Contribution of capital, labour and TFP ("innovation/technology component") to growth in the "golden age" of selected countries.[40]

However, we can attempt a historical comparison. Table 1 compares the "golden age" of high economic output growth of selected economies in the west as well as the "East Asian Tigers" - South Korea, Taiwan, Hong Kong and Singapore with that of China. It estimates the drivers of output growth experienced in the respective economies. Growth, as the table suggests, can follow different patterns: The "technology-initiated" pattern of Western European

[39] Fu (2004), p. 6. Li and Handberg (2002) go further and describe it as a technology related factor "Although it consists of a variety of factors, such as institutional efficiency, TFP is usually identified with the level of national technology." Thus, a TFP growth would indicate a growth in the level of national technology. We adopted the broader term of innovation/technology, since a significant share of TFP growth could be caused by institutional reforms.

[40] Li and Handberg (2002) based on Crafts (1998).

countries plus Japan and the "factor-driven" pattern of East Asian countries, including China.[41] In the Western European and Japanese growth experience during their golden age, TFP growth contributed substantially to the overall output growth, in fact, more than any other factor, albeit for Japan, the contribution is not as pronounced. For the East Asian Tiger countries and China, capital and labour growth was a more important growth factor.

The period for China's growth contribution factors considered in the table was from 1960-1994. However, 1994 was a long time ago and there are indications that innovative activities in China are picking up. Not least did the TFP contribution to overall output growth increase faster than the other factors from 1993 to 2004 and – according to official estimates – seems to have reached the 40% mark.[42] However, there is more evidence for innovation activities on the rise in China:

China's total R&D expenditure rose dramatically

One of the commonly cited input indicators related to the innovation capabilities of a country is R&D expenditure, presenting a benchmark for how much the country invests into building the national innovation system. Despite being used extensively in all sorts of arguments, R&D expenditure is by no means an all-explaining figure especially as it does not tell us anything about the result of this investment in terms of economic value added or knowledge creation for that matter. Having said that, one could assume that the more a country spends on R&D the more output one should see even if some countries may be more efficient with their investments than others are.

Gross domestic expenditure on R&D (GERD) is the sum of R&D undertaken by businesses, the government, higher education institutions and private non-profit organisations, representing the total amount of R&D undertaken in an economy. According to statistics of the OECD, China's GERD surpassed that of Germany in 2002 and that of Japan in 2006 (see Figure 4).[43] In 2006, it amounted to USD 136 billion, adjusted for purchasing power parity (PPP), ranking second only to the US with an expenditure of USD 330 billion. The cumulated GERD of the EU-25 ranges in between these two single country figures, at an estimated USD 230 billion. From 1995 to 2006, China's absolute R&D expenditure rose by 21% annually compared to that of the US's and Germany's which grew by only 5%.

[41] Li and Handberg (2002). There is some discussion about the actual TFP growth contribution level for the case of China. See same article.

[42] Bhattasali (2001) mentions various estimates, see also Whalley and Zhou (2007). MOST press release (17 March 2006), cites Xu Guanhua, then Minister of Science and Technology in a press conference held on 10 March 2006 in the course of the Fourth Session of the Tenth National People's Congress. "First of all, economic growth primarily depends on labour force, capital and S&T progresses. Estimates show that for the GDP of China to increase by two folds by 2020, the contribution rate of S&T progress must be raised from the current 39% up to 60%, even if China maintains a 40% investment rate in the future."

[43] All R&D figures OECD (2006) or Droege & Comp. estimates based on OECD publications, unless mentioned otherwise.

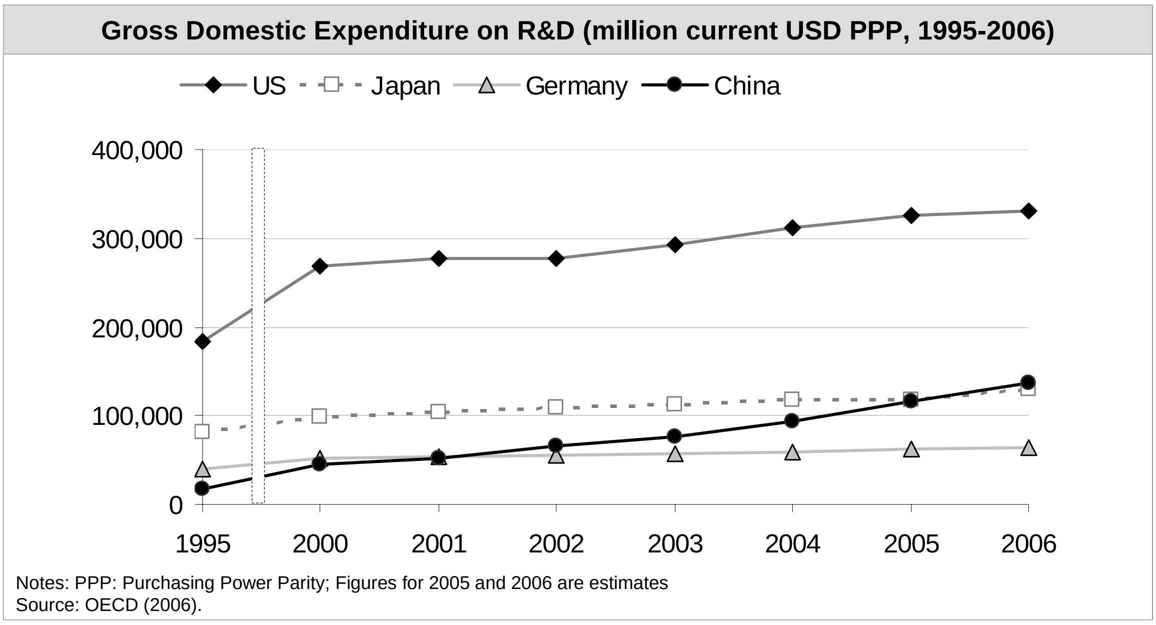


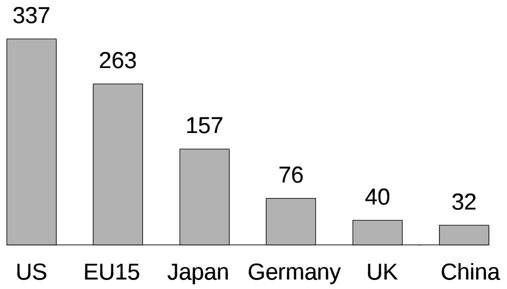
Figure 4: Gross Domestic Expenditure on R&D, adjusted for purchasing power parity. Comparison of US, Japan, Germany and China (1995-2006).

As mentioned, these figures are weighted with a multiple to adjust for differences in purchasing power. As OECD acknowledges, in the case of China this method probably leads to an overestimation of R&D expenditures.[44] Chinese laboratories or company R&D departments probably purchase at least part of their advanced equipment abroad – in which case the market exchange rate conversion would be more suitable in order to reflect the Chinese Yuan's *international* purchasing power. However, just to convert the figures expressed in Chinese RMB at market exchange rates (see Figure 5) will lead to an underestimation of China's total R&D expenditure, since people are a major factor within these expenditures and the wage levels as well as other costs in China are obviously much lower than elsewhere.[45] Therefore, a more accurate value to estimate China's spending on R&D lies somewhere between the purchasing power adjusted measures and the nominal values. Although China surpassed Germany only in PPP adjusted terms, its nominal spending is approaching Germany's spending fast as well.

[44] Not to mention the initial difficulty of different purchasing power levels in different Chinese regions. A dollar spent in Shanghai will certainly buy you less than a dollar spent in the western Chinese city of Kashgar near the border to Kyrgyztan.

[45] Of China's R&D expenditure in 2005, 21% were spent on labour, 15% on equipment and 64% on operating expenses.

Gross Domestic Expenditure on R&D (billion USD at market exchange rates, 2005)



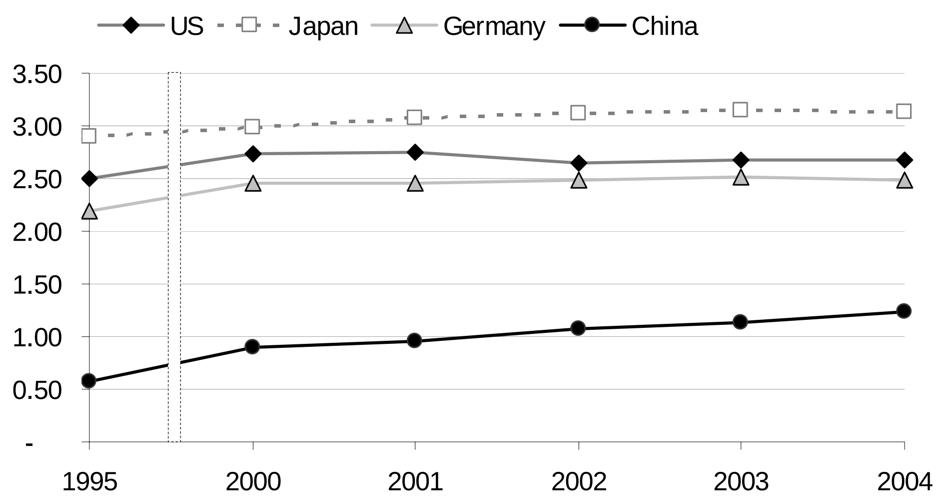
Source: Eurostat (12 January 2007).

Figure 5: Gross Domestic Expenditure on R&D, at market exchange rates Comparison of US, Japan, Germany and China as well as EU15.

However, depth of R&D appears lacklustre

The intensity of GERD is an indicator of an economy's overall commitment to growth in R&D relative to its economic growth. China's R&D intensity has more than doubled from 0.6 to 1.3% of GDP since 1995.[46] By contrast, GERD intensity in Germany, US and Japan is higher than 2.5%, indicating that China's national commitment to R&D is still much lower than that of more developed countries (see Figure 6).

Intensity of Gross Domestic Expenditure on R&D (% of GDP, 1995-2004)



Source: OECD (2006).

Figure 6: Intensity of Gross Domestic Expenditure on R&D. Comparison of US, Japan, Germany and China.

R&D intensity is highly associated with GDP per capita, which is still very low in China. Among its country peers, China does not fare badly with respect to R&D intensity; in fact, it exceeds the average for a low and low-middle income

46 OECD (2006).

country.[47] Notably, China is committed to change its domestic R&D investment intensity. China's State Council recently stated that it plans to lift GERD intensity to 2.5% by 2020, which would equal to an annual average investment of USD 116 billion.[48]

R&D system's structure became more competitive after 1985: Business R&D took centre stage

In theory, a socialist planned economy aims at a relatively perfect division of labour, thereby eliminating competition on a large scale. The reasoning goes as follows: Companies mostly do not create internal competition among functions, as it would be a waste of productive resources, for example to have several competing and independent R&D centres in one company researching into the same topic. For an economy to operate like a single company, it would "only" need good management – the government and its planning activities – to bring the divided labour back together to create economic value.

Prior to 1985, the Chinese "national R&D department" consisted of more than 7,000 research institutes employing some 323,000 scientists and engineers.[49] Different levels of public administration took care of linking these professional innovators to relevant production entities. The organisational separation proved powerful in inhibiting vital interconnections between the two spheres, thereby hampering the economy's innovativeness. In recognition of this major weakness, the Chinese government launched a series of reforms of the science and technology system in order to restore the *"organic linkage between scientific research and production"* in 1985.[50] Today, the number of R&D institutes stands at just above 4,000.[51] In the past 2 decades, a large share of R&D institute sector turned into businesses or merged with companies.

With the declining role of research institutes business R&D gained importance: The business sector's share of R&D expenditure stepped up from 30% in 1994 to 67% in 2005, thereby matching Germany's business share in R&D expenditure to the percentage point.[52] Since business innovation is crucial for an economy as a whole to be innovative, we should expect a positive impact on China's innovation power – if firms are ready to contribute.[53]

[47] OECD (2006-1).

[48] RMB 900 billion p.a. see Science and Development Network (10 February 2006).

[49] According to Gu and Lundvall (2006) by 1980 there were 4,690 research institutes at the central, provincial and regional/city level as well as an additional 3,000 county level institutes.

[50] Gu and Lundvall (2006), quoting the then Chinese Prime Minister Zhao Ziyang (1985).

[51] OECD (2007), p. 30.

[52] Schwaag Serger and Breidne (2007), p. 139. German figure from Eurostat (12 January 2007).

[53] Chapter 2.2. investigates business sector innovation in China in depth.

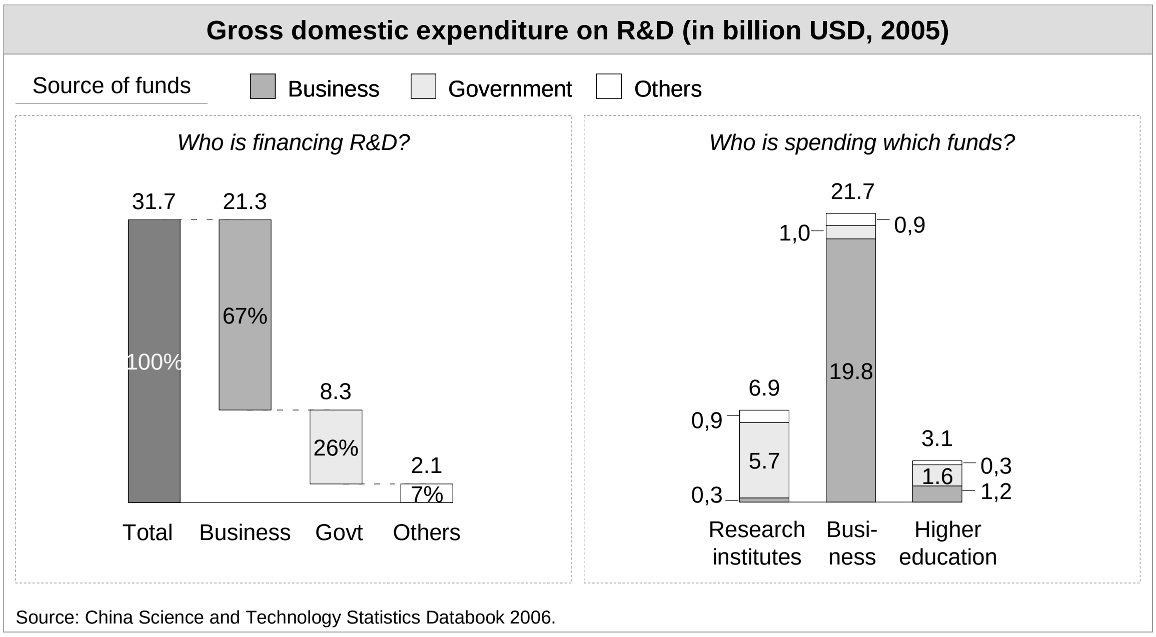


Figure 7: Gross domestic expenditure on R&D (GERD) in USD billion in 2005.

As Figure 7 shows, business R&D financed by companies largely stays in companies, to a much smaller extend it flows into institutes of higher education and even less into research institutes, which receive the bulk of publicly financed R&D expenditure.

There is little "R" and a lot of "D" in China's R&D

Chinese statistics distinguish among three types of research:

- *Basic research:* Basic research is the search for unique, new findings that in contrast to applied research are generally applicable. Basic research, which is very theoretical, is mostly published in the form of research articles.
- *Applied research:* Applied research's starting point is basic research, which is developed further and applied to only single specific objects and targets. That is, applied research is more practical and is likely to be published in the form of new fundamental models.
- *Product development:* Product development is even more practical than applied research, because it utilizes the acquired knowledge from basic and applied research to come up with new products or new product specifications. Another prominent way to publish product developments is in the form of patents.

The focus of the Chinese national R&D capacities lies in product development; some 77% of the funding went into this type of research in 2005. Another 18% were associated with applied research, while the remainder of 5% of funding were spent on basic research. In contrast, the US, for example, spent 19% of their much larger national research budget on basic science while Japan channelled 15% to basic research (see Figure 8). Basic research is associated with longer-term projects, more risks but also potentially ground breaking results or patentable inventions. Since comparably little funding is allocated to these type of projects, it may explain China's insignificance in this field compared to other nations.

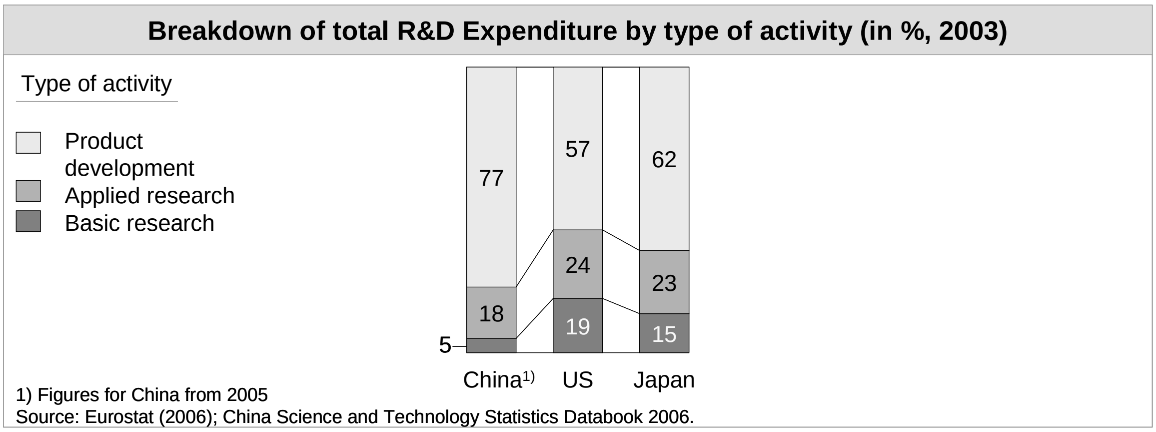


Figure 8: Breakdown of total R&D Expenditure by type of activity.

In theory, one would expect the state-funded Chinese research institutes to account for the lion's share of basic research. However, just like research facilities, colleges and universities spent USD 700 million of their much smaller budget on basic research. Potentially that indicates a larger basic research prowess of universities compared to public research institutes in China.

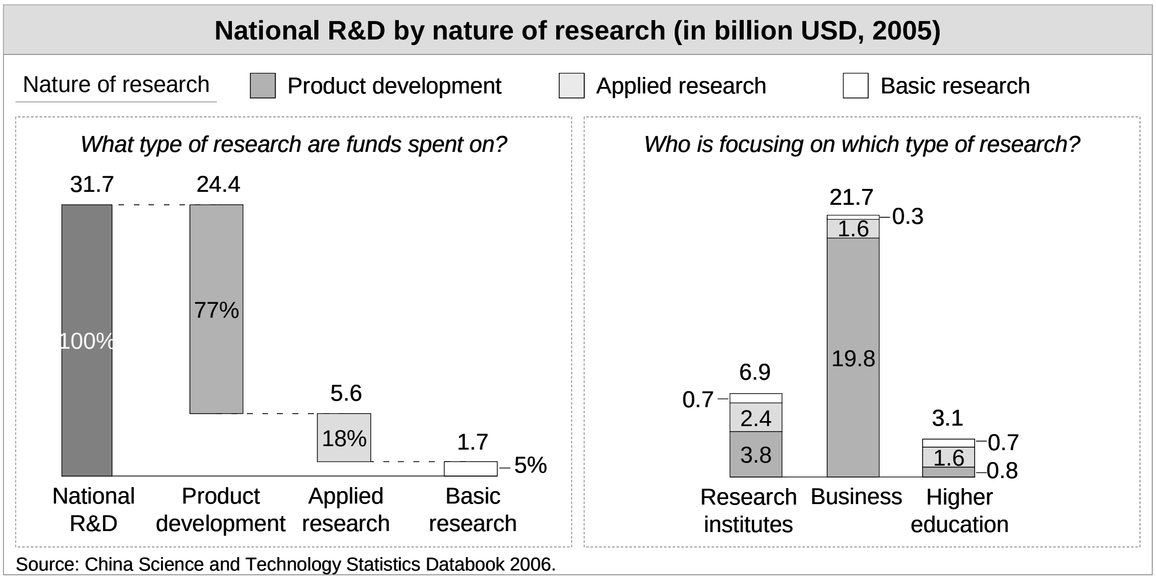


Figure 9: National R&D by nature of research.

The main part of product development, the lowest risk – and most direct category of research, is undertaken by companies in China, which was to be expected, as businesses are usually not interested in "rocket science" but rather in pragmatic research that can be easily translated into products. Interestingly, some 55% of research institute budgets in China are spent on product development as well. This may be a relict of the past when public research institutes still served as the R&D centre of (state-owned) companies in China. The extent of co-operation between businesses and public R&D institutes in China remains high compared to other countries.

Number of people employed in R&D grew steadily

R&D expenditure is but one important input factor into the innovation system, skilled people are another. The number of researchers employed in different R&D activities increased by 77% since 1995, reaching 926,000 in 2004.[54] By that measure, only the US surpasses China (see Figure 10), employing 1.3 million scientists. Yet taking China's very large population into account, the intensity of R&D personnel (ratio of R&D staff and total staff) is low, equalling to about one seventh of the OECD average.

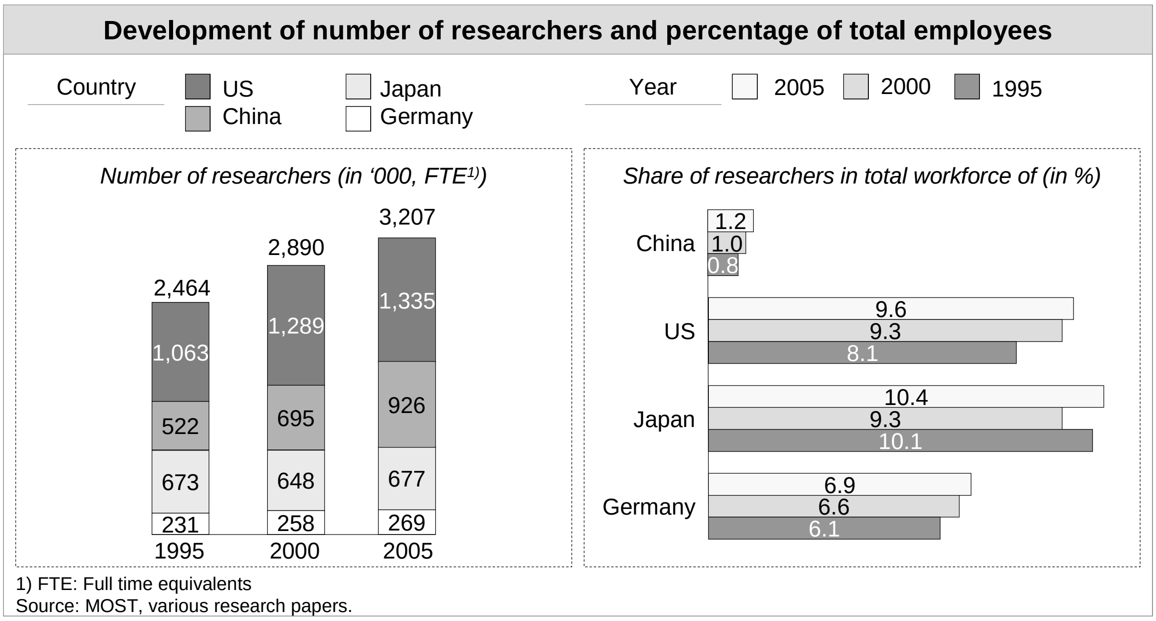


Figure 10: Development of number of researchers and percentage of total employees.

While R&D expenditure had risen exponentially, the number of people engaged in research followed a linear trend between 1992 and 2003.[55] This divergence of trends suggests that research funds spent on capital equipment grew faster than the ones used to pay labour input.

Patent filing in China picked up, but large share of patented inventions is filed by foreigners

So far, we looked into selected input factors of China's innovation system on a macro-level, such as R&D expenditure and labour input. An important output measure is for example the number of patents granted. While one could argue that not all innovations are patented, patents are still a good proxy for the

[54] OECD (2006).

[55] Jin and Rousseau (2005).

change of innovative activity when observed over a certain period. Furthermore, they indicate the innovation or novelty was significant enough to be worth protecting.[56]

There are three types of patents in China's patent system: Invention, utility model and design.

- *An invention patent* refers to a new technical solution relating to a product, a process or an improvement; the patent is applicable for a physical product or a new method for manufacturing or operation. Novelty, inventiveness and practical applicability are prerequisites features for the patent. The term of protection for an invention patent is 20 years from the filing date.
- *A utility model patent* can be granted for a new technical solution, for a product shape, structure or a combination thereof for practical use. A utility model patent entails more practical applicability than novelty or inventiveness compared with an invention patent. The utility model patent is only applicable for a product. Its term of protection is 10 years from the filing date.
- *A design patent* is not a technical solution but an industrial design for a product's appearance including the shape, colour, pattern or texture, or their combination of a product. The term of protection for a design patent is 10 years from the filing date.

Common patent statistics distinguish between patent applications and patents grants each year. According to the World Intellectual Property Organization China ranks third after the US and Japan worldwide in terms of filing patent applications. Filing reached 573,000 in 2006. China's patent filing applications have grown more than 20% annually for the past 8 years. The grand total of filings since the Chinese Patent Law came into force in 1985 amounts to 3 million.[57]

However, a patent applied for is not a patent granted, so the figures for actual patented rights are lower, amounting to 268,000 in 2006 (see Figure 11). Nearly 80% of these granted patents were utility models and designs, reflecting that China's patent applicants focus on smaller modifications to existing products. As mentioned before, an invention patent requires a higher degree of novelty and inventiveness, which would also be crucial criteria to gauge China's capabilities domestic to create original innovations.

[56] This assumes that there is a functioning intellectual property right protection in place. Otherwise filing patents may be counterproductive, since publishing the respective information would increase the likelihood of compromising one's invention.

[57] China's first patent was granted to Mr. HU Guohua, a Beijing engineer on April 1st, 1985. It took 15 years for China to file the first 1 million patents on Nov. 11th, 2001; the number of patent rocketed up to 2 million only 3 years later on Mar. 12th, 2004; only two years later on Jun. 26, 2006 the number reached 3 million.

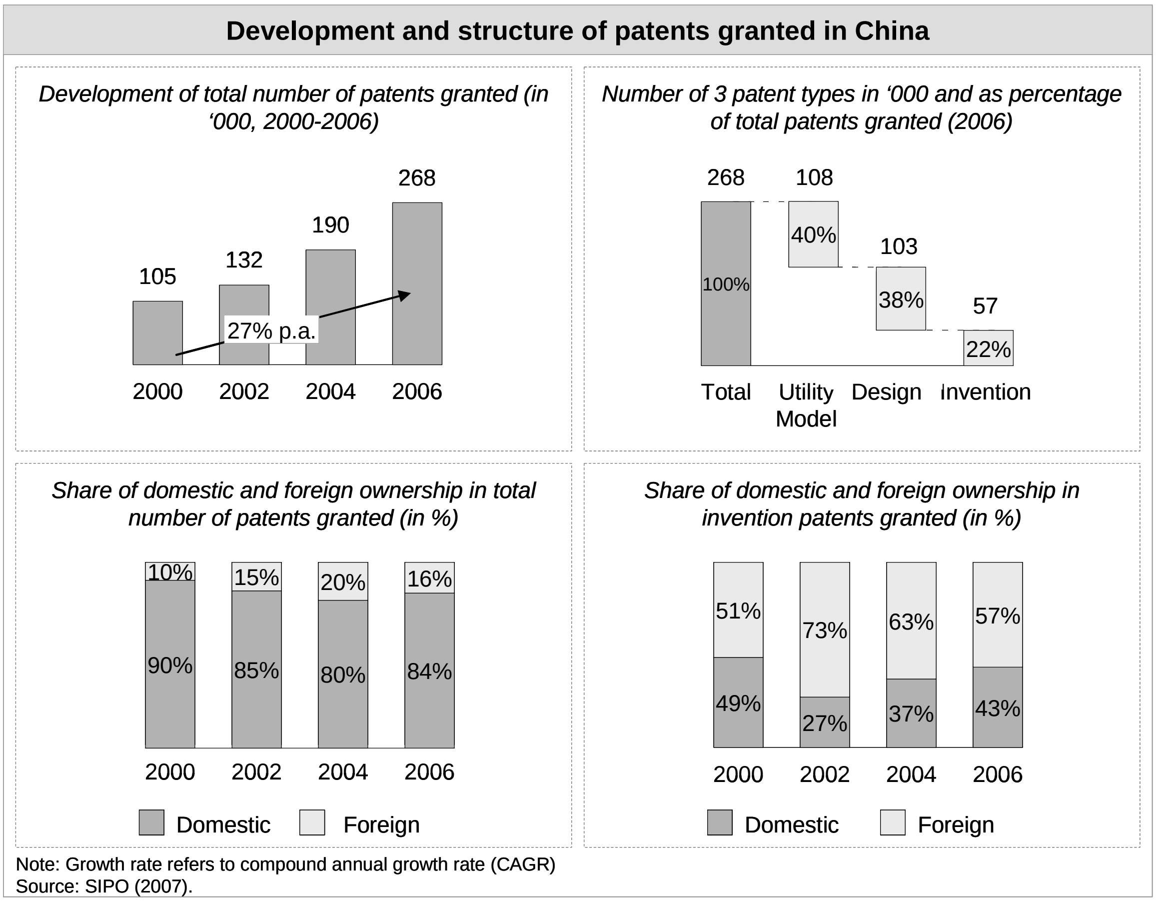


Figure 11: Development and structure of patents granted in China.

Scrutinising invention patents, which account for 22% of the patents granted in China in 2006, foreign ownership shares deviate from the norm. The average foreign ownership share for all three patent types combined fluctuated between 10 and 20% between 2000 and 2006 (see Figure 11). By comparison, between 51 and 73% of the invention patents granted in China belonged to foreign owners in that period.[58] Foreign ownership in a country's invention patents is not unusual, but compared to China, the share of foreign applicant for invention patents in Germany, US and Japan is relatively low (see Figure 12).

The majority of Chinese invention patents are from the fields of Chinese traditional medicine and food and beverage items; while foreign owned invention patents concentrated in high-tech industries such as wireless transmission, ICT and genetic engineering which gives further evidence for China not being in the position yet to qualify as a technology giant in its own right.

[58] SIPO (2007), online statistics.

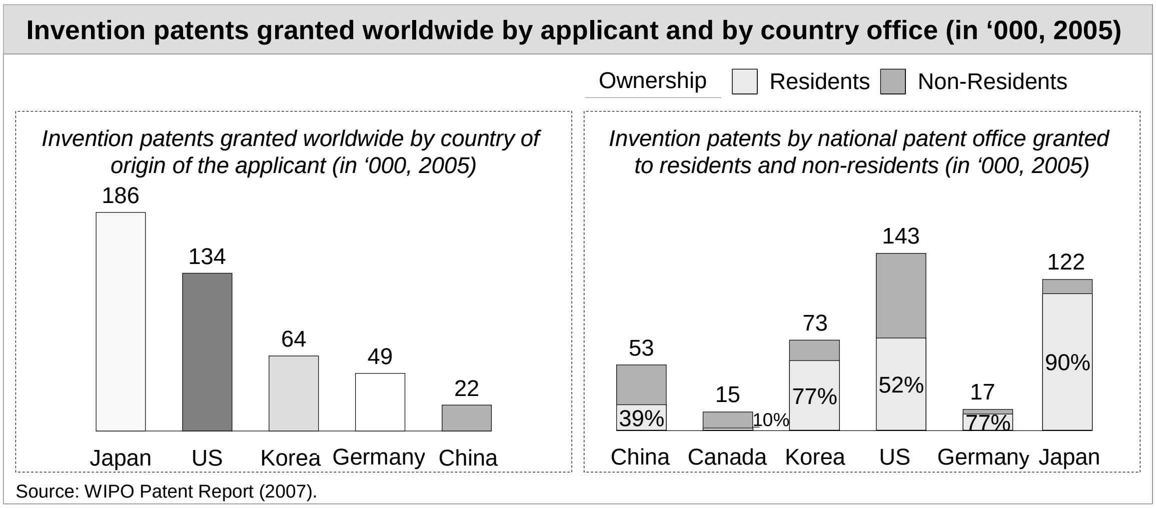


Figure 12: Invention patents granted worldwide by applicant and by country office (in '000, 2005).

There are several reasons for these baffling figures, which are frequently cited by Chinese authorities and media alike, not all of which have something to do with the inferiority of the Chinese National Innovation System:

- *The law of attraction:* In order to have an invention protected in China, foreign patent holders must register their patent in China at the Chinese Patent Office (SIPO). They will only do that if the patent is worth the hassle, so it should be very relevant for the company or other patent holder – hence it is more likely to be an invention rather than a minor modification of some product or design. This again will only happen, if China is an attractive market to sell the patented knowledge to – and it is attractive indeed for various products and technologies. Hence, China should have an above average share of foreign invention patent.
- *Little in – little out:* Chinese private companies generally under invest in R&D. From interviews conducted with Chinese mechanical machinery companies in the years 2004 and 2005 for IMPULS Stiftung, we found that on average less than 1% of these companies' turnover was invested in R&D activities. The intensity of total countrywide R&D expenditure in China is also lower than in developed countries. Furthermore, there is less expenditure per research personnel, meaning that people work with less efficient tools and other means. Data of the Ministry of Science and Technology show that USD 16,800 are spent by state-owned LMEs per research staff compared with USD 31,000 for their counterparts in MNCs in China.[59]
- *Add some inefficiency:* As we will see in Chapter 2, spending on innovation inputs is without a doubt important but efficiency in using these resources makes a difference. For example, the average Chinese SOE needs 137 people (research staff) for each invention patent. MNCs

[59] MOST Circular (2006).

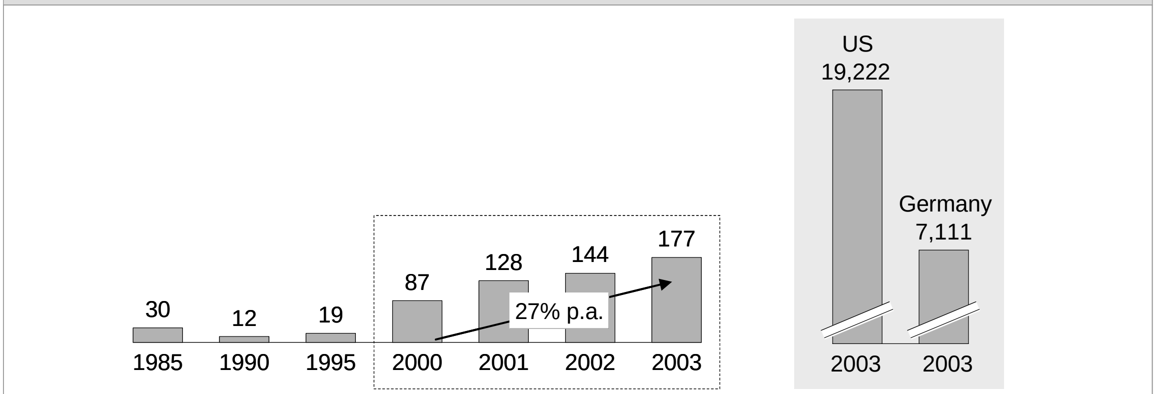
in China need 23.[60] That could speak for superior capabilities of foreign MNCs compared to domestic SOEs. Aside from better equipment, MNCs tend to be more generous, hence more successful attracting the crème de la crème of local talents.

- *Attention - disclosure.* A patent application process involves the disclosure of technical and other specifications to the public. Under the precarious Chinese IPR protection regime, patent rights are still hard to enforce. Thus, Chinese inventors' may think twice before they patent anything since it may be less risky to protect their respective ideas by other means.

Chinese citizens start to file for patents abroad, indicating a better quality of patents

Chinese inventions can be protected at home or internationally. Since the leading world economies markets are the US, the European Union and Japan, patent indicators used by the OECD are based on "triadic patent families" (TPF). These patent families are a set of patents granted at the respective patent offices USPTO, EPO and JPO sharing common features. Such a data pooling has the advantage of diminishing the home bias of single patent office data.[61] Patents included in triadic patent families tend to have higher values as patentees will not make the effort and bear the costs of applying for or extending a patent in these three markets unless the patent is worth protecting.

Number of Triadic Patent Families filed by Chinese inventors (numbers,1985-2003)



Note: Number of Triadic Patent Families by earliest priority date and country of residence of the inventors, estimates for 2000-2003
Note: Growth rate refers to compound annual growth rate (CAGR)
Source: OECD (2006).

Figure 13: Number of Triadic Patent Families filed by Chinese inventors.

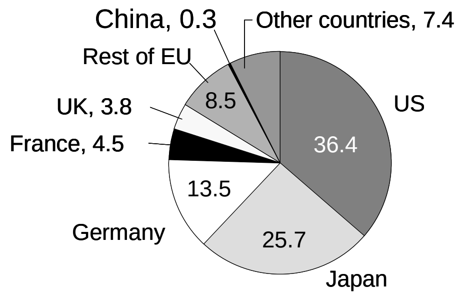
According to these patent data, Asia and especially China has experienced a surge in innovative activities, with China even entering the top 20 among the countries of origin in 2003. It has thus gained 10 positions since 1995. Despite

[60] MOST Circular (2006).

[61] The home bias towards patents of residents of the European Union, the US and Japan remains, since EPO, USTPO and JPO are obviously the respective home countries. Data about triadic patent families in this chapter are from OECD (2006a) unless mentioned otherwise.

China's share in patent filing multiplied by 10 between 1991 and 2003, the total number of patents from China remains relatively low at 0.3% of the TPF patents or 177 patents – compared to for example more than 19,200 from the US or 7,100 from Germany.

Share of top 5 and selected other countries in total Triadic Patent Families (in %, 2003)



Source: OECD (2006-3).

Figure 14: Share of top 5 and selected other countries in total triadic patent families (%).

As the Chinese government uses IPRs owned by Chinese citizens as one of the main indicators for the progress of China's innovation capabilities, nationals and domestic enterprises are encouraged to file for patents abroad. Thus, in March 2007, SIPO established a special fund to support Chinese citizens and companies interested to protect their IPR in international markets. Additionally, local governments chip in money for international patenting: For example, the Beijing government subsidises local companies with up to almost USD 65,000 for each qualified enterprise. Many Chinese universities and research institutes also have similar funds to assist researchers to apply for patents both in China and abroad. Hence, more patent filing by Chinese IPR owners are to be expected in the future.

Citation wanted: Quality of scientific papers remains low

The number of peer-reviewed scientific papers that have been published by its researchers often gauges a country's scientific impact. The impact is measured in three basic S&T output indicators: Number of papers, number of citations and average citations per paper. The total number of papers gives a rough quantification of a country's overall scientific community, the number of citations reflects the significance of the papers and the average citations can be used to assess the quality of the papers. However, these indicators may be misleading as factors such as the population of the country as well as the official language of the country may affect the results of the indicators.

China enjoys a steady growth in terms of total number of papers collected by SCI, EI and ISTP[62], rising from 11th position in 1996 to 4th position, overtaking

[62] SCI: Science Citation Index, an indicator of current and retrospective bibliographic information, author abstracts, and cited references of the world's leading scholarly science and technical journals mainly on basic research. EI: Engineering Index, a major indicator for engineering periodicals, journals and papers around the world. ISTP: Index to Scientific & Technical Proceedings, an indicator of proceedings papers delivered at prestigious international scientific and technology conferences.

Germany in 2005. Like Chinese patent applications, scientific papers by Chinese authors are increasing with striking speed but the quality of the papers remains low as shown by the low citation rates of Chinese papers internationally. According to SCI statistics, among 145 countries, China now ranks 13 by total citations in a ten-year window (1996-2006) but only ranks 117th for average citations per paper. That means very few researchers worldwide refer to Chinese peers in their corresponding fields. One exceptional case is China's material science, and in particularly nanotechnology, field which currently ranks among the top nations in the world. A paper by Li Wenzhi, a nanotechnology researcher from China Academy of Science, published in the journal *Science* in 1996, has been cited more than 767 times by many leading scientists in this field.

Rank	Country	Number of papers	% of worldwide total	Cumulated rank of citation (1996-2006) referring to SCI
1	United States	666,360	29.9	1
2	United Kingdom	160,595	7.2	2
3	Japan	159,060	1.1	4
4	China	153,374	6.9	13
5	Germany	148,570	6.7	3

Table 2: Top 5 countries in scientific paper output (2005), referring to SCI, EI and ISTP.[63]

Chinese universities are the main contributors for both China's domestic as well as international science papers. Although Chinese enterprises are the largest R&D expenditure providers today, their scientific papers are negligible: 4.6% of domestic papers came from the industry. This highlights the Chinese industry's R&D focus on product development and limited interests in basic research as in general, scientific papers mainly indicates a country's basic research performance.

However, with its steadily increasing R&D expenditure, a very large base of scientists, engineers, and strong government policies encouraging innovation, China is expected to improve its science papers' quality and at the same time, increasing the quantity in the future.

Cross-border technology transfers unidirectional: China on the receiving end

To assess China's innovation performance on the national level, so far we presented selected input factors into the "innovation black box" like R&D expenditure and people input as well as patents as an output factor. Technology balance of payments (TBP) is a construct of both input and output indicators. TBP measures international transfers of technology, including licenses, patents,

[63] China's Science Papers Statistics Report (2005); China Science and Technology Databook (2006)

know-how and research and technical assistance.[64] TBP reflect a country's ability to sell its technology to other countries and absorb foreign technologies. One should be careful to attribute a deficit position with low competitiveness since high values of imports and exports merely suggest a high level of integration into the global economy.

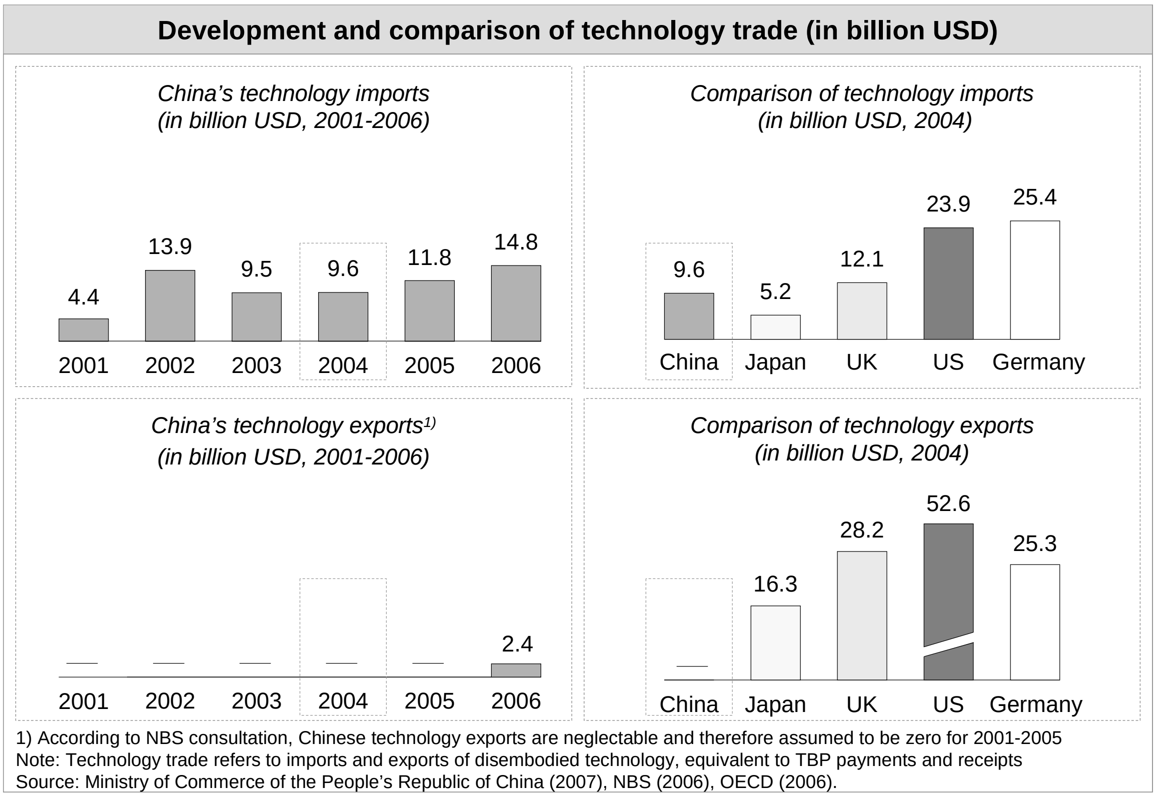


Figure 15: Development of China's technology trade and comparison to other countries.

Unlike R&D expenditure in a company where the output is much less certain, TBP flows refer to disembodied technologies that are production ready. For many countries, these cross-border transfers of technology usually go in both directions. Germany, for example, received USD 25.3 billion for technology exports and paid USD 25.4 billion for technology imports, resulting in a small deficit in TBP in 2004.[65] The US leads the list of the biggest technology exporters worldwide; delivering technology worth some USD 52.6 billion to other countries, followed by the U.K., Germany and Japan (see Figure 15). China's exports are virtually non-existent in the comparable year with only some activity starting in 2006.[66] As most of these transfers of "disembodied technology" are operations between parent companies and affiliates, we assume, this is a sign

[64] See OECD (1999).

[65] Figures from OECD (2006). 2004 figures for technology exports (receipts) and imports (payments) are OECD estimates.

[66] Figures from MOST (2007).

of foreign-invested and internationally integrated R&D centres of large MNCs producing first results.[67]

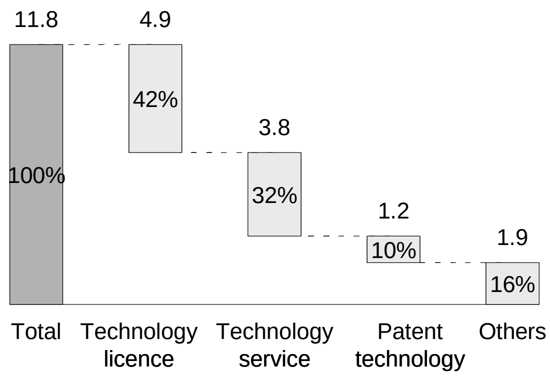
For technology importers, Germany leads the pack with large imports of USD 25.4 billion in 2004 (see Figure 15). Meanwhile China's technology imports fall between that of Japan and Great Britain.

China's total TBP (exports minus imports) was negative in 2004 and on a rather high level compared to OECD countries, amounting to USD 9.9 billion.[68] In fact, China had been in deficit for the past three decades. China's large TBP deficit stands, in contrast to its big trade surplus, tightly tied to China's current development stage: China has realised its aspirations to become a global trade power with foreign-companies playing a crucial role in this development. However, it still has a limited knowledge base and foreign companies – including large MNCs – and has only recently started to contribute more to the Chinese homegrown innovation by setting up R&D centres.

In 2006, according to data from the Ministry of Commerce, China signed 10,538 technology import contracts with a total contract value of USD 22 billion, a 15.6% increase as opposed to the previous year and a new record for technology imports. The share of disembodied technology accounted for more than two thirds of the total contract value, or USD 14.8 billion (see again Figure 15).

Of the total Chinese technology import value in 2005, 42% fell under technology licenses, while technology consulting and service accounted for another 32%, and patents for 10%. For the past six years, the EU, Japan and the US were the three largest technology exporters to China.

Breakdown of China's technology imports (disembodied value in billion USD, 2005)



Note: Others include trade mark licenses, computer software, Joint-ventures and cooperative production and equipment
Source: China Science and Technology Statistics Databook 2006.

Figure 16: Breakdown of China's technology imports (disembodied value in billion USD, 2005).

[67] OECD (1999).

[68] OECD (2006) list 2004 figures for a number of OECD countries. However, a number of countries – including Korea, Singapore and some Eastern European countries among others – are missing. None of these countries come close to China's deficit in 2004, though Korea had a deficit of USD 2.4 billion in 2003.

Creation of lighthouses: Innovativeness is limited to Eastern Region

We have pointed out many national-level developments in China showing a recent surge in innovative capabilities, albeit virtually all of them starting from a low level. However, there is a large divergence of innovativeness with respect to geographies in China. Figure 17 summarises the characteristics of the three distinct "innovation stages" of the relatively advanced Eastern Region followed by the fast-catching-up Central Region, and the rather backward Western Region.

The Chinese geographic growth and innovation pattern is not unique although it worries Chinese politicians, since an uneven economic development results in an uneven distribution of wealth in China. Yet economies usually develop in clusters - where buyer and supplier relationships are present and companies can access common inputs (i.e., skilled workers, fresh graduates from local universities, infrastructure, and finance) or supply common customers at lowered transaction costs.

China is clearly dominated by industrial clusters – geographic agglomerations of enterprises in a particular industry, their suppliers and their customers that gain competitive advantages through being located close to each other. Industry clusters create "a mixture of cooperation and competition that can give rise to vibrant local economies".[69] China's Eastern Region has developed major industry clusters for example the Yangtze River Delta, the Pearl River Delta and the Bohai-Rim region in the north east, where companies are clustered and able to take advantage of the skills and capabilities, level of specialisation and resources locally available. According to our interviewee, a professor of economics at the renowned Shanghai Jiaotong University, these three industrial clusters developed different competencies. While the Bohai-Rim cluster is relatively advanced in R&D, the Yangtze River Delta excels in commercialising technologies and Pearl Delta is believed to have great innovation potential given its concentrated high-tech industries and new business models.

[69] LI & FUNG RESEARCH CENTRE (May 2006).

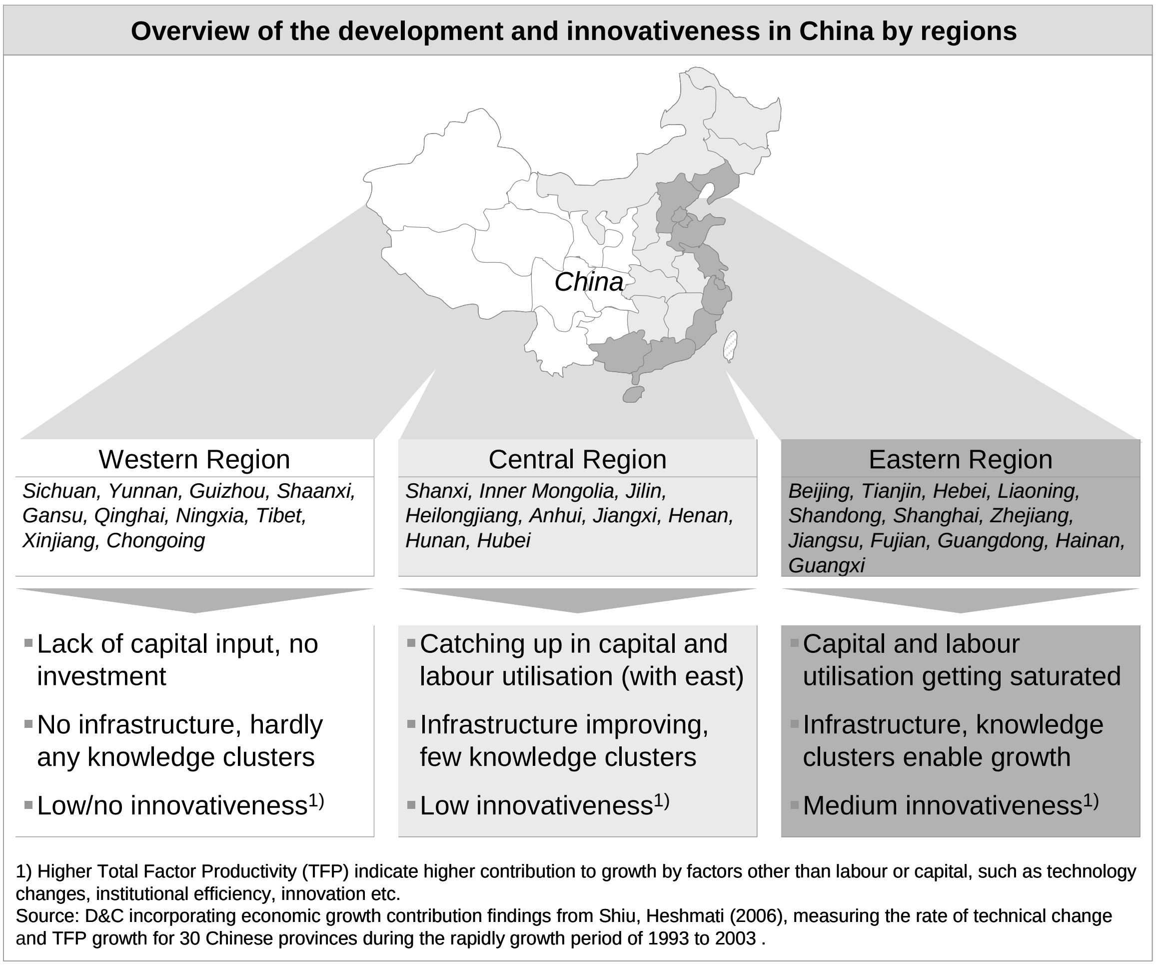


Figure 17: Overview of the development and innovativeness in China by regions.

As collaboration and competition between companies, institutes, universities and authorities is enhanced in China's east with its respective clusters, it is there that knowledge absorption and innovative capabilities of companies and their suppliers have picked up most.[70] Thus, high-tech industrial clusters are only to be found in the East, namely close to agglomerations of research institutes and universities. These types of clusters have a critical impact on the National Innovation System.

The role model of high-tech industrial clusters in China is Zhonguancun in Beijing that is situated close to high-level public research facilities of the Chinese Academy of Science as well as close to top universities such as Beijing and Tsinghua University.[71] Our interview participant at the Division of High-Tech Industries of the Beijing Municipal Commission of Development and Reform

[70] There is a measurable difference in the "innovation/technology component" of growth (Total Factor Productivity growth) contribution in output growth between the three Chinese regions. Also see Table 1 in this study and Shiu, Heshmati (2006).

[71] LI & FUNG RESEARCH CENTRE (May 2006), p. 6. Due to its dependency on public sector research facilities providing scientists and capital, Zhonguancun – unlike other industrial clusters in China – is dominated by SOEs.

pointed out that Beijing in general would have the greatest innovation potential among other Chinese cities citing various statistics:

- Beijing's R&D expenditure as a percentage of the local GDP was 5.5%, followed by Shanghai at 2.5%; Beijing's R&D expenditure growth rate was estimated at 20% per year for the past 5 years
- Beijing accounts for about one-third of China's national key labs and national engineering centres
- High-tech industries' contribution to GDP stands at 20% in 2006

There are various clusters in the Eastern Regions specialising in machinery production, for example Beijing and Dalian for machine tools and heavy machinery; Wenzhou for valves and general-purpose machinery; Hangzhou for large-scale machinery; Suzhou for knitting machinery and many others.[72]

China's Central Region is profiting from its proximity to the developed Eastern Region and very recently experienced an influx of capital investment from companies trying to lower their operating costs within China by moving further inland. Investment originates mainly from domestic companies but foreign investment also contributed to an upswing in this region. Infrastructure improvements have done their share to support the economic development that usually precedes innovative capability upgrading. China's Western Region however was left out of the positive development so far. Currently the region lacks clusters, which could serve as a seed for a local innovation capabilities to grow.

In this section, we looked into national-level evidence of innovative activities in China picking up. Various input and output factors of the National Innovation System were described in detail. It became apparent that China is indeed improving its innovative capabilities at a fast rate at least in some regions – but the absolute level of the indicators still compares unfavourably with developed countries. The following sections move away from the national level and examine the following major contributors to innovation: Businesses and the public sector, the latter comprising the public research and education system. Both business and public sector innovative capabilities are greatly enhanced by "issues of transfer and absorption of technology, knowledge and skills".[73] Therefore, these issues will be further examined in the following section.

[72] LI & FUNG RESEARCH CENTRE (May 2006), p. 9.

[73] OECD Oslo Manual (1997), p.18.

2.2 Business innovation in China

Innovation must be eventually commercialised in order to result in value added and companies are oftentimes the main drivers of commercialisation. Companies typically pursue several types of innovations (see Box 1).

Box 1: Innovation types within a company

Business innovation can change the products/services offered, the markets sold to and the way the organisation produces/delivers their products and services.

- Products and services innovation: Innovation that changes the current products and services offered by the company
- Market innovation: Innovation that ventures into previously not covered markets or increases market penetration of the current customer base
- Operational innovation: Innovation that improves processes to improve the efficiency of how products and services are created or delivered

None of these activities is exclusive; in fact, it is more about the right mix of innovative activities across these areas that make companies successful innovators.

The section of business innovation in China will be structured as follows: First, we will discuss a few main output indicators that are linked to innovative capabilities in Chinese businesses. Thereafter, we will look at two innovation perspectives of the firm - the internal and the external ones. Internal refers to the firm's own resources to innovate such as capital, labour and organisational efficiency. The external perspective explores the dimensions capital, labour and knowledge transfer issues between domestic companies to other domestic entities and thereafter, between the Chinese business sector and other countries.

However, let us first investigate selected indicators of a growing (international) competitiveness and potentially innovativeness of companies in China. We use output productivity and export performance and patenting as overall company performance measures that could indicate enhanced innovation capabilities.

Output productivity in the Chinese machinery industry grew fast, however factor inputs account for a large share of its growth

Output productivity in the machinery sector, measured in production output value per employee, surged in the period of 2002 to 2006 (see Figure 18).[74] On

[74] The figure distinguishes machinery into two segments power-generating equipment and mechanical machinery and equipment since both industry segments have rather different dynamics. The former tends to feature larger companies in terms of sales, especially foreign-invested enterprises (FIEs) seem to feature relatively high average sales figures compared to domestic private and state-owned companies. FIEs in power-generating equipment accounted for 18% of the companies but for 33% of the sales value in 2006. 72% of these companies were private Chinese businesses. Since power generation facilities in China are usually government-related, the government has much more impact on this part of the industry. Preferential treatment of local companies and technology transfers from foreign co-operation partners are therefore much easier to implement. Mechanical machinery and equipment companies on the other hand

average the output productivity in the power-generating equipment industry increased by 33% per year and in the mechanical machinery industry by 23% per year between 2002 and 2006. FIEs in both industry segments had the highest absolute productivity level, followed by private companies and state-owned enterprises (SOEs). Private Chinese companies producing power-generating machinery showed the highest productivity growth rates, followed by SOEs; in mechanical machinery, it was vice versa. In both FIEs showed the least improvements, which makes sense, as it is much harder to improve something that is already on a relatively high level.

Our output productivity figures displayed in Figure 18 are composed of two factors, sales and employees. Hence the productivity growth observed can be traced back to a high total sales growth (on average 48% and 32% for the two industry segments respectively), partly offset by a moderate employment growth (on average 12% and 7% respectively) in the period investigated. However, the fact that per employee the output was growing so much is still not explained: It is likely to be caused by several factors, some of which is a result of the respective company activities (resource input and/or efficiency growth); some are "environmental factors" such as price inflation.

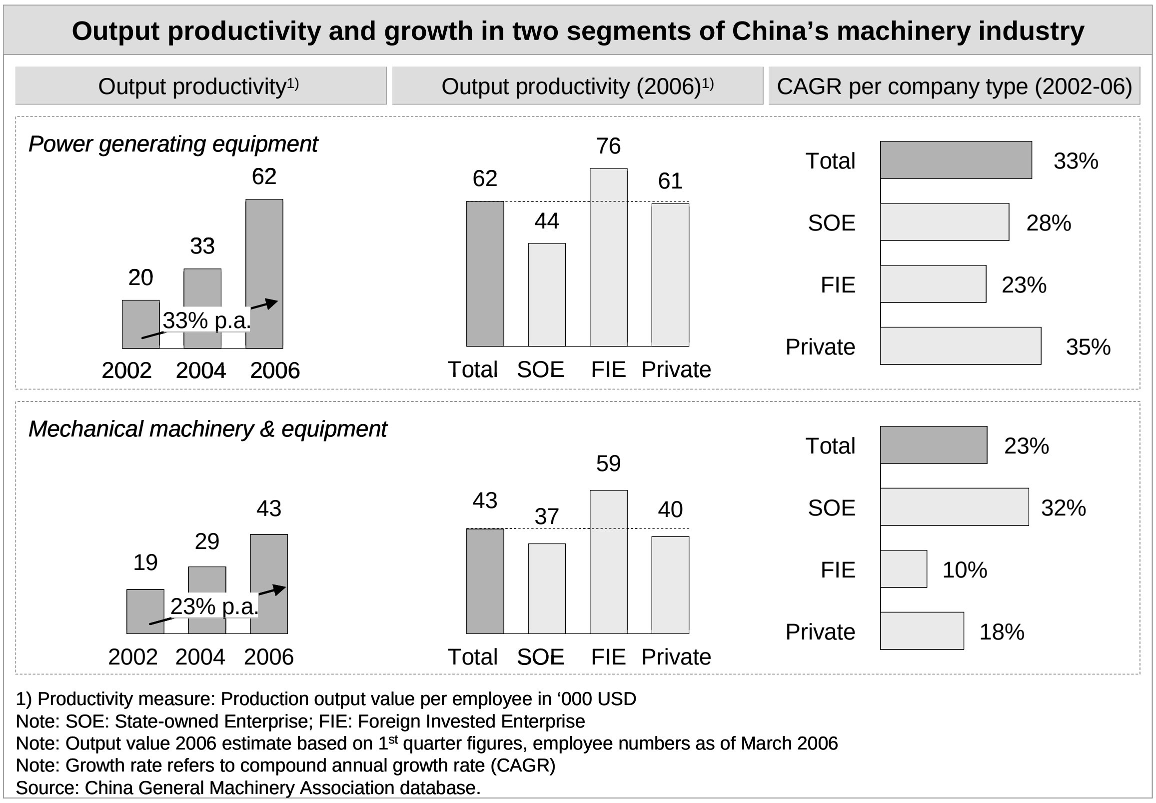


Figure 18: Output productivity and its growth in two segments of China's machinery industry.

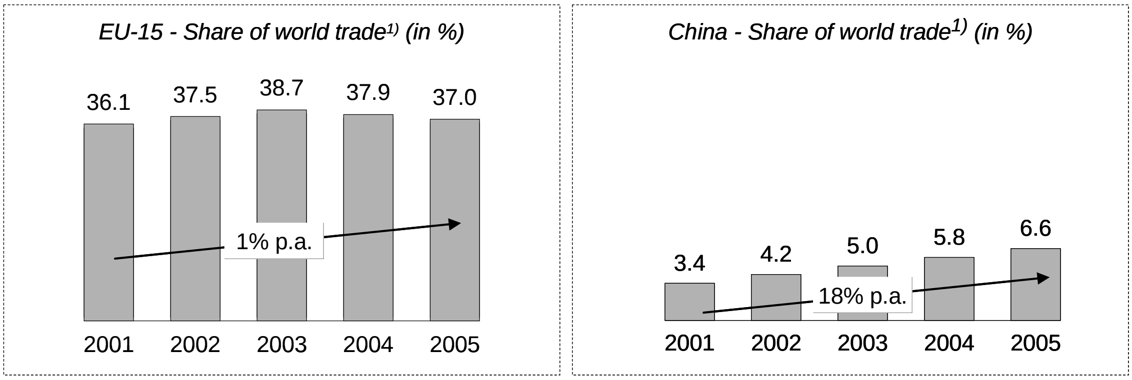
are smaller on average and their customer groups are more diverse. Thus, the impact of the Chinese government purchasing is less dominant.

On the resource input side, more or better machinery, learning, economies of scale in production come to mind as an explanation for the surge in employee productivity. Capital investment of companies in China has been substantial in the past 2 decades. The more capital employees have at their disposal, the better they are usually able to do their jobs, either in producing a higher output or of better quality. Additionally, organisational or employee efficiency might have picked up due to learning and applying innovative capabilities.

International competitiveness enhanced, resulting in surge in exports from China

In this millennium, companies around the world have increasingly profited from Chinese machinery becoming available. As they come on the cheap, they were exported first to other developing countries, greatly helping in their industrialisation process. The share of Chinese machinery in world trade grew from 3.1% in 2001 to 6.6% in 2005 (see Figure 19).

Share of world trade in mechanical engineering in EU-15 and China (in %, 2001 to 2005)



1): Without intra-EU-15 trade, calculated by the exports of 43 most important supplying countries in the mechanical engineering industry
Note: Growth rate refers to compound annual growth rate (CAGR); Figures 2005 based on estimates
Source: Ministry of Commerce of the People’s Republic of China (2007).

Figure 19: Share of world trade in mechanical engineering in EU-15 and China (2001 to 2005).

Since machinery imports to China recently stagnated at a high level, China’s machinery trade deficit still grew from USD 19 billion to USD 48 billion in the period of 2001 to 2006, however slowing its pace.[75] This deficit is likely to turn into a surplus in the decade to come.

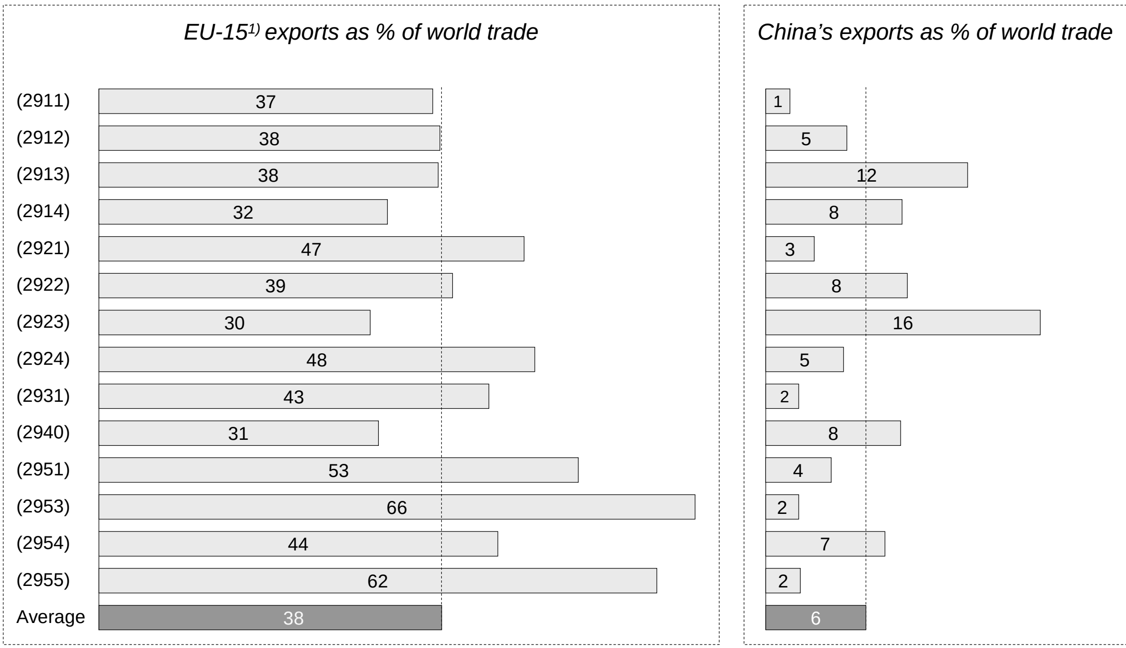
Machinery refers to a rather diverse group of capital goods; Figure 20 goes into more detail for selected machinery industry segments. Each machinery sub-industry’s share in world trade is compared with a benchmark – the average share of world trade of mechanical engineering products, which was 38% for the EU-15 and 6% for China in 2004.[76]

[75] UN Comtrade database (May 2006), Droege & Comp. estimates for 2005 and 2006.

[76] European Commission, VDMA (October 2005): Shares in world trade. (Industrial furnaces refers to NACE Rev. 1 – 2921). The world trade share is calculated by the exports of 43 most important supplying countries in the mechanical engineering industry.

Put side by side it becomes apparent that the competitiveness of the machinery sub-sections is quite different and usually exclusive: Europe's outperformance of its own benchmark generally coincides with China's underperforming its average share in world trade of mechanical engineering products, indicating a competitive advantage of the specific European machinery industry. This holds true, for example, in industrial furnaces that need a mastery of highly complex and energy-intensive processes; agricultural tractors, profiting from Europe's highly mechanised agriculture and a consolidated equipment industry; metallurgy machines, food and beverage (F&B) as well as large-scale paper production machines.[77] The same holds true for machinery sectors, where Chinese companies outperform their respective benchmark. This was the case for industrial cooling and ventilation equipment, for taps and valves (including a large category of low-tech valves and taps for buildings), lifting and handling equipment, bearings and gears among others.

Trade performance of selected machinery products: EU-15 vs. China (in %, 2004)



(2911) engines, turbines
(2912) pumps, compressors
(2913) taps, valves
(2914) bearing, gears
(2921) industrial furnaces
(2922) lifting, handling equipment
(2923) industrial cooling, ventilation equipment
(2924) other general purpose machinery
(2931) agricultural tractors
(2940) machine tools, woodworking machinery etc.
(2951) metallurgy machinery
(2953) machinery for food and beverage
(2954) textile machines
(2955) paper production machines

Note: Without intra-EU-15 trade, Shares in world trade, calculated by the exports of 43 most important supplying countries in the mechanical engineering industry. "AVERAGE" refers to average share of country (group) in world trade of mechanical engineering products. Numbers in brackets refer to European NACE Rev. 1 product classification
Source: European Commission, VDMA (October 2005).

Figure 20: Trade performance of selected machinery products: EU-151) vs. China (in %, 2004).

[77] See also Virtual Engineering (1 November 2005); South China Morning Post (20 September 2005).

The improvements in machinery exports from China point to a growing competitiveness. They also tell a story about the type of innovations Chinese businesses have been pursuing in the past. The majority of Chinese machinery companies had new geographic markets among their top targets in their internal innovation agendas in the past, right after the expansion of their core customer base. The latter was achieved primarily by expanding their direct sales force in China as well as establishing relationships with distributors for their export markets.[78]

Business patenting picking up

If business innovation in China had picked up, we should be able to see some movement on the output side of the innovation system, for example in business patenting.

According to China's State Intellectual Property Office, 46.2% of total domestic invention patent applications were filed by Chinese enterprises in 2006; however only 38% of domestic invention patents were granted to these companies. The number of invention patents filed and granted to the Chinese enterprises however grew steadily for six consecutive years since 2000. Yet, only 1.1% of Chinese enterprises have been granted patents at all, for invention patent the number is even lower at 0.17%.[79]

Box 2: China's national champions for filing invention patents – Huawei, ZTE and Sinopec

Despite the growth in patenting, Chinese companies are no patenting champions. However, there are exceptions, for example the national top three patentees: Huawei Technology, ZTE and Sinopec Corporation (China Petroleum & Chemical Corporation). In 2006, Huawei filed 5,593 invention applications (501 invention patents granted), thus ranking first among all domestic and even foreign patent applicants in China ZTE came second on invention patents application.

For foreign companies in China, electronics giant Samsung held the top position having filed 3,770 invention patents in 2006: Matsushita Electric Industrial Co. (including its subsidiary National Electric) followed in second place in terms of applications. However, Matsushita beat Samsung and all local champions in the number of invention patents actually granted. The company was granted 1,380 invention patents in 2006 in China, as opposed to the most innovative Chinese company Huawei's having 501 invention patents granted.

At a share of 62% of invention patents granted to foreign companies, foreign companies dominate this field. This is another concern spurring Chinese authorities' recent emphasis on *independent* innovation.

[78] See for example IMPULS Stiftung, VDMA (2005), IMPULS Stiftung, VDMA (2006), IBM Global Business Services (2007), p. 9.

[79] SIPO (5 December 2006).

2.2.1 The internal perspective: Making the best of the company's own resources

Organisations, just like people, can have strong or weak innovative capabilities. These capabilities are embedded in people, in technology used, in the organisational structure, processes applied and in the collective culture prevailing. A company ultimately needs own resources and capabilities to innovate and absorb knowledge. These resources are the major production factors labour and capital that are allocated on innovative activities. Furthermore, companies can be more or less efficient in using their internal resources, which is related to productivity, organisational skills and knowledge application.[80] Therefore, this section on the internal perspective of business innovation will distinguish between the resources (capital, workforce and knowledge embedded in workforce) and organisational efficiency.

R&D input (capital, labour and internal knowledge) on low level, albeit increasing

We have established earlier, that in the past three decades the innovation weight in the Chinese economy shifted from public research labs to enterprises, and – to an extend – to universities. For the future, the Chinese government expects the enterprise sector to contribute even more to the innovativeness of the country, especially for meeting the targeted R&D expenditure (2.5% GERD intensity by 2020) as an innovation system input indicator. There may be a problem with reaching these indicators, unless the currently introduced government stimuli and incentive programs bear fruit.

On a first glance, the accentuated growth of the business R&D expenditure seems promising. Yet, the rapid increase of business R&D results to a significant extend from turning public R&D institutes into companies or merging them with existing companies in the course of fundamental S&T reforms. From 1998 to 2003, 1,050 public R&D institutes in China were restructured and transferred to businesses, along with 204,000 employees.[81] Thus, R&D previously undertaken in R&D institutes merged into the Chinese business sector.

In 2005, a share of 91% of the R&D expenditure in companies originated from the businesses themselves. Another 5% came from the government (see once more Figure 7 earlier in this report). In Chinese business R&D, again 91% is spent on product development, while 7% is allocated to applied research and the remaining 2 percent on basic research. A major share of product development in business R&D is obvious since companies should be more interested in new products and applications. However, the overall low level of business R&D expenditure has an impact on the type of innovations favoured by Chinese companies, namely incremental rather than fundamental product and process innovations. This level may be too low to yield any significant

[80] Here again, the three growth contributors labour growth, capital growth and growth in Total Factor Productivity (TFP) shine through. See discussion in section 2.1.

[81] More than 50% of the transferred staff was S&T staff. OECD (2007), p.31.

returns if the suggestion of our interview partner from the National Research Centre for S&T Development[82] holds true. He suggested there might be a threshold that a country's R&D expenses have to surpass, in order to get any significant return on R&D. This would imply that R&D expenses and innovation outputs do not relate to each other in a proportional manner.

Taking the high sales growth into account, the percentage of R&D expenditures over sales in the Chinese private technology sector has decreased considerably from 11.5% in 1993 to 2.1% in 2002.[83] Business R&D expenditures over sales in general are hovering around 0.6%.[84] For large and medium sized enterprises (LMEs), R&D intensity was somewhat higher at about 2.2%.

In the machinery industry, private Chinese companies interviewed in the course of previous IMPULS studies in 2004 and 2005 indicated an average R&D investment rate of less than 1% of their turnover.[85] Germany's machinery companies by comparison spent on average 5.2% of their sales value on R&D in 2005.[86] Yet R&D expenditure as a share of sales might differ substantially, depending on the specific machinery sector. Our interview partner at the Beijing Machine Tool Institute denoted that in the average R&D expenditure was higher in the machine tool industry compared to other machinery segments. It was also mentioned, that local machinery companies had received government subsidies for importing and reverse engineering advanced machinery up to the beginning of the 1990s to upgrade the industry knowledge base. Today the government would mainly support by mediating between companies and research institutes as well as by directly subsidising companies participating in specific research programs. Machine tools may be a specific case among the different machinery sub-industries anyway since it receives special government attention (also see chapter 3.2.3).

There are three main company types operating in China – state-owned enterprises (SOEs), private companies and foreign-invested enterprises (FIEs). These companies differ in their resource input into innovation according to their incentive systems as well as depending on their stock and access to knowledge and capital:

- *SOEs are incentivised to invest in people and R&D by authorities.* Thus, the internal company motivation to invest into innovation is replaced by an external mechanism, which is not market driven. Although the government does not necessarily interfere with daily operational decision

[82] Research body under Ministry of Science and Technology.

[83] Whalley and Zhou (2007), p. 26.

[84] Whalley and Zhou (2007), p. 26.

[85] In the course of several VDMA studies carried out in 2004 and 2005, Droege & Comp. interviewed about 200 Chinese machinery companies from the fields of foundry and textile machinery, machine tools, plastic and rubber machines, wood working machines, industrial valves and packaging machinery. A company visit typically included a structured interview with a company executive in order to track the trends and transformations of the respective industry. See for example IMPULS Stiftung, VDMA (2005) and IMPULS Stiftung, VDMA (2006).

[86] ZEW Innovationen Branchenreport (2007).

making in SOEs, we suspect the incentive to comply with government guidelines to be high for SOE managers. Since innovation is currently a much-favoured concept in Chinese politics, we expect the incentive structure of SOE managers to comply with this national goal. Given their significant resource input in terms of capital and people, SOEs are not very efficient knowledge producers. Interestingly, they appear to be as good in knowledge absorption and application as other companies including FIEs in China.[87]

- *Private Chinese companies' motivation for R&D and innovation is market driven, but their resources are limited.* The view of our interview partner at the China Academy of Machinery Science and Technology, a leading Chinese research institute in the field of machinery, was that most Chinese machinery enterprises couldn't afford high-cost and thus high-risk R&D at this time. Private Chinese companies, especially SMEs, which may want to invest into R&D, however face limited resources with respect to innovation. Companies could be forced to choose between investing into expansion projects rather than into quality projects that require more innovation capabilities. Currently, Chinese private businesses seem to vote for the expansion route first. This trend is supported by the tight skilled labour market and insufficient investment in training.
- *Foreign companies' motivation for R&D and innovation is also market driven, but foreign companies need a good reason to innovate in China.* While many companies managed to move parts of their production to China and other low cost countries, R&D seems to be one of the less mobile activities of businesses. R&D activities and patenting are largely carried out in the home country of international companies. The major reasons for this immobility might be twofold. First, technological capabilities feed on tacit knowledge and experience and they are often found in agglomerations of skilled people. Their very dependency on the characteristics of certain people makes technological capabilities not easily transferable and result in location "stickiness".[88] Furthermore, R&D, just like production, marketing or other functions, exhibit economies of scale, hence they profit from being pooled at few places instead of being dispersed. Control is a further issue that is important since R&D activities tend to be expensive and risky. For all these barriers to mobility of technological capabilities, companies, especially SMEs, prefer their home turf for R&D locations as well as for the prototype production.[89] Table 3 gives an overview of incentives and disincentives for foreign

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[87] OECD (2007), Fu (2004). See also Jefferson et al (2006), p.364: "SOEs exhibit the lowest efficiency in knowledge production. However, once they acquire new knowledge, SOEs appear to be able to use the innovations as effectively, or sometimes more so, than enterprises of other ownership forms." Fu Xiaolan (2004)

[88] Pavitt and Patel (1999).

[89] Foreign LMEs were among the least R&D intensive in among the different ownership types, but those that have proper R&D are mostly high-intensity R&D performers. See Yu (2001).

companies to establish R&D in China. Nonetheless, according to Chinese statistics, by the end of 2004, 750 foreign R&D centres had been set up in China, most of them founded after China's accession to the World Trade Organization in 2001. The interviews with German machinery companies in China carried out for this study showed, for example, that one out of 15 the companies had established a major R&D function in China since their high share of customised products (more than 50%) required them (and their R&D) to be close to their customers in China. Another 7 companies had rather limited developing functions, enabling the Chinese operation to make slight modifications to their standard products developed in Germany.

Field	Incentives for establishing R&D in China	Disincentives, obstacles for establishing R&D in China
Market	Large potential customer base, special/local needs may require local R&D or product adaptation Decentralised R&D can react faster to emerging market trends, enhancing product development flexibility	Overcapacity in certain industry segments Substantial learning required of the foreign company to get familiar with Chinese consumers
Labour	Availability of low cost workforce Availability of skilled labour in some industries	Lack of experienced/qualified specialists (automotive, machinery and other industries) High employee turnover eroding incentive to invest in knowledge and training
Knowledge	New knowledge sources for the company to integrate in innovation pipeline	Knowledge spill-over to competitors Duplication of resources for knowledge creation in R&D may be inefficient (established R&D team and resources at headquarters)
Institutions	Official requirements for setting up of R&D centres (if attractive market outweighs know-how exposure) Policy support and incentives	Official requirements for setting up of R&D centres (outweighing the attractions of the Chinese market) Exposure to uncertain institutional framework for IPR protection and a large number of competitors

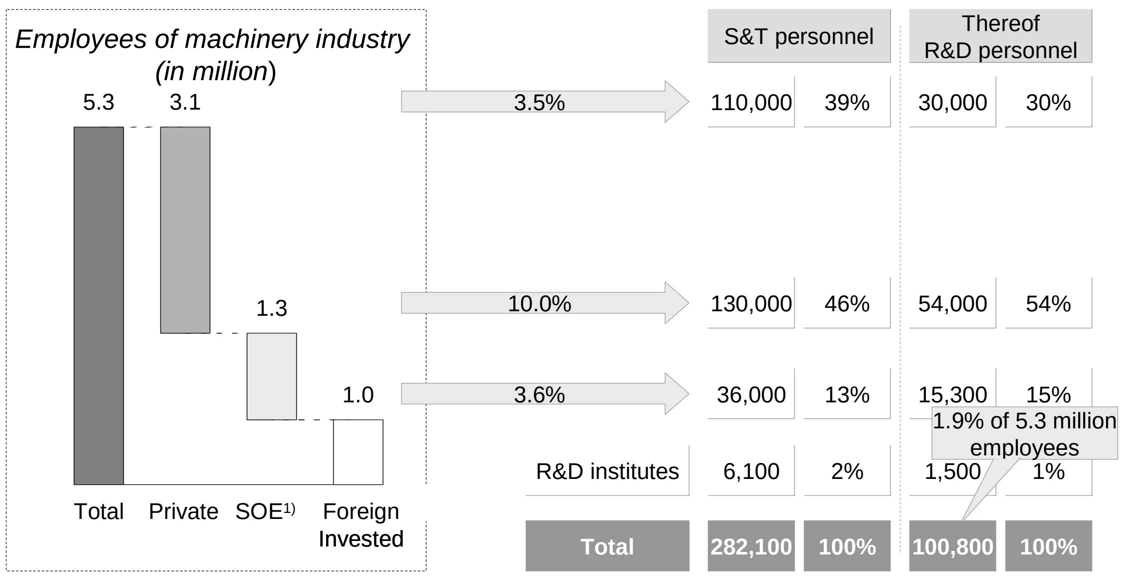
Table 3: Incentives and disincentives for foreign companies to establish R&D in China.

Human resources: Fishing for expertise and initiative

Companies rely on their innovative and skilled staff as the backbone of companies' overall innovative capabilities. Not all company employees need to be innovative in order for the company to be innovative as a whole.

In the total machinery sector, 3.5% of the staff is employed in S&T positions, referring to R&D staff, technicians and other skilled technical personnel, less than 2% are employed in R&D itself (see Figure 21). SOEs in the machinery industry employ the highest share of S&T personnel of all company types; about 10% of their workforce is engaged in technical jobs and 4% in R&D. Both foreign-invested and private businesses invest much less in R&D and have a smaller share of R&D staff (1.5% and 1% of their total staff respectively).

S&T and R&D employees in the machinery industry by company type (FTE, 2005)



Note: FTE=Full time equivalent, SOE=State-owned enterprise, S&T=Science and technology, R&D=Research and development
Source: China Statistical Yearbook on Science and Technology (2006) National Bureau of Statistics, Ministry of Science and Technology.

Figure 21: S&T and R&D employees in the machinery industry by company type.

Skilled people are in short supply in China, particularly people with skills related to creativity, risk-taking, initiative and managing abilities.[90] A recent survey of enterprises in 44 cities by the Ministry of Labour and Social Security pointed out, that companies would need about 14% of their workforce to be skilled; however the current share was only 4%.[91]

In the machinery sector, staff with sound technical training and profound experience on the job like machine operators and technicians is rare. The technical personnel in Chinese machinery SMEs interviewed in previous IMPULS studies was usually young, inexperienced and therefore not well paid, with the result that new product development and new technology introduction being excessively long, or the company resorted to reengineering products. Even skilled workers did not necessarily follow standardised manufacturing and quality control processes, since these processes lack formalisation. Inexperience workers on the other hand seemed to try to find their own ways by learning on the job, as there was little to no training provided. Both results in inconsistent product quality, inefficient product development processes and a general lack of the employee expertise needed to be innovative.

[90] The Economist (14 April 2005).

[91] China Daily (14 December 2006).

However, innovative capabilities of employees are expected to rise with training and education. Our machinery SME evidence is likely to have a bias, since it focused on private SMEs in the machinery sector. State-owned and foreign-invested companies invest more in staff training then private domestic companies.

In a market where demand outstrips supply for talented staff, personnel fluctuation should be high, and indeed ever-increasing turnover rates for professional staff in China reflect the scarcity of individuals with transferable professional skills. The nationwide staff turnover rates rose from 8.3% in 2001 to 11.3% in 2004, although state owned companies had better and FIEs had worse retention rates in China.[92] By contrast, the average annual job fluctuation rates in the US were about 6% in 2005.[93] In China, the average tenure of the staff aged 25 to 35 years had fallen from an average of three to five years in 2004 to an average of one to two years in 2005. Employees in R&D seem to have an even higher turnover rate than those from other departments.[94] To keep their employees and avoid replacement costs, which typically range between 25 and 50% of the respective annual salary, companies frequently have to pay higher salaries or try to implement other benefits.[95] But the elevated job mobility has also several consequences for the innovation capabilities of companies:

- *From a macro-perspective – mobility is wanted:* Employee mobility is an important knowledge spillover factor and fresh talent can increase innovativeness. The overall business sector in China should benefit from this type of knowledge circulation since if one company loses a skilled employee another company gains one. Knowledge is rarely lost, it is rather transferred and increased. Yet, too much mobility can backfire.
- *Mobile too soon?* If the experience gained in a job is thorough, the leaving employee is likely to benefit the next company he will work for. Whether the average tenure of just one to two years in one particular job among the 25 to 35 years old professionals in China is sufficient for a positive effect on the innovative skills of is uncertain.[96] There could be an optimal turnover rate that maximises innovativeness such as there seems to be an optimal employee mobility that maximises productivity. Too little change could be just as bad as too much of it.[97]

[92] Wellins et al (2005).

[93] For US figure, see Wellins et al (2005).

[94] Yang and Jiang (2007), p. 346.

[95] Going Global (30 August 2006), citing a survey by Mercer Human Resource Consulting, covering 114 organisations in Greater China. 24% of the participating companies were from the high-tech industry, 19% consumer, 14% chemical, 11% pharmaceutical, 8% automotive, 6% from the service industry and the remaining 18% were from other industries.

[96] Going Global (30 August 2006).

[97] "The conflict between retaining workforce stability on the one hand, and flexibility on the other, gives rise to the potential existence of an "optimal" turnover rate." See Harris et al (2003).

- *R&D and innovation benefits cannot be realised.* Firms invest in R&D to make money, i.e., yield temporary "monopoly rents". High turnover of skilled employees will make imitation by competitors faster, so that the innovative firm cannot protect its knowledge long enough to profit from it.
- *… hence firms have less incentive to innovate*. If innovations cannot be appropriated due to employees leaving too fast which again is elevated by a lack of supportive legal environment in China, companies will not have less incentive to innovate. Companies in China indeed invest less money into R&D relative to other countries. Of course, there are many other factors for this figure like finance, quality of the HR, etc which were mentioned earlier, but staff mobility factors play a role too
- *… and may continue to invest too little in employee training*. Training needs resources, may it be money or time or the input of other skilled people. If employees are leaving too fast, companies are tempted to skip staff training, since the payback period is too short.

Organisational efficiency: Little formalisation of processes yet but great progress

Improvements in organisational efficiency are a form of process innovation. The aim of such improvements can be cost reduction or supporting business growth and ensuring a proper functioning of the operations. Since costs are mostly low already, Chinese businesses tend to focus on growth. While smaller companies do not need as much formalisation, bigger companies do. One of the company functions that lacks formalisation in China is R&D. The surge of output productivity per employee especially for private and state-owned companies in China suggests that companies indeed enhanced their organisational efficiency (see once more Figure 18). While many leading European manufacturers have established clear innovation goals, priorities and product development procedures, Chinese machinery R&D does often take the form of an ad-hoc project, gathering teams of people from other functions such as service engineers etc, that dissolve as soon as the project is over. This resulted in a strategy type often labelled as "fast follower" or "replicator".

Among large and medium-sized enterprises (LMEs) in China, 24% had established R&D centres in 2003, while in smaller enterprises the share was only 9%.[98] Germany's machinery business, some 66% of companies have an established R&D function.[99]

For companies to be successful innovators, internal resources usually do not suffice. Integrating external resources into the business innovation pipelines, affects companies' innovative capabilities positively.

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[98] OECD (2007), p.30.

[99] ZEW Innovationen Branchenreport (2007).

2.2.2 The external perspective I: Tapping on resources outside the organisation

Companies and their employees do not operate in isolation but in informal and formal networks. Individually, companies typically possess too little resources to innovate entirely on their own. Interactions within the network to distribute knowledge augment learning opportunities to all innovation players, but primarily to companies as the main economic value creating entity. This section will explore China's "knowledge distribution power", referring to the "capacity to stimulate and optimise the diffusion sharing and creative use of ideas in any form…"[100]

The firm-level exchange with its environment is a great impetus for doing things differently or for doing different things, which is the core of what innovation stands for. Maybe unsurprisingly, companies financially outperform their peers if their level of interaction with their respective environment was elevated.[101]

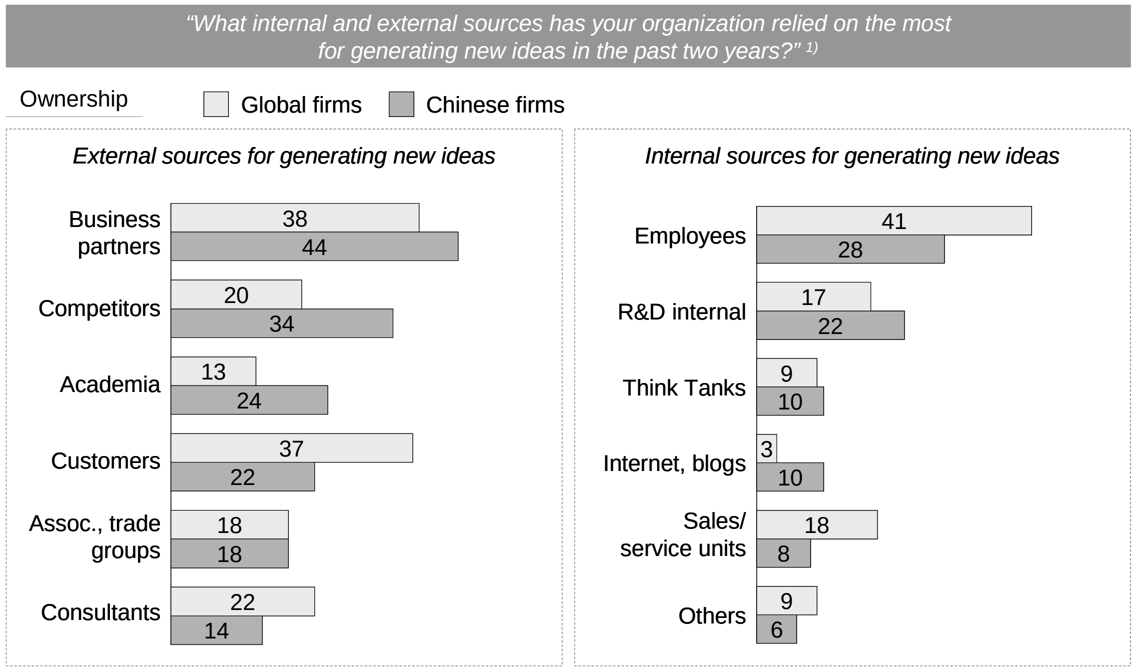
Companies lack internal resources and thus turn to external ones for new ideas

From a firm-level perspective, ideas are the starting point of a process that culminates in an implemented innovation with an economic value. Potential sources for new ideas within companies are various. Both internal sources such as employees and own R&D activities as well as external sources, for example business partners, competitors or customers are relevant (see Figure 22). This is not a unique feature of Chinese businesses. However, an interesting finding of a recent IBM study on innovation highlighted a difference between global and Chinese businesses: It seems that in absence of a sufficient number of skilled employees showing initiative and creativity, Chinese companies turn to external sources for innovations such as new products, business models and operational improvements. While the top source of ideas for companies globally was their own staff, businesses in China tend to get more ideas from business collaborations and competitors than from their employees.

[100] OECD (2007-2), p.41.

[101] The study reports that the financially outperforming companies sourced 30% more ideas from outside the company than their les successful peers. IBM Global Business Services (2007), p. 17.

Internal and external sources for generating new ideas (answers in %, 2007)



1) Answers from in-depth interviews with CEOs & senior executives; sample size: Global (n=765), Chinese (n=100) respondents; multiple answers possible
Source: IBM Global Business Services (2007), p. 17.

Figure 22: Internal and external sources for generating new ideas (answers in %, 2007).

Business partners, firm-level networking

Companies worldwide and in China heavily rely on business partners as a source of new ideas. Those partners can refer to suppliers and joint venture partners. Collaborating reduces the costs of innovations but at the same time, it can contribute to higher quality of products and services offered ultimately resulting in a higher customer satisfaction. From the knowledge perspective, co-operations also give access to more information and knowledge, hence the opportunity to learn the fast track. However, innovation-oriented collaboration between firms and within their networks in China remains immature.

Collaborations between companies and their suppliers are common in developed countries where both parties have achieved a high degree of technology and operational competencies. In such co-operations, companies are able to tap onto each other's specific expertise in order to innovate. However, in China, local suppliers are still in the process of building up their competencies and are largely dependent on their customers (multi-nationals or local companies) for technology transfer and direction. Due to the lagging capabilities of local suppliers, companies have little opportunity to collaborate with their suppliers in developing new ideas and products.

Nonetheless, there are cases in which strong Chinese suppliers collaborate with their customers in innovation. For instance, Santui Construction Machinery and Sinopec, both technology and market leaders in their respective domain in China, have formed a strategic alliance to jointly develop new technology and products for both parties. While Sinopec helps upgrading Santui's capabilities Sinopec became the exclusive supplier of certain chemicals. Such partnerships are expected to become more common in the future, as both Chinese companies and suppliers continuously upgrade their capabilities.

Research joint ventures and R&D alliances between companies gives the opportunity to pool risks and resources and reduce duplication or research. The Chinese government, acknowledging the importance of firm-level innovation network, encourages indigenous joint development of core technologies and discourages duplication of resources through public-private research alliance. Industry associations such as the China Technical Association of Paper Industry (CTAPI) and the Printing and Printing Equipment Industries Association of China (PEIAC) also promotes technology exchange and collaboration. However, the results of these endeavours have yet to materialise.

Joint ventures between foreign and local companies have more potential for upgrading the local knowledge base of companies simply because the knowledge gap is so apparent. To push the knowledge transfer from foreign to local industries, much of the early inbound foreign direct investment in the 1980s and 1990s was restricted to partnerships with local Chinese. Today, many industries, including the majority of the special and general machinery sectors are open to 100% foreign-ownership.[102] Foreign business partners are often "competitors turned partners" and therefore have the incentive to share only the minimum of necessary knowledge with the Chinese partner to make the collaboration pay off. Thus, international businesses in China tend to keep the higher-end production and development of their product and process innovations in their home countries. Joint ventures established in China mainly carry out manufacturing and assembly of less sophisticated components and products in the machinery sector.

Nonetheless, there are more and more foreign-based companies establishing R&D centres in China. The R&D conducted in those centres is largely limited to customising a product developed elsewhere to the local market(s). As such, the activities of FIEs in China require less involvement and innovation from suppliers and local networks than the higher-end operations they have in their respective home countries.

Customers

Customers did not rank very high on the list of top idea sources for innovations in Chinese companies (Figure 22). Most likely, integrating customers into the idea pipeline of a firm – again – requires employee and organisational skills that Chinese companies might not have enough of at this stage. To investigate customer problems or needs and develop ideas to solve them arguably requires more creativity and problem solving skills of company employees and management than to have a problem as well as a solution already clearly

[102] The large section of transport equipment faces more ownership restrictions, but is not covered under our definition of machinery in this study.

defined.[103] One suspects the latter is more common when competitors or business partners are the source of an idea new to a respective company or country for that matter.

Competitors

Companies put effort into new products and services, a more efficient organisation and rethinking their business model in order to realise a temporary advantage and surplus over their competitors. The advantage is temporary since competitors will imitate whatever innovation has been introduced by a company, once they observe the market success. After cycles of adoption throughout the competition, an innovation becomes a standard.

We established earlier, that many Chinese companies lack the human, capital and knowledge resources to innovate on their own. Under these conditions, companies will naturally move into the "follower" position with minor adjustments of competitors' products, services or business concepts. This is also the case in the existing geographical industry clusters (see also section 2.1), where one would expect well established linkages between enterprises and their suppliers on one side but also between competitors, since companies each lack the scale to be able to invest in upgrading innovation capabilities on their own.

In general, formal collaboration remains weak even in the established clusters, as many Chinese industry clusters specialise in low-value added, labour intense production with low market entrance barriers for new SMEs and frankly, not much technology knowledge to share.[104] Due to the resulting competition among the companies, these SMEs then individually turn to "short term innovations", i.e., "re-innovation", which filters through to the competing companies in each cluster within a very short period.

This is possible because the knowledge absorption power of Chinese companies is relatively extensive when it comes to reverse engineering of existing structural or product designs. However, capabilities with respect to absorbing knowledge in technological processing are more limited, since processing capabilities are largely based on tacit knowledge of skilled and experienced people (sic). There is some evidence for a different knowledge absorption power, depending on geographies too. For example, the cities of Wenzhou and Guangzhou seem to be synonymous with fast copying and entrepreneurial "can do" attitude. In these areas, companies are facing particular challenges to keep ideas, staff and business advantages to themselves. It is unlikely that this ultra-competitive environment breeds innovation.[105]

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[103] Sternberg (1997), p.171 points out the difference between solving well-structured problems, where problem and solution path are clearly defined, as opposed to ill-structured problems, where the solution path is open. Educational systems, so the author points out, focus too much on teaching students how to solve well-structured problems.

[104] LI & FUNG RESEARCH CENTRE (May 2006), p. 14.

[105] In order to reduce the threat of their machinery design being further copied, one interviewed packaging machinery company, had moved their product development, marketing and sales to Shanghai, away from

However, in some industry clusters there are some interesting collaboration examples to be found for competing SMEs to get the economies of scale with the ultimate aim to become more competitive. In the city of Wenzhou, small family-run machinery manufacturers teamed up and established a roof company with a common sales force and at times, a common brand. A common R&D is often planned at a later stage to make up for the individual company's lack of size and investment prowess.[106] This concept seems to work to an extent, but in the meantime has its drawbacks: So far R&D functions (used here in the widest sense, since R&D is mostly not even formalised in these companies) and financial control remained with each individual family-owned SME largely forfeiting the possibility to upgrade the innovative capabilities within these collaborations.

A working system of inter-firm innovation-oriented collaborations relies on a respective institutional framework protecting property rights, so that innovators can appropriate their ideas before their competitors (or partners) erode the competitive advantage. Institutional frameworks also set the standards with respect to market forces and competition, motivating companies to create economically useful knowledge to outperform other companies. Despite continuing its reform path, there is still room for improvements (see Box 3).

Academia

A striking difference between global and Chinese businesses is that Chinese companies have more interconnections with and receive more idea input from universities as well as research institutes (academia) than their global peers (see once more Figure 22).[107]

Historically, public R&D institutes in China served as external R&D departments. Companies had neither the task nor the employee base to engage in R&D. Instead, a formalised connection between public sector research institutes and businesses were assigned to fill the gap. These relationships are less prominent after the reform of the public R&D sector (see chapter 2.3.1), but still more important to Chinese businesses compared to their global peers.

Especially for state-owned companies and "local champions", local governments initiate and support exchanges between public research institutes and businesses with the aim to facilitate knowledge transfer.

In opposition to these findings, some of our interviewees of Chinese authorities and academia perceived a lack of collaboration between companies and academia due to the low value added most public research institutes could offer to companies and their distinct incentive system. However, the interview partners also perceived the situation to be improving.[108]

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their factory in the city of Wenzhou where the company originated. The company perceived Shanghai a better place to safeguard their knowledge, as the knowledge absorption power in the Wenzhou area was basically too high.

[106] See IMPULS Stiftung, VDMA (2005) and IMPULS Stiftung, VDMA (2006).

[107] IBM Global Business Services (2007), p. 17.

[108] For example our interview partner from the National Research Centre for S&T Development, a research body under Ministry of Science and Technology; China High-tech Cooperation (CHC) Organization; the

Box 3: The curse of weak institutional framework conditions for knowledge protection

China is a developing country with evolving institutional frameworks for protecting property rights of all kinds. Intellectual property rights are a subcategory of property rights that are recognised in China only since the Chinese Patent Law came into force in 1985. The combination of lagging behind developed countries in terms of knowledge creation and weak property right protection has two noteworthy aspects to weigh against each other from a country perspective. The first aspect is that the knowledge transfer balance between other countries and China is rather unidirectional, meaning China "imports" more knowledge than it exports, as it is at the development stage of learning from developed countries. China's system of intellectual property rights protection – whether intended or not – favours access to knowledge over protection of the rights of knowledge owners. Since the larger part of knowledge property rights owners are foreign and the winners of a potential transfer are Chinese, the system was and still is largely "discriminating against foreign intellectual property right holders".[109] Thus, our interview partners in German machinery companies invested in China described IPR infringements as "omnipresent" in China, extending to company names, brands, products and technologies. For China's domestic knowledge base, this dynamic should have a positive result, aside from the complaints of foreign countries on behalf of their citizens and companies.

However, there is a downside of the story: The weak institutional framework dampens the incentive to innovate for domestic inventors and potential knowledge owners as well. The perception taking shape from a series interviews with Chinese domestic machinery companies in the course of previous IMPULS studies[110] was that these companies regard patenting in China as a pure prestige measure with no further value attached to it, since the rights were too expensive or tedious to enforce. In fact, many interviewees claimed that patenting would even foster knowledge transfer to competitors since information has to be revealed to a third party as well as to the public.

At this stage of China being a net importer of knowledge, the bottom line results may still be positive for the country. However, it will only be a matter of time until the development of China's homegrown knowledge base reached a point where the upsides outweigh the downsides of the current IPR protection regime. At that time, we expect the institutional framework for IPR protection to have reached a more mature state and enforceability will have improved substantially.

Our interview partners perceived the role of the Chinese government in the current IPR protection regime as ambivalent, pointing out different goals of central and regional authorities: While the central government generally supported a stronger IPR protection regime, local authorities may favour local GDP growth over IPR protection – even if that may result in the violation of property rights.

S&T Innovation Management Center of the Graduate University of the Chinese Academy of Sciences, and others.

[109] Pendleton (1985).

[110] See for example IMPULS Stiftung, VDMA (2005) and IMPULS Stiftung, VDMA (2006).

2.2.3 The external perspective II: Tapping on resources outside the country

Cross-border knowledge exchange with developed countries helps building innovative capabilities within domestic companies. This exchange can take on various forms: Organisational exchange, such as inbound and outbound foreign direct investment (FDI), exchange of goods in cross border trade and finally international people mobility.

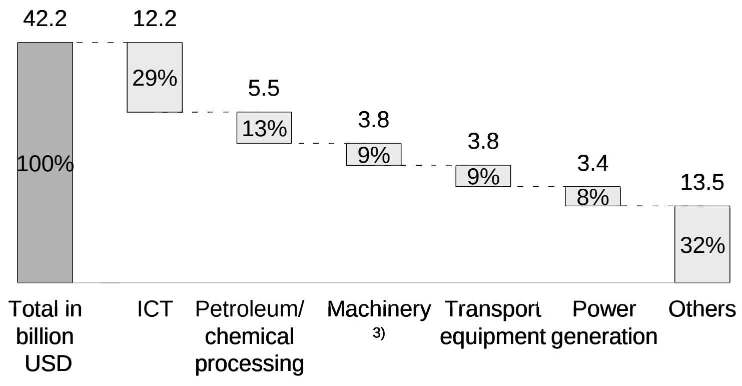
Openness to foreign investment improves knowledge base in China, even if no R&D is established

On a macroeconomic scale, the exchange of knowledge between China and the rest of the world would need to be considered, when we enquire into China's evolving innovation system. Foreign investment has a special role within this knowledge exchange.

Even before the arrival of multinational companies from North America and Western Europe during the mid- and late 1990s, Chinese "diaspora networks" have played a crucial role for bringing in knowledge. When China increasingly opened to Foreign Direct Investment in the 1980s, ethnic Chinese from Hong Kong, Chinese Taipei (Taiwan), Singapore and other areas were the first to invest in Mainland China on a greater scale.[111]

In 2005 China attracted FDI worth USD 60.3 billion, 70% thereof was targeted at the manufacturing sector. Within the manufacturing sector, information and communication technology (ICT) industry attracted the largest inbound FDI share (29%), followed by the chemical and petrochemical industries (13%). Machinery however, still ranked among the top three FDI target industries in the manufacturing sector (13%), receiving USD 5.5 billion in 2005.

Realised inward FDI in China's manufacturing sector (in billion USD, 2005)



Notes: FDI: Foreign direct investment; ICT: Telecom, electronics, computers; Machinery refers to Chinese product category of 'general and specialised equipment'
Source: NBS, Ministry of Commerce, Department of Foreign Investment Administration: www.fdi.gov.cn (2005).

Figure 23: Realised inward FDI in China's manufacturing sector (2005).

[111] Gu and Lundvall (2006).

Foreign companies investing in China may have several effects on the domestic innovation capabilities and activities:

- *Increasing total investment into Chinese R&D, but lowering average Chinese business R&D intensity:* If foreign companies set up R&D centres in China, they contribute to the country's knowledge creation. However, as pointed out earlier, the average R&D intensity of foreign-funded industrial R&D lags behind that of China's domestic firms, somewhat depressing the overall rate of China's industrial R&D intensity. Realising this, it is hardly surprising that the Chinese government implemented incentives as well as restrictions, so that foreign companies that want one thing (producing cheaply) give another thing (knowledge, technology access etc). While foreign technology companies might complain about being pressed to deliver blueprints, technology or platform know-how, one could argue that this qualifies as "voluntary technology transfers". Apparently, the potential economic gains from the company activities in China are higher than delivering some of the "documented part" of knowledge. The tacit, undocumented part of technological knowledge is still not easily reproducible for the Chinese subsidiaries or Joint Venture partners. Yet the FDI landscape in China is very diverse, and there are examples of highly integrated R&D centres, while others keep engaging in manufacturing only. Since the machinery industry is dominated by SMEs, we expect foreign machinery SMEs to be less likely to have the capacity to establish and manage several R&D locations globally. For example, among our 15 interview partners at German machinery producers in China, only one company had a local R&D centre, which is one of the company's three global R&D centres. Seven other companies have R&D department, which only carry out minor modification to standard products developed by its home country R&D centres.
- *Motivating and facilitating domestic R&D intensification and learning:* Furthermore, infusions of FDI create competition, so that in order to survive, domestic firms are obliged to upgrade technologically, so that their product quality and production efficiency enable them to remain competitive. Concentrations of FDI create technological opportunities for domestic firms as they can use research funds to imitate products and processes that enter their geographic and technological space. Foreign companies engaged in China do not only increase competition for local companies, they also provide technological opportunities. Aside from partnerships with local firms, where a certain extend of knowledge spillover is wanted, the presence of FIEs in China motivates domestic firms to intensify their R&D operations.
- *Establishing and training local supplier networks:* Knowledge spillover does not only happen from companies to competitors but also supplier networks that need to learn in order to qualify. To decrease their costs, foreign companies have a considerable incentive to share their knowledge with their suppliers in China.

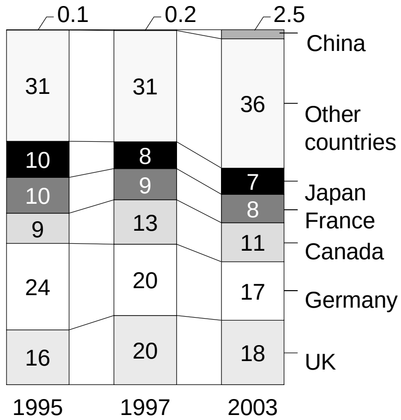
- *Training local staff and attracting the best:* Foreign companies offer many advantages for employees, that Chinese private companies find hard match. Aside from a better average pay, foreign companies offer plenty of learning opportunities that are not only a personal enrichment but also pay off in terms of market value of the respective employee for later jobs. Since overall employee turnover rates are high, local companies should eventually benefit from the training provided at foreign-invested companies

We have established earlier, that foreign firms investing in China usually relied on their headquarters' research and development (R&D) activities. In recent years, this paradigm changed – at least in multinational corporations (MNCs). Today large MNCs such as IBM, Ericsson, Dupont, Unilever, Bayer, Microsoft or Nokia have R&D facilities in different world markets to improve their overall innovativeness by tapping on various local resources and innovation networks.[112]

The US is one of the few countries that publish relatively up-to-date figures on geographical distribution of US R&D investment abroad. Between 1995 and 2003, the main trend was the rise of R&D expenditure of US subsidiaries in Asia-Pacific, particularly in China on the expense of R&D expenditures in Europe (see Figure 24). However, the top 5 receiving countries, UK, Germany, Canada, France and Japan) amounted to 69% of total R&D expenditure by US-owned subsidiaries abroad in 1995, shrinking to a share of 61% in 2003. Notably, R&D expenditure of US subsidiaries in Germany decreased substantially. Albeit still at a low level compared to the top 5 receiving countries, China, Singapore, Israel and Korea saw the highest jump of their share from 1995 to 2003. In China R&D expenditure by US-owned subsidiaries increased from USD 7 million to USD 650 million in the stated period. In the grand scheme of things, that might not be very much for such a large market. For example, R&D investment in the small Southeast Asian city-state of Singapore rose from USD 167 million to USD 589 million over the same period.

[112] Yang and Jiang (2007).

Geographical distribution of R&D expenditure by US-owned subsidiaries abroad (in %)

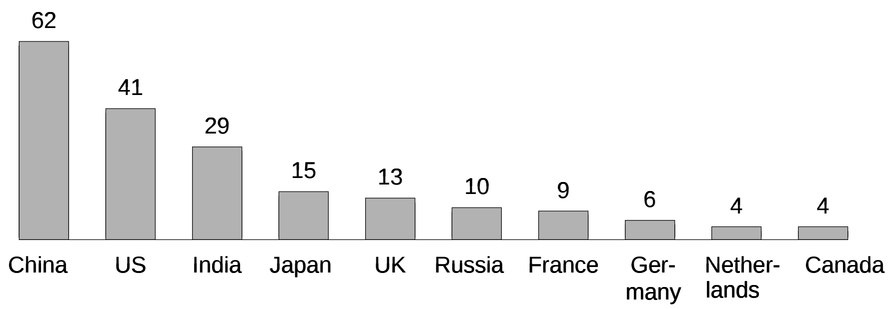


Note: Figures do not sum up because of rounding errors
Source: World Bank (2006).

Figure 24: Geographical distribution of R&D expenditure by US-owned subsidiaries abroad.

Ever reducing transaction costs, such as better communication technologies or improvements in intellectual property protection, as well as the improvement of the local skill sets will lower the barriers of foreign companies to invest into R&D in China. Hence, according to a recent UNCTAD survey, China scores highest when asked for the likely future target locations for investment into R&D facilities, the US and India ranking second and third (Figure 25). The low price and the increasing quality of human capital are the main future driver for locating R&D in China for foreign companies.[113]

Future foreign target locations for R&D investments (survey responses in %, 2005)



Note: Percentages refer to survey responses regarding future R&D investment locations and do not sum up because of multiple answers
Source: OECD (2006) p.135, based on UNCTAD survey (2005).

Figure 25: Future foreign target locations for R&D investment among survey participants.

Chinese outbound FDI picking up

Tapping on foreign knowledge base is not restricted to inward foreign direct investment. Knowledge from abroad can also be acquired through outward investments. China's outward FDI has gown by over 400% since 2002 to USD

[113] Schwaag (2006).

16 billion in 2006 (see Figure 26). What may seem astonishing is that despite being a top investment location for manufacturing activities, China has invested heavily in manufacturing operations overseas. China's outbound FDI in the manufacturing sector has reached USD 8 billion in 2005. However, China's total outbound FDI, accounting for 1.6% of the world's total in 2006, remains relatively small. Nevertheless, China's outbound FDI is growing and growth is expected to remain robust in the coming years.

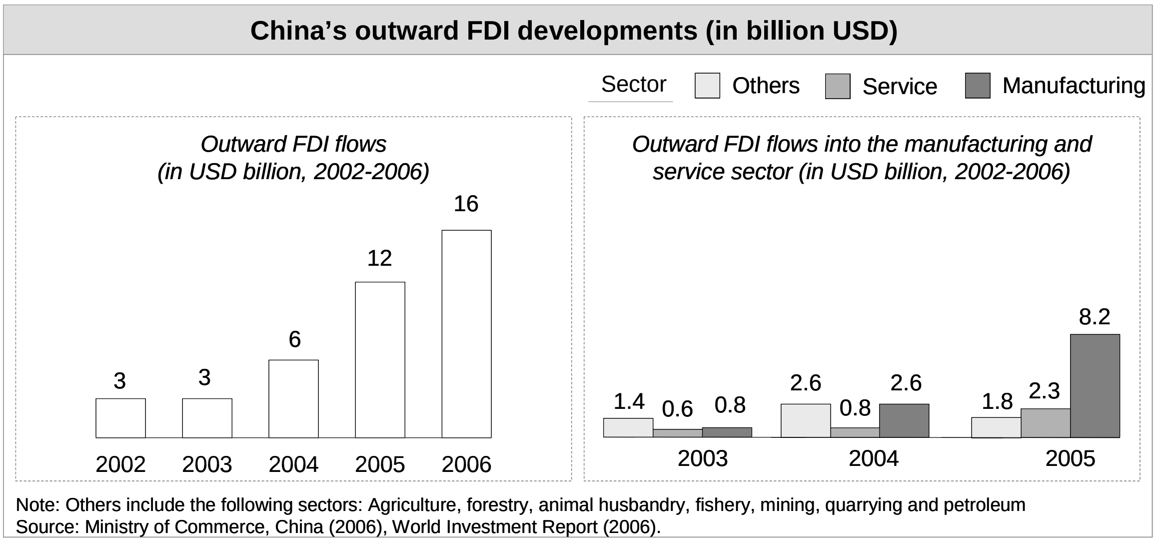


Figure 26: China's outward FDI developments (in billion USD).

SOEs and large private firms with close relationship to the government dominate China's outward FDI. This is because government approval is required for private Chinese firms to invest overseas. Furthermore, larger firms have more financial capability and incentives to venture abroad. In 2005, SOEs accounted for 83% of China's outbound FDI.[114] The marked increase in outbound FDI from 2003 onwards (as observed in Figure 26) was largely due to the government's successful encouragement of SOEs to globalise which started in 2003.

While investments abroad in the resource sector was motivated by the need to secure raw materials to fuel China's rapid industrialisation, investments in the manufacturing sector, mainly through M&A, was spurred by the desire to acquire world-class technology, managerial skills and assess to global markets. Notable examples of such outward investments include Lenovo's acquisition of IBM PC and the distressed German machine tool maker, Schiess, by Shenyang Machine Tool in 2004.

Chinese businesses, through their acquisition of foreign manufacturing operations, are able to gain technological competencies that would take years to develop organically. These companies are hoping to learn faster from foreign manufacturing and R&D staff to become more innovative and thus competitive.

[114] Cheng; Ma (2007).

Recently, larger Chinese firms aware of the importance of keeping abreast of global technology trends and knowledge have also been setting up their own Greenfield R&D centres overseas. For instance Haier, one of the world's largest white goods companies, has R&D activities across China, in Silicon Valley, London and Sydney. Competing against the world's most innovative companies such as General Electric and Siemens, Haier knows that since China's independent innovation capabilities are not as strong as those of the developed nations. Thus, it ventured overseas to develop world-class innovations. An example in the machinery sector is Haitian, the world's largest plastic injection moulding machinery manufacturer by production volume, which has recently acquired Zhafir, a German developer of high-end injection moulding machinery. Zhafir was established in Germany by Haitian's top executives to tap into the cutting-edge competencies of component and service suppliers in Germany to develop top-end machines that can compete against the best from Europe and Japan. With the acquisition, Haitian improves its capabilities from manufacturing mainly mid to low-end machines to high-end products.[115] So far, outbound Chinese FDI is rather anecdotal, but clearly growing. With more export success, Chinese companies will invest abroad more in order to be closer to their customers.

Trade in goods and services fosters learning and efficiency improvements, for example when using advanced machinery

In the course of the 20th century, China has largely relied on the import and consequently the adoption of advanced foreign technology as one of its technology upgrading strategies. The country's openness to international trade not only enabled it to import high-tech and capital goods, it also furthered its goal to attract Foreign Direct Investment. The latter is largely responsible for China's remarkable trade performance of late. Figure 27 shows that China's openness to trade measured in international trade as a percentage of GDP grew substantially and ranges not far behind Germany's in 2005.[116]

However, the quality of the trade is not indicating many innovative activities *within* the country. While China became a high-tech goods exporter, the value creation in China is rather limited to low-tech assembly of imported high-tech components. China became a preferred assembly location for foreign-owned multinational companies with international division of labour. However, the Chinese government would like to attract more value added parts of these global value chains in the future and may demand that for inbound FDI in the future.

[115] K-2007 (27 August 2007).

[116] International trade = Sum of imports and exports.

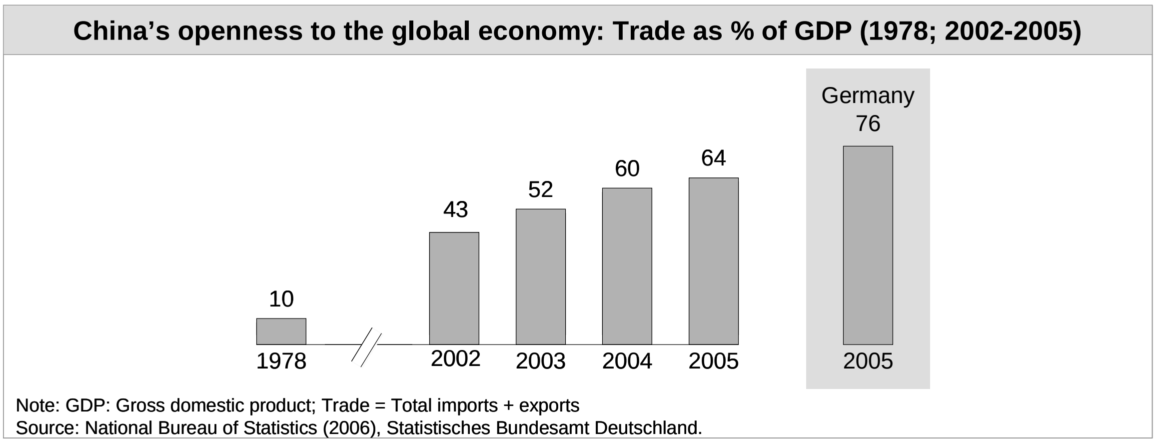


Figure 27: China's openness to the global economy: Trade as percentage of GDP.

Imported machinery always had a remarkable market share in China's demand. In 2004, domestically sourced machinery accounted for a 32% market share in China. By employing advanced machinery and learning to use them, product quantity and quality is improved, due to the processing knowledge embedded in machines. Knowledge import by means of machinery imports is however declining, if measured as the market share in China. In 2001, about 40% of the machinery bought in China was imported. Here one of the trends in the machinery market becomes visible: Import substitution. Interestingly, foreign manufacturers support this trend by continuously providing Foreign Direct Investment (FDI) to build their own manufacturing presence in China. They are probably one of the biggest contributing factors in substituting imported machinery, mostly having access to higher value-added technologies.[117]

As described earlier in chapter 2.1, disembodied technology can be traded as well, referring to purchased patents, licenses etc. Because most of this type of technology trade is firm-level trade, it is a very relevant knowledge upgrading process for Chinese companies.

2.2.4 Assessment

China's shift away from the concept of state-owned enterprises (SOEs) towards a private business economy revived the entrepreneurial culture and gave companies the freedom to pursue market-oriented activities including R&D. In the machinery sector, privately owned enterprises accounted for more than 70%

[117] Foreign Direct Investment (FDI) can take many different forms: Joint Ventures (JV's) and wholly foreign-owned enterprises being the most prominent. But not all FDI has access to advanced technologies: In JV's the technology transfer is very dependent on the actual agreement with the foreign partner. Furthermore an unknown percentage of foreign-invested firms are domestic investors who disguise their investment as foreign in order to benefit from lower tax rates.

of the companies in 2006 the remaining businesses being state-owned and foreign invested.[118]

With more market-oriented operations, company performance of Chinese domestic companies greatly improved in the past 2 decades. We have seen in this chapter that almost all measures of company performance have improved. Thus, slowly Chinese companies reach up for the medium quality segments of the markets, whereas they had been locked into the low-end before. Foreign machinery companies present in China therefore feel the market pressure rising in certain product segments. One interview partner at a German machine tool company, for example, described how they were only competing with another foreign producer in the Chinese market 10 years ago, while today they are facing 18 competitors, most of which are Chinese, and all of them having adopted the fast follower strategy. Unlike the high-end markets, which for the time being remained exclusively in foreign hands, the medium-quality market got more competitive in the view of the interviewee.

However, there are further improvements that deserve to be noticed with respect to innovation capabilities, innovation input and output:

- *In the past 5 years, Chinese "role models" of globally successful local companies with sufficient innovative capabilities emerged:* The Chinese government and the national press for that matter further promote these "national champions". Among the BRIC countries, China is the most successful breeding ground for companies that entered the Fortune Global 500 companies, listing 24 Chinese companies among the 500 largest companies worldwide in 2007.[119]
- *Technology SMEs are emerging*: In developed countries, SMEs form the backbone of fast moving innovative companies. Thanks to the number of science parks and freedom of universities to spin-off and commercialise their own inventions, the number of S&T-based small companies in China with fewer than 300 employees has increased by 52%; their patent applications for inventions more than tripled between 2000 and 2004.[120]
- *R&D formalisation increasing:* An increasing share of China's industrial large and medium sized enterprises (LMEs) establishes formal R&D

[118] China General Machinery Association database (accessed 22 May 2006). Machinery refers to mechanical machinery only, excluding electric equipment, office and household appliances as well as transport equipment.

[119] 24 Chinese companies listed in Fortune Global 500 (2007 edition); 6 from India, 5 from Brazil, 4 from Russia. The top Chinese positions are filled with resource companies like SINOPEC, banks and insurances, the only machinery related companies are automotive companies/suppliers like China FAW Group and Shanghai Automotive. See Fortune Global 500 (2007). In the machinery sector, companies cited frequently by our interview partners form Chinese authorities were Xuzhou Construction Machinery Group Inc. (XCMG, an SOE) and their competitor Sany (a private firm), suggesting their "national champion" position in the mindset of some Chinese interview partners. Both companies are large-size, producing heavy machinery and equipment in the field of construction. Both manufacturers got plenty of publicity in the Chinese national press since the US private equity firm Carlyle Group attempted to buy a significant share in XCMG in 2005, spurring nationalistic resentment against foreign buy-out of Chinese SOEs.

[120] OECD (2007), p. 32.

operations. This could be an indicator that companies are improving their R&D effort.

- *Fresh graduates with a sufficient educational background and ambition start to become available in the market* (which we will describe in further detail in section 2.3.).
- *Influx of foreign direct investment brought in additional R&D expenditure into the country, knowledge and people "spill over":* For local companies the presence of more advanced competitors enabled a steeper learning curve, as well as more incentives to catch up technologically. Large foreign MNCs but also SMEs with products requiring a high degree of customisation started to integrate China in their global knowledge networks by establishing R&D centres, a decade after the boom in inward foreign investment started. OECD estimates that currently foreign R&D accounts for 25-30% of total business R&D in China.[121]
- *Chinese companies tap on foreign knowledge bases by outbound FDI:* Larger Chinese companies with access to financing options increasingly engage in outbound FDI activities, creating operations in target markets, accessing resources or acquiring foreign companies that can add value to their business by providing opportunities to upgrade their knowledge.

Obstacles for Chinese companies to innovate

A 67% share of business R&D expenditure in China's total R&D expenditure initially suggests that businesses are already in the driver's seat among the players of the Chinese National Innovation System, as they are in other countries with a comparable business R&D share. Yet, the reality has a few more layers, addressed earlier. In fact, the vast majority of Chinese companies have neither extensive capabilities nor an inclination to innovate so far.[122] Output growth is mostly favoured compared to product quality upgrading, which may be a remnant of the planned economy's output quantity focus. But it is also a reflection of a lack of core people and skills in order to be creative and manage creativity. Meanwhile the institutional framework with its mechanisms favouring knowledge absorbers rather than knowledge creators join in to erode the private incentive to innovate, since knowledge cannot easily be appropriated in China.

The most significant short-term obstacles from a firm perspective to an increase in firm-level innovation are the following:

- *Process immaturity:* Since the upcoming private business sector in China is still young, companies are still establishing formalised processes to ensure smooth operations.
- *Lack of skilled people with the mindset on innovation:* From whatever perspective business innovation in China is looked at, one problem keeps occurring – the lack of people with the right skills and the initiative

[121] OECD (2007), p. 32.

[122] OECD (2007), p. 31.

to innovate and manage. This is in fact likely to be a long-term obstacle for a company innovation in China. As a company's CEO and participant in IBM's study on innovation explained, *"Human resources are the single greatest challenge facing our company today. Productivity can be improved by taking some measures, but 'human quality' is a long term problem that cannot be resolved in a short time"*.[123]

- *Limited funding and limited investment:* Funding for investments into upgrading innovation capabilities rely on the company's retained earnings and their willingness to invest in R&D and skilled people for example. Since access to other financing options is somewhat limited – especially for Chinese private companies, companies tend to economise taking more straightforward routes to innovate with less risk involved. Facing a lack of employee skills for innovation, they often opt for using their means for production expansion projects first, and as a compromise incrementally improve product or process quality.
- *Unsupportive culture:* Especially in Chinese SOEs, risk taking – and innovative activities are inherently more risky than doing what one has always done – is not encouraged. This causes some ambivalent situation for SOE managers since the recent policy focus is set on independent innovation. [124] There are other cultural factors affecting business innovations in China, from difficulties to change company leaders' mindset about quantity versus quality production to establishing an open team culture with people showing initiative to solve problems. Moreover, the cultural issues impeding independent innovation might run deeper than just the company culture. In the more pointed words of our interview collaborate at the China Academy of Machinery Science and Technology: "For thousand years the Chinese culture did not encourage creative ideas. In fact, Chinese do not tolerate very new or weird things or inventions. Copying or learning from the masters on the other hand is a cherished custom in Chinese society." However, the expert also mentioned, that the changes in this tradition over the past decades were palpable, the reason being China's opening up to the world.
- *Absence of a supportive legal framework:* The institutional framework in China with respect to more secure property rights and clear rules and regulations with respect to company operations and investment in China is still immature. Incomplete, ambiguous or contradicting regulations increase local authority discretion and ultimately companies' transaction costs.[125] Especially the weak IPR protection regime erodes the incentive to invest into major innovations in the first place.

All these factors result in a specific pattern of Chinese business innovation, that favours incremental improvements of product and processes over major,

[123] IBM Global Business Services (2007), p. 15.

[124] However re-innovation (re-engineering) is qualified as independent innovation as well.

[125] LI & FUNG RESEARCH CENTRE (May 2006), p. 14.

resource intense innovations; external sources of ideas over internal ones and in general well structured problems over ill-structured problems to solve to create a value added to their customers.

2.3 Extra-company innovation system

In the previous chapter, innovation activities have been described and analysed on the firm level. Yet the innovation system of a country also relies heavily on public sector activities, which include public sector R&D and an adequate educational system.[126] This chapter therefore deals with both these public sector responsibilities in China. Public sector R&D is of special interest since it is a professional form of knowledge creation. The educational system endows people – later employees, researchers, politicians etc – with relevant knowledge and problem solving skills that could support creativity and innovative capabilities.

2.3.1 Public research: R&D institutes and universities

The scientific research sector in China has gone through a series of remarkable changes and reforms in the past three decades. In 1952, China adopted a research system that separated research and education: Specialised research institutes under the Chinese Academy of Science undertook more in-depth research while universities handled educational tasks. Conducting research in universities' original goal was to promote teaching and learning but the role was broadened in the mid 1980s to encompass scientific research, starting with the establishment of national key laboratories at a number of leading universities, such as Peking University and Tsinghua University. The US research system had reportedly inspired the reform strategies with the aim of creating centres of excellence mostly for basic research embedded in universities.[127]

In 2005, the Chinese government channelled the majority of its R&D funds towards universities (1.7 billion USD) and research institutes (5.5 billion USD), together which added up to more than 66% of its total 8.3 billion USD of R&D budget. Both the Chinese universities and research institutes remain heavily reliant on funding from the government; 55% of the universities' R&D funding and an even higher proportion (83%) of the research institutes' funds came from the government as illustrated earlier in Figure 7.

Today, the role of universities within in the Chinese society can be divided into four parts: education, research, technology transfer and social service. For further analysis and a better understanding of China's academic landscape, a closer look on its structure is necessary. As the educational function of universities in China had already been discussed earlier and the social service function such as supporting the public authorities, health service, or organisation of social events is of less importance with regard to innovative capabilities of a country, the following paragraphs will focus on university research and its link to the industry.[128]

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[126] Lopes, Ilídio; Martins, Maria do Rosário: Nunes Miguel (2005).

[127] Ma (2007), p. 4.

[128] Haiyan, Wang; Yuan, Zhou (2006).

There are about 40 Leading Research Universities (LRUs) and institutes, which lead China's academic research and development. Their share of China's PhD graduates working in them is approximately 60%. Today, Chinese universities account for 16% of China's total R&D personnel (full time equivalent) and around 10% GERD in 2005, in contrast to research institutes' 15% of China's total R&D personnel and 21% of GERD[129]. These figures suggest that each university research personnel receive only half the funds compared with their counterparts in research institutes. On the other hand, universities' R&D output is more impressive: Their patent applications (invention, utility model and design) are double the applications of research institutes' total applications. Chinese universities also produce a higher number of scientific papers than research institutes. Tsinghua University, Peking University, Zhejiang University and Shanghai Jiaotong University rank highest in China with respect to their patent applications and scientific paper output.

A pool of 107 well developed universities form the second group of Chinas universities, the NKUs. They typically focus on specific fields of study and receive considerable governmental funds. The remaining universities receive very little or no funds from the government and are mainly focussed on undergraduate education.[130]Over the past 25 years, the Ministry of Education launched several programs dedicated to accomplishing two objectives: increasing China's international respect and prestige for S&T activities, and improving R&D activities in a range of fields. Additional programs aim at strengthening R&D in higher educational institutions to train highly qualified research personnel, for example (for overview see Figure 28):

- The 973 Programme was approved by the Chinese Government in 1997 and sponsors basic research, especially in the fields of agriculture, energy, information, natural resource and environment, population and health, and materials. This program addresses relevant R&D topics like new production technologies, materials, ICT and nanotechnologies. It is, to date, the largest governmental investment for basic research, with an amount of 330 million USD spent in the 9th Five-Year Plan (1997-2002). The Program is not only widely recognized in China's scientific society, it also acts as an incentive for returnees.[131]
- The 863 Programme, originally set up in 1986 in order to accelerate China's high-tech sciences, was approved in 2001 to continue for the duration of the 10th Five-Year Plan (2002-2006). Its objective is to stimulate the development of advanced technologies in a wide range of fields for rendering China independent of financial obligations for foreign technologies. Major tasks include the development of key technologies for China's information infrastructure, mastering new key materials and advanced manufacturing technologies to boost industrial competitiveness. In order to achieve these objectives, China wants to acquire IPR to

[129] China Statistical Yearbook on Science and Technology (2006), by MOST, p7

[130] SINOVA Innovation Research Center (2006).

[131] National Basic Research Program of China, (2004).

encourage innovation, enhance innovation capacity through application-oriented research, strengthen IPR management and protection, and encourage international cooperation.[132]

- The 211 Programme is targets the development of 100 universities to become internationally competitive in the 21st century. Significant research funding goes to selected universities to build their research capabilities. The Yangtze Scholars Programme was launched in 1998 and aims at improving China’s science through attracting outstanding researchers from China and abroad. In 1999, the Education Revitalisation Plan towards 21st Century was announced, in order to promote the collaboration among universities, research institutes and industry. Additionally, about 200 National Youth Centres of S&T Education have been established since 1999 with the goals towards improving scientific knowledge of the young generation.[133]

Programs of ministries to translate 5 year Science and Technology Plans into actions

Ministry of Science & Technology

	NKT[1] R&D Program	Spark Program	863 Program	Torch Program	973 Program
Launched in	1982	1985	1986	1988	1998
Aims at	Solve key national economic and social problems	Revitalise rural economy	China’s high-tech R&D	China’s high tech industrialization	China’s science and technology basic research
Scale	Funding of RMB 4b in 2006	Funding of RMB 117m in 2005	Funding of RMB 6b in 2006	Investment of RMB 900m in 2006	Funding of RMB 1.4b in 2006

	Ministry of Education			Ministry of Personnel
	211 Project	985 Project	Cheung Kong Scholars Prgm.	653 Project
Launched in	1995	1998	1998	2005
Aims at	Strengthening institutes of higher education	Founding of world class universities	Training country’s best and brightest young minds	Assist senior professionals to further education
Scale	Funding of ~RMB 24m till 2002	Funding of ~RMB 14b since 1998	Awarding max RMB 1m per scholar	Mainly from enterprise or private sector

Source: http://www.gov.cn (2007).

Figure 28: Programs of ministries to translate 5 year Science and Technology Plans into actions.

[132] Ministry of Science and Technology of the People’s Republic of China, (2006).

[133] ERAWATCH: Education policy for research (2007).

To achieve a stronger research orientation and improvements of quality and efficiency, several governmental initiatives pushed small and specialized universities and research institutions to merge into large-scale comprehensive universities. In order to cope with the growing number of enrolments, the government also encouraged universities to expand their facilities. The effects of merging the universities had been investigated by the University of Peking and were recently published in China's media. The study, including a survey of 76 universities, discovered that most of China's universities are in poor financial shape and heavily dependent on bank loans and governmental funds. The main reason for their financial crisis was, according to the study, the mergers into super-sized universities. On average, every educational institute has a debt of 57 million USD. However, while the top universities are able to generate sufficient income through relatively profitable daily operations, sophisticated R&D programs and above average funding, many of the remaining public universities are struggling due to having to spend their budgets on financing loan interests. With a debt-to-asset ratio of 55 percent, Jilin University (Changchun) is faring the worst; it has to pay more than 13 million USD in annual interests alone. [134]

University spin-offs commercialise innovations

University spin-offs are of interest for two reasons. Firstly, they promote technology transfer. Secondly, as the funds for universities are not distributed equally, oftentimes, there is a need for alternative funding sources. The industry's contributions to the universities' R&D funding have been steadily increasing. By 2005, more than one-third of the R&D funds for universities came from the industry.[135] Thus, the R&D achievements and the R&D income through technology transfers becomes an important issue in terms of today's university valuation and funding. As private enterprises traditionally do not have much R&D resources in China, the Chinese government launched a project called 'Enterprise-University-Institution Cooperation' in 1992. This led to an increase of enterprise funds in universities' R&D from 0.46 billion USD in 1998 to approximately 1 billion USD in 2004.[136] In 1998, the government initiated two other national programmes in order to encourage research and innovation in enterprises. The Torch Programme, which was funded by the government and the industry aimed at encouraging R&D institutes and universities to create high tech spin-off companies and market their innovations. In 2004, it received total funds of 9.2 billion USD with 71.9% coming from industry and 2.2% from government. The Spark Programme focussed on enhancing the technology capability of enterprises in rural areas. It received total funds of 2.7 billion USD, with 60% from industry and 5% from government.[137]

The total number of university spin-off remains constant around 2200 companies over the last years, but their revenues have tripled from 2000 to

[134] China Daily (August 2007).

[135] ERAWATCH: Research funding system (2005)

[136] Haiyan, Wang; Yuan, Zhou (2006).

[137] ERAWATCH: Research funding system (2005).

2004.[138] Most of these enterprises are situated in well-developed regions, innovation clusters and industrial networks like there are in Beijing, Shanghai, Liaoning and Shanxi. The top 10 spin-offs in terms of revenues are listed in Table 4.

As shown in Table 4 the largest university spin-offs in terms of revenues can be found in the ICT sector. There are two top-ten companies that are involved in engineering and manufacturing: Shanghai Tongji Science & Technology Industrial Co., Ltd., a stock listed spin-off from Shanghai's Tongji University, produces engineering machinery for construction works and manufactures high tech automotive products; Xian Jiao Tong Da Xue Chan Ye Group in Xian Shanxi manufactures compressors and computerised embroidery machines.

With total revenues of 10 billion USD in 2004, university spin-off companies represent only a fraction of the entire Chinese industry but they are vital for the further development of advanced technologies and the high-tech industry.[139] The Chinese Government encourages university professors to start up and run companies by allowing them to own shares and utilise spin-offs as additional source of funding for the universities.[140] Besides the fact that these companies have direct access to the research capabilities of the universities or institutes, there is another significant advantage: The inventions and results in basic research of universities and research institutes, carried out on behalf of clients like the military or the aerospace industry can be converted for civil use by the spin-off companies. The Chinese Government does not prohibit military applications from being converted into civil applications in order to develop new products. It provides seed capital for these companies free of charge in order to enable bringing these new products into the market. In return, the founding universities will not receive any further governmental funding but are allowed to keep the profits generated through its spin-offs.[141]

Rank	Enterprise	Annual Revenue $ million	Location	Main industry focus
1	**Founder Group** (Peking University)	2,127	Beijing	ICT: Software for digital printing, PC- Hardware
2	**Tsinghua Tongfang Co., Ltd.** (Tsinghua University)	894	Beijing	ICT: Internet information- and technical services
3	**Tsinghua Unisplendour Co., Ltd.** (Tsinghua University)	401	Beijing	ICT, Information security products
4	**Insigma Technology** (Zhejiang University)	384	Hangzhou, Zhejiang	ICT: Software, Telecommunication systems

[138] IFO (2007), p.37.

[139] ERAWATCH: Innovation Policy for Stimulation Research (2007).

[140] Chen, Zhanglian, (2006).

[141] Interview Droege, (China Special Pumps, 2005).

5	**Neusoft Group Ltd.** (North-East University)	282	Shenyang, Liaoning	ICT: IT-outsourcing, ERP
6	**Shanghai Tongji Science & Technology Industrial Co., Ltd.** (Tongji University)	198	Shanghai	Manufacturing, Engineering: Prod. of machinery for con-struction works, high- tech automotive products
7	**Xian Jiao Da Group** (Xian Jiaotong University)	196	Xian Shanxi	ICT, Manufacturing: compressors and computerised embroidery machines, Engineering, Pharmaceuticals
8	**Chengzhi Shareholding Co., Ltd.** (Tsinghua University)	193	Beijing	Manufacturing: Life sciences products, Engineering Pharmaceuticals
9	**Jiangzhong Holdings Co., Ltd.** (Jiangxi University of Traditional Chinese Medicine)	151	Nanchang, Jiangxi	Pharmaceuticals
10	**Shandong Shida S&T Co., Ltd.** (China University of Petroleum)	150	Dongying & Tsingdao, Shangdong	Chemicals / Petrochemicals

Table 4: Top 10 University spin-offs in terms of revenues.[142]

The government's attempt to encourage innovation and R&D activities of higher educational institutes through a commercialized approach by promoting university spin-offs, mergers of specialized R&D institutes and a commercialization of research applications. This leads to stronger linkages between the academia and industry while the know-how transfer between universities and enterprises is becoming more and more active.[143]

Besides universities, R&D institutes form the second source for public sector research. In the former planned economy, there was a true division of labour – R&D was mainly carried out in public research institutes while universities were only assigned with education and enterprises with production – with no overlap or direct exchange of experience. The central government was the only source of funding for thousands of research institutes. These institutes had the task to provide R&D input for the industry (state-owned companies), which did not engage in their own R&D activities. Knowledge was generally considered common property and was transferred from R&D institutes (producers) to producing entities (users) free of charge.[144]

In the course of China's transition from a centrally planned to a more market-oriented economy, the S&T system underwent various reforms and became more decentralised. In 1985, the Central Committee of the Communist Party of

[142] SINOVA Innovation Research Center (2006).

[143] Chen, Zhanglian, (2006).

[144] ERAWATCH: Research policy trends (2007).

China decided to reform the S&T landscape. One objective of the reform was to generate an interaction and mutual co-operation between science (public R&D) and production (enterprises). In addition, there was a shift in the focus of research policy; from basic research to high technology development.

By 1980, there were approximately 7700 public research institutes with 323,000 scientists and engineers employed.[145] Because of the structural transformation of China's R&D system, the country's traditionally large research institute sector was significantly reduced. R&D institutes were encouraged to create spin-off companies and a number of state-owned institutes were transformed into enterprises or incorporated as R&D divisions within existing companies.[146] By 2004, there were about 4,000 research institutes left.[147]

Another objective of the reform was to allocate value to knowledge, ultimately making knowledge a commodity to knowledge-users and granting ownership rights to knowledge-producers. Thus, in the late 1980s, China introduced its first IPR laws and regulations aiming at consistency with international standards, and joint international treaties and agreements on IPRs. With the new open-door policy, multinational companies also began to expand in China. Imported technologies and technology flow in the global market became important elements in R&D policies. Since the late 1990s, the research system dominated by governmental R&D institutes has changed towards a more enterprise-centred system. Although the 2000s have not witnessed further fundamental changes in China's research policy, enterprises have become more active in R&D activities.

2.3.2 Education: The role of schools and universities in the Chinese innovation system

Companies and other organisations require a sufficient share of innovative people in order to be innovative. People need creativity to be innovative, which again depends on certain skills or resources. There are various theories about what these skills may be. In her influential work, Teresa Amabile points out three components a person needs to enable creativity (see Figure 29):[148]

- Expertise: Relevant knowledge
- Creative thinking skills: Processes of how people approach problems, which depends on personality and working style
- Motivation: Intrinsic and extrinsic, with the former being more effective

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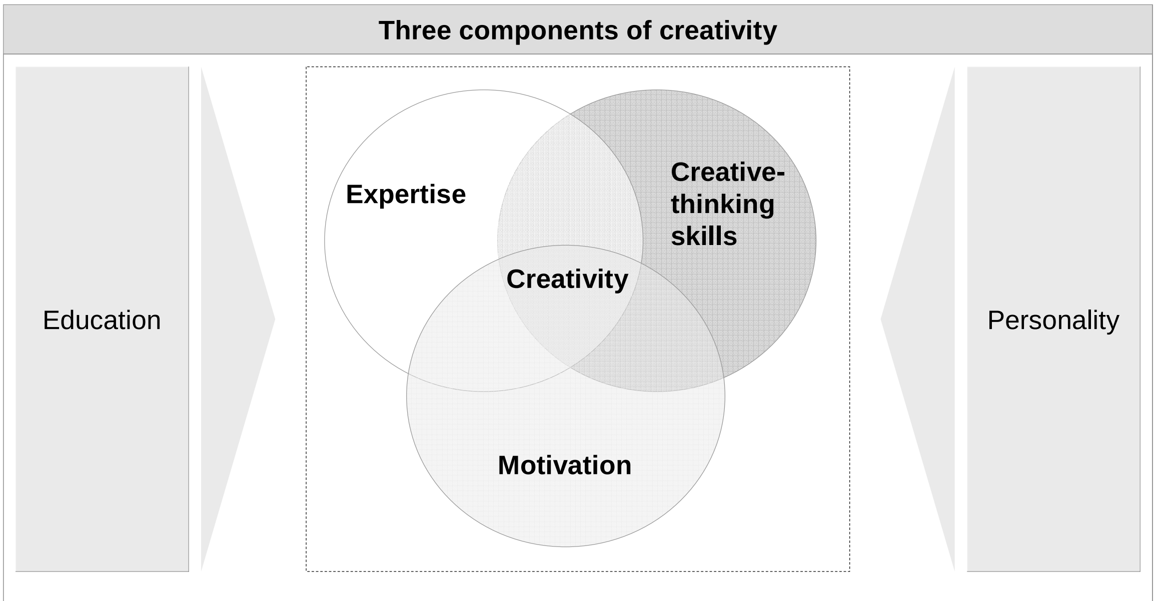
[145] Gu and Lundvall (2006).

[146] Schwaag Senger, Sylvia; Breidne, Magnus (July 2007).

[147] NBS (2005).

[148] "All innovation begins with creative ideas . . . We define innovation as the successful implementation of creative ideas within an organization. In this view, creativity by individuals and teams is a starting point for innovation; the first is necessary but not sufficient condition for the second". Amabile et al. (1996). p. 1154-1155. See also Amabile (1996); Adams (2005); Ekboir et al (2006), Aguilar-Alonso (1996), Sternberg (2001), McIntyre (1993) and many others.



Source: Amabile et al (1996); Aguilar-Alonso (1996); McIntyre (1993); McIntyre (1993).

Figure 29: Three components of creativity and major influencing factors for components.

Innovative capabilities are linked to formal education insofar as education can enhance all three factors mentioned above: It can endow people with structured, more or less specialised knowledge (expertise) that they can draw on when processing new information; influence people's ability to process information and solve problems; it may even (de-)motivate people.

The knowledge base needed to support innovation can differ substantially depending on the field of application: Scientists for example usually need a more formal training than artists do. Therefore, a country's educational system has to equip people with *relevant* knowledge and training for a variety of potential purposes within a society, may it be basic skills developed during schooling or specialised knowledge acquired in vocational schools, colleges or universities. Learning does not stop after leaving the formal education sector. Training on the job, for example, which was already highlighted in chapter 2.2.1 could be seen as a part of a county's educational system, but it is not part of the public sector and hence not covered in this section.

A better-educated workforce is not only important for the innovativeness of companies and other organisations, but would also increase their capabilities to absorb existing knowledge. Thus, an investment into the educational system is associated with high returns in terms of economic output growth. A study by the UNESCO and the OECD estimated that China's investment in human capital over the last two decades accounted for a half percentage point of its annual growth rates.[149]

[149] UNESO, OECD (2002).

Spending on education up, yet relative spending underwhelming

Total absolute spending on education in China grew an average 19% per year from 1992 to 2005 reaching about USD 110 billion in 2005.[150] The government share in total spending in that period declined from 84% to 61% in that period, offset by an above average increase of the private share of educational expenditure. Measured as a percentage of GDP, government expenditure on education amounted to 2.8% of GDP, while total expenditure – including all other sources of funds – reached an estimated 4.6% in 2005. Public spending on education is thus not only lower than the average in OECD countries, but also lower than a number of developing countries such as Thailand and the Philippines.[151]

Tuition and other schooling fees, which are largely privately paid accounted for nearly 20% of total educational expenditure in 2005. The government advocates a model of education where the consumer pays for a larger proportion of the costs involved by allowing educational facilities to raise tuition and other fees. Spending on the latter grew by an average of 32% per year from 1992 to 2005. Thus, the consumer had to rely more on his own savings for education. At the same time, China's one-child policy had resulted in much smaller family sizes which has enabled parents to spend more in relative terms per child, supporting the overall trend of people having to become more self-reliant. Currently, a large part of household spending in China is allocated to education – especially children's education, indicating the importance attached to it, since the average household income in China remains very low.

High total enrolment: More than 230 million people enrolled in primary, secondary and tertiary educational facilities 2005 (nearly 3 times Germany's entire population)

China has the world's second largest formal educational system in terms of total enrolments after India.[152] In 2005, more than 230 million students were studying on the primary, secondary and tertiary education levels, only surpassed by India's total enrolment of about 240 million pupils and students. By contrast, in the US and in Germany the total pupil and student population amounted to only 28% and 6% of the Chinese figures that year.[153] Figure 30 gives an overview of the structure of China's formal education system.[154] Children usually enter elementary school at the age of six followed by nine years of compulsory schooling. After six years of elementary-level schooling, they will proceed to 3 years of Junior Middle School. Compulsory schooling ends here, but several

[150] Spending figures in this section are estimates based on National Bureau of Statistics figures for education from 1992-2004 and real GDP data from 2005, exchange rate applied was fixed to USD 1 = RMB 7.73.

[151] OECD Observer (January 2006).

[152] UIS Statistics in Brief (2007).

[153] UIS Statistics in Brief (2007), AEP (2007), China Statistical Yearbook on Science and Technology 2006, p. 20-22.

[154] For simplification purposes, this report focuses on primary, secondary and tertiary education and leaves out the smaller sector of adult education.

roads are available from there – if the pupils manage the relevant entrance hurdles.

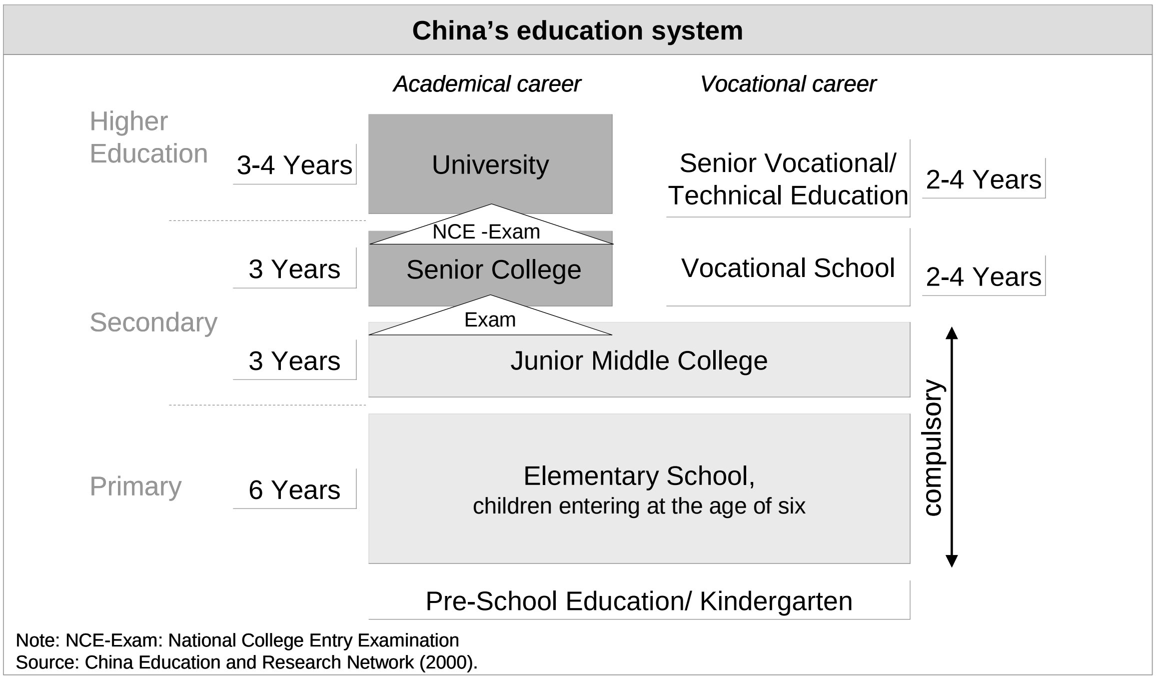


Figure 30: China's education system.

Practical / vocational training on the secondary level is underdeveloped

One option of acquiring professional knowledge and skills after finishing compulsory education is pursuing vocational training. Vocational schools such as technical secondary schools, vocational high schools and skilled workers' schools [155] offer programs to train medium-level skilled workers of all kinds, including managerial and technical personnel varying from two to four years. In 2005, 13.6 million pupils were enrolled in vocational secondary education, which represents less that 14% of the total current secondary enrolment. Put in an international context, China's vocational sector is larger than India's, which has less than 2% of all pupils on the secondary level enrolled in technical or vocational programmes. For Germany and the UK this percentage stands at 22% and 23% respectively (see Figure 31). [156] Evidently, in absolute terms, China's number of people studying in secondary vocational facilities is higher than in the compared countries; being more than 7 and 9 times higher than that of Germany and India respectively.

In terms of skill development for the domestic labour market, medium level workers with specialised skills and middle management are in short supply.

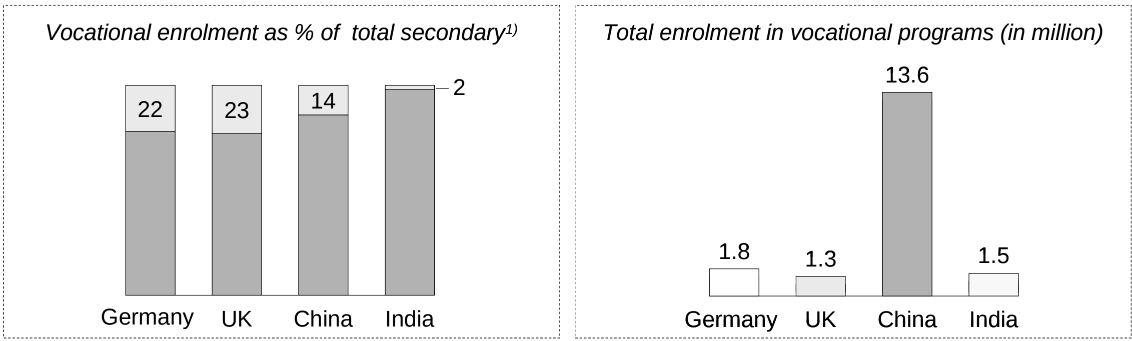
[155] Technical schools usually train mid-level technical personnel in courses lasting up to 4 years. Skilled workers' schools prepare Junior Middle School graduates for manufacturing jobs in programs for three years.

[156] UNESCO Institute for Statistics database.

Since vocational programs are rather specialised in terms of training offered, learning time and costs are greatly diminished when companies employ these graduates in their respective fields – making these new employees rather attractive for companies. In theory, company attachments support learning skills relevant for job. However, current enterprise attachment of vocational students is far from ideal, albeit slowly changing. In the future, students are supposed to spend half of their study time in classrooms and the other half on the job in companies. [157] However, – as often the case – this would depend on the company sector co-operation, assuming that China will not enact a law requiring companies above a certain size to take on vocational trainees. "The reality now is that most enterprises in China can't afford long-term internships and are unwilling to cultivate such relationships."[158] An interviewed director at the S&T Innovation Management Centre of the Graduate University of the Chinese Academy of Sciences shared with us, that vocational degrees are somewhat looked down upon in the Chinese culture. Thus for young people who want and can afford a professional education, universities and colleges are the number one choice, since their status (and salary) is expected to be higher thereafter. However, vocational graduates would find it much easier to be hired in China, especially compared to the large number of Bachelor's graduates that the market was not able to absorb lately.

Nevertheless, new enrolment figures in secondary vocational schools have picked up recently since the government saw the need to discontinue underinvestment into this sector[159]: For 2007 the number of new entrants into this type of schooling is targeted to be around 8 million students, half a million more than in 2006.

Comparison of technical/vocational enrolment in China and selected countries (2005)



1) Includes lower secondary (after 6 years of primary education) and upper secondary (after compulsory schooling)
Source: UNESCO (2007).

Figure 31: Comparison of technical/vocational enrolment in China and selected countries (2005).

[157] People's Daily Online (25 October 2006).

[158] Quote by Cheng Fangping, an expert in vocational education at the China National Institute for Educational Research according to People's Daily Online (25 October 2006).

[159] "… Vocational Education Law requires that 20 percent of the annual education budget goes to vocational education but the ratio is much lower in reality." See China Daily (14 December 2006).

Competition for higher education, surge in student enrolments

Prior to entering a higher education facility such as colleges and universities, pupils need to complete 3 years of Senior College first (equivalent to A' levels or the German "Abitur"), to which they get access after mastering a locally administered entrance exam. In 2005, enrolment in this upper secondary type of school amounted to 50% of the respective age groups in China – in Germany this share was higher at 96%, while it reached 88% in the US (gross enrolment ratio).[160] After successfully passing another test, the National College Entry Examination, several higher educational paths are open, such as higher professional education or further academic education, the latter starting with an undergraduate degree (Bachelor's) and later with a postgraduate degree (Master's, Doctorates) or their equivalents.

Figure 32 shows the development of new enrolments for each of the three academic tertiary degree types. The new enrolments for undergraduate degrees grew by 19% annually from 2001 to 2004 but at an extenuated rate in 2005 and 2006 (on average 11%). New enrolments for Master's degree programs had grown the most of all degree types in the period from 2001 to 2006, averaging 21% per year. However, here too, the period of 2001 to 2004 showed higher growth rates than thereafter. For doctorate degrees, the decline in growth rates is evident from 2003 onwards.[161]

Demand for tertiary education outstrips supply

Total tertiary graduate output numbers correspond – with some time lag – to the surge in new enrolments, growing on average 13% per year from 2000 to 2005 (see Figure 33). In total numbers, China produced some 3.2 million tertiary graduates in 2005, nearly 11 times more than Germany, more than 5 times more than the UK and about 30% more than the US. We estimate this number to surpass 6 million by 2010.

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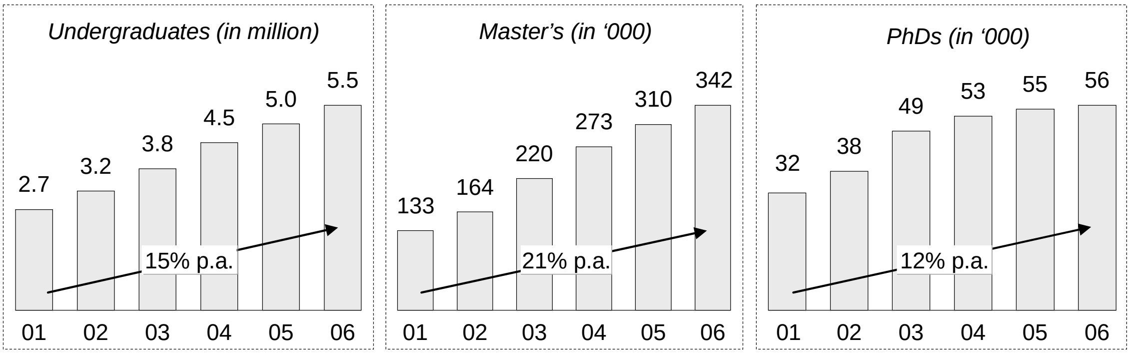
[160] UIS Statistics in Brief (2007). Gross Enrolment Ratio refers to the number of pupils enrolled in a given level of education, regardless of their respective age, as a percentage of the population in the theoretical age group for the same level of education. The rate indicates how well the education system manages to enrol students of a particular age-group. It can be higher than 100% as it may comprise over-aged pupils in the cohort.

[161] 2001 to 2003 average annual growth of 24% compared to 5% from 2003 to 2006.

Development of new enrolments in China (2001-2006)



Note: Growth rate refers to compound annual growth rate (CAGR)
Source: UNESCO (2007).

Figure 32: Development of new enrolments in China (2001-2006).

The Chinese higher education level has experienced two decades of expansion with large increases in new student enrolments across all degree types. In 1990, only three percent of the respective age cohort had enrolled at the higher education level, in 2005 this share had already increased to 20%. Nonetheless, higher education still represents a bottleneck in the Chinese education system. Approximately 8 million pupils competed for about 5.5 million places in undergraduate universities and higher vocational education in 2005.[162] Further up the academic educational ladder, competition does not lessen: About 1.2 million students with a Bachelor's degree vied for nearly 273,000 available Master's places in 2004.[163] Although the number of available postgraduate places increased to nearly 400,000 in 2006, demand still outstrips supply by far. The number of students to be admitted to study is determined centrally by the National Development and Reform Commission; the Ministry of Education then allocates graduate funding to the respective schools.[164] Students who do not gain access to Chinese higher vocational schools, colleges and universities may opt for alternatives such as going to a tertiary vocational institute, a private school or studying abroad if their budget allows for it.

[162] NESO (2005), p. 8.

[163] NESO (2005), p. 9.

[164] CIPA (2007), Ma (2007), p. 9.

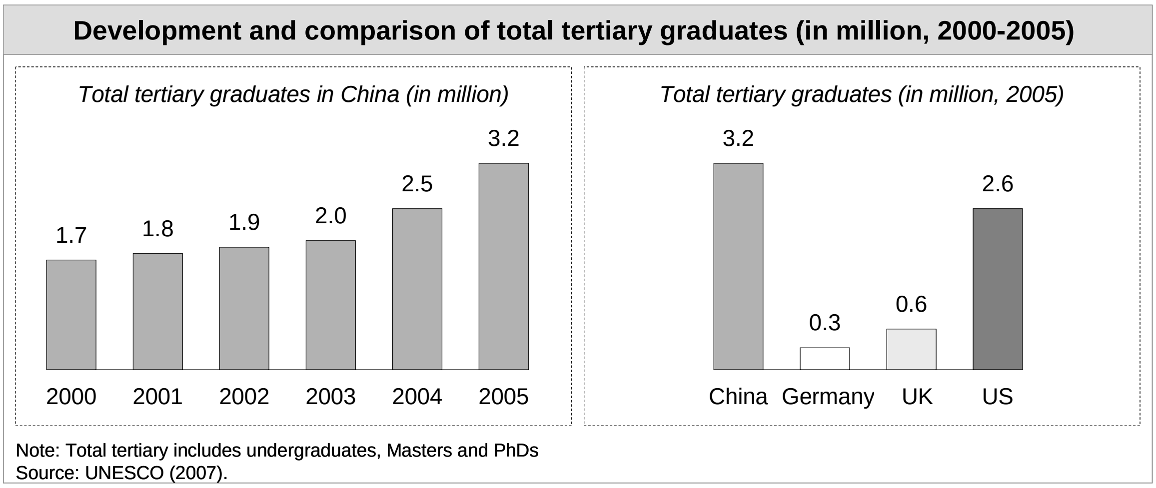


Figure 33: Development and comparison of total tertiary graduates (in million, 2000-2005).

Taken into consideration China's 1.3 billion people, decades of low higher education enrolments still show: Only 5% of the population have more than 13 years of schooling. Interestingly, in India – a country, where until recently 40% of the population did not attend any school at all, outperformed China in this aspect as Figure 34 depicts. In developed countries like Germany and the UK, more than 20% of the population had attended schools for more than 13 years.

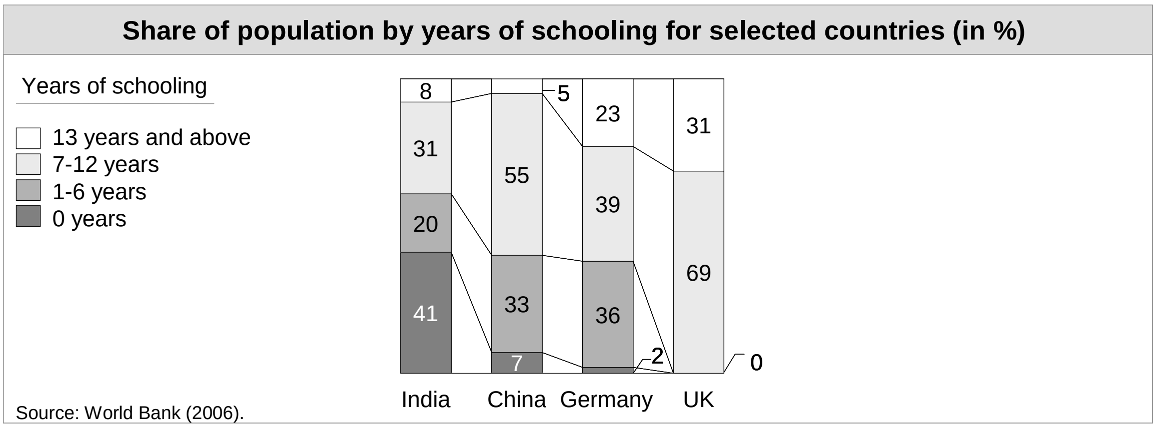
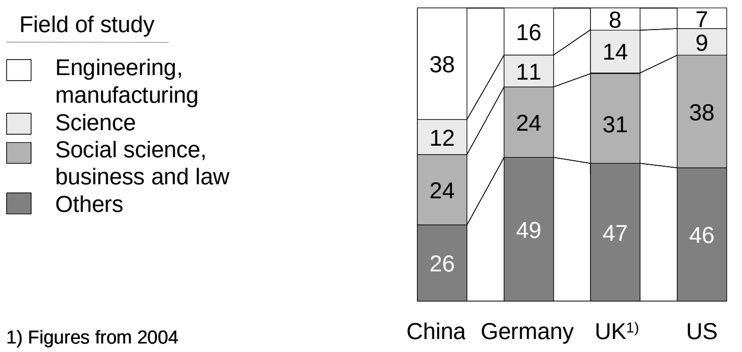


Figure 34: Share of population by years of schooling for selected countries (in %).

Engineering subjects preferred over social science and off-mainstream subjects

In higher education, the engineering subjects are most favoured by Chinese students, accounting for 38% of all tertiary graduates or 1.2 million people in 2005, followed by social science, business and law courses attracting 24% of them (see Figure 35). Noticeably, the share of students in engineering and manufacturing related subjects is very high by international standards: In Germany it was 16% and in the US only 7% of the total graduates 2005. This can be explained by a much larger variety of chosen subjects in developed countries while in a poorer country like China, students face much more pressure – by their families and peers – to choose a mainstream subject most likely to result in a higher income. The pragmatic solution for Chinese students seems to be to opt for an engineering subject, even if sociology, fine arts or philosophy were closer to their interest.

Distribution of graduates by fields of study in tertiary education (in %, 2005)



1) Figures from 2004
Note: Tertiary: Undergraduates, Masters and PhDs
Source: UNESCO (2007).

Figure 35 Distribution of graduates by fields of study in tertiary education (in %, 2005).

By pragmatic individual choice, China has become the second largest country by output of science and engineering graduates over the last decade, behind the United States. Nevertheless, a range of governmental programs aims at raising further awareness and interest in science among young people, such as mentoring programs with retired schoolteachers.[165]

Love for the title: High propensity to finish education with a doctorate degree once the Master's degree is accomplished

The pragmatism extends even further and in an unexpected way. High potentials in developed countries would not necessarily be expected to finish their educational degrees at the highest tertiary level with a doctorate. That seems to be somewhat different in China. Students who have completed a Master's degree in China are much more likely to continue with a doctorate than elsewhere. According to our estimates, around 40% of the Master's graduates had chosen to continue with a doctorate. This does not even include the graduates who went abroad for the PhD.[166] There is a high prestige attached to the doctorate title – potentially more than elsewhere and "…many first-class experts in their field believe that they would not be able to survive in their sector without a doctorate" in China.[167]

Internationalisation to enhance knowledge base

Just like for businesses, openness and mobility of people and organisations within the educational system facilitates knowledge transfer and learning.

[165] OECD (2006), p. 114.

[166] Assuming a 3 year time lag, since PhDs tend to last this long in China, we put the doctorate graduates in relation to the Master's graduates 3 years earlier, resulting in rates of 42-39% of the Master's had gone on studying in the doctorate graduate years 2004 to 2006. Data from China Statistical Yearbook on Science and Technology 2006, p. 20, 21, 22.

[167] China.org.cn (14 January 2007).

Cognizant of this, the Chinese government regards international co-operation as a priority for the development of the Chinese higher education sector. "China wishes to know more about the world and let the world know more about China," said Liu, Vice director of the international cooperation department of the Ministry of Education (MOE).[168] China's objective is to learn from specialists in the world in order to raise its standards in its education and research and to acquire modern management skills and teaching methods.

More specifically, the government aims at (1) training a core group of specialists and experts who should play a key role in the modernization drive in the country, (2) attracting advanced knowledge and technologies and (3) alleviating bottlenecks in domestic education and training capacity.[169]

Invite people in – so far on a small scale

China extended up to 10,000 governmental scholarships for foreign students and facilitated bureaucratic burdens. According to the Chinese educational office, the number of students from foreign countries studying in China has risen by more than 20 percent annually from 2001 to 2006.[170] However, the number of foreign students in China is still relatively negligible. For example according to the Chinese Ministry of Education, more than 1,200 German nationals come to study in China annually, with a rising share of business and economics as well as engineering students among them, meaning not just language students. That is only a fraction of the students from Mainland China attending courses in Germany: In 2004, their number exceeded 24,000, almost five times more than in 1997.[171]

The Ministry of Education has established a number of organisations providing information and services to domestic universities and foreign students. Universities offer competitive salaries for foreign researchers or entire teams to come to work in China. Training centres have been set up in order to provide language and other training for participants. Government organisations also provide funds to support incoming and outgoing student mobility. Considering the fact that more than 90% of the outgoing students are self-financed, this governmental support plays a minor role at encouraging people to study abroad.[172]

Send people out – never to return?

Strengthening the talent base does not only refer to home-trained people, but also to foreign-educated elites. Recruiting and utilising foreign-educated Chinese nationals, is a top priority for the Chinese government.[173]

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[168] China Education and Research Network, (2006).

[169] NESO (2005), p. 3.

[170] China Education and Research Network, (2006).

[171] DAAD China Info (Juni 2006).

[172] NESO (2005), p. 3.

[173] Li (2005).

The problem is that a majority of the students and researchers who have gone abroad for further education does not return to China – at least thus far.[174] From 1978 to 2006 about a million people had left China to study abroad, and only 275,000 have returned by now; 200,000 thereof having attained permanent residencies or citizenships abroad.[175] Albeit declining, the percentage of highly educated Chinese nationals remaining abroad is high.[176] The majority of these nationals abroad are still engaged in their studies, in research or academic exchange programs. The reasons for highly educated Chinese citizens staying abroad are numerous: Higher living standards, better job advancement opportunities, more freedom etc. Furthermore, despite family ties and national loyalty, returning to China is not always smooth sailing, which probably holds true in general for people who lived outside their home country for a number of years.[177]

In the course of this study, we interviewed a number of highly educated Chinese living abroad (e.g., the US and Singapore) about their potential return to China. In a true economist fashion, we wanted the participants to express all the different factors in their decision either to return to China or stay abroad in monetary terms – the salary in China expressed as a percentage of their current salary in the US or Singapore that would convince them to return to live and work in China right now. Although this survey might not be comprehensive and representative of all Chinese working aboard, our findings were nonetheless eye opening.

100% of our survey respondents have attained at least education levels up to Bachelor's degrees with half of them holding Masters Degrees and one-third of them holding Doctorates. Survey participants shared that companies in China would have to pay them an average of 156%, with a range of 90% to 300%, of their current pay before they can be enticed to return to China to work. However, when what would they be paid in China if they were to return to China today, participants estimated that they would only be paid an average of 56% of their current salary. This highlights the large disparity between the current realities of the job market in China versus the expectations of its foreign educated citizens. Our respondents also predicted that it would take an average of 10 years in order for China's salary to catch up with how much they are currently receiving. However, though extremely important, money is not the only motivator for a highly educated person to return to his home country, other challenges such as social instability and the Chinese infrastructure are also being taken into consideration. With its high growth potentials, China doubtlessly offers attractive

[174] Nature Magazin (11 March 2004), p204.

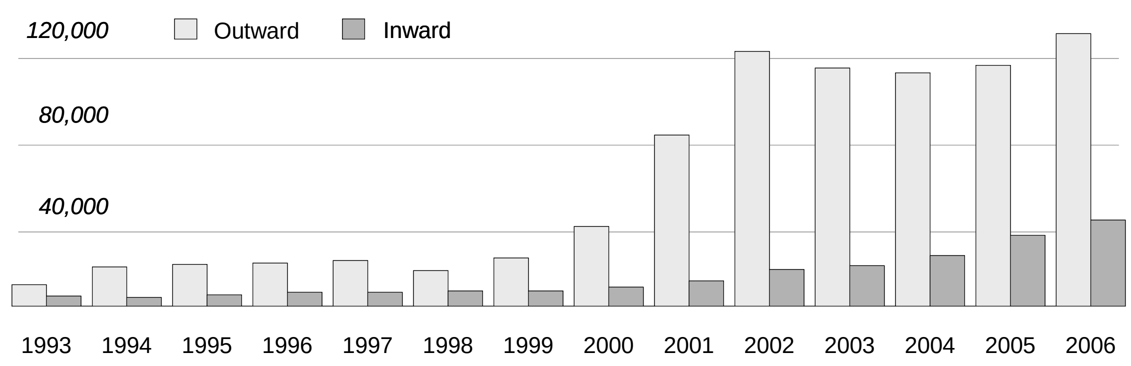
[175] Chinese Academy of Social Sciences (2007).

[176] The ratio of people returning each year to people leaving however slowly rises from a 7:1 in 2002, which was a temporary low, to the estimated current 3:1 in 2006, thus returning to the lower ratios of the early and mid 1990s.

[177] Wildson James, Keely James (2007): "There is some resentment towards returnees. People are happy that we are back to make money and share our knowledge, but we are kept outside the centre, in the import zone", said Li Gong, a Chinese software architect who spent 13 years in Silicon Valley before he returned to China.

opportunities for its future returnees. However, as one of the interviewees explained, many Chinese plan to 'get more exposure overseas first before finally settling back down in China'.

Outward and return migration of Chinese students (numbers, 1993-2006)



Source: OECD (2006), based on Ministry of Education, Educational Statistics Yearbook of China, 1990-2006.

Figure 36: Outward and return migration of Chinese students (numbers, 1993-2006).

In the past, governments of developing countries such as China were concerned about losing their talents. Nowadays, more and more people realise that these migrant scientists might become an asset one day, since good opportunities may convince these people to return to China even after many years of staying abroad. China has realized the problem and – for example – courts expatriate researchers to return home in order to reverse the ongoing brain drain. In fact, the increase in the share of returnees is largely attributed to attractive policy incentives and great opportunities in a booming home economy.

The Chinese Ministry of Personnel promotes the return of high-potentials (successful/talented researchers), and provides a number of incentives for returnees: For example, it tries to facilitate the logistic problems that returning Chinese graduates might face; about 60 industrial parks and several universities offer good job opportunities to returnees such as higher salaries and privileges.[178] Returnees are recruited by various sectors, politics, academia and business. In the political arena, the presence of foreign-educated returnees is visible in some high-ranking positions given to them. In his recent study into the role of returnees in the Chinese political leadership, Li Cheng stresses that less than 5% of the full members and 8% of the alternate members of the 16th Central Committee of the Chinese Communist Party (CCP) – formally the highest the highest organ of the Communist Party between party congresses – were foreign-educated in 2005.[179] The influence of foreign-educated Chinese on the business sector is unclear and evidence anecdotal at most. In Shanghai for example, about 3,000 businesses have been established by returnees.[180]

[178] Education Guardian (2 June 2007).

[179] In 2005, the Central Committee counted almost 200 full and more than 150 alternate members. Li (2005).

[180] Li (2005).

Nevertheless, it will still take several years for China to be able to offer enough incentives to it talented citizens formerly lost to foreign economies.

2.3.3 Assessment of the public sector spheres: Education system and Public R&D

Over the past 20 years, China's public sector has made great strides in order to contribute to upgrading the country's technological capabilities. Among its achievements, are the fact that its current undergraduate and postgraduate enrolments in science and engineering are higher than most developed countries including the US, Germany and Japan.[181] Its human resources engaged in S&T have also increased significantly, tripling from 12.2 million in 1990 to 38.5 million in 2003 (or a ratio of 10.8 in 1,000 people in 1990 to 29.8 in 1,000 people in 2003).[182] China's percentage share of world scientific publications has also increased from 2% in 1995 to 6.5% in 2004, overtaking France but still pales in comparison to the US's 30.5% share of world publications. China today publishes the most scientific papers for example in the fields of engineering science (among others).[183] However, despite the high number of graduates and publications, the number of high quality research papers published remains low. It is assumed, the high pressure on PhD students rather leads to quantity than quality.[184]

With the help of compulsory schooling, China's educational system successfully managed to reduce the country's illiteracy rate from 22% in 1990 to 8% in 2005.[185] As poverty and illiteracy are strongly linked, China has done a great deal to "empower the poor".[186]

In 2006, China reached an enrolment rate of 99.2% of school-aged children, which is comparable to Europe's enrolment rate.[187] By 2006, more than 17 million students were enrolled in the higher-education sector.[188] As academic achievements are highly valued in the Chinese society, families are willing to channel a large share of their resources into funding the education needs of their (often only) child. This increases the likelihood of the child attaining higher education standards compared to his parents.[189] Furthermore, as the one-child policy approaches the third generation, one adult child is expected to support two parents and four grandparents (the so-called "one-two-four" problem). This

[181] OECD (2007)

[182] Ibid.

[183] DG Research - European Commission (2007).

[184] Wildson James, Keely James, (2007).

[185] Refers to illiteracy rates of adults of 15 years or older. See UIS Statistics in Brief (2007).

[186] UNESCO (2002).

[187] NBS (2006).

[188] CIPA, (2007).

[189] Yang Cunzen, Gale Trevor (2005).

imposes additional pressure on the child's education and career to outperform their peers, so they are highly motivated students and workers.

However, despite the impressive achievements thus far, there are several weaknesses in China's public sector that might lower its ability to contribute to improving China's National Innovation System.

Challenges remain

Although the educational system has undergone numerous reforms over the last 25 years aiming at modernisation and increasing its efficiency and quality, the sector, as a whole, remains a thorn in the Chinese government's side. In 2005, government expenditure on education only comprised of 2.6% of China's GDP although the government had planned to budget 4% of GDP on education by 2000. This has led to strong criticisms both from the public and within the government for its allocation of funds; with other sectors of the economy seemingly given higher priorities than the education sector.

The rapidly increasing number of students and lack of funding has forced the Chinese government to concentrate its resources on handling quantities at the expense of quality even though they are aware of the trade-offs. In a statement by Zhang Yaoxue, Director of the Ministry's Department of Higher Education, "Undergraduate education is the most important part of higher education. Only if the quality of undergraduate education improves, can higher education produce more leading professionals for the country's development." [190] In 2007, a nationwide project with USD 320 million government funding was launched by the Ministry of Education to improve the teaching quality of undergraduate education. The project includes presenting awards to 500 outstanding teachers annually and sponsoring of 15,000 university students to conduct innovative experimental projects.[191]

China is also aware of the importance of education for further development of the country to convert the existing educational system from memory-based learning to more creative thinking based as well as to utilize a more interactive approach.

Furthermore, due to insufficient funding, access to higher and especially high-quality education is limited which results in accessibilities varying based on several socio-demographic parameters (e.g., the accessibility of education varying greatly students throughout China).

A common criticism about China's educational system is its focus on rote learning, leaving Chinese graduates ill equipped with skills related to creativity or independent problem solving skills, or in other words – with innovative capabilities. Our interviewee of the Science and Technology Department at the Ministry of Education recapitulated: "Chinese students are good at knowledge absorption but weak in independent thinking and practical skills. The current Chinese school curriculum still focuses on knowledge transfer only. China's

[190] Xinhua News Agency (27 January 2007).

[191] People's Daily Online (27 January 2007).

educational curriculum should put more attention to training students' practical skills." China has a long history of standardised tests; national tests determine which level of education a student will attend.[192] Pre-college education focuses mainly on achieving high examination scores and pays less attention to the development of abilities in areas like sports, music or arts. For a student's general career path, examination scores are still by far the most important factor. Consequently, the capacity for memorisation of Chinese students is often highly developed, but generally, the educational system 'does not encourage students to think critically and creatively.'[193]

Since the 'National College Entry Examination' strongly focuses on repetitive knowledge, it systematically restricts the access to higher education for students with higher 'practical creativity'.[194] In order to become an innovation juggernaut, this might prove to be an obstacle.

Furthermore, cultural rather than economic aspects could present obstacles for improvements in scientific research. Hofstede defines culture as "the collective programming of the mind which distinguishes the members of one group or category of people from another". According to his five cultural dimensions, China has a very high Power Distance Index (PDI) of 80. This indicates that there is a wide acceptance for unequal distribution of power between members within the Chinese society. The PDI suggests that a society's level of inequality is endorsed by the followers as much as by the leaders. The world average PDI lies at only 55.

China has a very low Individualism Index of 20, which indicates a strong collectivistic orientation (compared to USA with an Index of 91). This means that people are integrated into strong, cohesive in-groups, often with extended families which continue to protect them in exchange for unquestioning loyalty (the word 'collectivism' in this sense has no political meaning: It refers to the group, not to the state).[195]

This spirit of conformity and respect for authority influences the style of scientific research and learning. Thus, the deference to authority tends to result in the usage of common paradigms instead of raising new questions and hypotheses.[196] Furthermore, assertiveness in pushing for one's ideas, an attribute that generally recognised as positive in the western world, is considered a negative trait as it increases the risk of other people or oneself 'losing face'. This reflects back to the incentive systems within the educational and public research spheres, where open criticism is difficult, thus making it difficult to learn from discourse.

In this chapter, we covered many aspects of China's National Innovation System, starting from the national level evidence, then focusing on businesses

[192] The Globalist (19. April 2006).

[193] Balaram, P. (25 March 2004).

[194] IFO (2007), p.33.

[195] Hofstede, Geert, (2003).

[196] Nature Magazin, (11 March 2004) p.204.

and their innovation activities and last but not least, we identified major developments in the public sector contribution to China’s innovative capabilities. China is a diverse country and thus we tried to give a diverse picture of the players of its National Innovation System. In the next chapter, we will describe the strategies involved in innovation activities in China. While the business strategies with respect to innovation are self-organising and mostly self-motivated, public sector strategies are not. The strategic entity within the public sector is the government. Since we haven’t mentioned this important factor in China’s innovation system yet, we will do so extensively in the coming chapter.

3 The plan:
China's innovation strategies

不改则废

bu gai ze fei

Mend or end

3 The plan: China's innovation strategies

China would not the first nation to overcome an allegedly insurmountable gap to reach technologically advanced capabilities. Other Asian nations serve as good examples of the way China might try to pursue: Post-war Japan, the 1950s Korea, Singapore or Taiwan could be mentioned here.[197]

Aside from pure business incentives to innovate (see 3.1), implementing pragmatic and targeted policies to increase the industrial value added were key to these countries' success stories (see 3.2). These policies concentrated on certain strategies, despite differences in the respective weighing of each item:

- Promoting exports
- Improving infrastructure
- Restructuring state-owned companies (focus on market mechanisms) – diminishing the direct influence of the government on the national science and technology system
- Developing national capabilities

Having dealt extensively – and still ongoing – with the first 3 issues in the past two decades, China's current government focus rests on the last point - developing national capabilities – especially innovative capabilities.

3.1 The economic incentive to innovate: Business innovation strategies

According to the "Medium- and Long-term Programme for Science and Technology Development" (2006-2020), firms will become the focal driving force for China's innovation. Therefore, it is crucial to anticipate Chinese firms' innovation strategies to provide sound countermeasures. In this section, we will first describe an overview of Chinese firms' innovation characteristics followed by a detailed breakdown-analysis that differentiates potential innovation strategies adopted by SOEs, SMEs and spin-offs.

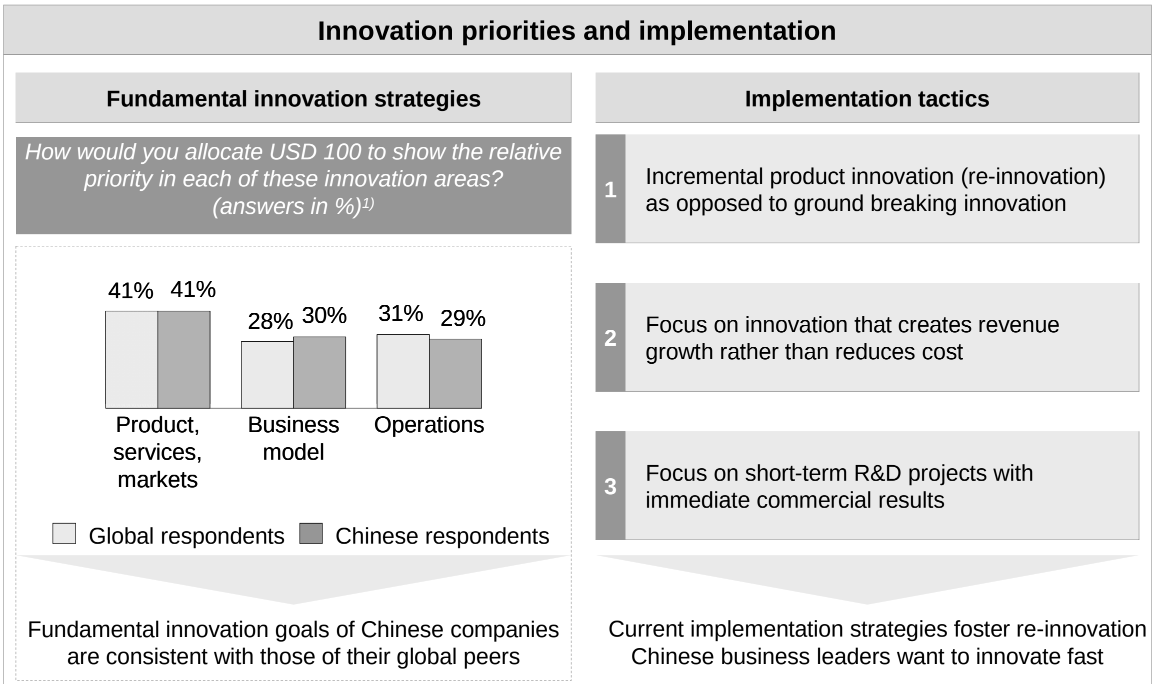
3.1.1 Chinese firms' innovation priorities and implementation

As revealed in a recent survey among global company CEOs conducted by IBM[198], the innovation priorities of Chinese companies are consistent with those

[197] There is a large body of studies researching into country growth pattern. See for example Vestal (1993), Lee and Yu (2005).

[198] IBM Global Business Services (2007), p. 8

of their global peers. When asked how they would invest USD 100 across the three innovation categories of 1) products & services, 2) business model and 3) operations based on their relative importance to their companies, the interviewed Chinese firms allocated 41% to products & services, 30% to business model and 29% to operations innovation. This is almost the same like the global respondents' choice of 41%, 28% and 31% (see Figure 37).

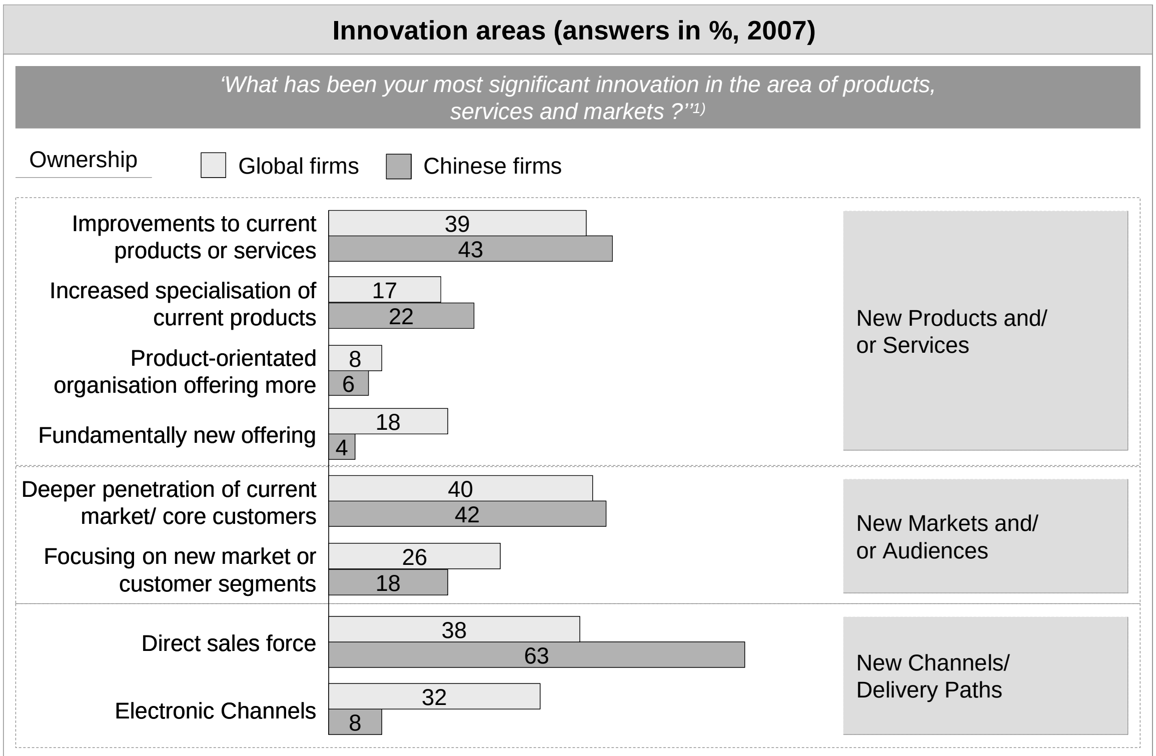


1) Answers from in-depth interviews with CEOs & senior executives; Global vs. Chinese respondents
Source: IBM Global Business Services (2007), p. 8.

Figure 37: Innovation priorities and implementation.

While innovation priorities are similar, the tactics – the approaches these strategic goals would need to be implemented – differ from each other. As shown in Figure 38, Chinese firms chose to allocate more resources for improving current products/services (43% versus 39%) and for the specialization of current products (22% versus 17%), whereas foreign firms dedicated significant portion of resources for offering new services (8% versus 6%) and new products (18% versus 4%). A second observation is that Chinese firms are also more conservative in exploring new markets and/or audiences. While emphasizing slightly more on competing in existing market (42% versus 40%), the Chinese firms chose to step back when considering new market or customer segments as their strategic option (18% versus 26%). In addition, the survey results showed that Chinese firms were still relying on traditional channels for sales. Majority (63%) Chinese firms quoted "Direct sales force" as the area of significant innovation, but less than 10% of these firms were successful in coming up with significant innovation in electronic channels.

In general, by focusing on existing products/services in the current market through traditional channels, Chinese business leaders seem to be more inclined to opt for the more immediate implementation tactics compared to their global counterparts. Short-term R&D projects with immediate commercial results are therefore the most likely innovation strategy adopted by Chinese firms.



1) Answers from in-depth interviews with CEOs & senior executives; Global vs. Chinese respondents; multiple answers possible
Source: IBM Global Business Services (2007), p. 9.

Figure 38: Product, service and market innovation areas of Chinese versus global firms.

Another distinctive difference is that Chinese firms were consistently focusing on strengthening their abilities to increase revenue whereas the importance of reducing costs was relatively neglected. Figure 39 shows that Chinese firms tend to be more interested in operational improvements in customer facing processes, product/service R&D, and human capital management; areas that are notably crucial for boosting revenue. As for areas with cost-saving potentials such as manufacturing, procurement and G&A processes, Chinese firms are far less committed than their global peers. On one hand, this reflects China's fast expending market size and huge demands that raise great incentives for Chinese firms to produce and sale more products/services. On the other hand, it implies that the unsaturated market provides high tolerance for less cost-competitive firms to survive.

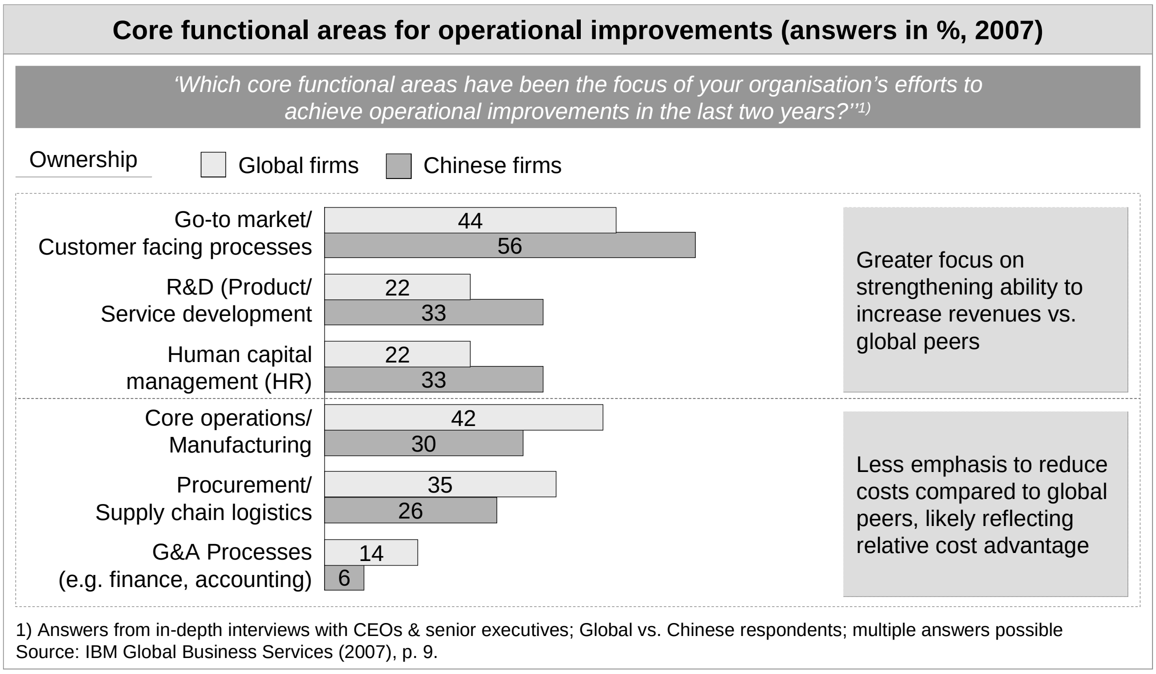


Figure 39: Core functional areas for operational improvements.

3.1.2 Chinese firms' strategies and measures for innovation

Though Chinese firms are currently more conservative and short-term oriented in innovation strategy in general, the foreign firms should not lessen their innovation efforts. After a long period of manufacturing knowledge accumulation, Chinese firms are gradually upgrading their processing skills and product design capabilities. Given time, the huge market potential will feed currently inferior technologies and result in direct competition in high-end market segments.

Recognizing the high value-add of self-owned brand products in high-end market segments, both the Chinese government and firms are motivated to shift their competitive strategies from low-cost based to high-tech based. Improving the processing capabilities and product development skills are two basic ways adopted by local competitors. Process innovation mainly refers to improvements in manufacturing efficiencies to increase productivity and reduce material and energy consumption, and product innovation focuses on introducing new functionalities of products/services or achieving existing functionalities in a different manner.[199] Analysing the two dimensions of technological innovation will reveal the firms' different approaches depending on their own business strategies and competitive strength as detailed below:

Product innovation of Chinese firms

Due to differences in financial strengths, market positioning, and company strategies, different types of Chinese firms may follow different roadmaps

[199] Yuan et al (2007).

towards their product innovation blueprint. SOEs/large private firms, and SMEs are analyzed separately as below:

SOE and large private firms:

The innovation literature provides architectural and component innovation as one type of categorization[200] for product innovation. Architecture is defined as the overall design of certain products/services, which describes how the sub-systems of the product functioning together. Component refers to independent modules that can be decoupled from the overall product yet are able to achieve certain functionalities in a collective way. A new design of gravure printing machinery that can upgrade the overall printing speed and/or paper size, for instance, is considered an architectural innovation, whereas the development of a new type of water roller is deemed as component innovation. The merit of distinguishing these two types of innovation is that architectural innovations are often breakthrough innovations that can greatly improve the overall technology level, and further promote the component innovation through the design platform. Therefore, architectural innovation is both radical and influential. Correspondingly, architectural innovation requires quite intensive R&D investments and years of lead-time before product launching, and its risk is much higher than component innovation in terms of both market and technological uncertainty. As such, only large firms have the necessary technological reservoir and financial capability for architectural innovation. Moreover, as SOEs are the backbone of China's economy and the government is aiming to shape SOEs into the innovation champions by assigning basic research tasks and providing substantial subsidies. Hence, we speculate most architectural innovations would be introduced by SOEs especially those leading firms with strong technological, financial and sometimes political strength.

Shanghai Electric, among other large SOEs, is recognized for its high innovativeness in basic researches and development of architectural innovations that spanning across cutting-edge technological areas (see Box 4).

[200] Matusik， S.F. and Hill， C.W.L. (1998) 'The utilization of contingent work, knowledge creation, and competitive advantage', Academy of Management Review, 23(4), pp. 680-697

Box 4: Example of innovation strategy in leading SOE

Revenues of China's largest machine manufacturer rose 250% from RMB 12 b in 2002 to RMB 43 b in 2006. Even more spectacular is its 400% increased in profits from RMB 0.6b to RMB 3 b in the same period. Listed on the Hong Kong Stock Exchange since 2005, state-owned Shanghai Electric Group (SEG) comprises of four main divisions: Power Equipment Division, Electromechanical Equipment Division, Transportation Equipment Division and Environmental Systems Division. With progressive financial results and its dedication to invest 4% of its revenues to R&D annually, SEG is moving towards its goal to become an excellent equipment-manufacturing conglomerate. Indeed, many of its products are now competing amongst the best from Europe, USA and Japan. How did SEG develop such competencies and how will it approach innovation moving forward?

SEG has been focused on learning from international leaders. To date, it has formed 15 joint ventures with leading foreign enterprises such as Alstom, Kronospan, Mitsubishi Electric and Siemens. While the foreign partner contributes the technology, SEG is able to provide assess to China's markets and local operational knowledge. The activities of these joint ventures, though mainly limited to manufacturing, product development and adaptation for the local market, has allowed SEG to raise its technological and innovation capabilities.

In segments where SEG is interested in but lacks a competitive edge, it adopts an acquisition strategy. For instance, in 2002, it acquired Akiyama, a financially distressed Japanese manufacturer of high-end printing presses. With the acquisition, SEG, whose printing press technology was lagging by three decades then, was able to upgrade its technology and compete in the high-end market of Japan. More recently, SEG has acquired Ikegai Corporation from Japan and SMAC Werkzeugmaschinen from Germany to strengthen its foothold in the machine tool industry.

Through learning from its partners and acquisitions, SEG was able to build up a robust technology and innovation foundation. As it nears the leaders in technological capability, SEG acknowledges that in order to be truly and continuously amongst the world's best, it is imperative that it creates its own cutting-edge innovations. Hence, in 2006, SEG pooled its resources to consolidate its R&D and related activities in a 1,000 staff Central Research Centre (CRC). The responsibility of the CRC spans across its business divisions and comprises of:

- Basic research: development of new cutting edge indigenous technology
- Applied research: application development and testing of developed technology, exploration of technologies in potential new growth areas
- Product development: design, testing, new material application
- Innovation management: Strategic planning, information collection, IP management

The holistic approach adopted by the CRC reflects the innovation strategy of SEG and other leading SOEs. Not only are these SOEs satisfied with being a fast follower supported by the government, local universities and research institutes as well as having the financial clout, they are aggressively pursuing the development of their own technology and innovation capabilities. In addition, they are adopting a systematic and modern approach to innovation planning, technology and IP management.

Large private firms are another importance source for architectural innovation. Though typically equipped with less technology compared to SOEs due to their shorter histories, large private firms are more adaptable to market mechanisms in their fast decision-making processes and risk-taking attitudes. This adaptability makes large private firms better positioned to undertake architectural innovation and are more agile to environmental changes, thus we deem it as a complementary source for SOEs in architectural innovation.

CHINT Group, a leading large private firm in low-voltage electrical and power transmission/distribution industry, is representative for large private firms' innovation strategies (see Box 5).

Box 5: Example of innovation strategy in leading private firms

"Innovation involves risk. Indigenous innovation involves greater risk. We must reward the success and respect the failure of risk-taking." The words of Mr. Nan Cunhui, Chairman of Zhejiang Wenzhou Zhengtai Group (CHINT Group), reflects the culture of China's leading manufacturer of devices and equipment for low-voltage electrical and power transmission and distribution. Established in 1984 as a home workshop of 7-staff, CHINT, through its dedication to indigenous innovation, has evolved into a modern enterprise with 15,000 employees and revenues of RMB 10 b. In 2006, CHINT was ranked 15^{th} on Forbes top 100 private companies in China.

The private firm, with over 150 patents and an annual R&D expenditure equivalent to 5% of its revenue, is acknowledged as a global technology leader in its domain. Today, CHINT has product development and testing activities within its manufacturing stronghold in Zhejiang, a R&D centre in Shanghai and another in Silicon Valley (USA) for new technology development and exploration of new products and growth areas for the group. Furthermore, it is preparing for another R&D centre in Europe. Though adopting an indigenous R&D approach, CHINT's strategic positioning of its R&D activities has allowed it to be abreast of global technology trends.

CHINT's commitment to its innovative culture and people enabled it to continuously develop new technology and products as well as attract the best brains. In CHINT, R&D personals are the most respected employees and the most well paid. In contrast to traditional risk-adverse Asian culture, CHINT encourages its R&D personals to take risks in the pursuit of innovation. As such, CHINT is able to attract world-renowned experts such as Dr. Yang Liyou, an international thin film solar cell expert, to spearhead its venture into photovoltaic.

As highlighted in the above two case studies, typical approaches of large Chinese firms' architectural innovation can be categorized into two parts: measures to stimulate innovation yield, and measures to bridge innovation with market.

The two firms adopted different measures to enhance their capabilities in breakthrough innovation. Shanghai Electrics, well networked in the industry and strong in financing, leveraged its market access and financial advantages for acquiring knowledge in basic research and cutting-edge technologies. Setting up joint ventures with leading MNCs and acquiring distressed firms with technological excellences are the two distinctive tactics of Shanghai Electrics. While JVs provided more incremental knowledge, acquisition of Japanese and German firms equipped Shanghai Electrics with completely new technological framework and enabled its leapfrog growth in printing machinery industry. CHINT Group, on the contrary, followed a more indigenous path by advocating its internal cultural support for risk-taking, implementing motivation systems in favour of key R&D personnel, and establishing global R&D centres to tap with the new technological trends. The similarity of such exogenous/indigenous approach is that either approach would necessitate quite extensive R&D investment, 4% of total revenue as observed in Shanghai Electrics and 5% as of CHINT Group. This also strengthens our speculation that architectural/radical innovations are not SME-friendly as they simply are unable to afford it.

While methods in generating architectural innovations vary, the way of bringing such innovations into market and hence profitability remains similar. Both Shanghai Electronics and CHINT Group leverage architectural innovation into multiple product series through product platforms. For instance, based on its proprietary technology of Gas Insulated Switchgear (GIS), CHINT developed a platform for GIS products and reduced its R&D cycle from 5 years to 2 years[201]. Having acquired 14 key patented CNC technologies, Shanghai Electrics managed to penetrate into high-end large-scale CNC product series[202]. Another similarity is that both firms have also invested resources for the development of complementary technologies. Shanghai Electrics' Central Research Centre (CRC) has two divisions, applied research and product development, to industrialize its basic research and further leveraged into product series through architectural design. CHINT's R&D centre in Shanghai and product development division in Zhejiang serve the role of bridging breakthrough innovation into profitable products.

It is important to note that large firms' focusing on architectural innovation does not exclude them from component innovation. On the contrary, as product architectures or system integrators, large firms are in a better position to come out with new components which fit better into the overall product frameworks. In addition, along with the trend of value-chain integration in China, large firms also turn to acquisition of small firms with advanced component knowledge to improve the firms' overall competencies and thus, become component innovators as well. In fact, one of the core competitive advantages of large firms is that they have a two-layer innovation structure combining architectural and component innovation. While architectural innovations help them to upgrade products into next generation and stay at the industry edge, component innovations enable firms to deploy the platform and quickly penetrating into differentiated market segments. In this sense, architectural innovation is more like a strategy of product innovation whereas component innovation is more like a tactic of product innovation.

SMEs and Spin-offs:

Compared with SOEs, Chinese SMEs are not only more adaptable to market mechanism but also more flexible in re-directing company strategy to catch up with the newest trends in the industry due to their small size. Moreover, as SMEs are widely scatted into different market segments and many of them have formed close network circles for information sharing. Thus, SMEs are quite alert to environmental changes. Indeed, given the 65% share of invention type of

[201] http://www.chint.com/xwzx_jt.asp?mainid=1161&classid=3

[202] http://brandpromotion.mofcom.gov.cn/aarticle/k/200610/20061003370765.html

patent and 80% of new product introduction, SMEs are the most active innovation force in China.[203]

However, there are certain disadvantages that affect SMEs' innovation strategies that push SMEs to focus more on incremental innovations. The most serious problem that SMEs are facing in defining their innovation strategy is their funding. While SMEs account for over 50% of GDP, only 30% of government's R&D subsidies get into their pipelines. As a result, the ratio of R&D investment over revenue for SMEs is less than 1%[204]. This is also reflected in the previous IMPULS Stiftung[205] where for SME packaging machinery manufacturers, the ratio was estimated to be less than 0.75%.

The innovation strategy for SMEs is also limited by their high-risk adversity. Lacking capital and R&D capability, SMEs cannot afford long-term research, and even if promising breakthrough innovations were to be achieved, SMEs can hardly leverage such benefits into product series because of the lack of complementary technological skills that bridge the innovation with market demands.

Attracting and retaining talents is another barrier that SMEs need to cope with. While R&D staff can enjoy higher responsibility and flexibility in SMEs, they concern more about larger research funds and better research equipments and teams. As such, the turnover rate for R&D people is much higher in SMEs[206].

Last but not least, due to high costs of IPR application and litigation for infringement, SMEs are less protected by IPR laws and thus, are less able to benefit from relevant government policies in promoting innovation.

In general, due to the lack of people and capital, and weak capabilities in IPR protection and low tolerance for risk, Chinese SMEs follow a "pragmatic" innovation strategy that majority of them would imitate or copy existing products regardless IPR issues. Many of them might not even have R&D staff, as observed from packaging machinery and valve industry[207].

Spin-offs, however, is quite a unique segment of SMEs that is more active in product innovation activities. Two aspects differentiate them from the other SMEs. Firstly, the company origins are different. While many SMEs are rooted from trading firms and OEM plants, most spin-offs have strong technological background. Spin-offs from big firms normally hold patents that have been granted to their former companies, and in many cases, the spin-off took place because of a different technological route taken. Due to the small size and new organizational structure, spin-offs are more suitable for exploiting innovations that are not in line with their former firms' main technological body. Secondly, the spin-offs have stronger social network capability. No matter whether they

[203] http://www.gzkj.gov.cn/rkx/newsDetail.jsp?infoId=82938

[204] http://www.gzkj.gov.cn/rkx/newsDetail.jsp?infoId=82938

[205] IMPULS Stiftung, VDMA (2005) and IMPULS Stiftung, VDMA (2006)

[206] http://www.gzkj.gov.cn/rkx/newsDetail.jsp?infoId=82938

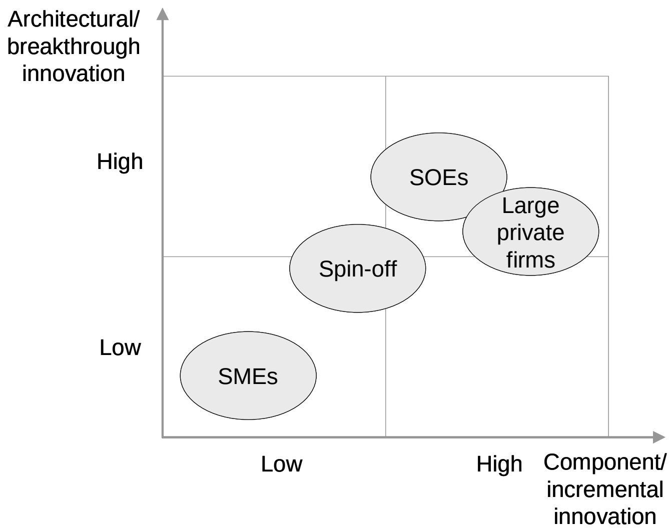
[207] IMPULS Stiftung, VDMA (2005) and IMPULS Stiftung, VDMA (2006)

are rooted from big firms, universities, institution labs or even military agencies, spin-offs are bridging different social circles and it is relatively easier for them to assemble complementary resources to bring innovations into industrialized products. Better prepared with technology and complementary resources, spin-offs perform better than their other SME peers do[208].

Mapping different players:

As architectural and component innovations are two directions of product innovation strategy, we build a two-by-two matrix with the two dimensions and map different types of Chinese firms discussed above into the matrix, as shown in Figure 40:

Competence in architectural and component innovation



Source: Droege & Comp.

Figure 40: Competence in architectural and component innovation.

SOEs and leading large private firms shape the first tier as product innovation champions, as they are capable in both architectural and component innovations. In addition, taking into consideration that SOEs are assigned with more basic research projects and collaborating closer with national key labs, we estimated that SOEs are more capable of coming out with breakthrough innovations. Leading large private firms, however, are more adaptable to market mechanisms and thus are more motivated to exploit their technologies through applied research and product platforms, and thus score higher than SOEs in component innovation dimension.

SMEs, on the contrary, are weak in both dimensions and form the third tier in product innovation. However, as discussed above spin-offs are more capable in both architectural and component innovations due to better technological skills and complementary resources, and hence they shape the second tier of innovative Chinese firms.

[208] An investigation on spin—offs from Chinese research universities, engine.cqvip.com/content/f/95997x/2003/021/004/jj29_f2_8280879.pdf

However, with strong push from the government to create an innovative nation, constraints for SMEs may alleviate in the next years and such positioning should not be viewed in a static manner.

Process innovation of Chinese firms

Through interviews, it is generally acknowledged that while China's product innovation capability may lag the world leaders by three to four years, its process innovation capability falls behind by at least fifteen years. The lack of process innovation capability and excellent manufacturing competency hinders the development of truly internationally competitive Chinese firms.

The Chinese have been importing cutting-edge equipment, the same ones that foreign firms are using, for production. However, it is common that the quality of their products is often not at the same level as that of their foreign competitors. This is because even though they are using the same equipment, the Chinese are relatively lacking in the process innovation capability to fully utilize the equipment and refine the manufacturing process.

Moreover, in addition to issues related to IP, a key reason why foreign firms are not shifting the production of their newest products to China is China's low level of process innovation capability and manufacturing competency. Foreign firms would first stabilize and fine-tune the production process of their products before shifting their lines to China for mass production.

As such, having a low level of process innovation to start with and coupled with less learning opportunity to learn from foreign firms, Chinese firms have not been making significant progress in the area of process innovation. It is typical that manufacturing practices and processes have not improved much in the last few decades. However, in recent years, Chinese firms, in the face of increasing domestic and international competition has started to realise the imperativeness of process innovation.

For instance, one of China's leading steam turbine manufacturers has only recently adopted a new type of cutting tool to replace the type that it has been using since the 1970s. In so doing, it is able to reduce its processing time for a manufacturing phase by fifteen days. The company has since started a series of process innovation projects.

China currently promotes product innovation

With limited resources, firms need to choose one direction as the focus for improving their competitive advantages. Currently both the Chinese government and Chinese market are giving more favour to product-based innovation, thus we speculate that local Chinese firms are more prone to follow a product-oriented development path.

With respect to the government policies, the government provides strong product development incentives through its "independent innovation" movement. For instance, in the 11^{th} 5-year plan for machinery industry the government initiated special incentives for product development in new types of textile and railroad equipments. According to Pan Yunhe[209], the vice dean of China Academy of Engineering, the government policy emphasises product innovation because this could help increase individual firms' profitability, but also improve the overall industry structures and thus enable Chinese products to be more competitive on global markets.

As for market incentives, 60% to 80% of the technologies for sale on the market are product-related innovations[210] and most technology buyers are looking to acquire these types of innovations. Therefore, investing in product-oriented innovation seems more attractive to firms. The importance of manufacturing/processing technologies, however, has been largely neglected thus far.

[209] http://www.zju.edu.cn/zdxw/jd/read.php?recid=19109

[210] http://zx.dlinfo.gov.cn/2005/11-9/09215778433.html

3.2 The guiding hand of the Chinese government

Most economies realise that in order to benefit from global innovation networks, they need to strengthen their domestic innovation capabilities. In order to do so, governments implement different national policy frameworks with varying incentives and projects and ultimately funding to increase these capabilities.[211] Like many other countries, China has adopted a long-term strategic plan to develop science and technology and foster innovation. The goal is to become a major innovation economy by 2020. Respondents in our interviews strongly believe that government policies are at the core of the national innovation system and therefore, the key drivers towards creating an innovative country. Thus, it would be critical for the government to institute structures that would allow quick decision-making processes and strong, centralised financial and administrative co-ordination. In order to achieve this goal a number of reforms and strategic projects are to be carried out.[212] Figure 41 provides an overview of the historical development of Chinese science and technology related initiatives, as well as its roadmap for becoming an innovative country in the future.

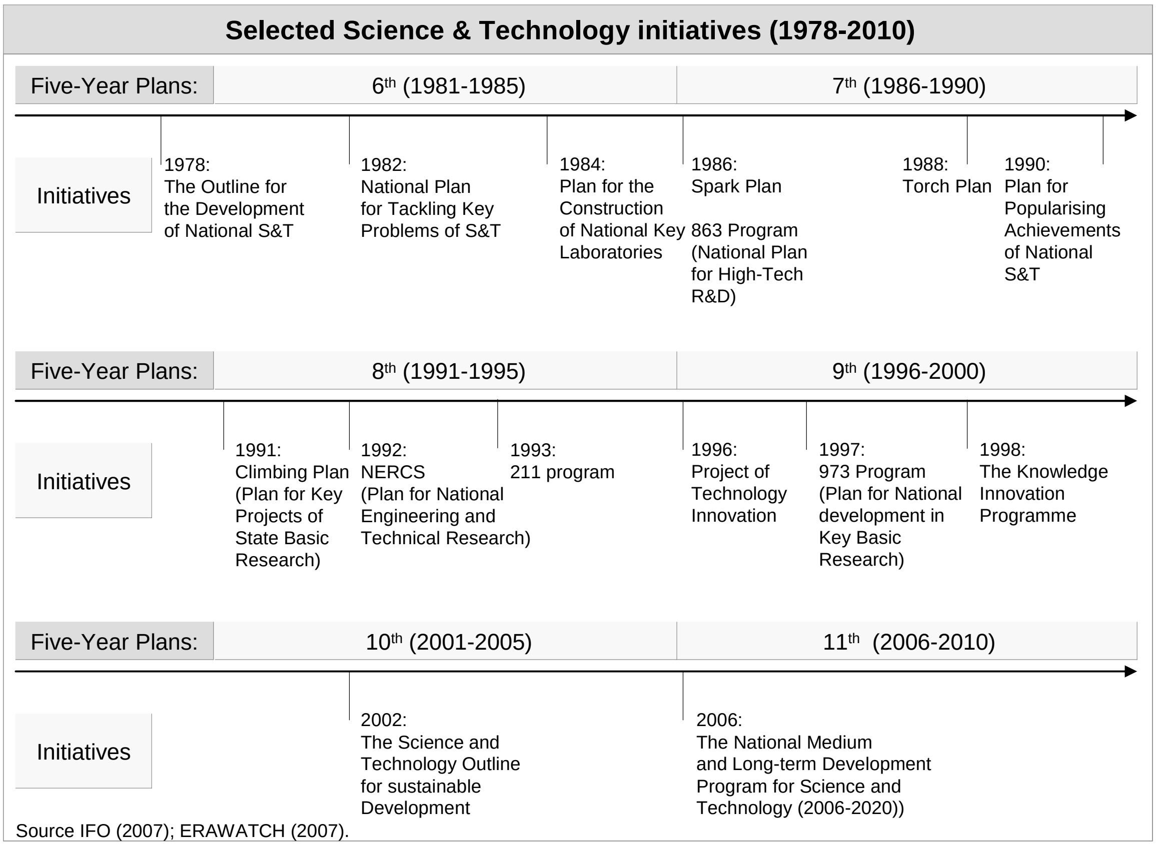


Figure 41: Selected Science & Technology initiatives (1978-2010).

[211] OECD (2006).

[212] OECD (2006), p. 88.

The 6th Five-Year Plan (1981-1985): First step of China's S&T policy

As demonstrated in the figure, "The outline of the development of national S&T 1978-1985" is the first national-wide science and technology plan[213]. The plan for the first time emphasised the crucial role of S&T in economic development, and focal research projects selected out in this plan had later on been incorporated into the 6th Five-Year-Plan in 1982 and renamed into "National plan for tackling key problems of S&T". Another distinctive progress during the 6th Five-Year-Plan was that China started to create a number of national key laboratories since 1984 to promote basic/applied research and further converting science and technology into industrial application. The plan also aimed to reduce redundant R&D investments and make batter use of S&T funds.

The 7th Five-Year-Plan (1986-1990): Generalizing the S&T reform

Following the initial kick-off and experimentation of S&T plan in China, the focus has been shifted to the generalization of the S&T plan in a broader area. Notably, given the importance of agriculture industry for China, the government launched its S&T plan for rural area in 1986, known as "Spark plan"[214]. The plan encouraged the introduction of S&T achievements into the economic development for rural area, boosting the growth of township enterprises by means of S&T, and improving the overall education level of rural area. 863 Program, as mentioned in Chapter 2.3.1, was also set up in 1986 for the development of advanced technologies. Two years later the "Torch plan" was launched by MOST for commercializing the S&T achievements[215]. The establishment of high-tech zones was one of the key points of the plan. In viewing the great challenges in converting S&T innovations into industrial application, the NSFC had further initiated the "Plan for popularising achievements of national S&T" in 1990[216] for not only increasing the conversion rate of new S&T, but also increasing the economy of scale of those converted S&T by popularising them to more firms.

The 8th Five-Year-Plan (1991-1995): Deepening the S&T reform

The generalizing of S&T innovations also revealed many blank areas of basic research that China were lagging far behind the world and thus dragged down the popularising of S&T. The "Climbing plan", a plan for key projects of state basic research, was therefore launched in 1991. The main purpose of the plan was to enhance basic research with crucial importance or broad influence for the economic and social development[217]. Besides, the "Plan for national engineering and technical research", following "Torch plan" and "Plan for popularising achievements of national S&T", was promulgated in 1992 for the conversion of those generic technologies and key innovations for applications

[213] http://www.library.imicams.ac.cn/webpages/policy/files/gh_1978.pdf

[214] www.cnsp.org.cn

[215] www.chinatech.com.cn/techachieve/intro/torchplan.htm

[216] http://www.nast.org.cn/

[217] http://www.chinaconsulatechicago.org/chn/kj/t39930.htm

especially those in secondary industry[218]. The S&T reform, started in 6th Five-Year-Plan and generalized in 7th Five-Year-Plan, had then been deepened into basic research and detailed industries.

The 9th Five-Year-Plan (1996-2000): Leveraging the S&T reform

While the concept of S&T development and innovation had been promoted national-wide and deepened into different industrial sectors, the 9th Five-Year-Plan focused on keeping on with the S&T reform and leveraging the results to a next level. For instance, the 973 Program, as described earlier in Chapter 2.3.1, focused on key basic research projects as well, and is closely related to "Climbing plan" and NSFC[219]. "Project of technology innovation", on the other hand, extended the "Torch plan" and highlighted the integration and coordination of different S&T plans[220]. During this period, the Chinese S&T policies and plans were more integrated and mature than before.

The 10th Five-Year-Plan (2001-2005): Aiming at sustainable development

After two decades of high-speed economic growth, the government sees the need to shift from resource-dependent growth to a more sustainable development model urgently. S&T was believed to be the key lever for such transformation. "Science and Technology Outline for Sustainable Development" was subsequently launched in 2002, which sketched the national-wide S&T strategy between 2001 and 2010. As such, the focus was set on population control and efficient utilization of non-recycle resources such as oil/gas, water and minerals.

The 11th Five-Year-Plan (2006-2010): Holistic approach for S&T upgrading

As the most crucial and holistic S&T document, the plan of "National medium and long-term development program for science and technology" was launched in 2006 and implemented into the 11th Five-Year-Plan. Independent innovation and the focal role of firms in innovation activities were the most important highlights of the plan.

Given its coverage of the whole country in every aspect of S&T development, and its duration for the next 15 years, the "Medium and long-term S&T plan" will be further analyzed in this section. We first explore what goals the Chinese government has with respect to innovation in China as well as what strategies and measures are put into place in order to reach those goals – in general and specifically for the machinery industry. The final section gives an overview about important governmental decision makers and their decision-making processes.

[218] www.cas.ac.cn/html/Dir/2004/11/30/7557.htm

[219] http://www.cas.ac.cn/html/Dir/2007/09/10/15/21/37.htm

[220] www.chinatech.com.cn/aspx/kejiziliao/kejijihua/chuangxin/chuangxin01.htm

3.2.1 Goals

Following three decades of resource-dependent economic growth, the Chinese government realized the need to shift its focus away from being resources-dependent economy to being more knowledge-based economy. The ambitious goal of the Chinese government is to create an environment, which would enable China to become one of top innovative nations in the world by 2020. In order to achieve this goal, the Chinese government has developed a set of indicators as shown in Figure 42[221] through initiatives by various government agencies.[222] Each of the plans set numerous ambitious milestones and targets to hit over the next five to fifteen years.

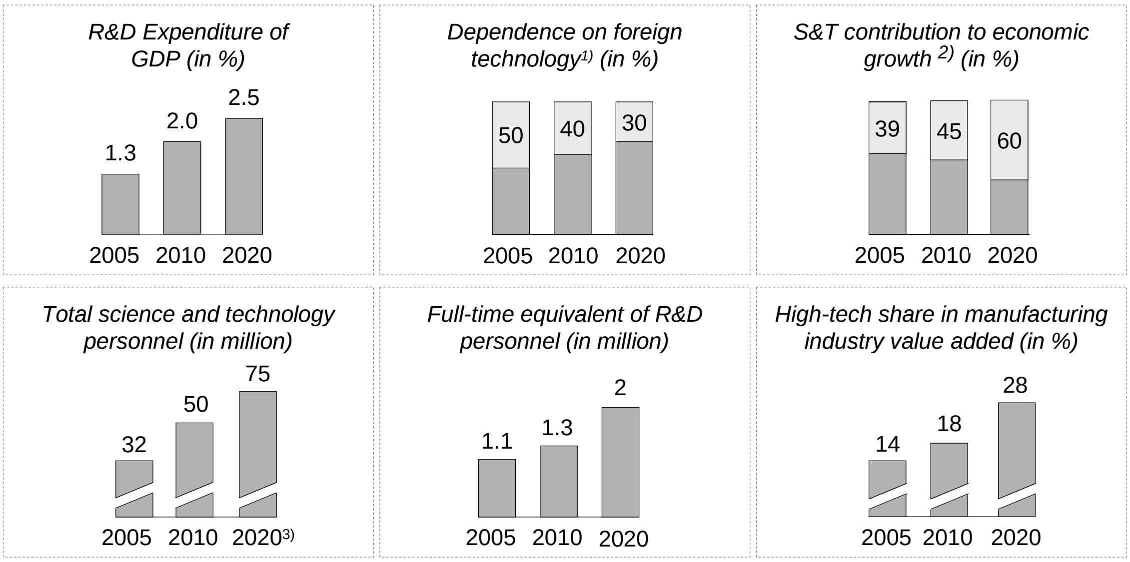
In 2006, the Chinese government and businesses allocated 1.42% of China's GDP to R&D, which was already a record high. But it plans to increase the proportion allocated significantly to 2.5% of its GDP by 2020. However, despite the heavy R&D investment, its dependence on foreign technology remains very high at more than 50% compared to most OECD countries, which are on average below 30% and the less than 10% in the US. China aims to bring its dependence on foreign technology down to 40% within the next five years and 30% by 2020, which shows that there will be increased emphasis on independent/indigenous [223] technology innovative rather than pure foreign technology imports. Similarly, the Chinese government plans to increase the proportion of high-tech in the manufacturing from its current 14% to 18% by 2010. As human resources are a critical component to enable China to achieve its goals, there are plans to increase the total science, technology and R&D personnel involved.

[221] Dependency on foreign technology is one indicator reflecting one country's innovative capabilities, it is defined by: dependence on foreign technology=technology imports expenditure/(R&D expenditure +technology imports expenditure-technology exports payments). In China, the technology export payments are neglectable, therefore this part is not taken into account when calculating the dependency on foreign technology.

[222] In February 2006, the Chinese government released its "*Guideline for the Medium- and Long-term Science and Technology Development Program (2006-2020)"*[222]. This guideline mapped out a blueprint of China's science and technology development for the upcoming 15 years. Shortly after, in March of 2006, the "*11th five year plan for national economic and social development (2006-2010)"*[222] was approved by the fourth session of the tenth National People's Congress, the five year plan deploys strategies and measures aiming to build a prosperous society in a holistic manner. In October 2006, Ministry of Science and Technology (MOST) revealed its "*11th five year plan for National Science and Technology*"[222] which focuses on the next five year's science and technology development priorities and specified a number of indicators to be achieved. Finally, in February 2007, National Development and Reform Commission, Ministry of Science and Technology and Ministry of Education jointly issued an 11th five year plan for *Building up National Independent Innovation Fundamental Capabilities.*[222] With the exception of the five year plan for national economic and social development, the other plans focus on science and technology development.

[223] "Independent innovations" or "indigenous innovations", both terms have been widely used to describe Chinese innovation strategies in many studies. There is no contradiction between them. The meaning behind the two terms to convey is basically the same. The independent innovation is hereafter used in this study.

Governmental targets for Chinese S&T indicators (2005-2020)



1) Dependence on foreign technology: Total technology import expenditure divided by (R&D expenditure + technology import expenditure-technology export receipts). According to NBS consultation, Chinese technology exports are neglectable and therefore assumed to be zero.
2) refers to contribution of Total Factor Productivity growth to total output.
3) Estimate based on consultation of Ministry of Science and Technology of China
Source: Ministry of Science and Technology of China.

Figure 42: Governmental targets for Chinese S&T indicators (2005-2020).

In addition to the input indicators of China's planned innovation growth, the government has also set a number of output indicators for 2010 and 2020. One of the targets set is to raise China's triadic patent family from its 2005 rank of 13th to top 10 by 2010 and top 5 by 2020.

However, the means to achieve these ambitious goals have caused a fierce debate between the policy makers and the public. The focus of the debate centres on whether the country should rely on foreign technology imports or on Chinese independent innovative capabilities in order to become a top innovative nation. From the Chinese government policies released and analyzed, the government's national strategy is to build up the country's independent innovation capabilities complemented and, where necessary, by importing and transferring of foreign technologies.

3.2.2 Strategies and measures for upgrading China's innovation capabilities

After the opening-up of China, the country has witnessed an enduring and fast economic growth. While Chinese people are enjoying the fruit of such developments, many major development barriers and conflictions emerge and demand the central government's focal attention. The most severe problems, among others, are heavily resource-dependent economic development model, which has resulted in environmental degradation, unbalanced industrial structures with distinct weakness in high-tech and service industries, and the lack of domestically-owned innovations and resulted poor competitive advantages of local Chinese firms. In recognizing the central role of innovation in reconciling such economic/social/environmental problems, the government has set its independent innovation strategies and corresponding measures.

Strategies and focuses

As a developing country, China has adopted a latecomer strategy for its development of innovative capabilities. There are two main dimensions in latecomer strategy; first to catch up with forerunners, and then surpass (also known as leapfrog growth) forerunners. Imitation and innovation are recognised as the appropriate approaches for the corresponding dimensions of the strategy. The Chinese government's innovation strategy exactly reflects such two dimensions.

1) Catching up with advanced countries: The government has chosen 68 research areas spanning across 11 sectors as the prioritized research tasks. The 11 sectors are those most important economic/social/environmental/ political aspects including energy, water/mineral, environment, agricultural, manufacturing, transportation, IT and service, human health, urbanisation, public security and national defence. The 68 research areas are those lagging behind technologies but have potential to be improved and able to catch up with forerunners quickly such as coal processing and extensive utilization, recycling processes and equipments for iron & steel production, high-speed rail transportation, etc.[224] As such technologies are not new-to-the-world but new-to-China, the Chinese government thus prefers an imitation strategy and notably stimulate the technology transfer by labelling it as "re-innovation"; one of the three types of independent innovation. By achieving great improvements in such underlying technologies, the government has every reason to believe that the gap between China and developed countries will gradually diminish.
2) Surpassing forerunners: the government has also chosen 16 special projects where China has potential opportunities to achieve leapfrog progress and directly compete with developed countries. The special projects include: Core electronic components, high-end general chip and basic software, very large-scale integrated circuit manufacturing and process technologies, new generation broadband wireless mobile communication, high-end CNC machines and advanced manufacturing technologies, exploration of large-scale oil/gas pool and coal bed gas, large-scale advanced pressurized water reactor and high temperature gas-cooled reactor, water pollution control and treatment, rearing of new transgenic organism, significant new medicine creation, prevention of major infectious diseases e.g., HIV and viral hepatitis, large-sized airplane, high resolution earth observation system, and manned spaceflight and moon exploration[225]. As there are no existing mature

[224] http://www.gov.cn/jrzg/2006-02/09/content_183787.htm

[225] http://news.xinhuanet.com/politics/2006-02/09/content_4157759.htm

technologies for such areas, China plans to invest heavily into these technologies to compete with other more developed countries. Two types of independent innovation, namely original and integrated innovation, are key approaches for technological competition in the world arena. Technological standardization can also be used as the measure to compete against developed countries. One of our interview participants also warned of having to fight with newly established Chinese technology standards, which the government creates in order to boost its innovations. Some examples include the 3G mobile network, digital TV networks and Intelligent Grouping & Resource Sharing protocol (IGRS). IGRS was initiated by Lenovo and other Chinese companies such as TCL, Hisense, Great Wall and Konka. IGRS has already been approved as the national standard and is seeking a broader international recognition. By achieving breakthroughs in these hotspots, the government believes that China will be able to obtain competitive edges in certain fundamental areas.

With a goal of building sustainable technological innovation capabilities, the Chinese government is trying to establish its technological reserves by highlighting eight aspects of cutting-edge technological research. They include biotech, IT, new material, advanced manufacturing, energy technology, marine technology, laser technology and aerospace technology; and 18 basic research fields spanning from math to physics, and from biology to earth science. Original innovations, among other types of independent innovation, are the core of these technological competitions.

From the above strategies, it is clear that the Chinese government is both pragmatic in defining 68 industrial research areas to close the gaps with developed countries as well as ambitious in choosing 16 special industrial projects to compete and probably surpass developed countries. Moreover, Chinese government is also preparing for the future technology development by highlighting basic research and cutting-edge technologies that are less connected to industrialized products.

Tactics and measures

With the quantifiable targets described in chapter 3.2.1 and the blueprint of future Chinese innovation, system briefly discusses in the above section, the question as to how China is going to achieve such goals and blueprint remains. Government tactics and measures will therefore be explored and described in the following section:

<u>Tactics of the Chinese government</u>:

In general, the Chinese government focuses on firms, research institutes/labs, universities, and central/local government agencies as the main parties for implementing the innovation strategies. There are specific tactics for each party:

1) Firms should become the central players in Chinese innovation: due to historical reasons, local Chinese firms are still not the main body for innovation. Taxation/financial policies will be implemented to encourage firms investing in R&D activates which means there is a possibility for firms to take over national R&D tasks. In addition to investments, the

efficiency of spending R&D money will also be emphasised. Firms especially SOEs would need to improve internal management skill and be more productive in terms of innovation. One government official we interviewed observed that the Chinese government would still consider professors to be better at conducting research rather than companies, since more money was allocated to R&D in universities and institutes while only a small portion goes to industry.

2) Research institutes/labs are the main bodies for basic and applied research: the previous mandates of Chinese research institutes were unclear and filled with many redundant innovation projects. Thus, the Chinese government aims to pull the scattered resources together and create R&D bases with distinct technological focus. In addition, the government will increase and stabilize its investment in basic research/cutting-edge research. The internal management of research institutes will also be improved by an innovation evaluation system and enhanced cross-institutes collaborations. Original innovation will be the ultimate goals for the research institutes/labs.

3) Universities' roles will be more diversified than before: universities will serve the role of both talent training and conversion of applied/basic research into industrialized products. In addition, they are evolving to play an increasingly important role in basic research. To achieve their goals, the government plans to attract experts and form strong teams in teaching and research, as well as adapt current regulations and management of universities to enable them to be more innovative.

4) Government agencies will make critical decisions more effectively and coordinate among different parties more efficiently. While institutional gaps existed in previous government agency settings, the government urges its local agencies to enhance the communication between different departments, between different geographical locations as well as between military and civil functions. At the same time, decision-making processes will be re-evaluated and standardized.

5) Coordination: policies and incentives are given for promoting the collaboration between different parties. "Many administrative bodies for S&T exist in China and the miscommunication compromise their efficiency", said Director of Statistic Analysis from MOST. Market mechanisms for circulating technological achievements, together with third party technological services, are emphasized to improve the situation.

The tactics are further detailed in executable measures in the following section:

<u>Detailed measures</u>:

While it is not feasible to list all the measures in current report due to volatile policies and page limit, we will provide some representative measures in each dimension to provide readers with a sense on the direction and power of the guiding hand:

1) Government agency related measures:

   a. The increment of government investment into science and technology should be significantly higher than the increment of fiscal recurring income, and the ratio of R&D expenditure over GDP should gradually increase
   b. The ability to enhance secondary innovation was adopted as one of the core criteria for evaluation and approval of inbound technology. As a professor from Tsinghua university shared, "…more stringent scrutinize will be applied to FDI… quality, not quantity, matters".

2) Firm related measures:
   a. 150% tax rebate on R&D expenditure will be implemented, and faster depreciations are applicable to R&D equipments
   b. Certain products with independent innovation will be included in the preferential government procurement and national security procurement programs
   c. SOE leaders' performance evaluations will be strongly based on their effectiveness in building up talent pools

3) Research institute/lab related measures:
   a. Public platforms for sharing basic research facilities and instruments are encouraged
   b. National labs for crucial/cutting-edge technologies will be strategically planned and built

4) University related measures:
   a. S&T oriented KPI system will be established and national prize will be awarded to leading researchers; researchers will be evaluated based on innovativeness rather than seniority
   b. Cross-discipline collaboration in universities are being promoted, and vocational training for teenagers are being emphasized

5) Cross-party collaboration measures:
   a. Market mechanism: preferred IPRs/products will be listed in the catalogue to direct IPR creation. China has achieved great improvements on its IPR protection as also benefits independent innovation and thus, firms/industries are encouraged to create Chinese standards
   b. Third party services: establish platforms for bridging venture capitals with high-tech SMEs and platforms for converting military technologies into civil application

The above dimensions of measures demonstrate the Chinese government's dual role in independent innovation: on one hand, the government is stepping back and promoting firms as the central player for independent innovation. On the other hand, it remains the decision maker/initiator for critical industries/fundamental technologies. Moreover, the Chinese society is now allied much tighter after cross-border collaborations are promoted than it had been previously under the umbrella of independent innovation. As such, we can expect higher internal efficiency of the Chinese innovation machine and hence, higher yields of innovation.

One of our interview partners from a Chinese authority pointed out that many of the government's strategies and measures are formulated at very high, abstract levels. The government would typically invest in infrastructure (e.g., high-tech parks, highways, bridges, and power plants) and not on individual projects or firms. Thus, it is up to the local governments to formulate implementation plans specific to their situations. For example, in the Shanghai government's Mid-long term S&T implementation plan, it (1) encourages S&T activities with the building of a science park; 2) provides a public platform for R&D by promoting the sharing of research equipments and data; 3) gives tax rebates and rental subsidies to promote technology transfer; 4) invests directly in R&D projects funding for universities/institutes, and firms 5) awards special "one-for-one" subsidies for high-tech start-ups. Our interviewee also noted that often, there would be conflicts between the central government and the local ones. He raised an example of while the central government tries to be more responsible towards IPR protection, local governments might deviate away from this target, as they are interested in output growth.

3.2.3 Strategies and measures with respect to the machinery industry

Machinery industry has a unique and crucial role in the overall economic and social development of China. Firstly, with 8 categories and 185 sub-categories of products, machinery industry is not only the largest sector of Chinese secondary sector but also the largest sector in international trading. "Made in China" is therefore, literally, the name card of the country. Secondly, due to its broad connection with upstream/downstream industrial sectors, machinery industry is also the underpinning force for the overall economic development. The upgrading of machinery industry not only provides advanced equipments to improve the productivity and energy efficiency at the firm level, but it also helps the restructuring and upgrading of the industrial structures for other industry sectors. Moreover, advanced machinery can fuel the conversion from technologies into products and increase the manufacturability of prototypes, therefore further boosting the development speed of other sectors. Thirdly, as the machinery industry is also a labour-intensive industrial sector, it can provide mass job opportunities to the society and therefore, keep the country more balanced and "harmonious" along its way towards fast development.

Given the strategic importance of the machinery industry, the government has planned more specific and detailed innovation strategy and corresponding measures for the industry.

Strategies and focuses

Realising its shortcomings in low levels of product design and manufacturing and high levels of foreign technology dependency, the government aims to form a number of large machinery groups with domestically-owned IPRs and advanced manufacturing capabilities by 2010. Grounded on such technological bases, a more specialised industrial structure is expected to emerge, with manufacturing of critical machinery, high-tech machinery, basic machinery, and common machinery complementary with each other.[226]

Certain strategies were adopted to tackle the current drawbacks and to achieve the 2010 targets. Compared to China's overall innovation strategy, the strategy for machinery industry is more pragmatic and aims at closing the gaps with developed countries, rather than an ambitiously leapfrog growth. This is partially due to the weak foundation of the Chinese machinery industry that lags approximately two to three decades behind its western peers[227]. There are three main aspects emphasized by the government: secondary innovation, market mechanisms, and government regulation, as discussed below:

<u>Secondary innovation</u>: Given China's low level of development in machinery industry, it is not surprising to observe the term "secondary innovation" in the guiding strategies. Aware that much remains to be learned from other countries, the Chinese government firstly emphasises on enlarging the areas for Sino-foreign collaborations to ensure that the channels for knowledge transfer are wide open. Secondly, the government stresses on enhancing the absorptive capacity of local firms. A closer collaboration between research institutes, universities and firms, together with a group of innovative talents, are believed as the most appropriate approaches to enhance the absorptive capacity of the country. In doing so, the transferred knowledge could be better deployed in Chinese products and thus create more value-add.

<u>Market mechanism</u>: In line with the government's transformation of roles in innovation, machinery firms are pushed to play a more central role in independent innovation. Resource allocation by the market is deemed more appropriate than a hierarchical system in eliminating redundant R&D investments and improving the overall structure of the industry. Moreover, market competition could also push firms to improve their internal innovation capabilities to survive the dynamic environment and thus, further improve the competitiveness of the machinery industry as a whole.

<u>Government regulation</u>: The government remains the decision maker in the critical/fundamental machinery R&D and development of common manufacturing technologies. In addition, the government also stimulates the technological dissemination and encourages leading firms to build close partnership with key suppliers to improve the development level of the entire value chains.

[226] http://www.gov.cn/gongbao/content/2006/content_352166.htm

[227] http://news.ieicn.com/5123.html

The 11th Five-Year-Plan has chosen 10 products/families as the focus for machinery innovation. They are: large-scale high performance clean generators, super high voltage transmission and transformation equipments, large-scale ethylene production equipments, large-scale coal chemical plants, large-scale metallurgy equipments, coal mine comprehensive excavate equipments, large-scale naval equipments, rail transportation equipments, environment protection and resource extensive utilization, and CNC machines. Such "most wanted" list on one hand shows that there are significant existing technology gaps for the above listed industry sectors/machineries and thus, opportunities of collaboration between foreign companies and Chinese firms. On the other hand, it gives foreign investors a relatively clear outlook that their ideas and knowledge will be quickly disseminated and copied by competitors.

Tactics and measures

As specific policy measures are applicable to different sectors of the machinery industry, we will only list some generic measures and map them into the above three strategic dimensions for readers to get a sense on the guiding hand in machinery industry.

<u>Secondary innovation:</u>

a. Local firms are exempted from import taxation when importing key components/modules that are necessary for secondary innovation of critical equipments
b. Revoke the previous preferential policies in tax exemption for imported complete machineries, especially those in mining, food, packaging, metallurgy, etc. For areas where local producers cannot meet the domestic demands, the government will evaluate and grant the preferential policies on a case-by-case manner
c. The government will closely scrutinize imported critical machinery sets, and Chinese research institutes/R&D centres must be involved in such importation

<u>Market mechanism:</u>

a. Insurance mechanisms are introduced to the important first-sold equipments developed by local firms
b. Local firms are encouraged to obtain financing on the stock market and issue corporate bonds for their R&D activities
c. SOEs will decrease their "social responsibilities" to their employees (e.g., building kinder gardens for their employees) and local government will take over the roles

<u>Government regulation:</u>

a. The government will increase its investments and subsidies on influential R&D projects/product developments
b. The government will promote the upgrading of its national/ industrial standard systems

c. When purchasing critical machinery sets, the government will favour Chinese-designed products

The above measures convey a strong signal that the Chinese government is now both tougher on foreign machinery firms, and more protective to its own machinery industry. Such attitude change reflects that after years of technological accumulation, China is now more independent on machinery technologies and local manufacturers can cover most of its demands. Furthermore, the local firms are still weak in independent innovation and therefore require more guidance and protection from the government.

However, as pointed by one of our interviewees, "currently government's role in machinery industry R&D is more important, yet less effective."

Box 4: Example for public-private partnerships for independent innovation

Founded on 29 April 2007, the Beijing CNC Equipment Innovation Alliance is an example of China's public-private partnerships in innovation. The alliance, supported by the Beijing Municipal Science & Technology Commission and Beijing State-owned Assets Supervision and Administration Commission, includes mainly SOEs, universities and research institutes.

The objectives of the alliance are:

1. To build a platform in fostering exchange of technology and services between the member companies, academia and national research institutes
2. To push for the development of sophisticated CNC machines with proprietary intellectual property rights held by member companies
3. To consolidate resources in implementing the relevant National Science & Technology guidelines [228] that encourages mastering the technology of high precision CNC machines so as to reduce China's dependency on imports

The alliance reflects the change of China's government direction and strategy in encouraging innovation. In the 1990s, the government encourages reverse engineering activities of local machine makers through subsidising their imports of advanced CNC machineries. However, the government now promotes the development of local product innovation through public-private partnerships. For instance, the alliance pilot program, "High Efficiency and High Precision CNC Key Technology Research and Application" seeks to leverage on China's technology foundation in machinery and industrial products to develop proprietary CNC machines capable of processing aircraft engines and satellite parts amongst a range of other high-precision components. Instead of subsidising imports, the government has also shifted towards a cost-sharing approach. In the first financing phase of the alliance (2007-2009), the Beijing Municipal Government will contribute RMB 20 m while industry members will inject RMB 40 m.

Not only is this form of public-private partnerships prevalent in the CNC machine industry, such strategic alliances can also be found in areas concerning steel, coal, chemicals and agricultural equipment.

Members of Beijing CNC Equipment Innovation Alliance:

Industry members	Universities and research institutes
Beijing Jingcheng Mech. and Elec. Holding	Beijing Machine Tool Institute
Beijing No. 1 Machine Tool Plant	Beijing Mechanical and Electrical Institute
Beijing No. 2 Machine Tool Plant	Beijing Aeronautical Mfg Tech. Research Institute
Beijing Shouke Catch Electric Technology	Beijing University of Technology
Beijing Xingdahao Technology	Beijing Information Science and Tech. University
	Beijing Productivity Promotion Centre

[228] National Guidelines: "Medium- and Long-term Programme for Science and Technology Department" (2006-2020)

3.2.4 Decision makers

Policymaking

The State Council, Chinese central government, plays a fundamental role in developing China’s science and technology policies. The formal organization of State Council and linkages between its ministries and agencies will be discussed briefly to explain China’s policymaking process for science and technology development.

Among the State Council’s ministries, commissions, bureaus and agencies, there are some that exert a more direct influence on the country’s science and technology policies than others do. These organizations can be broadly categorized into three groups: (i) Players involved in general policy making, (ii) players involved in conducting R&D and (iii) players involved in business and financial policies relevant to science and technology development.

The players directly involved in general policymaking are The Ministry of Science and Technology (MOST), Ministry of Education, State Intellectual Property Office (SIPO), National Development and Reform Commission. The Chinese Academy of Sciences is the largest public research institute in China to conduct R&D. Other ministries, for example, the Ministry of Information, Ministry of Health and Ministry of Agriculture also play an important role in their respective sectors regarding R&D activities. Finally, the Ministry of Commerce, State Administration of Taxation, Ministry of Finance and National Natural Science Foundation of China (NSFC) are important players focused on business development and financing relevant to the science and technology development. The linkages and interactions between these ministerial level agencies are illustrated in Figure 43.

A coordinating committee known as the “*Steering Committee for National S&T and Education*[229] *,*sits above the State Council level and orchestrates the various players involved. In addition to the above mentioned government bodies, other players influencing Chinese science and technology polices include Chinese universities, other public research institutes and China Association of Science and Technology (CAST) - a non-government organization which provides consulting advice to government decision makers on science and technology policies.

[229] (guo jia ke ji jiao yu ling dao xiao zu), 国家科技教育领导小组, the committee was found in 1998 with nine ministry level members of the State Council: Ministry of Science and Technology, Ministry of Finance, Ministry of Agriculture, Ministry of Education, National Development and Reform Commission, Ministry of Commerce, Commission of Science Technology and Industry for National Defense.

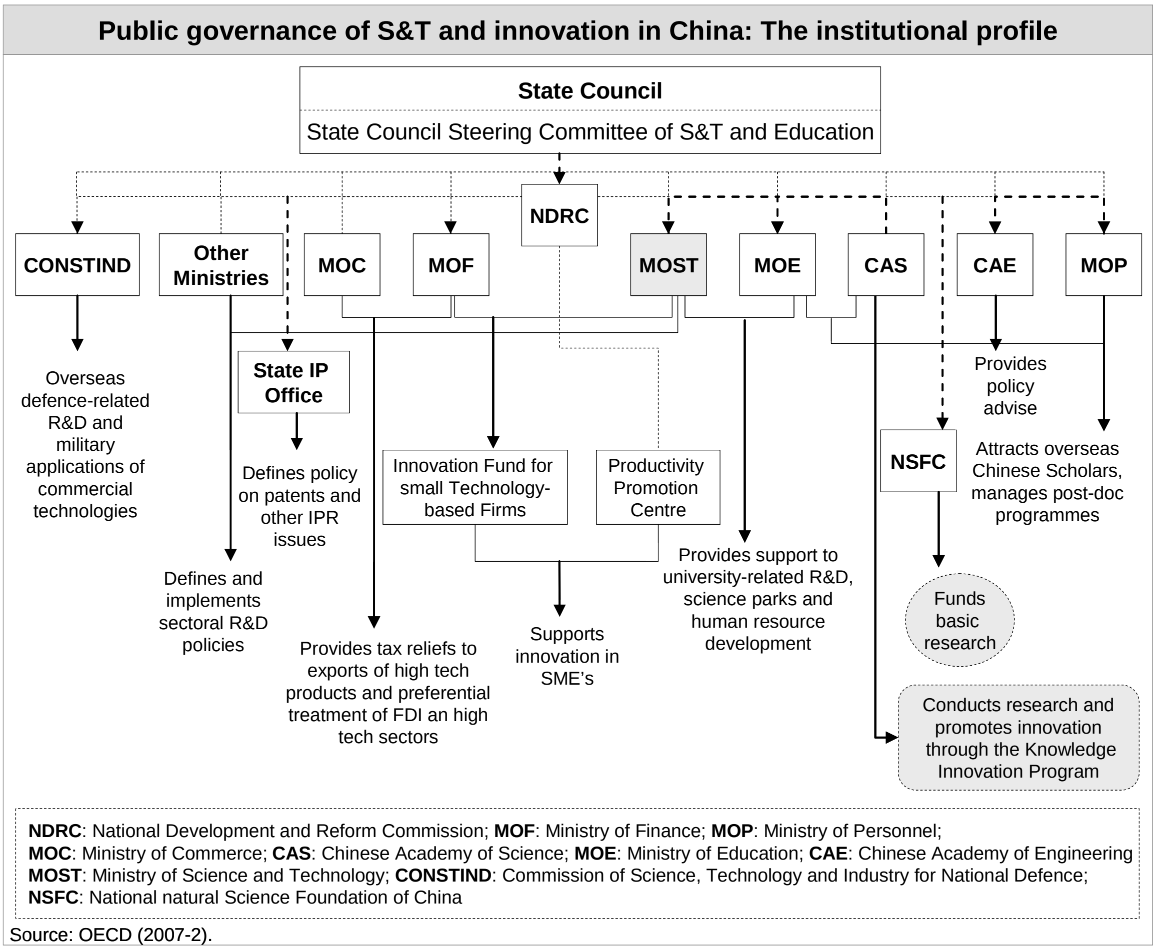


Figure 43: Public governance of S&T and innovation in China: The institutional profile.

Roles of major players in Chinese government

Ministry of Science and Technology

The Ministry plays a leading role to China's science and technology policy-making. Its mission and responsibilities include:

- Formulating strategies, priority areas, policies, laws and regulations for S&T
- Promoting the building of the national innovation system
- Conducting research on major S&T issues related to economic and social development
- Guiding reforms of the S&T system
- Formulating policies to strengthen basic research, high-tech development and industrialization
- Designing and implementing programs to fund basic and applied research, to enable firms to innovate, to create science parks, incubators, etc.;
- Developing measures to increase S&T investments;
- Allocating human resources in S&T and encourage S&T talent development;
- Promoting international S&T cooperation and exchanges.

National Development and Reform Commission

The commission is one of the most powerful government organizations in the State Council. It was founded in 2003 with the integration of three former State Council agencies: State Development and Planning Commission, Office for Restructuring the Economic System, and part of State Economic and Trade Commission. The Commission's overarching mission is to:

- Formulate and implement national economic and social development's long term (e.g., the Five-Year-Plan) and annual plan
- Monitor the overall national economy balance and optimize its economic structure
- Examine and approve major infrastructure and industrial projects
- Advance the economic system restructuring

The Commission has 26 departments/bureaus/offices with functions, which range from the overall national economic policy, rural area economy, and national energy, transportation to high-tech industry and price policies. Among all the divisions, the department of high-tech industry plays the most direct role to China's innovation performance. This department makes the policies, strategies and guidelines for China's high-tech industry; identifies priority fields and carries out pilot projects for the priority fields; organizes and promotes coordination between industry, academia and research institutes.

Another mission of the commission is to fund large science and technology infrastructure projects, particularly for basic research, such as the upgrade project, costing USD 83 million of Beijing Electron-position Collider.

Ministry of Education

The Ministry is in charge of China's overall education policies and regulations. Its main mission is to:

- Develop the Chinese education system reform and development strategies and guidelines
- Disburse funds to all levels of the education system and supervise the fund expending
- Formulate basic and secondary education curriculum and syllabus
- Supervise higher education, graduate education, higher vocational education and adult education.

There are 19 functional divisions in this ministry, which cover general policymaking, basic education, vocational education higher education, and higher education R&D and so on. The department of Science and Technology is the division in charge of universities' R&D. Its functions include setting the guideline for science and technology development in Chinese universities, organizing universities to participate in national major S&T programs, promoting universities' R&D results industrialization and strengthening coordination between industry, academia and research institutes.

Chinese Academy of Sciences

Founded in 1949, the Academy is China's largest public research institute, which is directly under the State Council. It currently has 108 research institutes in 12 locations across China, with 47,000 staff and 34,000 of them are scientific personnel. The mission of the Academy is to:

- Conduct research in basic and technological sciences
- Undertake national major S&T projects
- Provide science and technology consultation for governmental decision-makers.

In 2006, the Academy's R&D expenditure reached USD 1.4 billion and filed 3,510 invention patents application.

Linkage and coordination between the players

A holistic, coordinated approach is critical to enable the Chinese government to achieve its ambitious goals mentioned in 3.2.1 and build up an innovative nation[230]. Through interviews, we were able to have an insight into how these players coordinate in planning and decision-making.

The medium- and long-term S&T development program (2006-2020) is a comprehensive framework with clear directions and corresponding roadmaps on China's push towards a knowledge based economy. As illustrated in Figure 44, the development of the program is a holistic process whereby all players contribute and integrate their ideas top down and bottom up approaches.

The top down approach involves senior officials from the Communist Party in the various ministries such as the MOF, MOP, MOC, MOE and the MOST. Through internal discussions, these senior officials formulate national wide long-term goals and directions. They set the vision and mission for China's development.

The bottom-up approach complements the top down approach. A more democratic process, the bottom up approach involves scientists, economists and legal professionals from the CAS, CAE, CONSTIND, other government agencies and the industry. Through open discussions and cross-functional teams, these professionals leverage on each other's expertise to arrive at specific targets and implementation plans for their domains. The medium- and long-term development plans are then embodied and translated into short-term plans (i.e., China's Five-Year-Plans).

[230] OECD Reviews of China's Innovation Policy, OECD 2007, p50.

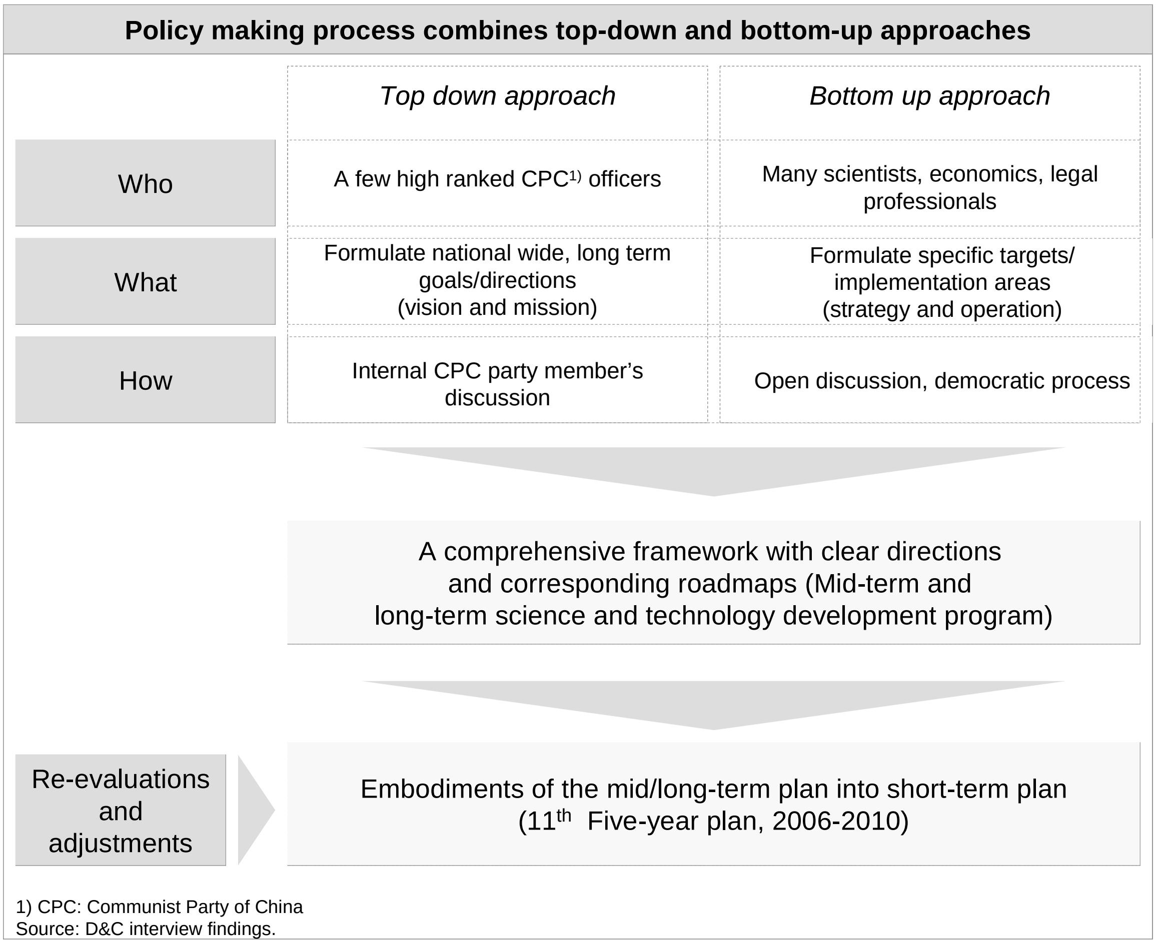


Figure 44: Policy making process combines top-down and bottom-up approaches.

The formulation of the medium- and long-term S&T development program took more than three years and included more than 2,000 government officials, professors and managers. The policy making process, hailed as open, transparent and efficient, is a showcase of the capability and workings of China's system of coordination between the various government entities.

4 The outlook:
What does that mean?

有志者，事竟成

you zhi zhe, shi jing cheng

Where there is a will, there is a way

4 Outlook: What does that mean?

Will China be able to succeed in transiting into a knowledge-based economy and a firm centric innovation juggernaut? The jury is still out. However, China has been going through a series of successful steps since the late 1970s (see Figure 45).

In the experimentation step (1978-1985), the government's view of science and technology was modernised and their importance and role towards economic prosperity acknowledged during the first National S&T conference in 1978. This paved the way for the beginning of the S&T reform (1985-1995) whereby state-owned firms spearheaded the commercialisation of technology. Innovation network amongst firms, universities and public labs was also established. Innovation then was limited as the focus was on starting up manufacturing capacity and learning from foreign investors. Nonetheless, through exposure and experience with capitalism, modern practices and competition, the Chinese were motivated to innovate. As such, the development of the S&T reform (1995-2005) was a period in which the Chinese made significant progress in their innovation capabilities.

Moving forward, the government realised that the fast follower innovation approach adopted by Chinese businesses and public research institutes would not be able to give them a true advantage on the global stage and that innovation could only be sustainable if driven by profits. Hence, its game plan for the future is to encourage independent innovation and a firm centric system.

Reviewing the collaborations between the Chinese machinery firms and foreign investors in the past decade, there are roughly three phases: 1) prior to China joining WTO in 2001, 2) between 2002 and 2006, and 3) from 2007 onwards to 2020. Along with the accumulation of technological capabilities of Chinese firms, the competitive landscape is constantly evolving.

The infant phase of China machinery industry:

Up to the end of the 20th century, most Chinese machinery companies were distressed SOEs with obsolete technologies and inappropriate governance structures. There were many "blank" areas where the Chinese did not have any IP and the domestic demands were purely reliant on imports. Given the circumstances, the main strategy of Chinese government then towards foreign investment was 1) importing high-end machineries to fulfil market demands, and 2) start joint ventures with foreign firms to become familiar with modern corporation governance and advanced management methods. As a result, long-term contracts were signed, and JV with minority foreign shares established.

Improvements in the 10th 5-year plan:

With the spillover effect of foreign investment, talent pools were created, industrial structures upgraded, and firms' internal management practice improved. Moreover, along with the long-term boom in economy, Chinese firms began operating under better financial conditions, which allowed them to catch up with their foreign peers quickly.

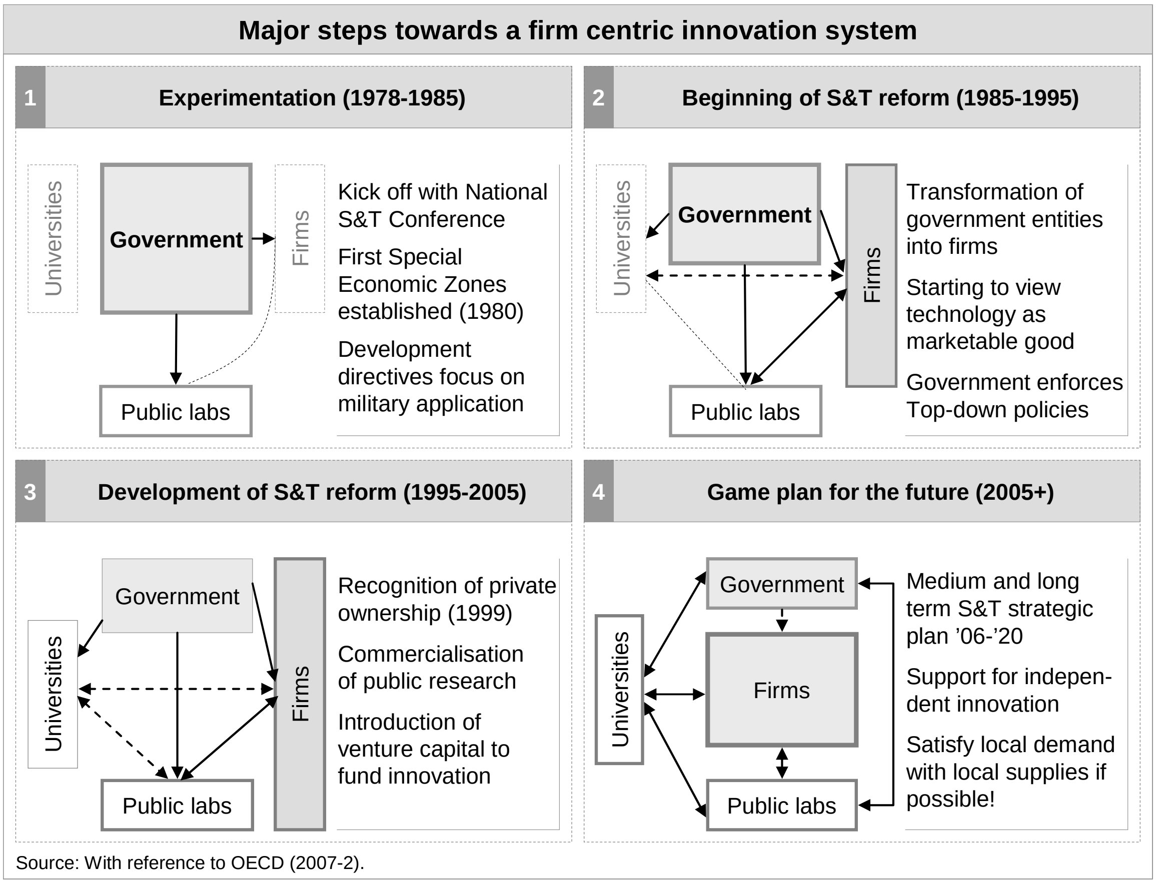


Figure 45: Major steps toward a firm centric innovation system.

Changing competitive landscapes for machinery exporters

Less distressed Chinese companies were aiming at long-term development, and were hungrier for advanced technologies. The government then promoted exchanges of technology within the booming market. In lieu of importing machines, the government had shifted its target to importing capital. Capturing this wave of opportunity, many foreign firms acquired majority shares of Chinese firms especially those of leading machinery firms.

However, the plan of "market in exchange for technology" was not successful (e.g. in automotive industry) and many acquired leading SOEs lost their competitive advantage. These trends increased the nationalistic sentiments to protect local brands/leading firms and resist acquisitions by foreign investments.

Ambitious moves in the next decade:

The Chinese firms are more ambitious nowadays not only in protecting their home market but also in expanding into international markets. As a result, they are starting to acquire foreign firms, establish their own technological standards, and try to compete on different technological structures to achieve "frog leap" developments.

With stronger competitiveness, the government is no longer willing to sacrifice domestic market in exchange for technology, but instead, prefers to encourage independent innovation. With technologies upgraded, talents assembled, governance structures smoothened, the Chinese machinery firms are now aiming at markets beyond its shores.

Nevertheless, foreign investments are still "welcomed" in China but now they are more restricted to acquisition of second tier companies for majority shares. In this sense, the Chinese government is now encouraging transfer of technology, rather than machines or capitals.

Figure 46 summarizes the above discussion on evolution of FDI in China.

Phases of foreign investment environment in machinery industry

	Before joining WTO (- '01)	First five-years ('02 – '06)	New trends (now - 2020)
Chinese machinery situation at the time	▪ Lagging far behind; blanks in many sectors ▪ Financially/structurally in trouble	▪ Catching up quickly with improved absorbing skill ▪ Better financial situation, clearer governance struct.	▪ Trying to challenge advanced tech./standard ▪ Modernized governance structure & sufficient R&D funds
Purpose of Chinese government	▪ Filling up blanks ▪ Get "sneak preview" of modern corporate management	▪ Exchange adv. technology with its own large market ▪ Practicing new govern. struct./training managers	▪ Dev. adv. technology to fight in new markets ▪ Optimise struct./talent pools at global arena
Main collaboration approach	▪ Exporting equipments ▪ Long-term contracts ▪ Minority share in JV	▪ "Exporting" capital ▪ Majority share/full takeover ▪ Aiming at leading firms	▪ "Exporting" technologies ▪ Minority share in JV ▪ Collaboration with 2nd tier

Challenges emerge for foreign investment in coping with the new trends in risk mgmt:

- Market risks: More competitive landscape with local firms upgrading their capabilities
- Technology risks: Increased concern on tech. leaking to local firms with their improved absorptive capacity
- Policy risks: Government policies today are more dynamic and increasingly in favor local firms

Source: Droege & Comp.

Figure 46: Phases of foreign investment environment in machinery industry.

4.1 China's innovative capabilities in 2020

China's fast economic growth as well as its history of fundamental changes and reforms makes predictions about future developments extremely difficult. Various estimates place China's S&T capabilities among that of western nations in as little as 10 years.[231] We would like to join the ranks of the sceptics, at least if we are talking about the entire country and entire industries within the short time frame of a decade.

The Chinese government is known to make pragmatic decisions with respect to developmental issues. It is aware that economic development is not equally distributed throughout a country or industry for that matter. Thus, the government focus rests on the already developed Eastern Regions as well as national key industries. It is expected that these regions and companies pull up the development of the surrounding regions and business networks. For the coming decade, we expect "centres of excellence" to arise and strengthen, especially around China's national top universities. In these centres, there is high S&T spill over into businesses, model foreign-invested companies are present and well-educated talented people as well as other resources available for innovative capabilities to grow.

However, the development of centres of excellence needs time and the initiative of many parties, only one of which is the government. Innovation cannot be ordered by government decree but needs to arise out of the available resources and motivation of individual companies and people to get creative. Resources (such as R&D expenditure, skilled people etc.) can be poured into the system but the innovation outcome will only grow correspondingly if the motivational issue is tackled simultaneously.

Here the problems are not easy to resolve. First, the input side China's innovation system will face difficulties to reach the proclaimed resource-related innovation goals (e.g., employing more money and people for S&T activities) as it heavily relies on (private) business initiative and (private) capabilities. Chinese domestic businesses however are currently at the stage of operationally mastering their own growth and upgrading their capital bases. Thus, research and development is just formalising on a larger scale but remains under-funded. On top of that, the Chinese educational system does not provide businesses with sufficient numbers of skilled people that can solve problems and show initiative. In order to change that, the government would need to reform and fund the educational system – a massive task on its own considering some 230 million people are currently enrolled in China's education system.

Most importantly, the motivation for individuals and organizations to innovate would need to improve fundamentally. This will only occur if the institutional frameworks – especially property rights – are secure and predictable. This is where we see the major fault line in China's National Innovation System: The impetus to innovate relies on a framework that makes the appropriation of the

[231] Forster (2006).

respective profits by the innovator possible and likely. Even if people in China had all the resources and the expertise to commercialise an innovation right now, in the current environment of fast track knowledge absorption by businesses and no effective enforcement of property rights – we should not see many innovative companies in China – and in reality, we do not. At this moment, China is at the stage of knowledge absorption more than "independent" knowledge creation. Output growth was put ahead everything else by the government and businesses alike for a long time. The shift in government policy to promote "independent innovation" could therefore be seen as a "reminder" or guideline – at least for government-affiliated organisations – to change their focus from resource intensive to a more knowledge intensive production.

China's economy will undoubtedly continue to grow and eventually overtake other major world economies in terms of output. In order for the economy to keep growing, lifting the living standard of the Chinese people, technology and knowledge base, skills and institutions will need to improve. Thus, China must replace the input factors that are likely to decline in the coming decade, such as capital input and labour input, FDI. The strong political will of the Chinese Communist Party to do its best in order to achieve this, can be taken at face value since it may be a question of proving one's right to exist or to rule for that matter.

Relative to other nations in the world, there is one obvious and fundamental difference: If (or when) China makes another "Great Leap Forward"[232] – this time in a growth and knowledge direction – similar to other Asian nations, the impact on the world economy and ecology will be tremendous. With 1.3 billion people, more than every 5th person living today is a Chinese national. China is simply in a different league than most other countries when it comes to size. Hence, even if China does not become an innovation juggernaut by 2020 in the sense that we will see major product and technology innovations over the next decade being created in China, the economic impact and market pressure coming from this Asian giant will still change the industrial landscapes of the west.

[232] "The Great Leap Forward" refers to the 2nd Five Year Plan for 1958-1963 by the People's Republic of China. Its goal was the country's rapid transformation towards an industrialised communist nation, away from the dominance of the primary sector. This social and economic plan was applied from 1958 to 1960 and in combination with mismanagement and bad harvests proved disastrous for China's rural population.

4.2 Threat and opportunity: Impact on German machinery firms

Having seen the massive potential of China to become an innovation juggernaut, managers from around the world may ask themselves the following questions: what are the typical measures that Chinese competitors will adopt to compete with my firm? How severely does the competition endanger my firm's competitive advantage? Moreover, what are the dynamics that drive the changing competitive landscape? Recognizing the importance of IPR in the overall competition, we focused our study on issues of IPR infringement and the guiding hand of the government. In total, 15 German machinery firms operating in China were interviewed between August to September 2007. All the interviewees are of general manager/vice president positions, which provided us not only a comprehensive overview of the business landscape, but also an in-depth view on how to deal with knowledge appropriation in China. To facilitate the interviewing process and cross-company analysis, we adopted a semi-structured approach, i.e. interview protocol was prepared and conducted through the interview, yet the conversations were not limited to the pre-defined topics in order to reveal more information and not to be constrained in the scope of the study. The interviews typically took 1 to 1.5 hours.

The following sections summarize the interview findings and provide a framework for German machinery firms to anchor themselves in the Chinese market. In addition, initiatives to change the competition landscape were analysed and recommendations provided.

4.2.1 Products are not the only thing to be emulated by competitors

While it is relatively common for latecomers to copy from market leaders and reduce technological gaps, illegal copying, i.e. the IPR infringement issue, is a major cause of concern in China.

Some of the interviewees cited Japan's development model in 1960s to justify their risk-taking behaviour. One of the pump producers maintained a R&D team of 10% of total working force and devoted 1.5% of its turnover to R&D activities in China. The R&D team's main task was to facilitate customization to fit local Chinese market. Aware of the possible knowledge appropriation from local suppliers, the manager was ready to suffer the lost as an "entry fee" to the market. He reasoned that Japanese firms were also copying from Europe and US in 1960s. Therefore, such IPR infringement behaviours are not unique to China and German firms should be prepared for such inevitable risks.

Other interviewees were more conservative when considering shifting of R&D activities to China. A lathe manufacturer, for instance, conducts all R&D back in Germany and only exports low-end machines to China. A few reasons underpin this decision. Firstly, China has a unique historical background of R&D evolvement. It was common for the government to fund research institutes and transfer outputs free of charge to its SOEs. Thus, the concept of free sharing was prevalent. Such mindset will not change in a short time. Secondly, in 2002, the Chinese government introduced a "China Compulsory Certificate" system (CCC), requesting firms to submit technical information regarding to their products listed in the CCC catalogue.[233] A few interviewees regarded this regulation as an open door to IPR theft. Finally yet importantly, punishment for IPR theft is rarely enforced in China. IPR infringements in China are therefore "omnipresent" as quoted by several interviewees and it could happen in many different aspects.

Copying of products

In most common situation, local competitors would copy appearances/industrial design of foreign products. For instance, an electronic sensor producer complained of local Chinese competitors' identical industrial design of the sensor. Since the appearances are frequently the easiest aspects to copy, it happens to products as well as components, and affects products with different levels of complexity.

"Upgraded" copying would be copying of parts/components of the overall products. As observed by one of the pump manufacturer, some local firms are producing faked spare parts for their products. Such type of copying would most likely happen to those easily worn articles, and/or those complex products that local firms lacking the capability to fully reverse engineer with.

The most threatening ones would be the copying of the entire product. On one hand, this causes a direct erosion of product sales while on the other hand, its implication is that the local competitors' R&D capabilities have evolved to a degree that given time, they may even surpass their foreign "teachers". A few wood/metalworking suppliers' great concerns on IPR theft have demonstrated the severity of such threatening trends.

Copying of image

Copying is not limited to products, it can be extended to company images. The pump company mentioned earlier complained that a local Chinese firm had exactly the same name with its Chinese translation. In another case, the woodworking firm found that local competitors are using a logo/trademark very similar to its own. Making things worse is the fact that the machinery market is so fragmented which makes it extremely difficult for foreign firms to keep track of all appropriations. Oftentimes, it is the end users' complaints that revealed the illegal infringement of copying of images.

[233] CCC online service, http://www.ccc-cn.org/cccindex.htm

4.2.2 Degree of threat is mainly defined by product / process dimension

Recognising the existence of different perceptions by the interviewees regarding competitors catching up fast as well as different technologies/processes involved in the industry sectors, we mapped the participating companies' products along two axes: Product complexity and processing difficulty (Figure 47).[234]

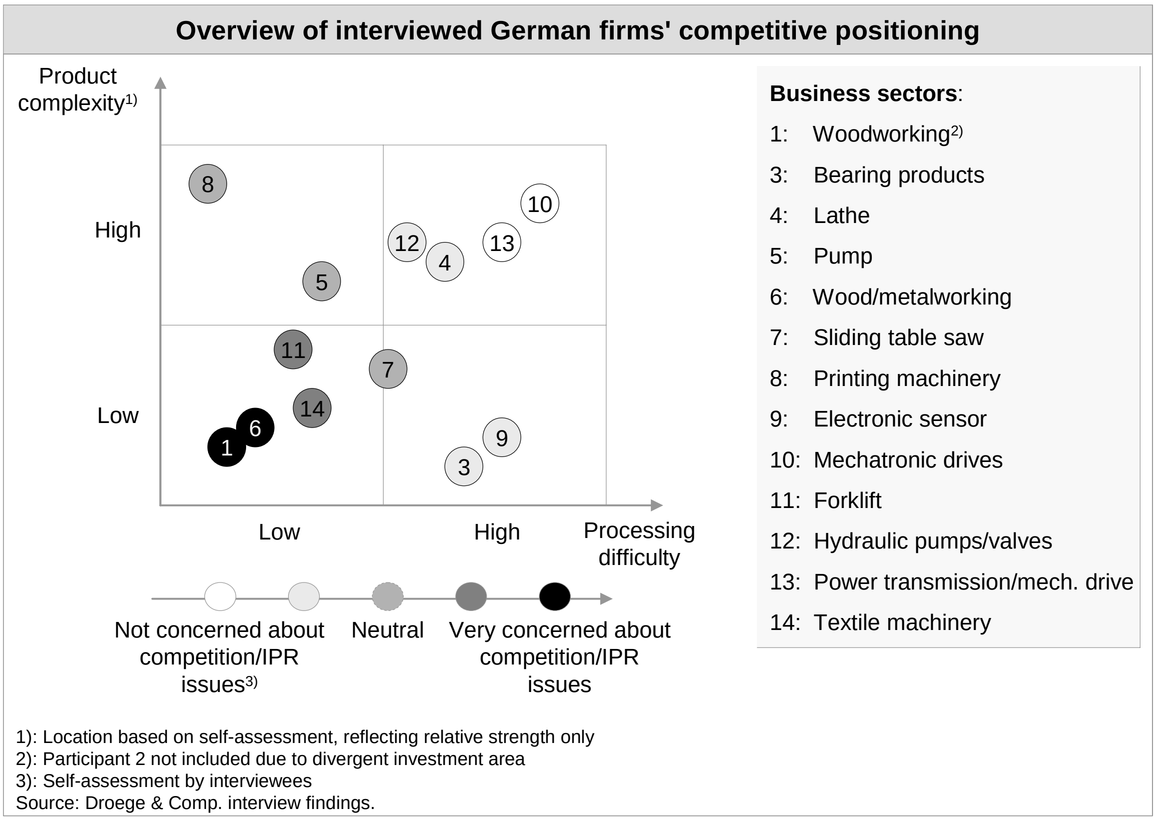


Figure 47: Overview of interviewed German firms' competitive positioning.

We asked the interviewees to evaluate the relative complexity/difficulty of designing/manufacturing their core products. By a rough assessment of "high" or "low" category, a two-by-two matrix was created.

Mapping of the *y*-axis is based on the assessment of product complexity. For instance, firm 8's core products are sophisticated high-tech printing machines; therefore the relative complexity to its Chinese competitors is quite high. However, although firm 14's textile machines are not simple products, the relative complexity is low because Chinese firms have accumulated much design knowledge in this area.

[234] One of the participating firm was not included in the analysis as its operation covers much broad range of products/services thus cannot be exactly mapped in the matrix

Mapping of the x-axis is based on the assessment of processing difficulty. For instance, firm 3 produces high-end bearings whose manufacturing process requires high-level precision and consistent quality. Local competitors are lagging far behind such level of processing capability.

We further fine-tune the relative positioning within each quadrant according to the tone of interviewees. For instance, firm 10 commented that *"there is still a huge gap that stems from a lack of true know-how with regard to design and processes*", while firm 4 noted *"local Chinese competitors so far don't pose a real threat due to their products' low quality and limited functions, but they will catch up quickly".* Therefore, firm 10 was positioned closer to the upper-right corner of the quadrant than firm 4.

The colour of each circle in the matrix resembles its represented firm's perception of the degree of threat posed by Chinese competitors or their re-innovation strategies. For instance, the wood/metalworking firms (firm 1 and 6) were concerned most and thus the circles are in black colour. Firm 10 did not perceive competitors or potential IPR infringements as a threat at all, thus falls in other end of the spectrum.

4.2.3 Recommendations for German firms to cope with Chinese firms' innovation strategies

While a rough estimation of relative product complexity/processing difficulty can help firms in anchoring their current position in China, the market and technology evolvement renders the positioning rather volatile. It is therefore critical to focus not only on a static picture, but also on the dynamics behind the competitive landscape.

As described in Chapter 3.1.2, Chinese firms are motivated to compete in high-end market through process/product innovation, i.e., by moving their positioning in the above product/process matrix. This leads to our first general recommendation to German firms: adopt countermeasures that could push your own positioning to the upper-right corner in order to maintain sustainable competitive advantages over Chinese firms. In addition, while moving up the product and quality ladder is more a firm-level strategy, extra-company relationships with local government, industrial associations, and sometimes, global competitors should be explored as complementary measures for firm-level strategies.

Firm-level strategies/countermeasures

In general, firms can differentiate their products/services from competitors by improving product innovation capabilities, and as a result, continuous product upgrading can provide firms a niche market and avoid competing in commodities markets. Alternatively, advanced manufacturing skills and quality management systems would enable firms to manufacture products with higher resolutions/precisions and lower quality tolerances and thus enjoy higher margins in high-end market segments. Even if firms cannot differentiate their technological skills in products or processes, they can still choose to outpace their competitors by deploying better management controls and thus achieving cost advantages. In worst scenarios, when facing well-managed competitors with technical advantages, a trump card one can play is the mergers or acquisitions one. Delicately conducted, it can not only eliminate most threatening competitors, but also enhance the technical strength of the strategic buyers.

The path of improving product innovation capabilities:

Two approaches can be adopted for pushing German firms up to the *y*-axis: proactive approach that increases the absolute innovativeness of products, and passive approach that prevents Chinese competitors from catching up with the product innovativeness level.

<u>Proactive approach</u>:

1) Fast innovation: “knowledge is like milk, it perishes,” one of our interviewees remarked. Indeed, for those industry sectors with short product life cycles and frequent new product introductions, protecting knowledge from appropriation is less meaningful. Fast innovation is thus, recommended for harvesting much higher margin from the niche of pioneer users. In addition, fast obsolete technologies would dampen local firms' incentives in copying existing product designs because reverse engineering and modification of manufacturing procedures takes time. The interviewed firm that produces mechatronic drives is one of the examples in deploying such knowledge. This countermeasure, however, requires intensive product innovation capability as well as a product platform to keep pace with rapid product introductions.
2) Focusing only on high-end products: one of the leading printing machinery firms was proud of its high-end sophisticated products that cannot be copied by local firms due to its complexity. This technology differentiating strategy is more suitable for industry sectors where larger product innovation gaps exist. However, local firms could increase their absorptive capacity at tremendous speeds, as observed in Shanghai Electrics case. By acquiring a distressed Japanese printing machinery firm, Shanghai Electrics greatly improved its product innovation capability and posed direct threats to other German firms.

<u>Passive Approaches</u>:

1) Small R&D teams in China: reducing the chance of unintended technology transfer is one of the most natural responses of our interviewees. German firms typically reduce their collaboration scopes to such a degree that only local customer adaptation job is assigned to the R&D team. For instance, the textile company utilised this strategy for its knowledge protection. However, two prerequisites apply: firstly given the limited R&D capability the product itself has to be standardised so that the local adaptation can be conducted with less effort. In addition, the industry itself has to be mature enough so that there would be little value-add to pursue product innovations further. Otherwise, it might disadvantageous for German firms not to learn and improve from the

feedback of such a huge customer base with innovative ideas possibly coming out from unexpected niches. Interestingly, some firms chose to collaborate with local universities to limit the potential knowledge leakage to direct competitors but still remain agile to Chinese market trends and enhance their R&D capabilities in customization or additional functionalities.

2) Low-end/simplified products: This is exactly the opposite approach to the proactive approach discussed above. The rationale is that there is not much to lose from such low-end or simplified products. The woodworking firm's general manager interviewed has adopted this approach. However, along with the globalization trend, market boundaries are more permeable and thus, there are no guarantees that Chinese firms would not learn from German products sold in Europe market or even other global leaders from the US or Japan.

The path of improving manufacturing skills:

Hold up craftsmanship: as discussed in Chapter 3.1.2, Chinese firms are lagging behind foreign firms in terms of manufacturing capabilities. Such gaps are more significant when compared with German firms. Thus, one of the common countermeasures is to "hide" the manufacturing secrets by not manufacturing in China. The electronic sensor firm we interviewed deployed this strategy and its presence in China is only limited to marketing and sales functions. Even though it is a good approach, it is only applicable to products with simple structures and thus, manufacturing capability becomes the key differentiator. If new approaches were developed for achieving the same quality/precision of current products, the market would be completely disrupted and competitive advantages would diminish.

Maintain stable labour force: for scenarios where German firms are forced to go to China for its manufacturing because of fierce competition and other global competitors' presence, the threat of leakage of "know-how" could still be contained to a certain degree by maintaining stable labour force at the shop floor. As the transfer of tacit knowledge such as process "know-how" necessitates long-term practice and master-apprentice relationships, a stable work force can alleviate the threat by setting up plants in China. Another interesting observation is that German firms start to shape strategic alliances by providing solutions (products/services) for the Chinese market. One of the leading printing machinery firms has actually allied with another post-printing supplier to set up plants in Shanghai. While the main purpose is to expand its service range and thus, be able to penetrate into more market segments, a close circle of German firms also hinders spillover of know-how as employee turnover could take place within the group.

Competing in the same position:

Leverage management excellence: while many German machinery firms are outstanding for their technological expertise, their management skills are limited. For industrial sectors with little differentiation in product functionalities or quality, German firms have to improve their management skills in order to compete in a commodity market. In addition to setting up plants in China in order to benefit from cost advantages such as labour and premises, they should also aim to improve their management skills such as how to optimize their value stream and cut off redundant procedures. More often than not, a professional manager would be able to manage better than the family members are able to do, and a modern corporate governance structure is often more appropriate to leverage core competences of firms. Japanese firms have actually set up good examples in their "exact copy" concept, where every procedure is standardized and disseminated to their plants worldwide.

Think outside of the box:

Mergers and acquisition: this powerful weapon is somewhat less utilised by German firms. For example, in the printing machinery industry, US and Japanese firms are much more active in setting up joint ventures with local competitive players or in some instances, acquire firms with high synergy potentials. The German firms, however, are less aggressive (or more afraid?) in involving Chinese partners in their own businesses. However famously said by Mobutu, a ruler of Zaire (now known as Congo), "keep your friends close but your enemies closer", there are several advantages for collaborating with Chinese firms. First and the foremost, by keeping competitors under the same roof, it is much easier to observe and control their R&D activities. Not only can German firms limit the scope of R&D collaboration to minimize potential leakage of key knowledge, they can also manipulate the R&D teams and direct them into less threatening technology tracks. Second, familiarizing with Chinese firms' R&D and manufacturing processes and behaviours, German firms can better estimate their true competitive advantages, and therefore enable better protection over such core assets and further make full use of them.

Extra-firm level strategies / countermeasures

Chinese and German governments, together with industrial associations, are the forces beyond firm level that can affect the gap of innovativeness between Chinese and German firms. While the Chinese government and associations are naturally trying to reduce such gaps and hence increase the competitive advantages of the country/industry, German firms can still exploit the policies by delicately collaborating with local government and industries.

Work with, not against, local government

Understanding the government interests and stick to the old rules:

Parties only collaborate when they have the same interests. Foreign firms that want to succeed in China must in return offer benefits to the local government. While promoting independent innovation, the government makes itself very clear that foreign investments are still welcome. "FDI, especially those that goes to high-tech industries such as R&D facilities and high-tech services sector, will continue to enjoy preferential policies because this will enhance Chinese science and technology innovation capabilities and optimise China's industry structure", said a President of NRCSTD[235] during an interview. Another interviewee stated, "Chinese government will stick to a long term and stable

[235] National Research Center for Science and Technology for Development

open policy to boost the sustainable economic and social development". The intention to stabilize its foreign policies, together with interests in KPIs in increasing tax and employment rate, make China still a favourable destination for FDI, and local government friend of foreign firms. However, due to the increasing nationalism, German firms should be more cautious in sticking to the old rules. FAG, for instance, acquired 51% share of Northwest Bearing, one of the leading bearing supplier in China, in 2001. The government was supportive during the time as both the local government and the firm were expecting some level of advance technology transfer as a return. However, after two years of joint operation and then fully acquiring Northwest Bearing, FAG laid off 800 workers out of in total 1,100.[236] Greatly hurting local employment, such internal lay-off caused great impact outside of the firm and local people start to question the local government of their poor supervision. The case was even been highlighted early this year in CCTV-1, the central TV station in China, which greatly stirred up nationalism and destroyed FAG's corporate image. By saving an operation cost of less than 1 million Euro (in contrast with turnover of 50 m Euro), a much greater loss of company image and potential politic risk is await. While German firms sometimes bend business rules, they should not push the limit to a degree that it might jeopardize the foundation of collaboration with local governments.

<u>Anticipating the policy direction and fit to the new rules:</u>

With the launching of Fifteen-Year Plan, the Chinese government has conveyed a few "wooing" signals where foreign firms should not miss when investing in China. First and the foremost, technology transfer is very much "appreciated" by the Chinese government. While counter-intuitive, offering core technologies to the local competitors might also be a way of competition. Kodak[237], for instance, had signed an agreement with Chinese government in 1998 and promised to transfer its core technologies for film making to Luckyfilm, the largest SOE in film making industry. Such technology transfer in return brought Kodak an exclusive license in operating in photosensitive industry for three years, which were fully utilise by Kodak to increase its market share from less than 25% in 1998, to over 50% in 2003. In contrast, Fuji Film, its largest competitor in China market, had suffered a dramatic market share loss from 48% to 15%. Lessons learned here is that when technology leakage is inevitable or technological advantage is not sustainable, foreign firms may choose to pre-empt their competitors in setting up exclusive collaboration with local government. Such strategy would gain significant marketing advantage, whereas the technological loss is inevitable and therefore minor. The strategy is especially applicable to dynamic industry sectors where multiple technology leaders exist. Under such setting a prisoner's dilemma exist: afraid of technological leakage from foreign peers, firms have to submit to the preferential policy and transfer core knowledge to local firms in order to avoid much higher losses. Social responsibility is another favoured trait of foreign firms. While Chinese government is more and more concern about the degrading environment and

[236] http://www.jsygktv.cn/2007/7-10/17040745036.html

[237] http://www.chinafiw.com/html/200610/n12786.html

harmony of the society, firms sharing government's concerns will be politically awarded. German firms could leverage the technological advantage in environmental protection to acquire favourable government supports and keep political, if not technological, advantages against local competitors.

Make use of industrial associations

While a few German firms felt that Chinese industrial associations facilitated "dissemination of technology" (meaning copying), these associations could also serve as a positive factor for enhancing the technological advantage of German firms. According to a recent statistics released by the Shanghai government, more than 60% members in most associations are SOEs. With exception of a few leading large SMEs, most of these firms are not competitive due to their small scales and limited technology competency[238]. As such, associations are motivated to involve more foreign firms to increase their impacts on the industry. This actually offers two opportunities for foreign firms. Firstly, regulations as regards to IPR theft can be enhanced with the existence of foreign firms, and the association could then serve as a platform to identify and punish misappropriations. Secondly, closer interactions with local competitors provides foreign firms better estimation of the strength and weakness of their local peers, and correspondingly adjust their R&D strategies in China and keep ahead of other members.

[238] http://news.xinhuanet.com/fortune/2002-11/24/content_639152.htm

Annex

Annex

The darker side of China's global competition: Product piracy

China's failure to protect intellectual property is a problem for German competitiveness, but other countries, notably the US are even more affected because their intellectual property industries contribute to more than half of all U.S. exports and represent 40 percent of U.S. economic growth.

The U.S. Chamber of Commerce estimates that the global intellectual property industry loses $650 billion annually in sales due to counterfeit goods. Some analysts estimate that China is responsible for as much as 70 percent of this counterfeit goods market.

After many attempts, the US finally succeeded on 26 September 2007 to get the WTO to open formal investigations into allegations that China is providing a safe haven for product piracy and counterfeiting of DVD's, computer software, luxury goods, books, shoes and pharmaceuticals. An investigative panel was set up, which initially has only to decide whether Beijing has taken sufficient action to protect intellectual property rights, but could ultimately authorize US trade sanctions against China.

Like so many things in China, the concept of Intellectual Property Rights can only be appreciated in the historic context: By 1864, China embarked on a "Self-Strengthening Movement" designed to industrialize the country and to develop modern arsenals, shipyards, and a strong military. Young engineers were sent abroad to study industrial processes, acquire sets of machine tools, and buy modern weapons. For 20 years, the Chinese armies and navies bought the best they could from the international market and then copied what they were able to in newly built arsenals. Chinese ships depended on foreign-made engines and propulsion systems. The guns came from Britain, Germany, and the United States. At the end of the 20-year period, Chinese arsenals and shipyards had reverse engineered some of the most modern rifles, cannons, and guns and produced them domestically.

Because of the long record of government-directed missions overseas to acquire the best military or civil technology available, reverse engineer it and claim it to be "Chinese", this practice is still widespread today. If all else fails, China has no hesitation to add foreign components to their Chinese-produced items.

The Communist system introduced collective ownership of material goods and of intellectual property. The results of Research efforts were freely available and free to share. In a way, R&D results were regarded as "Open-Source" items: Free to use, free to modify, free to commercialize.

Another remnant from the period of total State control is the system of gathering information. It is difficult for Outsiders, to classify the information-gathering activities into product piracy and industrial espionage because the government may or may not be involved to various degrees in the strategic collection of information and intelligence. This is not surprising for various reasons:

1. *China is still a state economy*
   The government is in charge of the army, but also in charge of strategic industries like telecoms, steel building, power generation etc. to obtain classified information on various industries, the Chinese government in the past utilised the same information channels as the military i.e. through embassies, delegated industry delegations or students delegated to internships in pre-selected companies. These intelligence systems are still in place and can be activated at will. The Chinese appeal to an individual's commitment and obligation as being part of the Chinese race to do something for China. Usually there is no money involved and the Chinese intelligence operations primarily rely on collecting a small amount of information from a large amount of people.

2. *Confusion of terms*
   The use of the terms “intelligence” and “information” refers to a concept for which in Chinese only one term exists. In the Chinese language and therefore in the minds of the Chinese, there is no difference between intelligence and information. The Chinese term "qingbao" refers to a concept that includes both English meanings "intelligence" and "information." The distinction is a Western one not shared by East Asian languages or by their speakers.

3. *Privatisation*
   China only began privatisation of the state-owned enterprises 17 years ago. Even if the central ministries now are beginning to see the need to comply with China's WTO obligations and subsequently have drafted a number of laws and by-laws, there are not enough Chinese scientists that have grasped the concept of intellectual property right protection or would be able to pass it on to provincial levels. Even if the appropriate legislation has been passed by the central government, there are not enough lawyers or experts to translate the laws into byelaws and implementation rules. Enforcement is even more difficult.

4. *Trade secrets law*
   China lacks an effective trade secrets law. The Anti-Unfair Competition Law and Criminal Law both have sections on trade secrets. However, it is difficult to get the Public Security Bureau to take on such a case. Moreover, the Anti-Unfair Competition Law provides only general guidelines for trade secret actions. Even western lawyers usually advise mitigation before they take on a legal case.

Local governments are also taking an active role in gathering technology as they build their own micro-economies. Many provinces and municipalities operate high-technology zones or "incubator parks" specifically designed to attract foreign businesses. They also give incentives to bring back Chinese nationals who have studied or worked overseas in critical high-technology areas.

When the entrepreneurs return to China with the targeted skills, they get free office space, loans, start-up capital, and administrative help in setting up a business designed to bring in foreign investment and technology.

The challenge that foreign companies face is a continuous pressure to disclose or introduce new technology into China, often as a condition of doing business. Foreigners cannot even demand to have the rules and byelaws explained to them and it makes no sense fro a Westerner to threaten Chinese violators of IPR rules because of the weak legal infrastructure and climate of low regard for intellectual property rights in China. When the local employees move to other companies or set up their own businesses, they often bring along the acquired trade secrets with them.

"Heaven is High and the Emperor far away"

In the main body of the IMPULS study, we demonstrated that the Chinese innovation based growth model is documented in a number of long-, medium- and short term plans. It is implemented by the bureaucracy through a variety of activity plans which are sometimes clearly laid down, but which most often are left to the individual interpretation of the executing officer. There is no need for the planners to translate all plans into detailed working instructions for every level of the bureaucracy, because through more than 50 years of state control, all government officials at every level know the meaning of the topics mentioned in the overall plans. It is left to the interpretation and imagination of local officials to implement the suggestions formulated in the plan as they see fit. This means that sometimes government officials develop byelaws, which may be even more stringent than the original plan, more often however, the basic concept is watered down, adapted to the local environment and designed to protect the local champion and keep the International competition out.
For local Chinese companies, enforcement is lax but foreign firms have to follow the letters of the law. Until recently, Foreign invested firms enjoyed greater tax privileges than local Chinese firms and this contributed to the feeling of local officials that something needed to be done to compensate local firms for the apparent tax disadvantage.

It has to be mentioned also, that sometimes lower-ranking Government officials also pretend that there are Government regulations and laws, which actually do not exist, just to achieve their own goal to force the foreigners to release the requested information or to comply. Sometimes, officials might not be informed about the latest legal changes and maintain their position because they do not want to lose face.

Army intelligence

China is officially still classified as a state economy. The communist party and the military are the most influential organs and traditionally it was they, who converted the state plans into action. For the transfer of know-how, the acquisition of trade secrets and for industrial espionage, a worldwide intelligence network was developed by the People's Liberation Army in order to enable China to acquire as much know-how as possible for the lowest possible price. Sometimes the required information was not available even against

payment, and then the army resorted to industrial espionage in order to obtain the desired data. The system is still in place today and is working so well, that the U.S. are complaining that China today takes no more than 2-3 years to introduce break-through technology from the west into China.
In 2005, China introduced two new classes of submarines: The nuclear-powered attack Type 094 and the nuclear-powered ballistic missile submarine, Type 093. Both were surprising to he West because of their sophisticated design and the speed of the production process.

There are a few other areas where China now excels in producing military hardware. Besides Russia, only China can arm its combat ships and aircraft with a hypersonic, nuclear-tipped cruise missile. China has now fielded a target acquisition and sensor architecture that will permit cooperative target engagement by multiple land-, air- and sea-based weapon systems.

With foreign assistance, the PLA has mastered air-to-air refuelling and has fielded airborne early warning radars. The PLA excels in electronic warfare and has excellent air defence systems. China has managed to field a large number of nuclear-capable, mobile short-range missiles and new classes of intercontinental ballistic missiles with multiple warheads and manoeuvring re-entry vehicles.

Experts hold China’s recent advances in the sensitive Taiwan Strait military force as the result of Chinese espionage against United States. It includes the new cruise missile system that mimics the American Tomahawk cruise missile and the coast defence system that was developed by stealing the blue print of the American Aegis weapons systems

Relationship between military and civil technology

Central to China’s science and technology development is the symbiotic relationship between military and civilian technology.
In March 1986, the Chinese Government launched a national high-technology research and development programme with the specific goal of benefiting China's long-term high technology development. This centralized program, known as the "863 Programme" (or Torch Programme), allocates money to experts in China to acquire and develop biotechnology, space technology, information technology, laser technology, automation technology, energy technology, and advanced materials. The 863 programme also represents China’s efforts to speed concurrent civil and military technology development. Similar to the old Self-Strengthening Movement, the program sends thousands of students and scientists abroad to pursue critical civil and military dual-use technologies.

The 863 Programme continues today along with the National Programme on Key Basic Research Projects (the 973 Program). The 973 Program, in which the government plays a role similar to that of a venture capitalist, focuses on the growth of small and medium enterprises in China.

Industrial espionage: How do the Chinese do it?

China uses a variety of collectors: students, business people, scientists or visitors abroad. They are different form the West insofar as they do not follow the Western system exclusively, and rely on both the private individuals and the professional intelligence officers from the Ministry of State securities or the PLA. There is actually much more hype than substance when it comes to evidence of Chinese industrial espionage. The problem exists and cannot be tolerated by the West. China, however, is being singled out because of her size, the dynamic economic development and the intertwined relationship China has with the rest of the world. Seen in perspective, the Chinese may not be that much different form other developing countries.

Typically, the Chinese spies are asked to take whatever they can find and the Chinese intelligence in Beijing will piece the puzzle together. "Collecting a small amount of information from a large amount of people". 80% of all Chinese spying relies on open-source material obtained from Government, the internet and the private sector.

There are not many documented cases of industrial espionage available because companies affected are ashamed and do not want to talk about the problem.

The main methods of industrial espionage apparently are as follows:

- *Chinese Individuals:* The method seems to be simple: Approach a Chinese individual who is preparing to go to an interesting company abroad and appeal to his National loyalty. No money is involved and no clear targets are set.
  Chinese students enrol at Western universities, study longer than their co-students, spicing up their studies through internships at interesting companies.

  Chinese technicians sent for training also fall into this category. They study diligently, grasp everything, ask many questions and are willing to do any amount of over time, preferably when everyone else has gone home. They are then said to copy confidential data from the company's computers, photocopy drawings and get samples of interesting new designs which are all duly passed on.

  In 2005, the student Li Li was working as an intern at Valeo, the French car part manufacturer. She was arrested for having Valeo data on her home computer. These included "confidential" data on future Valeo designs. Li Li was released and sent back to China.

  In 2006, Meng Xiaodong who worked for the US firm Quantum3D was charged for stealing a program "Mantis" used to simulate real world motion for military training purposes. He was also released.

- *Naturalised citizens:* In 2006, Chi Mak, a naturalized US citizen who worked as engineer for a California defence firm was prosecuted for having taken computer disks containing sensitive information from his workplace. He was

later discharged. In 2000, the US accused Lee Wen Ho, a scientist working at the Los Alamos national Lab, of stealing nuclear secrets for China. Lee was later convicted for "mishandling computer files".
In 1999, Katrina Leung, an employee of Boeing and part of a group that was to plant bugs on a plane built for the Chinese Premier, turned around and became a double agent, working for both the FBI and the Chinese government. In December 2005, Leung was released without charges.

- *Returned Overseas Chinese:* This group is only mentioned here for the sake of complete listing. For details, please refer to the main body of the report, Chapter 2.3.2.
- *Groups:* Chinese group tours are usually arranged to inspect a factory, inspect purchased goods, and get an impression of the technology they are interested in, undergo product training, participate in congresses, seminars or exhibitions etc. The group normally consists of technical experts and Party officials although these are not always identified as such. Some participants have their own travel agenda – not always business - and this is the reason, why many Germans complain that only half of the delegation actually turns up at their premises although all have been sponsored and paid for. The separated group members use the opportunity to establish contacts with academic colleagues in Germany visit Research institutes and hope that the visited academics will drop their guard when receiving an unannounced visitor and release confidential information.
- *Infiltration of organisations through "Flying geese"-concept:* It is said that another tactic of the Chinese is successful in infiltrating Research institutes and then gradually push the German researchers out and replace them with colleagues from China. In the final stage, a whole department of an institute is then run by Chinese and the results are all transferred back home. We have not been able to establish an institute where such a flying gees replacement has actually taken place.
- *Professional spying by government agencies:* There are the official state security organs with their established global intelligence networks that are occupied with industrial espionage, but these are not much different from the relevant departments in western countries.
  Due to the special status and relationship within a state-run economy, the official state security agencies are working hand in hand with organizations that look after state-owned enterprises and with public listed Chinese companies that are of strategic importance. There is for instance the closely-knit network of personal relationships among party officials. All Sino-foreign joint ventures have usually a 50 percent Chinese participation and there are normally two top managers delegated from the Chinese side. One is the manager and the other one is a party member. If for instance in the automotive industry, one joint venture manufacturer should have developed a certain innovative product, then this product knowledge can only remain within that particular company as long as the party tolerates it. As soon as the party member from another automotive joint venture manufacturer in China calls his colleague at the innovative joint venture, two members of the

same organization talk to each other and it is easy to imagine that no request for help will be refused.

- *Electronic eavesdropping:* The aspect of electronic espionage is probably the most over-hyped topic in the international press. It is not only from China, where hackers are trying to gain access to military computers in the west, but these attacks equally originate from Russia, North Korea or any other country. The notion that two individuals from China can disable America’s aircraft battle carrier fleet (The Times, 10 September 2007) through a cyber attack is simply nonsense. America alone suffers from about two million attacks every day and these attacks have been going on for more than 10 years. Besides, it is not only the West who complains, but increasingly the Chinese authorities themselves complain about electronic intrusions into their systems.

  Breaking into the database of a private company in the west, can probably be easier done by a disgruntled employee of that company then by a team of hackers trying to break through the company’s firewalls. It is therefore always the responsibility of the entrepreneur to judge, how much his intellectual property needs to be protected, how vulnerable his electronic infrastructure is and how he ensures that the latest anti-spyware is installed throughout his organisation.

  The decision of whether to admit a Chinese intern or a Chinese trainee, and what kind of freedom to permit, will follow the Corporate IT infrastructure rule.

  We are not saying that the danger of hacker attacks is non-existent, but we believe that the internet has meanwhile become part and parcel of normal business life, where every business has to guard itself against trojan attacks, worms, spear phishing attacks, malicious URLs, viruses, email hackings and the like. Western government agencies have installed firewalls that are much more sophisticated then those commercially available and it has meanwhile become a sort of a cat and mouse game among all malicious internet hackers as to who has the best firewall and who is the first one to break through.

  In 2003, the first systematic effort by hackers to penetrate the US government and industry computer networks came “most likely” from the Chinese military in Guangdong province. It was made out to be military because “the attacks came from someone with intense discipline”. There are various references of this alleged Chinese hacker attack which was labelled “titan rain” and the reported damage ranges from a few gigabyte to 20 terabyte of data that had apparently been downloaded from the non-classified router of the U.S. Department of Defence.

Obtaining know-how through patent infringement

One element of the Chinese government’s plan for science and technology development is encouraging patent infringement. The government fosters patent infringement in several ways:

China Compulsory Certification (CCC)

On a variety of products, from industrial machinery to telecommunications equipment to automotive parts, the Chinese government requires a certification mark known as the China Compulsory Certification. This certification mark serves as evidence that the product can be marketed, imported or used in China. The certification requires that foreign companies provide product specifications, detailed information on applicable standards, and samples of their products for evaluation. The product specifications then are given to the organizations that will use them to compete against the IP owner. Thus, the Chinese state certification requirements give access to foreign product designs to the Chinese Academy of Sciences and other government sectors responsible for China’s science and technology breakthroughs.

Competitive Intelligence

China established the “Society for Competitive Intelligence” in 1995 in order to ‘‘leapfrog’’ China’s science and technology development. Similar Societies exist also in the West, but the Chinese intention is different. Members include the Chinese Academy of Sciences, representatives from state-owned enterprises, the academic community, and from the military. The present Chairman is a representative from NORINCO, a dual-purpose manufacturer of high-tech defence products, amphibious assault weapons, long-range suppression weapon systems, anti-aircraft & anti-missile systems, fuel air bombs, anti-terrorism & anti-riot equipment and small arms. Norinco was established in 1980 with the approval of the State Council of China, and is overseen by the Commission of Science, Technology and Industry for National Defence (COSTIND).
It is clear that the Chinese competitive intelligence system could and should be used to safeguard national defence and public security, hence placing competitive intelligence strategy in line with the Chinese government’s broader science and technology goals.

Registration of unprotected patents

The Chinese Academy of Sciences sees patents as key to China’s ‘‘leapfrog’’ endeavour in science and technology development: ‘‘High technology can be mastered more quickly through the use of patent information. While making use of patents, enterprises can also put inventions and technological innovations under patent protection.’’ Until end 2006, the website of the China State Intellectual Property Office (SIPO) still contained an article claiming that a firm can gain a competitive edge both by patenting its new IP before its competitors patent their similar products, and by reverse engineering similar items produced by its competitors. The article has meanwhile been withdrawn.

Transparency

As we have seen in the main report on the Chinese model on growth through innovation, for many years the Chinese government has published its long-term plans, the medium term activity plans as well as the short-term implementation plans. The same goes also for the industrial espionage side. Already in 1991, two of the most senior intelligences officers of the China National Defence Science and Technology Information Centre in Beijing wrote a 265 page book on "Sources and techniques of obtaining national defence science and technology intelligence". This centre coordinates the sharing of technology from some 4,000 Chinese intelligence organisations. The book which was declared as non-classified has recently been withdrawn from the market (we can provide a copy on request).

State subsidies and incentives for state-owned enterprises

In order to encourage domestically owned firms to move up the value-added chain, China currently is encouraging investment in high technology-based manufacturing and uses ''guidance'' as well as trade policy instruments for this purpose. For selected key industries, China provides subsidies by

- transferring facilities and land at below market prices
- providing debt to-equity swaps through state-owned banks
- providing debt forgiveness through state-owned banks
- providing tax benefits for export performance, and
- controlling the prices of raw materials

Subsidies such as tax benefits based on export performance are clearly prohibited by WTO rules. Many subsidies in China are distributed through China's banking system to state-owned institutions. Not all loans to state-owned enterprises fall into default although some loans are forgiven and some others are repaid. However, a significant portion of these loans eventually is written off, constituting an unwarranted subsidy. Standard & Poor's estimates China's Non-performing loans total at least €600 billion. In the past, this credit was provided from government funds to the state-run economic sector to fund pensions and other employment-related expenses. Now, the funds are mainly used to pay for ''extravagant real estate projects'' and a general ''overinvestment in fixed assets.''
With all these subsidies, it is not surprising that SOEs sometimes can compete with Western firms on a price level that is incomprehensible.

Their price calculation is, however, not following the same rules because they:

- do not include labour cost in their calculation
- have preferential financing conditions
- have preferential conditions for the supply of raw material
- have special tax conditions
- interpret environmental legislation generously

- have no obligation to maintain pension funds

How the Chinese machinery product pirates work

Chinese product pirates are in the same league as those from Russia or from other developing countries. They are no worse, but there are so many and therefore the attention of the world focuses on China. Product pirates use increasingly sophisticated methods to avoid detection by rights holders and law enforcement bodies.

Corporate practices
Chinese frequently use front companies or front men to register companies that produce counterfeits. This makes it difficult to identify the true players behind a counterfeit operation and make them liable for their unlawful acts. Furthermore, company production and sales records do not indicate that counterfeits are being produced and sold; rather, model numbers and code words are used.

Production processes
Chinese product pirates rarely keep inventories to reduce carrying costs and the risk of seizure. They produce only to order, making it difficult to seize large volumes of counterfeit products. If counterfeiters do keep stock, they usually keep it separate from manufacturing facilities in a secret location.

Excess production
Allegedly, some Joint Venture Managers detected that the factory was apparently running moonlight shifts of production with the finished goods bypassing the normal factory processing procedure and disappearing into the black market.

Factory overruns
Especially in textile production with small production runs and high complexity and many variations, it is quite common to produce more textiles than have actually been ordered. In case of a claim, the factory does not need to start a new production schedule. If there is no claim, the factory is under obligation to tear out the labels and dispose of the overruns, but this does not happen always.

Design to order
Some Chinese machinery manufacturers have blatantly copied western machine tool models from the internet and included the machines into their own catalogue. They wait until they receive an order for the machine and then either try to manufacture a similar machine themselves or approach the original manufacturer in the West with the prospect of a large project and an offer of cooperation.

Parallel factory
There are examples where the Chinese Joint Venture partner copied the complete design of a JV factory, built a mirror image of the JV factory around the corner of the original, waited until the Chinese staff had been trained by the foreign JV partner and then transferred the trained staff to his

own factory where he manufactured identical goods under his own label. A good example of this is the souring of the cooperation between Danone and Wahaha. It began in 2005, when executives at Danone noticed something peculiar in the financial figures coming from their joint venture in China with the Wahaha Group. After a lengthy investigation, Danone officials concluded that their closest partner in China, Wahaha's long-time chairman, Zong Qinghou, was operating secret companies outside the joint venture - companies that were mimicking the joint venture and siphoning off millions of dollars.

Sales and distribution
To avoid detection by investigators, counterfeiters do not provide samples to prospective "buyers" and will refuse to deal with potential customers who do not make a substantial purchase. This can make it difficult and expensive to confirm whether counterfeiting activities are occurring. To mount any type of civil or criminal case, it is generally necessary to have a sample of the counterfeit product.

How to slow know-how loss in technology transfer

Many companies transfer technology to China without taking into account the weaknesses in the legal system. Before transferring technology, companies should:

- Analyze the need to transfer technology Do not be blinded by partners' demands for technology. Ask whether it is necessary to transfer this technology.
- Carefully choose the recipient of the technology. If technology is transferred to a state-owned enterprise, there is a far greater likelihood of leakage than if it were transferred to a private firm.
- Attempt to break up the technology to be transferred so that it is harder for others to use, if misappropriated.
- Break down the production process into small, independent production steps with little communication from one production cell to the other. The foreign JV partner prepares an operating manual, which lists the manufacturing steps in detail without giving any information on the finished product. The manuals are only used for training of new staff and then being taken away again.
- Some Joint Ventures have, for instance, mounted flat panel TV screens at the work place, where instructions are being displayed one at a time. No written documentation exists that could be stolen.

Intellectual Property Right (IPR) protection

The implications of China's failure to protect IPR can be divided into two aspects:

1. Patent infringement serves to advance Chinese commercial interests as a form of government-coordinated industrial espionage that advances China's science and technology capacity.

2. The failure to enforce intellectual property rights (patents, copyrights, and trademarks) and the existence of intellectual property-related trade barriers violate China's WTO obligations while they relieve pirates of the cost of complying with the rules.

In the case of the former, the Chinese government has deliberately formulated various strategies to ''leapfrog'' its science and technology development to keep pace with that found in developed countries. In the case of the latter, China has failed to meet its international obligations to protect intellectual property.

China already has incorporated in its IPR law Articles 9 to 14 of the WTOs Trade-Related Aspects of Intellectual Property Rights (TRIPS) Agreement. Currently, there are three types of IPR enforcement mechanisms in China:

Administrative enforcement, which occurs at the local level, is characterised by dilatory implementation and inadequate penalties. In 2004, there were 51,851 administrative cases of trademark infringement and counterfeiting, only 5,494 of which involved foreign rights holders. The average fine was $620 per case and only 96 cases were referred for criminal prosecution. That same year there were 9,691 copyright infringement cases, 158 involving a foreign right holder, of which only 102 cases were referred for criminal prosecution. It should be noted that because the Chinese administrative enforcement system is opaque, it is not possible to determine the outcome of these cases and evaluate how the system is working in practical terms.

Civil enforcement provides a specialized, IPR-trained judiciary and nationwide jurisdiction. However, China does not have an independent judiciary. Further, damages awarded by Chinese 39 courts are difficult for plaintiffs to collect. From January to November 2005, there were 11,468 IP-related civil cases (5,240 copyright, 2,491 patent, and 1,482 trademark cases), about five percent of which involved foreign rights holders.

Criminal enforcement provides a stronger means of deterring piracy, such as the ability to imprison offenders. A 2004 judicial interpretation lowered the thresholds for criminal cases and included new provisions addressing online copyright piracy, accomplice liability, and the import and export of infringing goods.

Although IPR enforcement may be primarily the province of local or regional officials in China, under WTO rules the central government bears ultimate responsibility for all trade-related matters and, in particular, for the actions (or inactions) of any level of government.

What can German machinery manufacturers do to minimise the risk of patent infringements and product piracy

DEFENSIVE ACTION

1. Employ legal measures

Since China follows a first-to-file instead of a first-to-use principle, companies should register their works in China as early as possible. This is, in part, because China does not recognize international patents; if a company does not file in China, it has no rights in China. Wise companies file early.

2. Trademarks

When registering trademarks, companies should register their brands' English and Chinese names, carefully select the product categories and subcategories in which to file, and check subcategories for similar trademarks filed by competitors and infringers.

3. Patents

China offers design, invention, and utility model patents. (Design patents are used to register a new design of a shape or pattern; invention patents are used to register new technical solutions for a product or process; utility patents are used to register new technical solutions related to shape or structure.) Generally, companies should file both utility and invention patents for the same item, since utility patents receive little substantive review and are usually easier to acquire. Once an invention patent is granted, the utility patent can generally be dropped, as utility patents last only for 10 years from the date of application, compared to 20 years for invention patents. Companies should file applications for both their core **and** fringe technologies and make certain their patents are properly translated.

4. Copyright

China recognizes copyrights at the time of their creation. Though registration is not required, entities should consider registering their works with the National Copyright Administration (NCA), since registration provides a public record and serves as useful evidence in court. For software companies, registering for copyrights may be quite sensitive, since it may require providing some source code to NCA.

5. Trade secrets

As in Germany, a trade secret in China must be technical or operational information that is unknown to the public, economically beneficial to the owner, and reasonably protected by the owner. China also requires that the secret have "practical applicability." Trade secrets are often difficult to enforce because of the high burden of proof placed on plaintiffs. At a minimum, companies should mark confidential items, restrict access to trade secrets, and implement confidentiality policies and other agreements with employees.

6. Control the production process

First, companies should design products and the equipment that produces them so that they are difficult to copy. Second, companies should compartmentalize the production process so that no single unit can produce a complete product. Firms should also outsource different parts of a process to different companies to minimize the risk of inadvertently creating a new competitor. When possible, firms are advised to secure key technologies and procedures and keep vital designs or latest-generation technologies in their home countries.

7. Focus on human resources

From the start of the hiring process, personnel departments should run background checks on key hires. Firms should include non-compete and non-disclosure agreements in contracts because IP leaks commonly occur after an employee leaves a company. Once such agreements are in place, it is critical for companies to educate their employees about the firm's confidentiality requirements, maintaining clear rules and enforcing them. Firms should share information with their employees on a "need-to-know" basis only. It is also good policy to separate engineers from the sales force; when employees who possess knowledge of a firm's production process mingle with those who have access to clients, new competitors often emerge.

8. Be choosy when selecting suppliers and distributors

Before selecting a partner, firms should conduct comprehensive due diligence on suppliers and distributors, researching their networks and identifying weak points through which counterfeit products could enter the distribution network. Companies should also select partners with brand images and reputations of their own to protect. When a selection has been made, firms should include IP protection clauses in all contracts and agreements and clearly explain their policies and procedures to the contractual partners.

OFFENSIVE ACTION

Even after implementing all necessary preventive measures, companies must devote time and resources to detecting violations and taking legal action. A company's legal rights mean little in China unless the company chooses to protect them.

1. Take legal action

Companies must use China's legal system to enforce their patents, trademarks, and copyrights. They must also decide which battles to fight. Companies can choose from several routes to enforce their IP rights, including civil, administrative, and criminal actions.

2. Close competitor’s exhibition booth

With effect from 1 March 2006, the “Measures for the protection of Intellectual Property Rights” are in force in China. In addition, China’s action plan on IPR protection lists a host of measures to reinforce this message. It is thus not only possible to take legal action against counterfeiters at International exhibitions but also in China.

3. Civil actions

The civil suit is becoming increasingly popular among foreign enterprises in China as a relatively inexpensive method of halting patent, trademark, and copyright infringement. Civil suits are often used in cases of "look-alike" infringement or in complex cases when administrative authorities are unable to make a determination of infringement. The civil suit is also particularly useful in cases when the defendant is an established enterprise from which damages can be collected.

Civil suits have their drawbacks, however. Companies bear the responsibility of collecting evidence and packaging cases for the courts, and litigation can take up to two years if defendants use all available appeal options. Moreover, infringers can halt a civil suit for patent infringement by filing an administrative challenge to the patent with SIPO. Though civil cases are generally decided fairly, judges are not bound by precedents set in other courts.

While civil (and criminal) lawsuits for patent, copyright, and trademark infringement are being adjudicated, companies can also seek injunctive relief from courts. Preliminary injunctive relief can usually be acquired in clear-cut cases, although the plaintiff must be willing to post a substantial bond and demonstrate a strong likelihood of success in the case. Injunctive relief is easiest to acquire in trademark cases, but it can also be useful in copyright and patent cases. Though courts generally grant petitions for injunctive relief, China lacks methods and penalties for enforcing preliminary injunctions—a major flaw in the system. But when plaintiffs win IP-related court cases, permanent injunctive relief is often granted as part of the verdict, and these injunctions are generally enforced.

4. Administrative actions

When infringing products are found in China, companies may ask administrative agencies to undertake their own investigations and impose penalties. In these cases, companies often do significant preparatory work before submitting requests to authorities.

Do not take the law into your own hands! Organising a warehouse raid in China is a perfect recipe for any foreigner to get into a Chinese jail quickly. The same applies for debt collection where some Germans have been organising teams to break into the Chinese factory to get their unpaid machines out.

Often used in cases of clear infringement or pure counterfeiting, such as exact copies of trademarks or brand names, many companies find administrative actions—particularly raids by the local administrations of industry and commerce—easier and faster than civil or criminal suits. And because administrative penalties are generally low, they are an ineffective deterrent to repeat offenders. Companies should also be wary of the possibility that raids may be faked and that goods seized in raids may find their way back to the market.

5. Criminal prosecutions

Companies can request that cases of continuous infringement be transferred from administrative authorities to China's police, the Public Security Bureau (PSB). But criminal actions are often much harder to set in motion than administrative actions and civil suits. In most cases, however, the IP rights holder must generally do all of the investigative work and package the case for the local PSB, which may not have the resources to conduct a thorough investigation.

6. Control what walks out of your door with departing staff

Most firms should expect and plan for significant employee turnover. Companies must be prepared to spend resources to enforce their non-competition agreements against employees who leave for competitors.

Firms should also use information technology to carefully track data flows and file transfers and closely monitor the entry and exit of flash disks, portable hard drives, and laptops.

Summary

Product piracy originating from China constitutes a big problem for the international business community. The Chinese seem to grab anything and everything at will, import it into China, reverse engineer and modify the product, have it manufactured with cheap workers in run-down factories and then re-export to the international community at cutthroat prices. No country or industry seems to be immune and there are fears that the Chinese innovation juggernaut will soon dominate the industrial world just as China as a country begins to dominate the global political theatre.

The threat is real, but there is no need for German entrepreneurs to keel over, play dead and hope that his product niche is small enough to be overlooked by the Chinese. China will increasingly be able to copy the design of industrial goods from the west, but it is our opinion that it will take at least 15-20 years before China can even think of continuing the old tradition of producing breakthrough innovations for the world. Until the end of the Ming Dynasty (1547), China had for centuries produced quantum leaps in innovation and the Chinese inventions were sometimes hundreds of years ahead of the west. Many Chinese believe that this golden age is about to continue, but we are convinced that it will take quite some time until the armies of Chinese engineers that the system produces will be capable to become a real competition to Germany. Mass does not compensate for ingenuity.

The shorter the product cycles of a German manufacturer and the more innovative his products are, the safer he will be from the Chinese product pirates. German ingenuity and the ability to meld various technologies will ensure that the Germans will still be manufacturing the most sophisticated machinery in the world for quite sometime to come.

The Chinese are clearly trying to catch up with the west and they use improper means. When Deng Xiaoping opened China to the west 20 years ago, China opened her doors invited all foreigners to come in and do business with her. A Chinese businessperson in China could probably have gotten away with pirated products in the past, but now China is changing. For the first time, in the last 500 years, China is opening up to the world and companies are beginning to step outside of China. This means, that China has to accept and follow international rules of engagement, international laws and global standards.

We are convinced that the government in Beijing has recognised that China must change and must conform with international rules and standards in the future. This concept and the change from an inward oriented China to an extroverted China however is so radical that the Chinese bureaucracy and the Chinese business will require some time to adjust to these fundamental changes. Most Chinese are fully occupied to keep pace with the 20 percent or more industrial growth per annum so that there is little time to do anything else. In time, however, China will accept international practices and laws because Chinese business will become an international player rather than a domestic one.

The west should therefore beat the copy pirates wherever we meet them, but we should also extend a hand to the legislators in China and the industry organizations to show them how our laws and rules are implemented and followed. Pursuing the copy pirates wherever possible is right, but we should also give the Chinese a chance to understand western practice, western laws and the international rules of business engagements.

For German business people, there can be no definite set of rules apart from the advice to apply common sense and caution when dealing with China and the Chinese. We may know the business system in Germany and have faith in our democracy and our legal system. Other countries play by other rules and we have to adapt to their system when entering their territory. Similarly, we can expect the Chinese to accept our rules when coming to the West. In time, this will happen because the Chinese will want to become a reliable player in the International theatre, gain the trust and confidence from the international community and continue to prosper.

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Guidelines for the Medium- and Long-Term National Science and Technology S&T Development Programme (2006-2020)

(Excerpt)[239]

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The 16th National Party Congress, proceeding from the overall interests of building a well-off society xiao kang she hui in an all-around way and of accelerating socialist modernization, called for formulating a long-term national S&T development programme. The State Council has drawn up these guidelines in view of this.

I. Preface

Since the founding of New China, especially since the programme of reform and opening up was launched, China has scored great, internationally acclaimed achievements in socialist modernization. At the same time, we must clearly realize that China is in the initial stage of socialism and will remain there for a long time to come. Building a well-off society in an all-around way poses rare historic opportunities as well as a series of acute challenges. We rely too much on the consumption of energy and resources for our economic growth, and we experience serious environmental pollution. Our economic structure is unreasonable, our agricultural foundation is weak, and the development of our high-tech industries and modern service industries is lagging. Our independent innovative capabilities are quite weak, the core competitiveness of our enterprises is not strong, and we have yet to improve our economic returns. We need to urgently resolve numerous difficulties and problems in increasing employment, rationalizing distribution relationships, providing health safeguards, and ensuring national security. On the international front, China will face tremendous pressure for a long time to come due to the economic, scientific and technological, and other advantages enjoyed by developed nations. To seize the opportunities and meet challenges, we need to work on various fronts, including planning our overall development, deepening structural reform, expanding democracy and the legal system, and strengthening social management. In the meantime, we need to rely more on S&T progress and innovation than at any time in the past to bring about a qualitative leap in our productive forces and promote comprehensive, coordinated, and sustainable economic and social development.

S&T is the primary productive force; it is also an embodiment and a key hallmark of advanced productive forces. In the 21st century, a new S&T revolution is unfolding quickly, carrying with it the potential for new major breakthroughs, and it is expected to wreak profound economic and social changes. Information S&T is still in the early stages of development and remains a dominant force in sustained economic growth. Life science and biotechnology are developing swiftly and are expected to play a key role in improving and raising the quality of life for mankind. There is renewed interest in

[239] Xinhua (New China News Agency) on 2 February 2006, citing PRC [People's Republic of China] State Council.

energy-related S&T, which is opening up new avenues for solving global energy and environmental problems. New breakthroughs in nano-science and nano-technology have emerged in a steady stream and are expected to bring about a profound technological revolution. Major breakthroughs in basic research have created new prospects for technological and economic development. The pace of applying and commercializing S&T achievements has kept accelerating, giving rise to new opportunities for catching up and overtaking by leaps and bounds. Therefore, we must stand at the forefront of the times and meet the opportunities and challenges of the new S&T revolution with a global vision. Globally, many countries seek to enhance S&T innovation as a matter of national strategy, view S&T investments in strategic terms, and are vastly increasing their S&T investments. They also make advance plans for and develop cutting-edge technologies and strategic industries, execute major S&T plans, and work hard to enhance their innovative capabilities and international competitiveness. Faced with the new international situation, we must heighten our sense of responsibility and urgency; act more consciously and steadfastly to make S&T progress a primary driving force in economic and social development; regard the improvement of independent innovative capabilities as the centrepiece of our efforts to adjust our economic structure, change our growth mode, and improve the country's competitiveness; and view the construction of an innovative country as a future-oriented major strategic choice.

Thanks to the extraordinarily arduous and sustained struggle of several generations of people, China has scored heartening tremendous achievements in S&T endeavours during the 50-odd years since the founding of New China. A large number of major S&T achievements, signified by "two bombs and one satellite" [atom bomb, hydrogen bomb, and man-made satellite], manned spaceflight, hybrid rice, the theory of the continental origin of oil and its application, and high-performance computers, have greatly enhanced China's overall strength, improved China's international standing, and inspired our national spirit. At the same time, we must realize that China's overall S&T standard still falls quite far short of those of developed nations. This is mainly manifested as follows: Our self-sufficiency in key technologies is low, and we have few patents for inventions. Technological standards are still quite low in some areas, especially rural areas in the central and western regions. The quality of science research is not high enough, and outstanding and top-notch personnel are in relatively short supply. At the same time, our S&T investments are insufficient, and our structures and mechanisms are still significantly flawed. Although China is now an economic power, it is still not an economic powerhouse, and a fundamental cause of this is its weak innovative capabilities.

Heading into the 21st century, China, as a large developing country, still needs to work hard over a fairly long period of time if it is to accelerate its S&T development and narrow the gap with developed nations. At the same time, it has many conditions working in its favour. One, China's sustained and rapid economic growth and social progress have fuelled strong demand and laid a solid foundation for S&T development. Two, China has established a fairly complete system of disciplines, manned by a vast pool of human resources, and has the basis and capacity for great S&T development, with research and development [R&D] capabilities in some important fields among the world's advanced ranks. Three, our commitment to opening up to the outside world and our increasingly brisk S&T exchanges and cooperation with other countries have allowed us to share in the fruits of the new S&T revolution. Four, by upholding the socialist system, we can combine our political superiority in concentrating our resources on undertaking major endeavours with the basic role of market mechanisms in effectively allocating resources, thereby providing important institutional guarantees for the booming development of S&T endeavours. Five, the Chinese nation has a 5,000-year history of civilization, and Chinese culture is extensive, profound, and all-encompassing and is conducive to the formation of a unique culture of innovation. We can definitely score splendid S&T achievements that are worthy of the times as long as we enhance our self-confidence as a nation, implement the scientific development concept, thoroughly implement the strategy of rejuvenating the country through science and education and the strategy of building a strong country through the development of talent, do all we can to catch up, and work hard with an indomitable spirit over the next 15 years or even for a longer period of time to come.

II. Guiding Principles, Development Goals, and Overall Plans

1. Guiding Principles

The first 20 years of this century are a period of important strategic opportunities for China's economic and social development as well as for S&T development. We must take Deng Xiaoping Theory and the important thinking of the "Three representations" as our guidance, implement the scientific development concept, comprehensively implement the strategy of rejuvenating the country through science and education and the strategy of building a strong country through the development of talent, proceed from our national conditions, take a people-centred approach, deepen reform, open up wider to the outside world, promote the vigorous development of China's S&T endeavours, and provide strong S&T support for achieving the goal of building a well-off society in an all-around way and for building a harmonious socialist society.

The guiding principles for S&T work over the next 15 years are: Innovate independently, achieve development in selected areas by leaps and bounds, support development, and guide the future.

Innovating independently means proceeding from strengthening the country's innovative capabilities and stepping up efforts at original innovation, integrated innovation, importation, absorption, assimilation, and re-innovation. Achieving development in selected areas by leaps and bounds means doing things selectively and concentrating our resources on key fields with certain foundations and strengths that have a bearing on the national economy, the people's livelihood, and national security in order to achieve key breakthroughs and bring about development by leaps and bounds. Supporting development means proceeding from actual pressing needs and focusing on achieving breakthroughs in major key and generic technologies to support sustained and coordinated economic and social development. Guiding the future means taking the long view, making advance plans for cutting-edge technology research and basic research, creating new market demand, cultivating newly emerging industries, and guiding future economic and social development. These guiding principles, which were drawn up on the basis of summing up China's practical experience with S&T development in more than half a century, represent a future-oriented important choice for bringing about a great revival of the Chinese nation.

We must give prominence to improving our independent innovative capabilities in our overall S&T work. The party and government have always put a premium on and advocated independent innovation. We must earnestly learn from and fully draw on all outstanding achievements in human civilization in promoting socialist modernization under the conditions of opening up to the outside world. China has brought in technology and equipment on a large scale in the 20-plus years of reform and opening up, and these have played an important role in improving industry technological standards and promoting economic development. However, we must clearly realize that bringing in technology without paying attention to absorption, assimilation, and re-innovation will surely weaken our independent R&D capabilities and widen the gap with advanced international standards. Facts tell us that we cannot buy true core technologies in key fields that affect the lifeblood of the national economy and national security. To gain leverage in fierce international competition, China must improve its independent innovative capabilities and master a number of core technologies, own a number of proprietary intellectual property rights, and groom a number of internationally competitive enterprises in certain important fields. In a nutshell, we must improve our independent innovative capabilities as a matter of national strategy, which we must implement in all facets of modernization and in various industries, sectors, and regions, and vastly improve the country's competitiveness.

S&T personnel are the key to improving independent innovative capabilities. In our S&T work, we must give priority to creating a good environment and good conditions; to training and bringing together S&T personnel of all stripes, especially outstanding and top-notch personnel; and to fully inspiring the initiative and creativity of the broad ranks of S&T personnel; create a good situation in which talented people emerge in an endless stream, people can make full use of their talents, and talented people are put to good use; and build a large, rationally structured corps of high-calibre S&T personnel that is compatible with economic and social development and national defence construction so as to provide ample personnel support and intellectual guarantees for China's S&T development.

2. Development Goals

China's overall goals for S&T development through 2020 are: Markedly enhance our independent innovative capabilities and our ability to promote economic and social development and guarantee national security through S&T in order to provide strong support for building a well-off society in an all-around way; and markedly enhance our overall ability to conduct basic science research and cutting-edge technology research, score a number of S&T achievements with great influence in the world, and join the ranks of innovative countries in order to lay a solid foundation for becoming a world S&T powerhouse by the middle of this century.

After 15 years of hard work, China has achieved the following goals in a number of important areas of S&T: One is mastering a number of core technologies in the equipment manufacturing and information industries that have a bearing on China's competitiveness, and joining the world's advanced ranks in terms of technological standards in the manufacturing and information industries. Two is joining the top ranks of the world in terms of overall agriculture-related S&T capabilities, bringing about an improvement in overall agricultural production capacity, and effectively guaranteeing the country's food security. Three is achieving breakthroughs in energy development, energy conservation technology, and clean energy technology; promoting the optimization of the energy structure; and reaching or approaching advanced international standards in terms of the indicators of unit energy consumption for major industrial products. Four is establishing technological development models for a recycling-based economy in key industries and cities in order to provide S&T support for building a resource-efficient and environment-friendly society. Five is markedly improving the prevention and control of major diseases; curbing AIDS, hepatitis, and other major diseases; achieving breakthroughs in manufacturing new medicines and in researching and developing key medical apparatus; and owning industrial development technological capabilities. Six is that our defence-related S&T basically meets the needs of independently researching and developing modern weaponry and pursuing informatization, thereby providing guarantees for safeguarding national security. Seven is the emergence of a number of scientists and research teams of international standards, resulting in a number of innovative achievements with major influence in mainstream science development, and achieving advanced international standards in cutting-edge technologies in such fields as information, biology, materials, and aerospace. Eight is building several world-class science research institutes and universities as well as internationally competitive enterprise-based R&D offices, resulting in a fairly complete national innovation system with Chinese characteristics.

By 2020, we aim to increase the proportion of R&D investment in society relative to the gross domestic product to 2.5 per cent or more, strive for a contribution rate of 60 per cent or more [to the gross domestic product] by S&T progress, reduce our degree of dependence on technology from other countries to 30 per cent or less, and join the world's top five countries in terms of the number of patents granted annually for home-grown inventions and the frequency of citations in international science papers.

3. Overall Plans

China's overall plans for S&T development over the next 15 years are: One, identify several key fields, achieve breakthroughs in a number of major key technologies, and comprehensively improve the supporting capability of S&T in light of China's national conditions and needs. These guidelines identify 11 key areas of national economic and social development and select for arranging on a priority basis 68 preferential subjects for which there are clearly defined tasks and in which technological breakthroughs can be achieved in the near term. Two, implement several major special items with the country's goals in mind in order to achieve development by leaps and bounds and fill the gaps. These guidelines identify a total of 16 major special items. Three, make advance plans for cutting-edge technology research and basic research in order to meet future challenges, improve sustained innovative capabilities, and guide economic and social development. These guidelines identify 27 cutting-edge technology issues and 18 basic science issues in eight technological fields for planning on a priority basis and propose four major science research plans. Four, deepen structural reform, perfect policies and measures, increase S&T investments, step up efforts to train personnel, and promote the construction of a national innovation system in order to provide reliable guarantees for bringing China into the ranks of innovative countries.

In keeping with the urgent requirement for building a well-off society in an all-around way, the trend of S&T development in the world, and China's national strength, we must set strategic priorities in S&T development. One is giving priority to developing energy, water resources, and environmental protection technologies and showing determination to resolve the major bottlenecks that are impeding economic and social development. Two is seizing the rare opportunity stemming from the upgrading of information technology and the swift development of new materials technologies over the next several years to make the acquisition of proprietary intellectual property rights over core technologies for the equipment manufacturing and information industries a breakthrough point in improving the competitiveness of China's industries. Three is stressing biotechnology in trying to catch up with other countries in high-tech industries and making greater use of biotechnology in such fields as agriculture, industry, the population, and health. Four is accelerating the development of aerospace and marine technologies. Five is strengthening basic science research and cutting-edge technology research, in particular, interdisciplinary research.

III. Key Fields and Priority Subjects

China must develop S&T on the basis of making overall plans and advancing on all fronts, and make plans and arrangements for key fields and priority subjects in order to provide comprehensive, strong support for resolving pressing problems in economic and social development.

Key fields refer to industries and sectors that need to be developed on a priority basis and that urgently require support from S&T in national economic and social development and national defence security. Priority subjects refer to technology groups that urgently need to be developed, have clearly defined tasks and a fairly sound technological basis, and can yield breakthroughs in the near term in key fields. The principles for identifying priority subjects are: one, they can help break free of bottlenecks and improve the ability to sustain economic development; two, they can help master key technologies and generic technologies and improve core industrial competitiveness; three, they can help resolve major S&T issues that affect the public interest and improve the ability to serve the public; and four, they can help develop technologies for both military and civilian uses and improve the ability to ensure national security.

1. Energy

Energy occupies a strategic place of special importance in the national economy. Currently, there is an acute imbalance in China's energy supply and demand, which is unreasonably structured, with poor efficiency in energy utilization. Coal figures predominantly in primary energy consumption, and the massive consumption of fossil energy has caused serious environmental pollution. Meeting the energy demand for sustained, rapid growth and making clean and highly efficient use of energy over the next 15 years present major challenges in the development of energy-related S&T.

Development ideas: (1) Give priority to energy conservation and reduce energy consumption. Gain mastery over key energy conservation technologies in major energy-consuming fields, actively develop energy conservation technologies for buildings, and vigorously improve efficiency in primary and ultimate energy utilization. (2) Promote the diversification of the energy structure and increase the energy supply. Vigorously develop nuclear energy technologies and acquire the capability to independently develop technologies in the nuclear power sector while at the same time improving oil and gas development and utilization and hydropower technological standards. Achieve breakthroughs in and apply on a mass scale technologies related to wind energy, solar energy, biomass, and other renewable energy. (3) Promote clean and highly efficient coal utilization and reduce environmental pollution. Vigorously develop clean, highly efficient, and safe coal development and utilization technologies and strive to reach advanced international standards. (4) Do more to absorb, assimilate, and re-innovate on imported technologies relating to energy equipment manufacturing and gain mastery over advanced coal power, nuclear power, and other major core technologies relating to equipment manufacturing. (5) Improve the technological ability to facilitate the optimum geographical distribution of energy. Give priority to developing safe and reliable advanced power transmission and distribution technologies and achieve large-capacity, long-distance, and highly efficient power transmission and distribution.

Priority Subjects:

(1) Industrial Energy Conservation

We will give priority to researching and developing energy conservation technologies and equipment in major fields that entail high energy consumption such as process industries like metallurgy and the chemical industry as well as the transportation sector; energy conservation technologies for electromechanical products; highly efficient, energy-saving, and long-lasting semiconductor products; and comprehensive energy cascading utilization technologies.

(2) Clean and Highly Efficient Coal Development and Utilization, Liquefaction, and Polygeneration

We will give priority to researching and developing highly efficient power generation technologies and equipment such as highly efficient coal mining technologies and supplementary equipment, heavy-duty gas turbines, integrated gasification combined cycles (IGCC), high-parameter and ultra-supercritical power plants, and large-scale supercritical circulating fluidized beds. We will vigorously develop conversion technologies such as coal liquidation, gasification, and chemical processing; polygeneration system technologies based on coal gasification; and technologies and equipment for the comprehensive control and utilization of fuel coal pollutants.

(3) Exploration, Development, and Utilization of Oil and Gas Resources Under Complex Geological Conditions

We will give priority to developing technologies to explore for oil and gas resources in complex environments and lithostrata, highly efficient technologies to develop low-grade oil and gas resources on a large scale, technologies to vastly improve recovery rates in mature oil fields, and technologies to explore for and mine deep-lying oil and gas resources.

(4) Low-Cost, Mass Development and Utilization of Renewable Energy

We will give priority to researching and developing large-scale wind power generation equipment, technologies and equipment for building coastal and land-based wind farms and areas with high concentrations of wind energy resources in the western regions, high-performance and low-cost solar photovoltaic cells and technologies to use them, solar thermal power generation technologies, integrated technologies for solar energy buildings, and technologies for developing and utilizing biomass and geothermal energy.

(5) Ultra-Large-Scale Electricity Transmission and Distribution and Power Grid Safety Assurances

We will give priority to researching and developing large-capacity, long-distance, direct-current power transmission technologies; ultra-high-voltage, alternating-current power transmission technologies and equipment; intermittent power grid merging, transmission, and distribution technologies; technologies for monitoring and controlling the quality of electrical energy; technologies for ensuring the safety of large-scale interconnected power grids; major key technologies for the west-to-east power transmission project; technologies for automating power dispatch operations; and information technology and systems for highly efficient power distribution and supply management [passages omitted on the development and utilization of water and mineral resources; the development of environmental protection technologies; the rehabilitation of ecosystems; and the improvement of farming operations]

(18) Healthy Livestock, Poultry, and Aquatic Products Breeding and Epidemic Disease Prevention and Control

We will give priority to researching and developing safe, high-quality, and highly efficacious feed and large-scale, healthy breeding technologies and facilities; create highly efficacious specific vaccines and highly efficacious safe veterinary medicines and apparatus; develop epidemiological technologies for advance warnings, monitoring, quarantine, diagnosis, immunization, prevention and control, sanitization, and eradication in the event of outbreaks of animal epidemics and zoonoses; achieve breakthroughs in technologies related to aquaculture on mudflats in coastal waters, aquaculture in shallow waters, and freshwater aquaculture; and develop technologies and facilities for deep-sea fishing and storage and processing at sea [passages omitted on sophisticated and downstream processing of farm products, modern storage and shipping, agricultural and forestry biomass development and utilization, the development of environment-friendly fertilizers and pesticides, and the development of modern forestry and dairy farming].

5. Manufacturing Industry

The manufacturing industry is the main pillar of the national economy. While China is a world manufacturing power, it is not a manufacturing powerhouse. It has a weak technological basis and poor innovative capabilities and primarily produces low-end products using manufacturing processes that entail heavy consumption of resources and energy and cause serious pollution.

Development ideas: (1) Improve equipment design, manufacturing, and integration capabilities. Take the promotion of enterprise technology innovation as a breakthrough point and basically achieve independent design and manufacturing of high-end numerically-controlled machine tools, lathes, major turnkey technologies and equipment, and key materials, components, and parts through tackling key technological problems. (2) Actively develop green manufacturing. Accelerate the application of relevant technologies throughout a product life cycle, from developing, designing, processing, and manufacturing materials and products to providing sales services to recycling, and develop highly efficient, energy-saving, environment-protecting, and recycling new manufacturing techniques. Join the ranks of advanced international manufacturing industries for resource consumption and environmental impacts. (3) Use new and high technologies to transform and upgrade the manufacturing industry. Vigorously apply information technology in the manufacturing industry; actively develop basic raw and semi-finished materials; vastly improve the grades, technological content, and added value of products; and comprehensively raise the manufacturing industry's overall technological standard.

Priority Subjects:

(26) Basic Spare Parts and Standard Components

We will give priority to researching and developing key technologies for designing, manufacturing, and mass-producing key basic spare parts and standard components needed for major equipment, and develop technologies for shaping and processing large-scale and special parts and components, technologies for designing and manufacturing standard components, and high-precision testing instruments.

(27) Digitized and Intelligent Design and Manufacturing

We will give priority to researching and developing digitized design, manufacturing, and integration technologies and build digitized and intelligent design and manufacturing platforms for products in certain industries. We will develop digitized and intelligent innovation and design methods and technologies geared towards whole product life cycles in a networked environment, computer-aided engineering analysis and process planning technologies, and integrated technologies for design, manufacturing, and management.

(28) Process Industry Greening, Automation, and Outfitting

We will give priority to researching and developing green process manufacturing technologies; highly efficient and clean techniques, processes, and equipment that make full use of resources and associated process amplification technologies; systems integration and automation technologies based on ecological industry concepts; and sensors, intelligent testing and control technologies, equipment, and adjustment systems needed by process industries. We will develop large-scale cracking furnace technologies, large-scale turnkey technologies and equipment for steam ethylene cracking production, and large-scale energy-saving processes and equipment for producing chemical fertilizers.

(29) Recycling Iron and Steel Process Techniques and Equipment

As a typical example of a recycling-based economy, we will give priority to researching and developing new-generation recycling iron and steel processes that combine the three major functions of product manufacturing, energy conversion, and waste recycling on the basis of smelting reduction and the optimization and utilization of resources. We will develop secondary resource recycling and utilization technologies, technologies for coal-gas power generation during metallurgy processes and low-heat-value steam cascading utilization, highly efficient and low-cost clean steel production technologies, noncoking coal technologies, and large-scale integrated design, manufacturing, and systems coupling technologies for sheet-metal continuous casting and rolling machines [passages omitted on the development of marine technologies and equipment and R&D related to basic raw and semi-finished materials].

(32) New-Generation Informatic Functional Materials and Devices [no further details as received]

(33) Key Materials and Engineering To Supplement Military Industrial Production [no further details as received] [passages omitted on the development of technologies and equipment for building and maintaining transportation infrastructure, the development of high-speed rail systems, the production of automobiles that feature low energy consumption and are powered by new energy, the development of intelligent transportation management systems, and the development of technologies to ensure transportation safety]

7. Information Industry and Modern Service Industries

Developing the information industry and modern service industries is the key to advancing a new type of industrialization. The application of information technology in the national economy and society and the rapid development of modern service industries have imposed higher demands on the development of information technology.

Development ideas: (1) Break free of core technology impediments to information industry development; master core technologies related to integrated circuits, key elements and parts, large-scale software, high-performance computers, broadband wireless mobile communications, and next-generation networks; and improve independent development capabilities and overall technological standards. (2) Devote greater efforts to the integrated innovation of information technology products; raise design and manufacturing standards; give priority to resolving the issues of expandability, ease of use, and low costs for information technology products; nurture new technologies and services; and improve the information industry's competitiveness. (3) Attach importance and devote greater efforts to integrated innovation geared towards application demand, develop technologies and key products that support and spur the development of modern service industries, and promote the transformation and technological upgrading of traditional industries. (4) Develop network information security technologies and related products, with the emphasis on the development of highly trustworthy networks; establish a system of information security technological safeguards; and own technological capabilities for guarding against all kinds of unexpected information security incidents.

Priority Subjects:

(40) Information Technology for Supporting Modern Service Industries and Large-Scale Application Software

We will give priority to researching and developing key technologies needed for the development of such modern service industries as finance, logistical operations, online education, the mass media, medical care, tourism, e-government, and e-commerce, including highly trustworthy network software platforms, large-scale application supporting software, middleware, embedded software, network computing platforms and infrastructure, and software systems integration.

(41) Next-Generation Key Internet Technologies and Services

We will give priority to developing high-performance core network equipment, transmission equipment, and access equipment as well as core technologies in expandability, security, mobility, service quality, and operations management; build trustworthy network management systems; develop equipment and systems such as intelligent terminals and home networks; and support various broadband, secure, and ubiquitous new multimedia and network computing services and applications.

(42) High-Performance, Trustworthy Computers

We will give priority to developing computing methods and theories of advanced concepts, develop a high-performance and trustworthy petaflop supercomputer system and a new server system based on new concepts, and develop key technologies related to new architectures, mass storage, and system fault tolerance.

(43) Sensor Network and Intelligent Information Processing

We will give priority to developing various new sensors, advanced bar code automatic identification technologies, radio frequency identification tags, and intelligent information processing technologies based on multi-sensor information, and develop a low-cost sensor network and a real-time information processing system in order to create information service platforms and environments that are more convenient and have more powerful functions.

(44) Digital Media Content Platforms

We will give priority to developing key digital media content processing technologies that mainly feature video and audio information services and are oriented towards the cultural, entertainment, and consumption markets as well as radio and television services, and develop modern comprehensive media information content platforms that are easily interoperable and interchangeable, have copyright protection functions, and are easy to manage.

(45) High-Definition, Large-Screen, Flat-Panel Displays

We will give priority to developing high-definition, large-scale display products; develop various flat-panel and projection display technologies such as organic light-emitting display, field emission display, and laser display technologies; and establish an industrial chain of flat-panel display materials and devices.

(46) Information Security for Core Applications

We will give priority to researching and developing security technologies for the national basic information network and important information systems, and develop network survivability technology, active real-time protection technology, secure storage technology, Internet virus prevention technology, malicious attack prevention technology, network trust systems, and new password technology under large complex systems [passages omitted on safe birth control, the prevention and treatment of non-communicable diseases such as cardiovascular and cerebrovascular diseases, the prevention and treatment of common and frequently occurring diseases in urban and rural communities, the inheritance and innovation of traditional Chinese medicine, the development of advanced medical equipment and biomedical materials, urban planning, the upgrading of urban functions and the economical use of space, the development of technologies and equipment for designing green buildings and promoting energy conservation in buildings, the development of technology to monitor the quality of urban ecological and living environments, and the development of urban information platforms].

10. Public Safety

Public safety is the cornerstone of national security and social stability. China faces acute public safety challenges, which have given rise to major strategic requirements for S&T.

Development ideas: (1) Strengthen technological support for rapidly responding to and dealing with unexpected public accidents. Develop multifunctional and integrated national emergency response and safeguard technologies for public safety guided by the application of information and intelligent technologies, and form a public safety technological system featuring scientific forecasting, effective prevention and control, and highly efficient emergency response. (2) Improve early detection and prevention capabilities. Give priority to researching and developing monitoring, early-warning, and prevention technologies for production accidents in coal mines, unexpected social safety incidents, natural disasters, nuclear safety, and biosafety. (3) Enhance overall emergency response and rescue capabilities. Give priority to researching and developing emergency response and rescue technologies for coal mine disasters, major fire disasters, unexpected major natural disasters, hazardous chemical spills, and mass poisoning. (4) Accelerate the modernization of public safety equipment. Develop major public safety equipment and protective product lines to safeguard production safety, food safety, biosafety, and social safety, and promote the rapid development of related industries.

Priority Subjects:

(57) National Information Platforms for Dealing With Public Safety Emergencies

We will give priority to researching multidimensional and obstacle-free technologies for detecting, monitoring, precisely locating, and gaining information on sources of danger; multi-scale dynamic information analysis and processing and optimum decision-making technologies; and integrated technologies related to national decision-making and command platforms for dealing with public safety emergencies. We will build national decision-making and command platforms for dealing with emergencies that integrate early monitoring, rapid advance warnings, and highly efficient handling.

(58) Early Warnings and Rescue Operations for Major Production-Related Accidents

We will give priority to researching and developing early-warning, prevention, and control technologies for mine gas, mine flooding, and dynamic disasters, and develop prevention, control, and rescue technologies and related equipment for major industrial accidents involving fuel, explosions, and toxin leaks.

(59) Food Safety and Entry-Exit Inspections and Quarantine

We will give priority to researching key technologies for assessing risks, tracing the sources of contamination, drawing up safety standards, and conducting effective monitoring and testing with regard to food safety and entry-exit inspections and quarantine. We will develop intelligent technologies for preventing and controlling food contamination and safety monitoring and control technologies for high-throughput inspections and quarantine.

(60) Prevention and Swift Handling of Unexpected Public Incidents

We will give priority to researching and developing biometric identification, physical evidence tracing, rapid screening and verification, and simulated forecasting technologies as well as technologies and equipment for long-distance positioning and tracking, real-time monitoring and control, and baffle-penetrating identification and rapid disposal; for fire control in high-rise buildings and underground buildings; for detecting over long distances explosives, narcotics, other contraband, and sources of nuclear, biological, and chemical terror; and for on-site disposal and protection.

(61) Biosafety Safeguards

We will give priority to researching rapid, sensitive, and specific monitoring and detection technologies; testing technologies for products of metabolism by chemical agents in the body; new types of highly effective disinfectants and rapid disinfection technologies; toxin filtration and protection technologies; technologies for distinguishing, preventing, and treating dangerous vectors of transmission and for preventing and controlling biological invasions; and vaccines, immunoadjuvants, antitoxins, and drugs for dealing with unexpected biological incidents.

(62) Major Natural Disaster Monitoring and Defence

We will give priority to researching and developing key technologies for monitoring, warning of, dealing with, and handling earthquakes, typhoons, rainstorms, floods, and geological disasters; technologies for monitoring and warning of forest fires, dam and dike breaches, and other major disasters; and comprehensive risk analysis and assessment technologies for major natural disasters.

11. National Defence

IV. Major Special Items

Historically, China's implementation of a number of major projects, epitomized by "two bombs and one satellite," manned spaceflight, and hybrid rice, has played a vital role in improving overall national strength. The United States, Europe, Japan, and the Republic of Korea have regarded the organization and implementation of major special programmes tailored to national goals as an important measure for enhancing national competitiveness.

While identifying a number of priority subjects in key fields, these guidelines also further highlight key areas; select a number of major strategic products, key generic technologies, and major projects as major special items in which to achieve breakthroughs through giving full rein to the superiority of the socialist system in concentrating resources on undertaking major endeavours and to the role of market mechanisms; and aim to bring about the development of productive forces by leaps and bounds and to fill national strategic gaps through the realization of partial exponential growth in S&T. The basic principles for determining major special items are: One, keep firmly in mind the major needs of economic and social development and nurture strategic industries with core proprietary intellectual property rights that can give a significant impetus to improving enterprises' independent innovative capabilities. Two, accentuate key generic technologies that have an overall impact on and can provide a strong impetus to raising overall industrial competitiveness. Three, resolve major bottlenecks that impede economic and social development. Four, give expression to the principle of combining military and civilian production and embedding military capabilities in civilian capabilities, which has great strategic significance for ensuring national security and enhancing overall national strength. Five, act in line with China's national conditions and to the extent that our national strength can support. A number of major special items have been determined in accordance with the aforementioned principles with a view to developing new-and high-tech industries, promoting the upgrading of traditional industries, resolving bottlenecks in national economic development, improving the people's health, and ensuring national security. Major special items will be carried out one by one in keeping with the country's development needs and the extent to which the conditions are ripe for implementation. At the same time, major special items will be adjusted dynamically and carried out step by step in light of the country's strategic needs and changes in the country's development situation. Regarding major special items aimed at strategic products, we will give full rein to the principal role of enterprises in R&D and investment, make R&D on major equipment a breakthrough point in technological innovation by enterprises, make more effective use of market mechanisms in allocating S&T resources, and channel state-guided investments primarily towards tackling key and core technological problems.

Major special items refer to major strategic products, key generic technologies, and major projects that are to be completed within certain time frames through core technology breakthroughs and resource integration in order to achieve national goals; they are the priority of priorities in China's S&T development. The Programme Guidelines identify 16 major special items covering core electronic components, high-end universal chips, and basic software; very-large-scale integrated circuit manufacturing technologies and turnkey techniques; new-generation broadband wireless mobile communications; high-grade numerically-controlled machine tools and basic manufacturing technologies; the development of large oil and gas fields and coal-bed gas; nuclear power stations with large-scale advanced pressurized water reactors and high-temperature and gas-cooled reactors; water pollution control and treatment; the cultivation of new strains of genetically modified organisms; the manufacturing of new major drugs; the prevention and treatment of AIDS, viral hepatitis, and other major infectious diseases; large aircraft; high-resolution earth observation systems; and manned spaceflight and moon exploration projects. They encompass the fields of information, biology, and other strategic industries and involve major pressing issues of energy resources, the environment, and the people's health; dual-use military and civilian technologies; and national defence technologies.

V. Cutting-Edge Technologies

Cutting-edge technologies refer to forward-looking, pioneering, and exploratory major technologies in the field of high technology; they serve as an important basis for upgrading high technology and developing newly emerging industries in the future, and represent an overall embodiment of a country's high-tech innovative capabilities. The main principles governing the selection of cutting-edge technologies are: One, they represent the direction of the leading-edge development of high technology in the world; two, they play a role in guiding the formation and development of the country's future newly emerging industries; three, they facilitate the upgrading of industrial technologies and the realization of development by leaps and bounds; and four, they possess a fairly strong corps of personnel and a fairly sound R&D basis. We must make advance plans for a number of cutting-edge technologies in accordance with the aforementioned principles, give play to the role of S&T in guiding future development, and improve China's high-tech R&D capabilities and the international competitiveness of China's industries. [passages omitted on genetic target identification technologies, animal and plant species and drug molecular design technologies, gene manipulation, protein engineering, stem cell-based human tissue engineering technologies, and new-generation industrial biotechnology]

2. Information Technology

Information technology will continue to develop in the main direction of high-performance, low-cost, and ubiquitous and intelligent computing. Seeking new computing and processing methods and physical implementation are future major challenges in the field of information technology. The intersection and fusion of multiple disciplines such as nano-science and nano-technology, biotechnology, and cognitive science will promote the development of "human-centric" information technology based on biometrics, images, and natural language, and propel innovations in various fields. We will give priority to researching low-cost ad hoc networks, personalized intelligent robots, human-computer interaction systems, high-flexibility data networks that are immune from attack, and advanced information security systems.

Cutting-Edge Technologies:

(6) Intelligent Perception Technologies

We will give priority to researching "human-centric" intelligent information processing and control technologies based on biometrics and the understanding of natural language and dynamic images, as well as Chinese-language information processing. We will research systems technologies in relevant fields such as biometric identification and intelligent transportation.

(7) Ad Hoc Network Technologies

We will give priority to researching technologies related to mobile ad hoc networks, ad hoc computing networks, ad hoc storage networks, and ad hoc sensor networks; low-cost real-time information processing systems; multi-sensor information fusion technologies; personalized human-computer interface technologies; high-flexibility data networks that are immune from attack; and information security systems. We will research ad hoc intelligent systems and personal intelligent systems.

(8) Virtual Reality Technologies

We will give priority to researching technologies that synthesize multiple disciplines such as electronics, psychology, control technology, computer graphics, database design, real-time distributed systems, and multimedia technology. We will research virtual reality technologies and systems in various relevant fields such as medicine, entertainment, art, education, military affairs, and industrial manufacturing management.

3. New Materials Technologies

New materials technologies will develop towards composite structural functions for materials, intelligent functional materials, integrated materials and devices, and green preparation and utilization processes. We will achieve breakthroughs in modern materials design, evaluation, characterization, and advanced preparation and processing technologies. We will develop nano-materials and nano-devices on the basis of nano-science research; develop materials with special functions such as superconducting materials, intelligent materials, and energy materials; and develop new materials such as super-structural materials and new-generation photoelectric information materials.

Cutting-Edge Technologies:

(9) Technologies for Smart Materials and Structures

Smart materials and structures are quick or intelligent structural systems that combine sensing, control, and drive (execution) functions. We will give priority to researching smart materials preparation and processing technologies, smart structure design and preparation technologies, and monitoring, control, and fail-safe technologies for key equipment and installations.

(10) High-Temperature Superconducting Technologies

We will give priority to researching new high-temperature superconducting materials and preparation technologies, superconducting cables, superconducting electrical machinery, and highly efficient superconducting electrical devices. We will research sensitive detection devices such as superconducting biomedical devices, high-temperature superconducting filters, high-temperature superconducting non-destructive testing devices, and scanning magnetic microscopes.

(11) Highly Efficient Energy Materials Technologies

We will give priority to researching materials related to solar cells and relevant key technologies, key materials and technologies for fuel cells, high-capacity hydrogen storage materials and technologies, highly efficient secondary battery materials and key technologies, and super-capacitor key materials and preparation technologies. We will develop highly efficient energy conservation and storage materials systems.

4. Advanced Manufacturing Technologies

Advanced manufacturing technologies will develop in the direction of informatization, maximization, and greening; form the basis for the survival of manufacturing industries; and hold the key to the sustainable development of these industries in the future. We will give priority to achieving breakthroughs in extreme manufacturing, systems integration, and collaborative technologies; intelligent manufacturing and applied technologies; turnkey equipment and systems design and authentication technologies; and systems design technologies based on high-reliability large complex systems and equipment.

Cutting-Edge Technologies:

(12) Extreme Manufacturing Technologies

Extreme manufacturing refers to manufacturing devices and functional systems on extreme scales (ultra-large or ultra-small scales) or with extremely high functions in extreme conditions or environments. We will give priority to researching design and manufacturing techniques and testing technologies related to micro-electromechanical and nano-electromechanical systems, micro-and nano-manufacturing, ultra-precise manufacturing, giant systems manufacturing, and strong-field manufacturing.

(13) Intelligent Service Robots

Intelligent service robots refer to intelligent equipment integrating multiple high technologies that provides mankind with essential services in unstructured environments. We will research basic generic technologies such as design methods, manufacturing techniques, intelligent control, and application systems integration, focusing on the demand for applying service robots and hazardous operations robots [passage omitted on the development of technologies for predicting the service lives of major products and facilities].

5. Advanced Energy Technologies

Economical, highly efficient, and clean utilization and the development of new types of energy represent the main direction of future energy technology development. The development of such technologies as fourth-generation nuclear energy systems, advanced fuel cycles, and fusion energy are receiving increasing attention. Hydrogen, as the ideal energy vehicle that can be obtained through various means, will bring new changes to clean energy utilization. Fuel cell power and distributed energy supply systems with clean and flexible features will offer a new important form of ultimate energy utilization. We will give priority to researching mass hydrogen energy utilization and distributed energy supply systems and advanced nuclear energy and nuclear fuel cycle technologies, and develop highly efficient and clean fossil energy development and utilization technologies with near-zero carbon dioxide emissions as well as low-cost, highly efficient new technologies related to renewable energy.

Cutting-Edge Technologies:

(15) Hydrogen Energy and Fuel Cell Technologies

We will give priority to researching highly efficient, low-cost hydrogen production technologies using fossil energy and renewable energy; economical and highly efficient hydrogen storage, transmission, and distribution technologies; technologies for basic and key components preparation and stack integration for fuel cells; and fuel cell power generation and automobile power systems integration technologies, and develop norms and standards for hydrogen energy and fuel cell technologies.

(16) Distributed Energy Supply Technologies

Distributed energy supply systems are an important means for providing flexible, energy-efficient comprehensive energy services for end-users. We will give priority to achieving breakthroughs in end-use energy conversion and storage technologies such as mini-gas turbines based on fossil energy and new types of thermodynamic cycles and comprehensive heat, power, and cooling systems technologies, and develop distributed end-use energy supply systems based on mutual complementation between renewable energy and fossil energy and a mixture of mini-gas turbines and fuel cells.

(17) Fast Neutron Reactor Technologies

Fast neutron reactors are nuclear reactors in which nuclear fission chain reactions are set off by fast neutrons and which can achieve nuclear fuel breeding; they can make full use of uranium resources and process long-lived radioactive waste produced by thermal reactor nuclear power stations. We will research and master fast reactor design and core technologies and related nuclear fuel and structural materials technologies, achieve breakthroughs in sodium cycle and other key technologies, build 65MW experimental fast reactors, and realize critical and grid power generation.

(18) Magnetic Confinement Fusion

We will take the opportunity of participating in the construction and research of the International Thermonuclear Experimental Reactor to focus on researching large superconducting magnetic technologies, microwave heating and drive technologies, neutral beam injection heating technologies, blanket technologies, large-scale real-time tritium separation and purification technologies, diverter technologies, numerical simulation, plasma control and diagnostic technologies, and key materials technologies needed for demonstration reactors. We will deepen high-temperature plasma physics research and some non-tokamak exploration and research with energy as the target [passages omitted on three-dimensional maritime environmental monitoring technologies, fast and multi-parameter ocean floor survey technologies, natural gas hydrate development technologies, and deep-sea operations technologies].

7. Laser Technologies [no further details as received]

8. Aerospace Technologies [no further details as received] [passages omitted on the development of basic research disciplines; life process quantitative research; condensed matter; the deep structure of matter; the laws of physics governing the large-scale structure of the universe; pure mathematics; earth

system research; brain science and cognitive science; and the innovation of science experiment and observation methods, technologies, and equipment]

3. Basic Research Geared To the Country's Major Strategic Needs

A knowledge-based society has strong demand for scientific development, and the competition in overall national strength has been moved forward towards basic research and is becoming more intense. As a fast-developing nation, China must all the more emphasize the need for basic research to serve national goals and resolve key and bottleneck issues in future development through the conduct of basic research. The principles for setting the direction of research are: Having strategic, overall, and long-term significance for national economic and social development and national security; playing a key role in development despite weakness at the moment; and being capable of giving a strong impetus to the combination of basic science and technological science and guiding the future development of new and high technologies.

(1) Biological Basis of Human Health and Diseases

We will focus on researching the process of occurrence and development of major diseases and the molecular and cellular bases with which it interferes; the roles of the nervous, immune, and endocrine systems in health and the occurrence and development of major diseases; the transmission of pathogens; the laws of mutation; pathogenic mechanisms; the roles and mechanisms of drugs on the molecular, cellular, and overall regulatory levels; environmental interference with the physiological process; and the system of traditional Chinese medicine theories [passages omitted on biogenetic improvement in agriculture; the impact of human activity on Earth; global climate changes; and research into relationships among complex natural, social, and economic systems].

(6) Key Scientific Issues Relating To Sustainable Energy Development

We will focus on researching the physical and chemical bases of highly efficient and clean fossil energy utilization and conversion; key scientific issues relating to high-performance heat-work conversion and highly efficient energy conservation and storage; the principles of mass utilization of renewable energy and new avenues; the theory of safe, stable, and economical power grid operations; and the scientific basis of large-scale basic nuclear energy and hydrogen energy technologies [passages omitted on new principles and methods for designing and preparing materials, the laws of interaction between matter and energy, the micro-scale transportation of high-density energy and matter, and the precise expression and measurement of microstructures].

(9) Major Issues in Aeronautic and Astronautic Mechanics

We will focus on researching hypersonic propulsion systems, issues in ultra-high-speed mechanics, multidimensional power systems, complex motion control theories, compressible turbulence theories, high-temperature aerothermodynamics, magnetic fluids, plasma dynamics, microfluid and microsystem dynamics, and new materials structural mechanics.

(10) Scientific Basis Underpinning Information Technology Development

We will focus on researching new computing methods and basic software theories, the mechanisms of virtual computing environments, massive information processing and knowledge mining theories and methods, human-computer interaction theories, network security, and trustworthy and controllable information security theories [passages omitted on protein research and quantum modulation research].

(3) Nano Research

The strange phenomena and laws demonstrated by nano-scale matter will alter the existing framework of relevant theories and take people to an all-new level of understanding of the world of matter; they carry the potential for a new technological revolution and provide tremendous development scope in the fields of materials, information, green manufacturing, biology, and medicine. Nano-science and nano-technology have become the strategic choice of many countries for improving their core competitiveness and are also one of the fields in which China can hope to achieve development by leaps and bounds.

We will research the controllable preparation, self-assembly, and functionalization of nano-materials; the structure and outstanding and specific properties of nano-materials and their regulatory mechanisms; the principles of nano-processing and integration; notional and principle-oriented nano-devices; nano-electronics; nano-biology; nano-medicine; the optical, electrical, and magnetic properties of molecular collections and biomolecules and information transmission; the behaviour and manipulation of single molecules; the design, assembly, and regulation of molecular machines; nano-scale characterization and metrology; and the application of nano-materials and nano-technology in the fields of energy, the environment, information, and medicine. [passage omitted on reproductive care and growth research]

VII. S&T Structural Reform and the Construction of a National Innovation System

Since the programme of reform and opening up was implemented, China has adopted a series of major reform measures, achieved important breakthroughs, and made substantive progress in reforming the S&T structure, while focusing heavily on promoting the integration of S&T with the economy, setting its sights on enhancing S&T innovation and promoting the commercialization and industrialization of S&T achievements, and giving priority to adjusting structures and changing mechanisms. At the same time, we must clearly recognize that China's existing S&T structure is still incompatible in many respects with the socialist market economic structure and the requirements for great economic, scientific, and technological development. One, enterprises have not yet truly become technology innovators, and their independent innovative capabilities are not strong. Two, S&T forces in various fields exist as separate systems in a scattered and overlapping manner, with poor overall operational efficiency. S&T innovative capabilities in the arena of public interests are particularly weak. Three, there is a lack of coordination in overall S&T management, and the methods for allocating S&T resources and evaluation mechanisms are not suited to the new situation in S&T development and the requirement for changing government functions. Four, the mechanisms for providing incentives to outstanding personnel and encouraging innovation and pioneering work are not perfect. These problems have seriously held back the improvement of the country's overall innovative capabilities.

The guiding principles for deepening S&T structural reform are: Proceed from serving national goals and inspiring the initiative and creativity of the broad ranks of S&T personnel; focus on promoting the highly efficient allocation and overall integration of S&T resources in the whole society; take as a breakthrough point the establishment of a technological innovation system featuring enterprises as dominant players and combining industry, academia, and research institutes; comprehensively push forward the construction of a national innovation system with Chinese characteristics; and vastly improve the country's independent innovative capabilities.

The priority tasks in S&T structural reform at present and for some time to come are:

1. Support and Encourage Enterprises in Their Efforts To Become Technology Innovators

Competition in the marketplace is an important motivating force in technological innovation, and technological innovation is a fundamental way for enterprises to improve their competitiveness. As the programme of reform and opening up deepens, Chinese enterprises play an increasingly important role in technological innovation. We must further create conditions, optimize the environment, deepen reform, and conscientiously enhance the motivation and vitality of enterprises in technological innovation. One, we must give rein to the guiding role of economic, scientific, and technological policies and turn enterprises into primary R&D investors. We must accelerate the pace of perfecting the unified, open, competitive, and orderly market economic environment, and, through fiscal, taxation, and financial policies, guide enterprises towards increasing R&D investments and encourage enterprises, especially large enterprises, to set up R&D offices. We must establish national engineering laboratories and industry engineering centres with the support of restructured science research institutes or large enterprises with fairly strong R&D and technological diffusion capabilities and through the integration of colleges and universities, science research institutes, and relevant resources. We must encourage enterprises to establish all kinds of joint organizations for technological innovation with colleges and universities and science research institutes in order to enhance their technology innovative capabilities. Two, we must reform the methods of support under S&T plans and support enterprises in undertaking national R&D tasks. In drawing up national S&T plans, we must give more expression to the major S&T needs of enterprises and encourage more enterprises to participate. We must establish effective mechanisms by which enterprises take the lead in organizing and colleges and universities and science research institutes jointly participate in implementation. Three, we must perfect technology transfer mechanisms and promote technology integration and application in enterprises. We must establish sound incentive mechanisms and sound trading systems for intellectual property rights. We must vigorously develop all kinds of S&T intermediary service organizations that serve enterprises, and promote knowledge flows and technology transfers among enterprises and between enterprises on the one hand and colleges and universities and science research institutes on the other hand. We must give enterprises greater access to key national laboratories and engineering (technology research) centres. Four, we must accelerate the establishment of a modern enterprise system and increase the inner motivation of enterprises to engage in technological innovation. We must make technology innovative capabilities an important benchmark for evaluating state-owned enterprises and make the participation of essential factors of technology in distribution an important aspect of reform of the property rights system in new-and high-tech enterprises. We must adhere to the direction of corporatizing science research institutes that are oriented towards application and development, deepen reform of the property rights system in corporatized science research institutes, and develop sound management structures and rational and effective incentive mechanisms so that these institutes will play a key role in new and high technology industrialization and industry technological innovation. Five, we must foster a good environment for innovation and support small and medium-sized enterprises in technology innovative activities. Small and medium-sized enterprises, especially those that are S&T-oriented, are enterprise groups that are full of innovative energy but have a weak ability to withstand the risks of innovation. We must create a more favourable policy environment for small and medium-sized enterprises and draft and formulate relevant laws and policies that are favourable to their development such as granting market access and combating unfair competition. We must actively develop S&T investment and financing systems and venture capital mechanisms to support small and medium-sized enterprises, and accelerate the pace of building S&T intermediary service organizations in order to provide services for small and medium-sized enterprises in technological innovation.

2. Deepen Reform of Science Research Institutes and Establish a Modern System of Science Research Institutes

Science research institutes engaged in basic research, cutting-edge technology research, and research that serves the public interest are important forces for S&T innovation in China. The hope for developing S&T endeavours in China lies in building a stable and high-calibre research corps that serves national goals and is dedicated to the cause of S&T. Thanks to many years of reform involving structural adjustments and personnel reassignments, China has formed a number of highly competent science research institutes, for which the state must provide stable support. To give full rein to the important role of these science research institutes, we must set our sights on improving innovative capabilities, focus on introducing sound mechanisms, further deepen management structural reform, and accelerate the establishment of a modern system of science research institutes featuring "clearly defined duties, scientific evaluations, openness, orderliness, and standardized management." One, we must step up efforts to build science research institutes according to the duties defined by the state. We must conscientiously change the current situation in which the duties of some science research institutes are not clearly defined, their resources are scattered, and their innovative capabilities are not strong; optimize the allocation of resources; and concentrate our resources on forming disciplines and research bases that afford us advantages. Science research institutes that serve the public interest must give rein to their technological superiority in relevant industries, improve their S&T innovative and service capabilities, and solve major S&T problems in social development. Basic science and cutting-edge technology research institutes must give rein to their superiority in relevant disciplines, improve research standards, achieve theoretical innovations and technological breakthroughs, and solve major S&T problems. Two, we must establish S&T investment mechanisms that provide stable support for innovative activities in science research institutes. The formation of disciplines, the development of manpower, and the realization of major innovative achievements require long-term, sustained efforts. The state will provide relatively stable financial support to science research institutes engaged in basic research, cutting-edge technology research, and research that serves the public interest. In light of the different conditions in science research institutes, we must raise per capita funding rates to support long-term efforts to develop disciplines, carry out basic work, and train personnel. Three, we must institute operating mechanisms that are favourable to original innovation by science research institutes. Independent selection of topics for research is extremely important for improving the original innovative capabilities of science research institutes and for training their personnel. We must perfect the responsibility system for presidents of science research institutes, further expand the power of science research institutes to make their own decisions on their S&T spending and their personnel system, and improve the ability of science research institutes to coordinate and integrate their internal innovative activities. Four, we must establish a system for evaluating the overall innovative capabilities of science research institutes. We must establish a scientific and rational comprehensive evaluation system; comprehensively evaluate the overall innovative capabilities of science research institutes in terms of the quality of their science research achievements, their personnel training, and their management and operating mechanisms; and encourage science research institutes to improve their management standards and innovative capabilities. Five, we must establish effective mechanisms for fostering openness and cooperation in science research institutes. We must implement a personnel system that combines permanent employees with temporary employees. We must comprehensively practice a recruitment system and position-specific management and openly recruit science research and managerial personnel from society. Through the establishment of effective mechanisms, we must encourage science research institutes to forge various forms of collaboration with enterprises and universities and promote knowledge flows, personnel training, and the sharing of S&T resources.

Universities are important bases for training high-calibre innovative personnel in China, one of the main forces for basic research and original innovation in the high-tech arena in China, and a fresh force for solving major S&T problems in the national economy and for achieving technology transfers and the commercialization of S&T achievements. It is necessary to accelerate the pace of building a number of high-standard universities, especially a number of world-renowned, high-standard, and research-oriented universities, if China is to expedite S&T innovation and build a national innovation system. China has already established a number of high-standard, fairly large universities with comprehensive fields of study where talented people are brought together. We must give full rein to their important role in S&T innovation. We must actively support universities in making original innovations in the fields of basic research, cutting-edge technology research, and research that serves the public interest. We must encourage and promote all-around cooperation among universities, enterprises, and science research institutes, and step up efforts to serve national, regional, and industrial development. We must accelerate the pace of building key disciplines in universities and platforms for S&T innovation. We must train and bring together a number of leaders in specific disciplines with world-leading standards and build a corps of faculty members for colleges and universities that boasts a fine academic style and an innovative spirit and is internationally competitive. We must further accelerate the pace of reforming the internal management structures of universities. We must optimize the internal educational structures, S&T organizational structures, innovative operating mechanisms, and management systems of universities; establish a scientific and rational comprehensive evaluation system; and institute operating mechanisms that will help improve the training quality and innovative capabilities of innovative personnel, allow people to put their talents to good use, and bring forth a steady stream of talented people. We must actively explore ways to establish a modern university system with Chinese characteristics.

3. Push Forward S&T Management Structural Reform

In light of China's current conspicuous problems in overall S&T management, we must push forward S&T management structural reform, focusing on introducing sound national S&T decision-making mechanisms; on eliminating structural and mechanistic impediments; on strengthening overall coordination among departments and localities, between departments and localities, and between the military and civilian sectors; and on conscientiously improving the ability to consolidate S&T resources and organize major S&T activities. One, we must establish sound national S&T decision-making mechanisms. We must perfect the procedures for discussing the country's major S&T policy decisions and develop standard consultative and decision-making mechanisms. We must strengthen the state's overall planning and management of S&T development and strengthen overall planning for the formulation of major S&T policies, the implementation of major S&T plans, and the construction of S&T infrastructure. Two, we must establish sound national mechanisms for overall S&T coordination. We must establish the status of S&T policy as the foundation of the country's public policy and form a policy system featuring coordination and interaction between national S&T policies and economic policies in keeping with the goal of promoting S&T innovation and enhancing independent innovative capabilities. We must establish interdepartmental coordinating mechanisms for allocating S&T resources under overall planning. We must accelerate the pace of changing the functions of national S&T administrative departments, promote administration according to law, and improve the overall standard of management and service. We must improve the methods for managing plans and give full rein to the role of departments and localities in managing plans and implementing projects. Three, we must reform the S&T appraisal and assessment system. In appraising S&T projects, we must reflect the principles of fostering fairness, impartiality, and openness and encouraging innovation, and create conditions for the emergence of various types of personnel, especially young professionals. We must give expression to national goals in appraising major projects. We must perfect mechanisms for appraising specialists in the same fields, establish a system for appraising the credibility of specialists, institute mechanisms for allowing international specialists in the same fields to participate in appraisals, tighten supervision over the appraisal process, increase the openness of appraisal activities, and expand the scope of information to which those subject to appraisal have access. We must show special concern and support for highly innovative small projects, non-consensual projects, and interdisciplinary projects; pay attention to evaluating the quality, capabilities, and research standards of S&T personnel and teams; and encourage original innovation. We must establish an independent system for assessing the implementation of major national S&T plans, knowledge innovation projects, and plans for subsidizing natural science funds. Four, we must reform the system for evaluating and rewarding S&T achievements. In light of the different traits of S&T innovative activities, we must perfect the system for evaluating science research and the system of benchmarks in accordance with the principles of openness, fairness, scientific soundness, standardization, simplification, and high efficiency; change the phenomenon of too many evaluations; and avoid seeking quick results and instant benefits. For innovative activities such as market-oriented applied research and experimentation, the main criteria for evaluation should be whether they result in the acquisition of proprietary intellectual property rights and how much they contribute to industrial competitiveness. For science research activities that serve the public interest, the main criteria for evaluation should be whether they satisfy the public's needs and how they benefit society. For basic research and cutting-edge technology exploration, the main criteria for evaluation should be its scientific significance and academic value. We must establish a system for evaluating personnel that is suited to S&T work of different natures. We must reform the national S&T award system, reduce the number and grades of awards, and emphasize key areas for government S&T rewards. In addition to rewarding projects, we must also pay attention to rewarding people. We must encourage and regularize the introduction of awards by society.

4. Comprehensively Push Forward the Construction of a National Innovation System With Chinese Characteristics

Our goal in deepening S&T structural reform is to push forward the construction of a sound national innovation system. A national innovation system is a government-directed social system for giving full rein to the basic role of the marketplace in allocating resources and for fostering close links and effective interaction among various types of S&T innovators. In building a national innovation system with Chinese characteristics at the current stage, we must focus on the following: One, we must build a technological innovation system featuring enterprises as dominant players and combining industry, academia, and research institutes, and make this a breakthrough point in comprehensively pushing forward the construction of a national innovation system. Only if enterprises play a dominant role can we uphold the market orientation of technological innovation; effectively consolidate the resources of industry, academia, and research institutes; and truly enhance the country's competitiveness. Only through the integration of industry, academia, and research institutes can we allocate S&T resources more effectively, inspire the innovative energy of science research institutes, and give enterprises the ability to keep innovating. While seeking to vastly improve enterprises' technology innovative capabilities, we must establish new mechanisms for various forms of integration for industry, academia, and research institutes, with science research institutes and colleges and universities actively serving enterprises' needs for technological innovation, Two, we must institute a knowledge innovation system that combines science research with higher education. We must promote links and resource integration among science research institutes and between science research institutes and colleges and universities, centring on the establishment of open, mobile, competitive, and coordinated operating mechanisms. We must step up efforts to build a science research system that serves the public interest. We must develop research-oriented universities and form a number of high-standard basic science and cutting-edge technology research bases that share resources. Three, we must establish a defence-related S&T innovative system that combines military and civilian production and embeds military capabilities in civilian capabilities. We must promote the close integration of military and civilian S&T in terms of overall management, development strategy and planning, R&D activities, and S&T industrialization; step up efforts to develop technologies for both military and civilian uses; and foster a good pattern in which outstanding S&T forces across the nation serve defence-related S&T innovation, and defence-related S&T achievements are swiftly converted for civilian purposes. Four, we must build a regional innovation system with respective characteristics and strengths. We must take into full consideration the characteristics and strengths of regional economic and social development and make overall plans for building a regional innovation system and regional innovative capabilities. We must deepen local S&T structural reform and promote the integration of S&T resources at the central and local levels. We must give rein to the important role of colleges and universities, science research institutes, and national new-and high-tech industrial development zones in the regional innovation system, and increase support for regional economic and social development through S&T innovation. We must strengthen capacity-building for S&T development in the central and western regions. We must conscientiously step up efforts to build county (city) and other grassroots S&T systems. Five, we must build a socialized and networked S&T intermediary service system. To address the conspicuous problems of S&T intermediary service industries such as small scale, single-type functions, and weak service capabilities, we must vigorously cultivate and develop various types of S&T intermediary service organizations. We must give full rein to the important role of colleges and universities, science research institutes, and various social organizations in providing intermediary S&T services. We must guide the development of S&T intermediary service organizations towards professional, mass, and standardized operations.

VIII. Some Important Policies and Measures

To ensure the implementation of the various tasks laid out in these guidelines, not only should we solve structural and mechanistic problems but we must also draw up more effective policies and measures and perfect them. All policies and measures must help enhance independent innovative capabilities, inspire the initiative and creativity of S&T personnel, make full use of S&T resources at home and abroad, and support and guide economic and social development through S&T. The S&T policies and measures established in these guidelines were formulated in light of current major contradictions and conspicuous problems, and they will be constantly enriched and perfected in line with the development of the situation and the progress in implementing these guidelines.

1. Implement Fiscal and Tax Policies To Encourage Technological Innovation by Enterprises

We must encourage enterprises to increase their R&D investments and enhance their technology innovative capabilities. We must accelerate the implementation of consumption value-added taxes and include taxes levied on equipment purchased by enterprises within the scope of deductibles for value-added taxes. We must actively encourage and support enterprises in developing new products, new techniques, and new technologies on the basis of further implementing national preferential tax policies on promoting technological innovation, accelerating the commercialization of S&T achievements, and upgrading equipment; beef up incentive policies such as those allowing enterprises to make pre-tax deductions for R&D investment; and implement preferential tax policies aimed at promoting the development of new-and high-tech enterprises. In conjunction with reform of the enterprise income tax and the enterprise financial system, we must encourage enterprises to establish a system of special funds for technology-related R&D. We must allow enterprises to accelerate the depreciation of their R&D apparatus and facilities. We must provide necessary support in the way of tax policy for enterprises that purchase advanced science research apparatus and facilities. We must increase support in terms of foreign exchange and financing for enterprises that set up overseas R&D offices, and provide convenient and excellent services for their investments abroad.

We must comprehensively implement the PRC Law on Promoting Small and Medium-Sized Enterprises, support the establishment of small and medium-sized enterprises of different natures, and give full rein to the vitality of small and medium-sized enterprises in technological innovation. We must encourage and support cooperation in R&D by small and medium-sized enterprises through joint funding and commissioning and other means, and provide policy support for accelerating the commercialization of the results of innovation. We must draw up preferential tax policies to support technological innovation by small and medium-sized enterprises.

2. Enhance the Absorption, Assimilation, and Re-Innovation of Imported Technologies

We must perfect and adjust the country's industrial technology policies and enhance the absorption, assimilation, and re-innovation of imported technologies. We must draw up policies to encourage independent innovation and restrict the indiscriminate importation of duplicate technologies.

Through adjusting the government's investment structure and focus, we must set up special funds to support the absorption, assimilation, and re-innovation of imported technologies as well as R&D related to key technologies and equipment and R&D related to key generic technologies for major industries. We must actively adopt policies and measures to increase investments through various channels to support the absorption, assimilation, and re-innovation of imported technologies with enterprises playing a dominant role and industry, academia, and research institutes making joint efforts.

We must make major national development projects an important vehicle for enhancing independent innovative capabilities. We must absorb and assimilate a number of advanced technologies, gain mastery over a number of key technologies that have a bearing on national strategic interests, and research and develop a number of major equipment and key products with proprietary intellectual property rights through the implementation of major national development projects.

3. Carry Out Government Procurement To Promote Independent Innovation

We must draw up detailed rules and regulations to implement the People's Republic of China Law on Government Procurement to encourage and protect independent innovation. We must set up mechanisms for coordinating government purchases of products of independent innovation. The government will implement a procurement policy to give priority to important new and high technologies and equipment with proprietary intellectual property rights developed by domestic enterprises. We must provide policy support to enterprises that purchase domestically produced new and high technologies and equipment. Through government procurement, we must support the formation of technological standards.

4. Implement Intellectual Property Rights Strategy and Technological Standards Strategy

China needs to protect intellectual property rights and safeguard the interests of rights holders not only to perfect the market economic structure and promote independent innovation but also to establish its international credibility and carry out cooperation with other countries. We must further perfect the national system of intellectual property rights, foster a legal environment of respecting and protecting intellectual property rights, promote greater awareness of intellectual property rights in the whole society and higher standards of management for intellectual property rights in the country, increase the protection of intellectual property rights, and severely crack down on various infringements of intellectual property rights in accordance with the law. At the same time, we must establish special screening mechanisms for intellectual property rights involved in enterprise mergers, technology transactions, and other major economic activities to prevent the loss of proprietary intellectual property rights. We must prevent abuse of intellectual property rights from imposing improper restrictions on normal market competition mechanisms and from hindering S&T innovation and the popularization and application of S&T achievements. We must incorporate intellectual property rights management into the entire process of S&T management and make full use of the intellectual property rights system to improve China's S&T innovation standards. We must promote greater awareness of intellectual property rights among S&T personnel and S&T management personnel, and encourage enterprises, science research institutes, and colleges and universities to attach importance to and strengthen intellectual property rights management. We must give full rein to the important role of industry associations in protecting intellectual property rights. We must set up a sound system of professional qualifications and social credibility that is favourable to intellectual property rights protection.

In light of national strategic needs and industrial development needs, we must produce a number of inventions and creations with great significance for economic, social, and S&T development with the aim of forming proprietary intellectual property rights. We must organize joint efforts by industry, academia, and research institutes to tackle key problems with enterprises playing a dominant role, and offer them support in terms of patent applications, the formulation of standards, and international trade and cooperation.

We must make the formulation of technological standards an important goal of national S&T plans. Government departments in charge of relevant affairs and industry associations must strengthen guidance and coordination for the formulation of important technological standards and adopt these standards on a priority basis. We must push forward efforts to establish a system of technology-related laws and regulations and a system of technological standards; promote the combination of standards formulation with science research, development, design, and manufacturing; and ensure the sophistication and effectiveness of standards. We must guide industry, academia, and research institutes in pressing ahead with joint efforts to study, draw up, and adopt on a priority basis important national technological standards. We must actively participate in the formulation of international standards and push for China's technological standards to become international standards. We must step up efforts to build a system of technical measures on trade [passages omitted on instituting mechanisms, laws, regulations, and policies to promote the development of venture capital investment in high technology; building new and high technology industrial development zones; and supporting the popularization of agricultural and industrial technologies].

7. Perfect Mechanisms for Combining Military and Civilian Production and Embedding Military Capabilities in Civilian Capabilities

We must strengthen overall planning and coordination for combining military and civilian production. We must reform the S&T management system that separates military and civilian production and institute a new S&T management system that combines military and civilian production. We must encourage military science research institutes to undertake civilian S&T assignments, open defence-related S&T work to civilian science research institutes and enterprises, and expand the procurement scope for military products to civilian science research institutes and enterprises. We must reform relevant management structures and systems and ensure that science research enterprises and institutes that are not engaged in military industrial production will equally participate in competition to undertake science research and production related to military equipment. We must create basic S&T conditions and platforms that combine military and civilian production and are shared by the military and civilian sectors.

We must set up new mechanisms that are suited to the characteristics of defence-related science research and dual-use military and civilian science research activities. We must make overall plans and coordinate basic military-civilian research, enhance the integration of high-tech R&D forces for military and civilian applications, establish coordinating mechanisms to promote effective interaction between the military and civilian sectors, achieve the coordinated development and production of military products and civilian products, and promote the integration of various links of S&T for military and civilian purposes [passages omitted on encouraging science research institutes and colleges and universities to set up joint laboratories or R&D centres with overseas R&D institutes; supporting Chinese enterprises in increasing exports of new and high technologies and related products and in setting up overseas R&D offices; taking an active part in major international science projects and international academic organizations; spreading scientific knowledge among the general populace; increasing S&T investments by government and enterprises; improving the returns on funds used on S&T projects; building national laboratories, science research experimental bases, large science projects and facilities, scientific data and information platforms, a system of national standards, measures, and testing technologies, and a system of policies, laws, and regulations for sharing S&T resources; accelerating the training of world-class senior specialists; bringing the role of education into full play in training science research personnel; encouraging enterprises to recruit and train S&T personnel; formulating and implementing policies to encourage students pursuing studies abroad to return home to work; and fostering an innovative cultural environment].

Efforts in a wide range of areas over long periods of time and very stringent demands are required for the implementation of the Guidelines for the Medium-and Long-Term National Science and Technology Development Programme . We must step up efforts to organize, lead, make overall plans for, and coordinate relevant work, and adopt actual and effective measures to ensure the fulfilment of various tasks. One is promoting a greater convergence between these guidelines and the 11th Five-Year Programme [gui hua] for National Economic and Social Development. To make the guidelines more practicable, at present we must closely integrate the relevant contents of the guidelines with the 11th Five-Year Programme for National Economic and Social Development in order of importance and priority, including priority subjects, major special items, cutting-edge technologies, basic research, the construction of basic conditions and platforms, and S&T structural reform. From these, we must select key tasks that need to be launched immediately or that urgently need to be resolved during the "11-5" period, and move expeditiously to make specific arrangements and plans under the 11th Five-Year Programme for National Economic and Social Development. Two is drawing up a number of supporting policies. The development goals, key tasks, policies, and measures specified in the guidelines have a directive and guiding nature. We need to draw up a number of feasible and practicable supporting policies, including policies to support enterprises in becoming technology innovators; policies to promote the absorption, assimilation, and re-innovation of imported technologies; government procurement policies to inspire independent innovation; policies to increase S&T investments and improve the returns on funds; policies to deepen S&T structural reform and push forward the construction of a national innovation system; policies to speed up the industrialization of new and high technologies; policies to train more S&T personnel; and polices to promote combined military and civilian production and embed military capabilities in civilian capabilities. We must task relevant departments to take the lead in formulating these policies with the participation of other departments concerned. We must promote mutual coordination and close integration between S&T policies and such economic policies as industrial, financial, fiscal, and tax policies on the basis of full investigations and study, and move expeditiously to introduce and implement relevant policies. Three is setting up mechanisms for making dynamic adjustments to implementation of the guidelines. In light of the swift S&T development in the world and constant changes in domestic economic and social development, we must set up mechanisms for making dynamic adjustments to implementation of the guidelines on the basis of economic and social analyses, technological forecasts, and periodic evaluations. We must make timely and necessary adjustments to the development goals and key tasks specified in the guidelines in light of new trends and breakthroughs in S&T development at home and abroad and of new requirements for China's economic and social development, since some of them will need to be enriched and shored up and others will need to be adjusted appropriately. Four is stepping up efforts to organize and lead the implementation of the guidelines. Under the unified leadership of the party Central Committee and State Council, we must give full rein to the enthusiasm and initiative of all localities, departments, and social organizations in jointly pushing forward the organization of efforts to implement the guidelines through energetic teamwork. In particular, overall management departments at the national level such as those in charge of S&T management, development and reform, and finance must cooperate closely, conscientiously assume responsibility, and strengthen specific guidance. Provinces, autonomous regions, and municipalities directly under the central government must implement the guidelines in light of their actual local conditions.

Implementation of these guidelines has a bearing on the realization of the goal of building a well-off society in an all-around way, on the success of socialist modernization, and on the great revival of the Chinese nation. Let us take Deng Xiaoping Theory and the important thinking of the "Three representations" as our guidance, enhance our confidence, go all out to make the country strong, and work hard to build an innovate country and implement the grand blueprint for China's S&T development under the leadership of the party Central Committee with Comrade Hu Jintao as general secretary.

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China's Action Plan on IPR Protection 2007

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Part I. A Brief Note on China's Action Plan on IPR Protection 2007

To give a comprehensive, systematic and substantive outline of China's measures for IPR protection in 2007, to effectively dictate nationwide IPR protection efforts and to follow guidelines of the National Working Group for IPR Protection, member agencies of the Working Group Office are pleased to present this Action Plan on IPR Protection for 2007, which details 276 measures in 10 areas.

In line with the 2007 Action Plan, relevant authorities will draft, formulate and revise 14 laws, regulations, rules and administrative measures on trademark, copyright, patent and customs protection as well as 7 judicial interpretations and guidelines. On the enforcement side, 14 dedicated campaigns including Fight Piracy Every Day, crackdown on pirated textbooks and teaching supplements and Operation Blue-sky, coupled with 11 standing enforcement programs will be carried out. With regard to trails, 8 measures will be in place to keep self-innovation and IPR inventiveness alive. With regard to institutional building, 8 areas of efforts involving 46 measures will follow to establish a highly potent enforcement coordination mechanism and to improve and standardize the functions of the IPR Service Centers. 74 publicity measures in 8 forms such as large promotion events, media programming and press conferences will continue. 36 training measures in the forms of reading materials, training courses and workshops will target party and government leaderships, grass-rote enforcement agents, corporate and non-corporate organizations, lawmakers as well as university, middle and primary school students. In international exchange and partnership programs, 26 measures such as dialogues, study visits, exchanges and training cooperation will be implemented to further engage China in international activities of trademark, copyright and patent protection. To advance IPR protection at the business level, 9 measures such as building a business priority watch-directory in the public security system and formulating Opinions on Strengthening IPR Protection in Large State-owned Enterprises will be introduced. In addition, 8 measures will be at the service of right-holders, including a regular meeting mechanism to consult and coordinate with foreign-invested enterprises, and a hotline and online platform for overseas IPR disputes. Last but certainly not the least, 23 thematic studies on IPR protection will be organized.

Part II China's Action Plan on IPR Protection 2007

I. Legislation

(I) To revise laws and regulations on trademark protection and unfair competition

1. To accelerate the process of revising the Trademark Law and to finalize the draft amendment.

2. To continue making improvements on the Law against Unfair Competition.

3. To speed up revision to the Provisions for Identification and Protection of Well-Known Trademarks.

(II) To draft, formulate and revise laws, regulations and rules regarding copyright protection

1. To engage in research and formulation of the Regulations on Copyright Protection for Folk Literature and Artistic Works in order to strengthen the protection of folklore and literature, a traditionally strong area of China.

2. To promulgate the Measures on Copyright Contract Registration Documentation to facilitate the implementation of copyright laws and regulations.

3. To promulgate the Measures on Remuneration for Statutory Licensing of Textbooks by taking into consideration China's reality.

4. To revise and promulgate the Measures on Voluntary Registration of Works in order to lower the protection costs for right-holders and to secure copyright transactions.

5. To ensure successful research on the second amendment to the Copyright Law in response to new situations and challenges facing copyright protection.

6. To speed up the formulation of the Measures on Remuneration by Radio and Television Stations for Broadcasting Statutory Licensed Phonograms in accordance with the Copyright Law.

(III) To draft, formulate and revise laws, regulations and rules regarding patent protection

1. To study on the improvement of the Patent Law.

2. To accelerate the revision of the Regulations on Patent Agency to standardize patent agency services.

3. To formulate the Measures on Cross-Region Enforcement in Patent Cases.

(IV) To draft, formulate and revise laws, regulations and rules concerning IPR protection in foreign trade and through customs

1. To formulate the Measures of IPR Protection in Foreign Trade.

2. To improve the Implementing Rules of the Regulations on Customs IPR Protection.

(V) To study and formulate IPR judicial interpretations and regulatory documents

1. Based on experience in IPR criminal trials since 2004 and in line with the reality of criminal IPR protection and features of IPR crimes, to accelerate study and further improve the Judicial Interpretation on Issues Concerning Application of Law in Dealing with Criminal IPR Cases issued by the Supreme People's Court (SPC) and the Supreme People's Procuratorate (SPP).

2. To formulate and issue the Interpretation of the SPC on Issues Concerning Application of Law in Dealing with Civil Cases of Unfair Competition.

3. To formulate and issue the Provisions on Application of Law in Dealing with Right Disputes over New Varieties of Plants.

4. To continue the study on formulating judicial interpretations on judicial determination of well-known trademarks, conflict of right between store names and trademarks, and MTV copyright.

5. To advance the study on the determination of patent violation, and to formulate judicial interpretation on determination standards in due course, depending on the status of revision to the Patent Law and with a view to addressing outstanding issues on law application in trial practice.

6. To further study the scope, standards, procedures and ruling approaches for judicial review of administrative IPR cases and to promulgate judicial interpretation when conditions become ripe.

7. To formulate the Opinions of the SPC on Strengthening the Role of IPR Trials in Providing Judicial Assurances for Building an Innovative Country.

II. Enforcement

(I) Dedicated Campaigns

1. To launch a Fight Piracy Every Day campaign to come down harshly on infringement and piracy activities and to enhance the profile of the Chinese government in IPR protection.

2. To carry out dedicated campaigns across China, focusing on textbook and teaching supplements piracy, and to severely penalize schools purchasing and using pirated textbooks and supplement materials.

3. To concentrate on cyber infringement and piracy for effective protection of the rights and interests of Chinese and non-Chinese right-holders.

4. To continue Special Operation Blue Sky at trade shows.

5. To launch nationwide crackdown on pirated compressed DVDs and to intensify rectification of the audiovisual products market.

6. To organize raids against street vendors and booths selling audiovisual products and against unlicensed operations.

7. To carry out campaigns to better protect the Olympic logos.

8. To continue special investigations and enforcement actions against major cases of unfair competition and to severely penalize copycats of the product names, packaging, designs or business logos of well-known brands.

9. To organize special campaigns to protect the proprietary trademarks of farming tools and materials, trademarks and geographical indications of agricultural products to effectively protect the rights and interests of legitimate producers and operators.

10. To target special enforcement checks on teas, fruit products, wines and subsidiary foodstuff to protect their geographical indications.

11. To maintain the accomplishments of the special online regulation campaign and to continue special actions against cyber piracy and infringement.

12. To consolidate the regulatory progress on computer software preloading and to continue special actions against unauthorized computer software preloading.

13. To organize intensive enforcement activities around March 15 and April 26.

14. To combat dupery under the disguise of patent awards or similar events.

(II) Day-to-day Enforcement

1. To jointly supervise and urge investigation into a number of principal and large IPR cases.

2. To timely issue arrest orders and to prosecute IPR offenders.

3. To continue implementing the Measures on IPR Protection at Exhibitions and Fairs and to monitor the implementation more closely.

4. To penalize smugglers of electronic gaming products.

5. To continue enforcement in high-incidence areas and sectors, mainly including customs ports in Guangdong, Zhejiang, Shanghai and Fujian and in postal and express delivery service.

6. To severely penalize offenders using proprietary trademarks of farming tools and materials; to intensify protection on the trademarks and GIs of agricultural products, especially in relation to well-known trademarks; to give priority to farmers' trademark claims and trademark protection for farming products (especially farming materials like pesticides and seeds) and special-purpose goods frequently used by farmers, to protect farmers' rights and interests

7. To strengthen supervision over wholesale and retail commodity markets which are under the close scrutiny of the Chinese and non-Chinese public; to regulate the operations of the market owners and tenants; to stem the distribution channels for trademark-infringing commodities.

8. To intensify day-to-day regulation on trademarks focused on trademark printing and producing, OEM and commodity markets; to regulate the use of trademarks and to build on the long-standing mechanism of containing trademark violations from the very source.

9. To step up efforts in the recognition and protection of well-known trademarks and to rigorously combat violations of proprietary well-known trademarks; to effectively protect trademark-related rights and interests of trademark-owners.

10. To aggressively investigate and penalize offenses including Internet-based unfair competition and IPR violation.

11. By working from big and critical cases, to investigate and severely penalize the production and printing of forged labels and packages, faking and unauthorized use of other companies' name and address designations, especially of well-known domestic and foreign brands, faking and unauthorized use of other companies' quality marks, and standard-incompatible markings; to improve oversight and sample checks on geographical indications of goods, to enhance day-to-day enforcement and examination against counterfeit GI-protected goods and IPR infringement via OEM.

III. Trials

(I) To bring judicial IPR protection into full play and to keep indigenous innovation and IPR creativity alive

1. To impose harsh penalties on IPR offenders in accordance with the law, and bring criminal and judicial IPR protection into full play; to harness criminalization tools to achieve better punitive and deterrent effects; to direct case hearing in an attentive and timely manner; to prevent and effectively contain IPR offenses.

2. To lawfully process civil IPR cases. To strictly maintain orderly market competition; to reasonably and appropriately protect products of innovation; to equally protect the legitimate rights and interests of Chinese and non-Chinese stakeholders; to foster the healthy development of emerging industries; to fully mobilize the leading role of civil trial in protecting IPR and stimulating indigenous innovation.

3. To supervise and support enforcement activities of administrative agencies. To ensure the judicial review function of administrative trial against administrative IPR enforcement; to support administrative agencies to penalize offenders, thus protecting the legitimate rights and interests of IPR-holders, safeguarding IPR administrative order and promoting administrative IPR protection.

4. To strengthen trial supervision in relation to law application. To focus on cases which are tried against different standards by different courts, which are exemplary in terms of universal law application, and which involve common standards for judicial review of affirmed patents and trademarks; to strengthen coordination among associated cases and to build a case guidance system.

5. To strengthen the supervision and guidance on people's courts at various levels in IPR criminal trials; to continue to work closely with relevant departments, to strengthen monitoring of major IPR criminal cases and to ensure lawful punishments.

(II) To remain in close collaboration with relevant departments and take a hard-line stance on combating IPR crimes

1. Courts, public security agencies, procuratorates and other administrative enforcement agencies will continue to work in close coordination and communication with one another while fulfilling their own duties, and will try criminal IPR cases in time to achieve satisfactory trial results.

2. Given the nature that civil and criminal IPR cases are easily mixed up, to continue making a clear distinction between conviction and acquittal, and between different charges in case trial.

3. To report crime leads or suspected criminal offences uncovered during civil and administrative case handling to public security organs for further investigation and actions.

IV. Institution Building

(I) To strengthen macro management over IPR

1. To study and facilitate the formulation of the National IPR Strategy Program.

2. To study and facilitate the formulation of the 11th Five-Year Development Plan for China's IPR Undertakings.

(II) To establish a highly potent enforcement coordination mechanism

1. To perfect the multi-department joint enforcement mechanism and establish working mechanisms for cross-region case transfer, information sharing and supporting investigation.

2. To improve and broaden the functions of such working platforms as information service, oversight on case handling, data and statistics, status evaluation and monitoring and early warning so as to organically inter-connect enforcement coordination and administrative enforcement agencies with public security units and judicial departments.

3. To continue to supervise and urge the implementation of the Opinions on the Timely Transfer of Suspected Criminal Cases in Administrative Enforcement.

4. To continue to intensify coordinated enforcement according to the requirement of Provisional Regulations on Intensifying Coordination and Collaboration in the Crackdown on Criminal Infringement upon Exclusive Right of Trademarks.

5. To continue to intensify coordinated enforcement according to the requirement of Provisional Regulations on Intensifying IPR-related Enforcement Collaboration.

6. To continue to intensify coordinated enforcement according to the requirement of Provisional Regulations on Intensifying Coordination and Collaboration in the Crackdown on Criminal Infringement upon Copyright.

7. To establish an inter-ministry consortium meeting mechanism led by the National Copyright Administration for the promotion of use of legitimate software.

8. To get an MOU on Strategic Cooperation signed by the General Administration of Press and Publication of China and Trademark and Patent Office of the US.

(III) To perfect and standardize the service functions of IPR Service Centers

1. All localities should formulate implementing rules according to the Opinion on Establishing the Working Mechanism of IPR Service Centers (Document 2006 No. 42 of Office of the Rectification and Standardization of Market Order), establish a highly effective coordination mechanism of IPR enforcement and gradually build an IPR protecting system jointly contributed by administrative protection, judicial protection, safeguarding of IP holders' right, self-discipline of industries, services of intermediary institutions and social supervision.

2. To further perfect the building of IPR Service Centers with an extended coverage of key cities and regions and expanded service functions, improve the supervisory system and ensure the standardized operation of IPR Service Centers.

3. To promulgate Regulations on Effective IPR Protection during Fairs and Exhibitions by IPR Service Centers.

4. To promulgate Opinion on IPR Service Centers Serving the IPR Protection of Development Zones, High-tech Zones and Service Outsourcing Base Cities.

5. To organize the signing of Cooperation MOU by 50 IPR Service Centers and 54 State-level Development Zones during the Central China Expo, Fair on Cooperation, Investment and Trade between the East and the West and China International Fair of Investment and Trade.

6. To guide and organize IPR Service Centers to strengthen learning of laws, regulations and basic knowledge, compile and issue to various localities IPR Q&A.

(IV) To perfect the enforcement supervision mechanism

1. Procuratorates at various levels should play their role of legal supervision, seriously examine the duplicate of Decision of Administrative Penalty copied and submitted by the administrative enforcement units. In the case where suspected crimes can be determined which should be transferred for criminal liabilities but not transferred, a written opinion of transfer should be issued to administrative enforcement units, with the implementation of such transfer supervised and urged. An opinion of correction should be issued when a case that should be filled has not.

2. Prosecuting agencies at various levels should continue to seriously investigate and penalize the discipline-violating offences and crimes of people working with the state functionaries behind those IP crimes, thus resolutely removing the "protective umbrella" of those crimes.

3. Efforts should be focused on working out resolutions for the specific problems arising in connecting administrative enforcement with criminal prosecution. Earnest studies should be carried out to resolve such problems as the criteria and evidence requirement for the transfer of suspected IP infringing criminal cases, thus advancing the work on administrative-judicial connection into greater depth.

4. Studies should be intensified over the introduction of standards and a long-term effective mechanism to the relevant work on administrative-judicial connection, with a complete legislative proposal tabled when necessary.

5. All regions should be mobilized to fully exploit hi-tech means and approaches to set up an information-sharing mechanism.

6. To continue to earnestly implement such systems as joint meetings, information notification and consultation of individual cases.

7. To rigorously follow through an accountability system for administrative enforcement, changing the entities assuming responsibility from the original authorities in charge to the enforcement entities. To clearly define the enforcement entities for different types of offenses, thus giving more prominence to the direct responsibilities borne by the enforcement entities.

(V) To explore and improve the working mechanism of judicial IPR Protection

1. To continue to step up the placement of IPR tribunals in courts at various levels and optimizing the allocation of human resources, thus reinforcing the strengths in the hearing of IP cases and beefing up judicial protection of IPR.

2. To press ahead in working out a right-definition and dispute-settlement mechanism for such industrial properties as patents and trademarks.

3. To properly adjust the level criteria of court jurisdiction over civil cases by extending as much as possible the scope of cases of preliminary hearing accepted by the Intermediate People's Courts, gradually barring the Higher People's Courts from hearing cases of preliminary hearing the proceedings and nature of which do not carry universal legal applicability.

4. To explore the trial adoption of investigation orders. For evidences that are kept by relevant state authorities and are off limits to the parties concerned, and other evidences that the parties concerned are not able to collect on their own due to external reasons, they can be accessed for investigation and collection by the court-authorized lawyers representing the parties concerned.

5. To explore the mechanism of guarantee for discontinuance of proceedings and of interests agreement by the parties concerned. In the case where the stability of the rights and interests is hard to determine, proceedings may not be discontinued if the right-holders are willing to provide effective guarantees, or, decisions on whether or not to discontinue the proceedings will depend on the situation of the agreement on calculating methods for the entitled interests or incurred losses on the part of the parties concerned.

(VI) To improve the management system for IP professionals

1. To formulate through studies the strategic objectives and implementing plans in advancing the contingent building of high-caliber IP lawyers.

2. To improve the management system that fully taps into the roles and contributions of IP lawyers.

(VII) To set up a comprehensive platform of early warning, right-assurance and regulation

1. To set up an IP early warning mechanism for the information industry.

2. To work on the establishment of an overseas right-assurance mechanism for the IP of enterprises.

3. To set up a system of "blacklisted" infringing enterprises at conventions and exhibitions, formulating corresponding measures of penalty.

4. To work on a "blacklist" of enterprises, customs brokers and individuals exporting infringing goods. To conduct more checks on the goods declared by blacklisted enterprises and individuals within a certain time span.

5. To organize efforts to develop an "enforcement system of customs IPR protection" for better information-sharing by customs authorities across the country on IPR cases, helping them make targeted and timely adjustments to the key areas of enforcement.

6. To set up a regulatory platform for digital copyright, giving full play to the positive role of science and technology in administrative copyright enforcement and further improving the regulatory framework.

7. To improve and fully leverage upon the China patent technology information release platform.

8. To launch a systemic project of national cultural market regulation; to prepare for the establishment of an IPR office network for the cultural market; to explore the possibility of a reward fund for culture-market infringement reporting.

(VIII) Others

1. To prepare for the creation of the Eagle-Eye Taskforce for combating internet-based IPR infringing crimes, with such main responsibilities as prevention, investigation and control of internet-based IPR crimes.

2. To promote the incorporation of IPR evaluation into the uniform registration and management system of judicial evaluation, thus gradually legalizing and standardizing the work on IPR verification.

3. To further improve regulation of the audio-visual markets and set up a regulatory system of long-term effectiveness. Great attention should be devoted to the regulation of law-abiding shops marketing audio-visual products, accompanied by regular checks and rigorous prosecution and penalty for illicit business activities.

4. To set up and launch the "reward fund for reporting and penalizing infringement and piracy", encouraging and rewarding the people reporting, investigating and prosecuting infringement and piracy cases.

5. To organize dedicated supervisions and inspections of printing and copy-making enterprises, investigating and penalizing according to law relevant infringing cases and crimes in the area of printing and copy-making.

6. To set up a patent information platform of relevant medicines and step up efforts in building an information network for medicine registration.

7. To vigorously follow through an accountability system of enforcement coordination.

8. To carry out review and evaluation of patent enforcement.

9. To strengthen documentation and publication of the relevant information on IP enforcement.

V. Publicity

(I) Positioning

1. To reinforce education among the public, improving society-wide awareness on the respect for and protection of IPR.

2. To report timely the typical cases wherein the relevant authorities have strengthened enforcement efforts and adopted measures to combat piracy and infringement, thus educating the public and deterring the criminals.

3. To step up publicity and orientation of positive cases, shedding light on a number of leading individuals and enterprises in IPR protection.

4. To strengthen online publicity and education, and organize publicity activities of IPR protection over the Internet.

5. To increase publicity efforts to the outside world, taking the initiative in shaping international media attitude.

(II) Large-scale Publicity Events

1. Hosting the opening-up ceremony of the publicity week as of April 20, 2007.

2. To organize a "volunteer program of IPR protection".

3. To carry out large-scale and concentrated destruction of infringing and pirated publications across the country in April, destroying such illegal publications as optical disks, electronic publications, software, books, newspapers and other paper-borne publications.

4. In coordination with the "IPR publicity week" in 2007, to instruct various regions and authorities to carry out an intensive series of IP publicity and education initiatives through such programs as workshops on IPR-related legislations.

5. To strengthen law-related publicity and education of IPR, rolling out programs of law penetration into government authorities, rural area, communities, schools and enterprises.

6. To organize on-site information services for law-related publicity programs of IPR.

7. To continue the nomination and voting for annual major inventions in the information industry in an effort to promoting independent innovation and enhance the innovation and IPR protection awareness of the businesses.

8. To organize the 9th National Legal Publicity Campaign in the Audiovisual Products Market featuring "Protecting IPR and Combating Infringement and Piracy".

9. To organize activities to destroy illegal audiovisual products.

10. To organize a series of publicity campaign featuring "Anti-Counterfeiting and Anti-Piracy".

11. To organize a road show on the theme of "Copyright Protection for Economic Development" in early April 2007.

12. To organize an education campaign on copyright protection, calling university students to say no to piracy.

13. To launch a themed publicity campaign, entitled "Enjoy the Music, Respect Artistic Creation".

14. To organize an online publicity campaign by producing a cartoon series to promote IPR awareness, entitled "A Networked World and A Copyright-Friendly China".

15. To organize an "IPR Protection Day Gala" on April 26.

16. To organize a campaign to collect a suite of songs on the theme of IPR protection.

17. To organize a public visiting day with the purpose of letting more people better understand IPR.

(III) Greater Enforcement Transparency

1. To comprehensively implement the system to open IPR trials to the public, to continue online disclosure of court verdicts for criminal IPR cases, and to enhance the capacity and profile of the China Website on Court Verdicts and Trial Information.

2. To select some influential cases for public hearing and invite delegates of the People's Congress, members of the CPPCC, representatives of industry associations, relevant departments, foreign governments and resident agencies of international organizations, as well as experts and scholars, to attend these hearings in order to increase the transparency and creditworthiness of the court trials.

3. To release the important information and typical cases relating to IPR trials at appropriate times, which will become a supplement to the press release system of people's court and, provided that normal proceedings in the court and the rights of the parties concerned are not compromised, offer the greatest convenience possible to the media in a bid to maximize the role of the press release system in the judicial protection of IPR.

4. To publish on a regular basis typical cases and verdict information, among others, on public journals as such People's Judicature, China Trials, Law Application, intensify the reporting and publicity on cases of public attention and the achievements of the work, and strive to publish such information to the outside world in the English language if conditions permit.

5. To disclose on a timely basis the progress of IPR protection efforts and typical cases on the procuratorial front through Procuratorial Daily, the Justice Website, and other forms of media.

6. To promote the software legalization efforts of the enterprises, with the gradual release of legal software information by the National Copyright Administration of China and the Ministry of Information Industry on their respective websites.

(IV) Media Programming

1. One feature with the Dialogue program on CCTV.

2. A 12312 Brand Camp with Lucky 52.

3. Special programming on the theme of stronger trademark protection.

4. TV series featuring IPR protection.

5. Special promotion videos on GI-protected products and the system for GI protection.

6. A press conference on GI products.

7. A series of public service advertisements on IPR protection.

8. To try to create a group of influential TV programs on IPR-related subjects.

9. A series of promotion videos on typical IPR cases.

(V) Press Conferences

1. A press conference on "IPR Week 2007" in early April 2007.

2. To organize press conferences, forums and co-organize IPR Week 2007 events based on results of Mountain Eagle II special campaign in order to continue publicity efforts and to highlight the advantages of publicity work, including information disclosure, education, warning and emotional appeal.

3. To organize a press conference on the trend of patent application in the information industry and organize information tracking and release events on industry-related patent applications and technological developments according to the reality of the information industry.

4. To organize a press conference to brief the public on the information relating to trademark protection by the State Administration of Industry and Commerce.

5. To organize a press conference featuring "Fight Online Infringement and Piracy, Use Legalized Software" to release information on major cases.

6. To organize a press conference on "China's Status of IPR Protection in 2006"

(VI) Forums and Exchange Activities

1. To organize a China IPR Protection High-level Forum, 2007.

2. To organize a forum on the judicial protection of IPR.

3. To organize a forum on the criminal protection of IPR and release information on the major cases in the special campaign Mountain Eagle II in 2006.

4. To organize a Summit Forum on IPR Protection in the Information Industry to improve the IPR management awareness and capability of businesses.

5. To organize seminars on IPR property to promote the exchange of ideas and cooperation between Chinese and foreign participants.

6. To organize a forum on IPR in the pharmaceutical industry.

7. To co-organize a forum with China Daily featuring the theme of increasing core competitiveness on the basis of intellectual property rights.

8. To organize a forum on global IPR protection and innovation.

(VII) Publications

1. To compile A Complete Guide to Defending IPR by Chinese Enterprises Overseas.

2. To enhance the professional guidance over IPR law enforcement personnel and compile a book on IPR knowledge for the law enforcement personnel.

3. To forcefully launch IPR legal publicity activities and compile a book on IPR Knowledge for the citizens, which will be distributed among the grass-root units.

4. To publish books and publicity brochures on the strengthening of trademark protection.

5. To produce publicity programs, books and posters on China's IPR protection culture.

6. To produce a compilation of typical patent cases.

7. To organize innovation contests for the youth and publish readings for the young people.

8. To ensure the good quality of China Intellectual Property News.

(VIII) Disclosure of Typical Cases

1. To publicize the top 10 cases in the 2006 anti-piracy Sunshine Campaign organized by the cultural authorities.

2.To publicize the top 10 customs-related IPR protection cases in 2006.

3. To compile and publicize typical domestic and foreign-related trademark infringement cases on a regular basis.

4. To compile and publicize typical suspected criminal cases transferred to judicial departments.

5. To publicize typical cases of IPR protection concerning quality inspection, supervision and quarantine.

(IX) Others

1. To organize the selection of 2006 Top 10 IPR Protection Events in China.

2. To organize an IPR Protection Essay Contest.

3. To launch an online survey on IPR protection and to solicit opinions from the general public.

4. To hold a Quiz Contest among staff of IPR Reporting and Complaining Service Centers.

5. To select materials to produce animated cartoons and to strengthen education.

6. To cite Excellent Court IPR Ruling Documents in the 2nd national contest of this kind.

7. To strengthen overseas IPR publicity efforts, disseminate the achievements and progress scored in China's IPR protection, correctly guide the shaping of overseas opinions and build a positive image of China in IPR protection.

8. To continue to educate through websites, and to enrich the contents of the website of China Trademark.

9. To organize on-line interviews on IPR protection by quality inspection, supervision and quarantine authorities.

10. To publish a special edition on IPR protection in China and launch a quiz contest on proprietary innovation and IPR.

VI. Training and Education

(I) To formulate training plans and compile teaching materials

1. To organize the compiling of teaching materials for IPR training.

2. To revise the professional training programs for IPR ruling at a proper timing, and strengthen the training on basics of civil and commercial law, professional ruling skills and basic scientific and technological knowledge.

3. To compile the loose-leaf Handbook on Identifying Infringing Goods, which could be updated frequently, and to distribute the handbooks to customs checkpoints.

4. To formulate, print and distribute the Guidelines on National IPR Education and Training.

(II) IPR training for leading officials

1. To hold a "Training Program on IPR Criminal Protection" for law enforcement and judicial officials at the Director-General level.

2. To implement the China-Germany IPR Administrative Enforcement Training Program and organize three training sessions.

3. To include special seminars on copyright protection into training programs for relevant leading officials.

4. To hold a Training Program on IPR Strategy for leaders at the municipal level.

(III) IPR training for grass-root judicial and law enforcement personnel

1. To give full play to the role of the National Judges College as a major channel for intensive training at a regular basis, and try to extend to every IPR judge one training opportunity at the National Judges College every two years.

2. To organize two training sessions on the comprehension and application of new judicial interpretation at training institutions including the National Judges College.

3. To jointly hold a training program with China Intellectual Property Training Center on ruling of IPR cases for grass-root courts.

4. To focus on strengthening training of IPR judges based in the western regions. The Supreme People's Court will grant preferential policies to courts located in the western regions in terms of case study, dedicated training and subject research.

5. To increase contents on IPR in this year's training program for prosecutors, and organize them to participate in the training activities held by the National IPR Protection Working Group Office.

6. To continue the training and education of public security officers on IPR enforcement through various forms including professional training and long-distance teaching on an organized and targeted basis.

7. To hold training classes on protecting copyright and fighting against infringement and piracy.

8. To organize IPR enforcement training classes for law enforcement staff at the director-general level and law enforcement police, strengthen the sense of responsibility of law enforcement team and solve the theoretical and practical problems encountered by the public security authorities in combating IPR violations.

9. To hold 3 or 4 training sessions for grass-root administrative enforcement team in the cultural sector based in different locations, and discuss the practice and experience in fighting against pirated audio-video products and illegal network-based culture-related business operation.

10. To hold a national working conference on network culture, reinforce the management of network culture market and strengthen the education and training of law enforcement personnel.

11. To continue to strengthen training of customs enforcement teams at different ports, in particular, to improve the competence of customs inspectors on the ground identifying infringing products. While ensuring the training of coastal ports, training of inland ports should be improved.

12. To strengthen practical guidance for provincial Administrations for Industry and Commerce, and organize national or regional training sessions for grass-root trademark enforcement personnel.

13. To hold one or two training sessions to disseminate the knowledge on international trademark registration.

14. To organize targeted training focused on the registration and protection of agriculture trademarks and geographical indications.

15. To hold a training class on international trademark registration for agriculture exporters, and steer and promote agriculture exporters to pay attention to international trademark registration.

16. To hold a training class on the protection of Olympic logos.

17. To conduct training on IPR protection competence for frontline enforcement team responsible for inspection and quarantine.

18. To organize training courses for copyright administrative and enforcement teams at the municipal level, and to strengthen training of new and grass-root personnel responsible for copyright administration.

19. To organize a senior IPR workshop.

20. To continue to hold the national training class for patent administrative enforcement teams.

(IV) IPR-Related Training for Businesses and Public Institutions

1. To open training classes on law for companies' management people in cooperation with relevant authorities in a bid to enhance IPR protection training on laws and regulations in companies.

2. To launch one to three training sessions on IPR management and practice for IT companies and institutions.

3. To provide trainings on protecting IPR abroad for trading companies, economic and commercial sections of Chinese embassies and local economic and trade authorities.

4. To hold training courses on copyright specially for the staff of companies, institutions and copyright and related right holders' organizations.

5. To organize IPR seminars for business leaders and IPR administrators.

(V) Basics Education

1. To provide trainings for IPR-specialized lawyers in a bid to intensify education of high quality human resources on IPR legal services.

2. To step up cultivation of IPR specialists attending on-the-job master programs in law and expand the scale of such cultivation.

3. To popularize education of IPR-related knowledge amongst university, middle school and primary school students.

VII. International Exchange and Cooperation

(I) On IPR Judicial Protection

1. To cooperate with the EU WTO Program Office in hosting trainings or seminars of two sessions on trade secrets and judicial determination of well-known trademarks.

2. To actively organize and engage in overseas inspections, exchanges and training programs on IPR judicial protection so as to reinforce communication and cooperation with international IPR organizations and relevant countries.

3. To discuss with the US on setting up an IPR Criminal Enforcement Working Group under the JLG framework where related work can be launched jointly including study on criminal law, training and exchanges as well as administrative enforcement.

4. To continue to engage in cooperation and communication with public security enforcement bodies of various nations.

5. To organize delegation of public security sector for enforcement training to Germany where training and inspection programs will be carried out.

(II) On Commerce and Customs

1. To keep on promoting China-US IPR dialogue.

2. To keep on promoting China-EU IPR dialogue and the implementation of China-EU IPR Cooperation Program (Phase II).

3. To move forward IPR-related communication and cooperation with relevant countries.

4. To further deepen international enforcement cooperation by customs.

(III) On Copyright

1. To hold joint conferences under the China-US collaboration mechanism on protecting copyrights of motion pictures on a regular basis where experiences of the mechanism can be summarized, exchanges and understanding between China and US can be reinforced and continued discussions about effective models of international cooperation on improving IPR protection conducted.

2. To send delegations to visit relevant countries and regions, study and collect information about IPR protection in the areas of e-games, animations and other games and draw upon their good experiences.

3. To jointly host the Asia-Pacific Seminar on Performers' Copyright and Related Rights with WIPO.

4. To jointly host the International Copyright Forum 2007 with WIPO.

5. To deliver good cooperation projects on copyright protection between China and foreign countries including the US, the EU, Australia, Japan and South Korea.

6. To send people to the US Copyright Office for middle and long term working exchanges.

(IV) On Trademark

1. To intensify communication and cooperation with trademark registration authorities of the US, Japan and the EU and hold high-level talks.

2. To organize the International Geographical Indications Seminar in collaboration with WIPO.

3. To cooperate with the US in hosting the Sino-US Seminar on Hot Issues in Trademark Registration and Application.

4. To sign the Work Plan of Sino-US Trademark Strategy and the China-Italy Trademark Action Plan 2007 in a bid to reinforce bilateral cooperation with the two countries in the field of trademark.

5. To intensify liaison with foreign trademark registration authorities and step up efforts in protecting Chinese trademarks abroad.

6. To select and send staff on trademark examination and administration to study abroad.

(V) On Patent

1. To organize high-level meetings with the IPR bodies of the US, Japan, the EU and international organizations.

2. To cooperate with the IPR bodies of the US, Japan, the EU and international institutions in organizing expert visits as well as sending people to attend trainings and seminars for better communication between professionals.

3. To send people to study at law schools in foreign universities in a bid to improve education for China's IPR personnel.

4. To co-sponsor seminars or training programs on IPR with international institutions such as WIPO and IPR authorities of some countries so as to enhance mutual understanding and increase the application, protection and management level of both the government and businesses on IPR.

5. To hold communication meetings for foreign embassies, representative offices, foreign-invested companies and chambers of commerce in China.

VIII. Advancing IPR Protection in Businesses

1. To develop a contact list of key companies for the public security authorities so as to lock well-known Chinese companies and key foreign companies in the IPR enforcement mechanism, providing enforcement guarantee for companies to protect IPR.

2. To sharpen the awareness of IPR protection amongst processing trade companies and enhance overseas IPR protection by companies.

3. To hold IPR work meetings for large SOEs at right timings where IPR work in large SOEs will be defined with the target of boosting indigenous innovation in large SOEs and the focus of enhancing IPR management and protection.

4. To organize reviews on relevant information about the implementation of IPR strategies by large SOEs and study on the formulation of Opinions on Enhancing IPR Work in Large SOEs.

5. To combine self-training with collective training, so as to strengthen IPR training within the companies; to carry out international IPR exchange activities; to guide businesses to raise IPR awareness and strengthen capacity-building.

6. To promote IPR operational skills within the companies and enhance the companies' capabilities of creating, applying, managing, and protecting IPR, so as to use various IPR strategies and skills flexibly and ward off IPR law-related risks.

7. To survey on Chinese companies' trademark registration and protection in foreign countries and foster more advantaged companies with independent trademarks and relatively strong international competitiveness.

8. To promote companies' IPR protection through carrying out the law enforcement campaign of cracking down on the counterfeits and protecting the brand names.

9. To put into place The Implementation Scheme of Promoting Companies' Use of Copyrighted Software, thus promoting the companies' adoption of legalized software.

IX. Services to Right-holders

1. To hold meetings with foreign-invested enterprises (FIEs) regularly for exchanges and coordinating mechanisms, and to solicit right holders' opinions and suggestions, address important issues proposed by the right holders.

2. To promote and guide the lawyers to expand IPR legal services and provide legal services in creating, using, managing and protecting IPR.

3. To establish hotlines and web-based service platforms for companies to protect their overseas IPR.

4. To improve trademark review system, thus enhancing work quality and efficiency and to focus on addressing issues that damage the trademark interests of the parties concerned such as prolonged trademark registration period, hostile application, hostile objection, hostile transfer, etc.

5. To work on trademark registration and Phase III of the management automation system so as to prepare for a complete operation of online trademark application and the overall online application.

6. To set up contact points for geographical indications and to carry out in-depth study on the role of protecting geographical indications in increasing the farmers' income and summing up and promoting the experiences in time.

7. To improve the building of collective administrative organizations for copyrights and promote the preparation for setting up collective administrative organizations for copyrights, such as in text, photography and film.

8. To establish and improve National IPR Protection Association and trade associations.

X. Thematic Studies

(I) On IPR Protection and Management System

1. To carry out the social supervision of IPR protection and study on coordination of law enforcement.

2. To carry out the evaluation of IPR protection and study on information early warning system.

3. To study on independent IPR and innovation.

4. To study on the relationship between IPR system and building an innovative country.

5. To study on issues related to creating, managing, protecting and using China's independent IPR at the current stage.

6. To study on the IPR management system and coordination mechanism.

7. To study on the integrated capacities of China's IPR-related work.

(II) On IPR Protection in Import and Export

1. To survey on IPR protection related to import and export.

2. To strengthen the study on the abuse of IPR and IPR in international trade.

(III) On Judicial IPR Protection

1. To strengthen the study on criminal, civil, administrative and judicial protection of IPR, and try to produce theoretical outcomes, thus providing a theoretical basis for revising and improving IPR-related laws.

2. To finish the survey on the evidences to be used in IPR lawsuit cases, and try to translate the survey's outcome into reality.

3. To put the survey on the judicial determination of well-known trademarks as a priority, and further regulate the trial process, make the judicial standards specified and uniform.

4. To strengthen the theoretical study on IPR judicial protection and try to produce theoretical outcomes, thus providing theoretical evidence for revising and improving criminal laws.

5. To sum up, study and make judgment on the overall status quo, features and development trend of China's current IPR infringement crimes, so as to provide theoretical support for the next step of IPR protection.

6. To study on law application in handling tobacco-related crimes.

(IV) On IPR Team-building

To continue the study on IPR legal services and the team-building for IPR lawyers.

(V) On Trademark Protection

1. To fulfill researches on the subjects of "Study on Trademark Strategy" and "Study on Trade Secret-Related Issues" in national IPR strategic researches and translate subject researches to subject implementation.

2. To strengthen investigation and law enforcement on how to crack down upon "fake brand names" and trade secrets infringement.

3. To study on how to protect well-known commodities effectively and on implementing the filing system for well-known commodities' proprietary names, packaging, and decoration.

(VI) On Copyright Protection

1. To carry out the project of "Survey on the Economic Contributions of China's Copyright-Related Industries" with WIPO.

2. To carry out the survey on the administration system for copyright agencies, and to study and draft Administrative Measures for Copyright Agencies.

3. To survey on and demonstrate copyright arbitration mechanism and to explore and promote a copyright arbitration system with Chinese characteristics.

(VII) On Patent Protection

To carry out study on protection of utility models and design patents in China.

National High-tech R&D Program (863 Program)

In 1986, to meet the global challenges of new technology revolution and competition, four Chinese scientists, WANG Daheng, WANG Ganchang, YANG Jiachi, and CHEN Fangyun, jointly proposed to accelerate China's high-tech development. With strategic vision and resolution, the late Chinese leader Mr. DENG Xiaoping personally approved the National High-tech R&D Program, namely the 863 Program. Implemented during three successive Five-year Plans, the program has boosted China's overall high-tech development, R&D capacity, socio-economic development, and national security. In April 2001, the Chinese State Council approved continued implementation of the program in the 10th Five-year Plan. As one of the national S&T program trilogy in the 10th Five-year Plan, 863 Program continues to play its important role.

1. Orientation and Objectives

Objectives of this program during the 10th Five-year Plan period are to boost innovation capacity in the high-tech sectors, particularly in strategic high-tech fields, in order to gain a foothold in the world arena; to strive to achieve breakthroughs in key technical fields that concern the national economic lifeline and national security; and to achieve "leap-frog" development in key high-tech fields in which China enjoys relative advantages or should take strategic positions in order to provide high-tech support to fulfill strategic objectives in the implementation of the third step of our modernization process.

During the 10th Five-year Plan period, the 863 Program will continue to aim at the forefront of world technology development, intensify innovation efforts and realize strategic transitions from pacing front-runners to focusing on "leap-frog" development. Through efforts made in the 5 years, the program will greatly enhance China's high-tech innovation capacity in selected fields and improve the international competitiveness of major industries. It will master a number of technologies with industrial potential and proprietary IPR. It will nurture a number of high-tech industrial growth sources which will optimize and upgrade China's industrial structure as a way of fostering both the individual and the overall strength of high tech industries. It will also develop innovative and enterprising talents for high-tech R&D and industrialization.

2. Major Tasks

In line with national objectives and market demands, the program addresses a number of cutting-edge high-tech issues of strategic importance and foresight during the 10th Five-year Plan period. They are:

1) Develop key technologies for the construction of China's information infrastructure.

The 863 Program will focus on developing a number of key technologies in the next five to ten years and establish systems of significant value for application. It aims to accelerate the national socio-economic development, drive industrialization through informatization, and enable China to approach or catch up with international pioneers in selected fields by the year 2005.

2) Develop key biological, agricultural and pharmaceutical technologies to improve the welfare of the Chinese people.

The 863 Program will concentrate on developing key technologies in agriculture, pharmaceuticals, and other related areas. It will enhance the overall bio-technological R&D level and capacity by a significant margin.

3) Master key new materials and advanced manufacturing technologies to boost industrial competitiveness.

The 863 Program attaches importance to developing nano-material and other new materials, along with related technologies for the development of aviation, the maglev train, information storage and access, in order to meet major demands of national security and economic development by utilizing China's characteristic resources, environment, and technical strength. Pursuant to advanced manufacturing technologies which cater to globalized agile manufacturing in the 21st century, the Program will develop advanced integrated manufacturing systems and common key technologies leading to the development and upgrading of China's manufacturing industry.

4) Achieve breakthroughs in key technologies for environmental protection, resources and energy development to serve the sustainable development of our society.

3. Development Priorities

In accordance with major tasks, development priorities are categorized into Priority Projects and Key Projects.

Priority Projects are guided by encouraging innovation, obtaining IPR proprietorship and addressing key technological issues. Priority Projects conduct R&D in 19 subjects which impose the most significant impact on enhancing China's overall national strengths. These subjects range over 6 high-tech priority fields in the civil sector, including IT, bio-technology and advanced agricultural technology, advanced materials technology, advanced manufacturing and automation technology, energy technology as well as resource and environment technology.

Key Projects are centered on major systems and projects and guided by pooling resource to address significant high-tech issues in line with demands of major national strategies, the market and application. These issues bear strategic significance on China's high-tech development and participation in international competition. They will facilitate the formation of new economic growth sources and industrial clusters with international competitiveness, and serve as demonstration. They are also crucial elements in enhancing the competitive edge of major industries, facilitating industrial upgrading, developing China's own features of high technologies, and realizing "leap-frog" progress in the high-tech field.

4. Organization and Management

1) Expert Responsibility System

During the 10th Five-year Plan period, the Program continues practicing an expert responsibility system to engage the full role of experts in technical decision-making and judgments of the high-tech development trend while further developing the decision-making role of the government. The system is tiered with expert committees (priorities) and expert panels (subjects). The former supervise, assess, and give advice on project implementation in relevant priority fields. The latter is responsible for technical decision-making on relevant subjects and their project process management.

2) Project Management

During the 10th Five-year Plan period, the Program adopts project management system which includes calculation of the full budget, total cost accounting, and a project leader responsibility system. To pool resource and focus on key issues, key projects are managed by the general expert panel. As for R&D budget management, priority projects will be mostly financed by the government and adopt a project budget system. Meanwhile, local governments, industries, enterprises and the whole society will be encouraged to increase input into high-tech R&D.

3) Relevant Measures

A series of measures have been adopted for the smooth implementation of the program in the 10th Five-year Plan period.

(1) Encourage innovation. In project award and evaluation, proprietary intellectual property right (IPR) acquisition is adopted as an indicator to encourage innovation.

(2) Enhance the innovation capacity of enterprises and push them to become technical innovation entities. For application-oriented research, we adopted measures in project application, assessment and evaluation.

(3) Strengthen IPR management and protection. We strengthen study and analysis of IPR before and during project implementation and clearly define the rights and interests of the State, project stakeholders, and concerned parties in the application, development, and utilization of IPR.

(4) Strengthen the integration of the Program with local high-tech development. We initiated guidance projects to guide local high-tech development and associated industries to nurture economic growth sources.

(5) Encourage international cooperation. Special funds are earmarked to facilitate the integration of the 863 Program with the "Program on Major International Cooperation Projects", and support and encourage the implementation of international cooperative projects within the framework of the 863 Program.

National Basic Research Program of China (973 Program)

The Origin and Strategic Significance

The National Basic Research Program (also called 973 Program) is China's on-going national keystone basic research program, which was approved by the Chinese government in June 1997 and is organized and implemented by the Ministry of Science and Technology. The 973 Program is created on the basis of existing research activities and deployments made by the National Nature Science Foundation and major dedicated pre-studies, to organize and implement basic research to meet the nation's major strategic needs. The Program has gathered together strong expertise to launch innovation studies of major scientific issues relating to sustainable development such as agriculture, energy, information, resources and environment, population and health and materials in line with the national goals and tasks for the economic, social and S&T development. Stipulation and implementation of the 973 Program is an important decision of our country to carry out the two development strategies of " Rejuvenating the country through science and technology " and " sustainable development", as well as to further reinforce basic research and science and technology work. It is an important measure of our country to achieve the great objectives of China's economic, scientific & technology, and social development by 2010-2050 , to upgrade the sustainable S & T innovative capabilities and to meet the challenges of the new century. Through the organization and implementation of the 973 Program, we will create an excellent scientific research environment, intensively support a group of outstanding scientific research teams, conduct important innovation research, and scale the peak of the world's science, thus promoting the magnificent development of the China's basic research and the hi-tech industries. This is of much significance for fulfilling the national strategic objectives.

The Objectives and Tasks

The strategic objectives of the 973 Program are to strengthen the original innovations and to address the important scientific issues concerning the national economic and social development at a deeper level and in a wider scope, so as to improve China's capabilities of independent innovations and to provide scientific support for the future development of the country.

This program has four main tasks. The first is to conduct multidisciplinary comprehensive research and provide theoretic and scientific foundations for the settlement of the important scientific issues regarding the development of the national economy and society as well as the science itself in the fields of agriculture, energy, information, resource and environment, population and health, materials, and etc. The second is to deploy relevant, important and explorative forefront basic researches. The third is to nurture a number of outstanding personnel with high scientific qualification and creative capability, whom could be to meet the requirements of development in the 21st century. The fourth is to built a group of high-level scientific and technological assignments of the country, thus constituting some interdisciplinary scientific research centers.

Overall Deployment of the 973 Program

Since the implementation of the 973 Program, we, in accordance with the principles of adopting a broad overview of the present situation and giving prominence to the focal points, and in line with the macroscopic guidance of national objectives, have defined the overall work deployment and made reasonable arrangement, reflecting the Chinese government's requirements of providing momentum and headspring to technical innovations, and providing support to the sustainable development of economic and society. Over years of evaluation of the research projects, we've already put 133 projects under the authorized program by the end of 2002, including 17 projects in the agricultural sector, 15 in the energy, 18 in the information, 24 in the resource and environment, 21 in the population and health, 19 in the material, and 19 in the synthesis and frontier science. We've appointed 175 chief scientists for the projects, and made financial investment of 2.5 billion RMB in the Ninth Five -Year Plan. 973 Program not only absorbs the largest investment from the central government among China's basic research programs since the founding of New China, but also is composed of single projects with the largest investment by the Chinese government. On average, every single project enjoys a strong support of up to 20-30 million RMB over a span of 5 years.

In the course of arranging 973 Program, we have not only intensified the analysis of and strategic research on the important demands of the country, but also conducted research on some important issues, such as industrial restructuring of the national economy, the development of new and high-tech industries, the economic and social informatization, the improvement of people's health and living standards, the natural resources and their effective utilization, the harmonious development of ecology, environment and society, the great development of the regions and etc.

Organizing and Managing the 973 Program

Establish a high-level advisor committee

In accordance with the decisions made at the third meeting of the former National Scientific and Technological Steering Group, the Ministry of Science and Technology has set up a high-level advisor committee through appointing two groups of eminent scientists numbering 33 successively, who not only have profound understanding of the basic research and important national demands, but also can fully reflect the opinions of the scientific and technological society. This committee is responsible for offering consultation advice, assessment and supervision on the stipulation of the National Key Basic Research Development Program, and the organization and selection of the research projects of the 973 Program, so as to fully assure the scientific, democratic and impartial feature when evaluating and putting the 973 projects under the authorized program. In recent years, under the leadership of Professor Zhou Guang-zhao, the advisor committee has made arduous efforts in facilitating the start-up and implementation of the 973 Program, and played an extremely important directive and advisory role.

Implement a mechanism of expert management of projects and supervision on the operations In the course of organizing and implementing 973 Program projects, we rely on the experts and give full play to them. We appoint chief scientist for the 973 Program projects, who are entrusted with full power of leadership. We've also established expert teams for the research projects, which offers much more room for the chief scientists and expert teams to make decisions by themselves, so that the research plans and preset objectives of the projects can be achieved successfully. A number of effective measures have also been taken to encourage and motivate all participants' enthusiasm and creativity.

In order to strengthen the dynamic management, supervision and inspection on the whole courses of implementing the 973 Program projects, we have also established excellent supervisory mechanism for the projects operations. We set up a consulting group, which appoint senior experts and scholars from relevant fields to conduct follow-up observation and research during the implementation of the projects. These experts in turn put forward their comments and suggestions directly to the Ministry of Science and Technology, so as to help chief scientists and project expert teams to fulfil the preset objectives more effectively. Carry out "2+3" new mode of project funding

For the funding of 973 Program projects, we adopt a new mode of "2+3", namely, a stage-by-stage funding. Two years after each project is implemented, a mid-term evaluation and inspection should be conducted. Based on the actual performance and the evaluating comments of a special expert group, the decision will be made on whether the preset tasks should be continued, or whether the preset amount of funding should be adjusted in the next three years. By doing so, we can avoid the situation that great efforts are made to put the project into the authorized program, while "research subject and team becomes rigidity and the thinking becomes ossified" during the implementation of the project. Hopefully this mode will help keep its fresh energy and vital force while promoting the competitions among different projects and subject teams.

Implement subject management system

In accordance with the international practice in the financial management of scientific and technological projects, we firstly implement the "subject management system" for funding the 973 Program projects in China. Namely, we conduct the total fund budgeting by subjects calculation, process control and full cost accounting inside of the projects. This gives chief scientists and subject leaders bigger decision-making power to employ high-level scientists from home and abroad to join the projects. Also, the allowances and wages of the employees can be defined and clarified through contracts. As an important breakthrough in the financial management of China's scientific and technological projects, this practice further embodies the actual value of the scientists and technicians engaged in the program and greatly motivates their activity and creativity.

The implementation results of the 973 Program

Over the past five years, the organization and implementation of the 973 Program has been going on successfully, which has drawn close attention and high recognition from China's scientific society, particularly those scientists who are engaged in the basic research. Furthermore, it has resulted in a bunch of exciting research achievements in a short period of time. According to incomplete statistics of the 87 projects of the 973 Program over the past four years, various scientific and technological articles releases home and abroad have totaled up to 15500, including more than 7300 SCI and EI articles and 221 relevant research books. And 485 patented technological inventions have also been licensed in the same period.

The implementation of the 973 Program has remarkable impact on the scientific and technological society, and greatly boosted the rapid improvement of China's international competitiveness. The Formulation of the 973 Program offers an important deployment for the strategic development of China's basic research. And the organization and implementation of the Program exerts an important influence on China's scientific and technological society and draws close attention and high recognition from both the scientific and technological society and other social circles. The entrance into WTO means that China will participate in the global economic competitions in a large scope and on a deeper level, which will surely result in important and deep impact on China's economy, society, science and technology. Presently, the developed countries are accelerating their paces to transfer their technological advantages into market monopoly throughout the would. This is vividly reflected by the protection of intellectual properties, possession of patents, and their restrictions imposed on the developing countries. The implementation of the 973 Program further emphasizes the original innovations and independent intellectual properties in China's research. At the same time, great efforts have been made to carry out the strategies of patent and technical standards, thus rapidly uplifting the number and quality of China's patents and improving the international competitiveness of China's science, technology, and economy.

Absorb and gather a bunch of outstanding scientific and technological experts, and foster a bunch of high-quality academic researchers.

The implementation of and strong financial support from the 973 Program promotes the stabilization of China's scientific research team and the training of the young and middle-aged experts. Plus, it provides a stage for the outstanding overseas Chinese people to return home to serve the motherland. The projects of the 973 Program have absorbed and gathered a big bunch of outstanding scientific researchers from home and abroad. Some of them are the older-generation scientists who enjoy moral eminence and high esteem, while others are young and middle aged researchers who are creative and pioneering. According to statistics, out of the 108 chief scientists who responsible for the 87 projects that have already been initiated and implemented, 2 persons are from the research institutes headquartered in a foreign country and Hong Kong. Since the 973 Program was started up, 166 CAS academicians and 59 CAE academicians have already taken part in the organization implementation of the Program and the research work of the projects. From the "Hundred Talents Program" of the CAS, the "Cheung-Kong Scholar Program" of the Ministry of Education, and the "National Science Fund for Distinguished Young Scholars" of the National Natural Science Foundation and some other national outstanding scientists assistance and training programs, a total of altogether 516 people have participated the project research of the 973 Program in succession. Over years of arduous work, 87 projects have trained 720 postdoctoral, 2671doctors and 2641 masters. We can believe that there will be more emerging outstanding young scientists after a period of implementation of the projects.

Promote the "trans-departmental and trans-field" cooperation among the research institutes, universities, companies and regions. Through the organization and implementation of the 973 Program, we have further enhanced the understanding of different social strata and the scientists about the importance of basic research. In particular, the idea that "in the new era, the basic research should be done in line with the important national requirements and aimed at resolving the important scientific issues regarding the development of national economy and society" has profoundly influenced the whole society. The industrial departments, local governments and companies have been gradually driven to pay close attention to and provide great supports for the strategic basic research, thus gradual overcoming the bias of "emphasizing research while ignoring application" which used to be quite popular among scientists and researchers for a long time. This has improved their understanding of intellectual property rights and economic effects. The implementation of the 973 Program has promoted the combinations and close collaborations among universities, institutes and industrial sectors, intensified the cohesive force of the scientific and technological society, spurred the intersection and integration of various disciplines, as well as greatly improved the actual capabilities of resolving important issues. This enables the scientists to utilize the limited resources and focus the strength on basic innovative research, in line with the national objectives, so as resolve the important issues in national economic construction and social development.

Important program has already been made in the 973 Program

The "Basic research on the new-generation iron & steel material" by applying the in-depth research on the mechanism of the formation of the micro-structures and the transformation inducements of the steel materials, as well as the exploration of the basic theories about metallurgy such as the micro-alloying of highly clean steel, through seeking the grain size number of the refined steel materials. It has made breakthrough in improving grain size number of the steel, the technological process and control technology for the improvement of the steel uniformity, and improvement of the intensity and life of the steel materials. Scientists conducted the industrial experiment of deformation-induced phase transformation on Q253-steel (annual production capability is 40 million tons all over the country) in Bao-shan and An-shan steel and Iron complexes respectively, and the reliability of the research achievements has been proved under industrial conditions, thus improving the yield strength of the carbon steel from 200 MPa to 400 MPa. This was the first large-scale experimental research in the would, which has transfered the achievements of the basic research into industrialized production site in a short period of time, displaying exciting application prospects.

The project of "Establishment of the theoretical and technological system on the disease genome" has located sites for pathogenic genes related to single-gene of multi-gene disease, established models for genetic esophagus and nasopharyngeal cancer, and conducted in-depth structure-function research on pathogenic genes of high-frequent deafness and leukemia. At the same time, the projects has carried out overall and multi-level research on disease models (such as liver cancer) on aspects of genome structure variation, expression spectrum, and biochemical adjustment network, indicating further breakthroughs in the near future. Scientists have also conducted overall research on the regulating gene in differentiation induction therapy of acute promyelocytic leukemia with all-trans retinoic acid", and successfully isolated 169 genes regulated by retinoic acid, thus providing theoretical guidance for the clinic comprehensive therapy, and the prevention of recrudesce and anti-drug mechanism of the disease. Scientists introduced the method of located candidate cloning technology, and did research on the genetic opalescence dentine genealogy, and figured out for the first time in the would that the pathogenic genes of the disease is DSPP. In-depth research on the pathogenic genes of the finger (toe) skeletal deformity genetic diseases have also been conducted, such as short finger (toe) disease, and found for the first time that the three variations of the IHH gene are the direct causes of A-1 type short finger (toe) disease.

For the project of "Nanometer material and nanometer structure", on the basis of directional growth of super-long (2-3 mm) carbon nanometer pipe arrays with large areas of underlay, scientists have successfully produced the super-thin carbin nanometer pipe with the inside diameter of only 0.5mm. They produced nanometer copper by using the electro-deposit technology, figured out that the material can obtain 5100% elongation rate under the normal room temperature, and pointed out the mechanism of elongation rate under the normal room temperature, and pointed out the mechanism of elongation is that high crystal integral of nanometer metal Cu is the important cause of super elongation. They have also made a series of creative progress, for example, the production of the sequential arrays of GaN mono-crystal uni-dimensional nanometer threads, the research and production of the coaxial nanomater cable with GaN at the core, BN outside and diameter of 50nm, the assembly of the thinnest probe with the best performance in the would by using the single-wall carbon nanometer pipes in channel-scanning microscopes, and the production of hexahedron GaN nanometer crystal with benzene heat prefabrication technology.

The "research on structural performance, molecular design, micro-structural design and manufacturing process of the photo-electrical functional crystal" has first discovered theoretically and then proved in experiments that inside the dielectric crystal lattice composed of piezoelectric and ferroelectric materials, there exists coupling between the super-lattice vibration and the electromagnetic waves. And the project has put forward the new concept of "ion type phonon crystal".

The researchers of the project have successfully produced high-quality big crystal, such as YCOB, Nd:YCOB, and GCOB, and have found out experimentally that the most effective power output direction is not on the main plane, which was recognized in the would. The YCOB direct double frequency has been obtained and the acquired output efficiency of the green light is 15% higher than the best result abroad. The Nd:YCOB crystal has been used to obtain the self double frequency green light output in the most effective power output direction. Through the super-lattice micro-structural design, the laser direct triple frequency theory and methods have been developed, and the big-sized triple frequency optical supper-lattices with different structure sequences have been produced. For the first time, the small and completely solid optical maser with two wavelengths of UV-green and red-blue has been produced. This achievement is the first experimental result with application value, regarding the quasi-crystal and quasi-period material in the field of non-linear optics since the quasi-crystal was found.

The project of "digital mechanization and automatic reasoning platform" puts forward three methods of automatic geometric construction: overall continuation, symbol computation and data value optimizing, which have been utilized resole the p3p space localization issue, the restriction conflict between Kempe connecting rod design and smart CAD, as well as divider and ruler construction issue. On this basis, the concept of "engineering geometry" has been brought forward. The project also saw certain breakthrough in the research on the application targets, and gave the mechanical method of the conformation and selection of small waves as well as its application in the dynamic image data compression, particularly the dynamic image data compression on the targeted areas. This technology has broad application prospects in confidential telecommunication, video telephone, remote sensing, tele-healthcare. And the proposal about "multi-elemental transformation" technology has been adopted by the JPEC 2000 image compression international standards and written into the related chapters of the second part of the final draft.

The "Forecast research on the evolution of China's future living environment and North China's aridity trend" develops the integrated model of regional environment system for the quantitative forecast of the aridity trend. The model has excellent capability of simulating the climate characteristics of North China's arid and semi-arid regions, and plays a leading role in the international plan composed of ten regional models for Asian area. The project puts forward the forecast of the aridity trend of North China in the coming 10-15 years. (1) As a result of the long-term evolvement of the natural environment, Northwest China will keep its aridity, and the weak fluctuation of the precipitation can't change the arid situation. (2) The North China and the west of Northeast China, where aridity has been fiercest in recent years under the actions of natural fluctuation, global warming and the human impacts, will continue to see accelerated aridity in the forthcoming 10-15 years.

In the next 30 years, the natural fluctuation will make the areas enter the relatively wet period. Provided that regional eco-environmental damages are controlled after the global warming trend is offset by the natural fluctuation, the aridity velocity may be reduced and the drought may be eased.

It can be estimated that, with the continuous development of the 973 Program, these on-going research projects will play an incredibly promotional role in China's economic construction, social advance and scientific and technological development.

Vision about the 973 Program during the Tenth Five-Year Plan period

During the Tenth Five-Year Plan period, the 973 Program, in line with the overall arrangement stipulated in the Tenth Five-Year Plan for scientific and Technological Development of China, will be oriented to meet the national important demands, and address the important scientific and technological issues concerning social advance and national economy, and to prioritize the improvement of China's original innovation capability. The 973 Program will follow the development concept of "stability, consolidation and perfecting", give prominence to key projects, enhance integration, and continue to plan a strategic development of national key basic research. Through the in-depth implementation of the 973 Program, we should be further upgrade the scientific and technological level, particularly the overall level of basic research, so as to make due contributions to the grand objectives of making China a scientific and technological power by mid-21st century.

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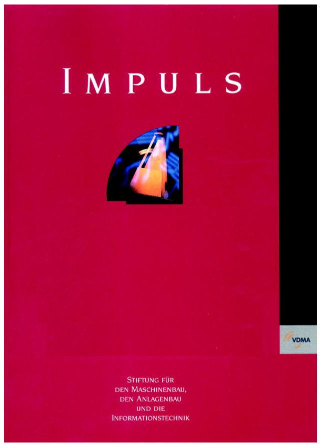

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