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The Impact of China's Five-Year Plans on Strategic Industries
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1. Introduction

In this initial draft of my testimony, I attempt to shed light on the following questions:

1. To what extent and in what ways is China's manufacturing sector catching up with US manufacturing?
2. What are the factors responsible for driving the catch-up process? What are the major impediments to catch-up? What are some of the relevant examples?
3. To what extent is China's innovation system advancing and catching with OECD countries?
4. What are the principal weaknesses of China's innovation system and impediments to the catch-up process?
5. What recommendations might emerge from this analysis?

2. Manufacturing Catch-up

In our research on China's manufacturing sector,[1] my research colleague, Professor Paul Deng at the Copenhagen Business School, and I find that two factors are highly statistically robust indicators of the rate of China's manufacturing catch-up, i.e., reducing the manufacturing labor productivity gap with U.S. firms. These two factors are i) the size of the initial labor productivity gap between the Chinese firm and the average productivity of the corresponding

[1] "Will China Escape the Middle- Income Trap?," draft, December 22, 2014.

U.S. 3-digit SIC industry and ii) the rate of productivity growth of the corresponding U.S. industry.

Highlights of Figure 1. The scatter plot shows a very clear relationship within Chinese manufacturing between the rate of firm labor productivity growth and the size of the productivity gap (measured as the log) with the U.S. frontier of the Chinese-based firm. The larger the firm's productivity gap, the higher its rate of catch-up productivity growth. The graph shows that at the firm level, Chinese-based manufacturing firms span a wide range of productivity gaps with the U.S. as well as a wide range of annual rates of labor productivity growth. Despite the variation, the inverse relationship between them is size of the gap and the rate of productivity growth is evident.

Highlights of Figure 2. Figure 2 shows the relationship between the same U.S.-China productivity gap and the related rate of *growth of catch-up*, i.e. the annual rate of growth of gap reduction. Because in this figure the firms have been aggregated by their 3-digit industrial classification, the spread is more concentrated than that shown for the individual firms in Figure 1. Since this graph represents the rate of catch-up, the rate of growth of the Chinese firm's labor productivity and the rate of growth of productivity at the U.S. frontier both matter. As shown in Figure 2, the relationship between the rate of gap reduction and the size of the initial gap is also extremely robust. In the figure, the industries in the northwest quadrant and those in the southeast quadrant have been highlighted.

The industries shown to the northwest are largely those in the primary metals sector, such as steel production. It turns out that for each of these industries, the rate of growth of productivity of their counterpart U.S. industries was relatively slow; hence for a given gap, the catch-up rate for the Chinese firms was unusually high. By contrast, for the industries in the southeast quadrant of the figure, the rate of productivity growth for the corresponding U.S. industries was relatively high. Hence, notwithstanding the large gap, this high U.S. productivity growth impeded the rate of catch-up for the corresponding Chinese firms, including petroleum and coal products, chemicals, apparel, and computer and electronic products.

Regression analysis shows that the rate of growth the productivity at the U.S. frontier critically affects the rate of productivity growth and catch-up for the Chinese-based firms. In general, every 1% increase in the rate of productivity growth of a U.S. industry (e.g., from 4% to

5%) boosts Chinese industry productivity growth by 0.3 to 0.4%. On the other hand, the same productivity growth for the counterpart U.S. firm slows catch-up by 0.6 to 0.7%, on average. That is to say, as the U.S. frontier shifts out its productivity, about one-third of the productivity advance at the U.S. frontier appears to spillover to China within 5 years of the advance; otherwise, productivity growth at the frontier slows the process of catch-up.

Highlights of Figure 3. Figure 3 tells a more granular story about the iron and steel industry. As described above, this industry appears to perform particularly well from 1998 to 2007. Figure 3 explains, in part, why that was the case. It shows the capacity utilization in the iron and steel industry rising prior to 2007 and then peaking in that year. Indeed, Table 1 will show that in 2007, the iron and steel industry (i.e., primary metals) had achieved the smallest gap with its U.S. counterpart (i.e. nearly 30% of the U.S. average). However, thereafter, in part due to the international financial crisis but also due to coordination problems, the industry fell into a period of a substantial decline in capacity utilization, mitigated only during 2009-2010 by the temporary Chinese stimulus.

Explanation of Figure 2. Figure 2 (from a paper by Dr. Markus Taube) summarizes China's pervasive problem of multiple principals. It shows the multiplicity of central government agencies that exercise oversight of China's iron and steel industry in which state-ownership is extensive and the vertical divide between these principals of the central government and the local governments and individual enterprises. While the central government is generally intent on rationalizing the distribution, product mix, and capacity of iron and steel, local governments are often hungry to expand their tax bases and employment thus encouraging redundant investment from the national perspective.

In an attempt to address this problem, China's 12th 5-year plan acknowledged the problem of a proliferation of Chinese-owned enterprises and plants. Ch. 9 sec. 4 sets forth the following provision: "Drive advantaged enterprises to carry out alliance, cross-regional merger and reorganization, and increase industry concentration with an focus on automobile, iron and steel, cement, machine building, electrolytic aluminum, rare earth, electronic information, and pharmaceutical industries, etc." Still, as shown in Figure 2, within the iron and steel industry the problem of overcapacity became more pronounced during the 12th 5-year plan. The problem is reflected in the next table (Table 3), which shows the share of sector production represented by the 10 most efficient industries in each sector. The 10-firm value-added shares for the industries cited in the Plan for consolidation include just 5% of value added in the primary metals sector, 4% in chemicals, and 3% in machinery.

Highlights of Table 1: Table 1 shows that for total manufacturing, from 1998 to 2007, the U.S.-China gap in the average levels of value added per worker declined from about 20:1 to 7:1. In both years, the top-decile productivity firms in China exhibit a much smaller gap, i.e. rising from just 30% of the U.S. average in 1998 to 70% in 2007. In the latter period, the top decile firms accounted for 35% of total Chinese manufacturing output, suggesting that the scale of the more efficient firms was well above average (3½ times the average size). In 2007, for 3 of the 18 two-digit industries, China's top decile firms show higher average levels of productivity than the corresponding (full) industry averages for the U.S. Table 1 also shows the average of China's 10 most productive firms in each industry. The ratio of productivity of the top 10 firms to the U.S. average is quite striking. In 1998, average productivity for two of the 18 industries exceeds the U.S. industry average. By 2007, the number of top 10 firm Chinese clusters exceeding the U.S. industry average rises to 15 of 18 industries.

This last result – the finding of the relatively high productivity of the top 10 firms within each industry – raises the possibility that China has created its own internal frontier. That is firms, such as Huawei in telecommunications equipment, BYD in batteries and electric cars, SunTech in solar panels, Haier in white goods, and Xiaomi in smartphones may themselves represent technology frontiers against which to measure the progress of the lagging elements of Chinese industry.

Highlights of Table 2. This table attempts to address the factors that are most important policy-related instruments that are driving China's productivity advance. An extensive literature shows a range of factors that bear upon the dynamic of catch-up, but two of these stand out. These are: i) technology or productivity spillovers from regions or industries with concentrations of foreign direct investment to Chinese-owned firms within those regions or industries[2] and ii) import completion that drives firms to upgrade.

Some of these studies also find evidence of a so-called "separation effect". That is, in the face of foreign entry and FDI and also, with or without FDI, in the face of import competition,

[2] Deng and Jefferson (2011).

Chinese firms that are relatively efficient tend to benefit the most, whereas firms that are relatively weak are more likely to struggle from a loss of market share. Specifically, the research shows that in the face of FDI and/or import competition, the stronger firms tend to load up on R&D in order to upgrade their capabilities, an effort, which may be facilitated by the very fact of FDI and/or import competition. Using R&D resources the more capable Chinese firms use their R&D to capture technology from the foreign firms within the same industry or geographic area or they may use imports in order to reverse engineer products that enter the markets in which they compete. Within these competitive product markets, Chinese firms may, in particular benefit from the phenomenon or "learning by using," which refers to the process of gathering feedback from markets which are purchasing and using one's own products as well as those of competitors.

Table 2 shows the China's top five manufacturing import sectors. Five of the 10 top imports are raw materials. The table also shows that these same five top manufacturing import sectors account for 5 of the 8 principal export industries. The top industry on both lists, i.e. electronic equipment, is a good example as it includes mobile phones and smart phones and computers. Whereas during the 1990s and early 2000s, China was a major importer of these products or the component that it assembled for re-export, presently Chinese companies have moved substantially up the value chain. For the mobile phone industry, the succession has moved from Motorola to Apple to indigenous smartphone suppliers, such as Xiaomi. For the computer industry, Chinese made and exported Hewlett-Packard laptops and printers have successively moved up the value chain as has Lenovo, in part through the acquisition of the IBM personal computer unit. These are key illustrations of the argument that FDI and imports competition are a critical aspect of the rising capacity of Chinese firms to establish a substantial presence on both domestic and international markets. They help to explain the dynamics of the progression of firms, as shown in Figure 1, and industries, as shown in Figure 2, to move down the GAP curve resulting in both a degree of catch-up, but also, in the process, experiencing slower growth of productivity and slower rates of catch-up.

Consistent with this account, my research with Professor Deng gives support to the notion of a separating effect in which as the U.S.-China productivity diminishes, we tend to observe the phenomenon of break-out firms. This is evident from the fact that within 3-digit industries with smaller gaps, we observe a wider spread (or standard deviation) of the firms that comprise those industries. Hence, catch-up seems to be a dynamic of the break out of a sub-group of firms, not so much the alternative in which the comparatively backward firms catch-up to the industry norm or drop out altogether.

The computer chip industry is added to the lists shown in Table 3. This is because it is such a critical industry and also because it may well be in the early stages of the dynamic in which an industry with a high intensity of imports transforms itself into becoming a substantial exporter. This testimony later references the computer chip industry.

Finally, with respect to the efficiency comparisons of the U.S. and China, Table A1, in the Annex, shows the comparative productivity of 3 U.S. firms and 3 Chinese firms. My colleague, Aiyi Zhang and I prepared undertook this analysis, so that unlike Table 1, which compares various groupings of Chinese firms with the U.S. average, we could instead attempt to compare the a Chinese frontier with a U.S. frontier. The firms used for Table A1, both the Chinese and U.S. firms, are virtually all publicly traded; some of the Chinese firms are well known. The comparisons show that relative to the all-industry gap comparisons, the U.S.-China gap using the top 3-firm data is somewhat smaller. At 2.28, the average 3-firm gap is about 25% smaller than the 3.06 gap for the comparative full-industry average comparisons. Five industries exhibit a gaps of 1.5 or less; while two of these – primary metals and computers – appear to match or better their U.S. counterparts. Clearly, convergence and occasional catch-up are ongoing phenomenon in Chinese manufacturing.

3. Comparisons of China's Innovation System with the U.S. and other OECD Country Systems

Clearly the surge in innovation effort and measures of innovation output is a critical part of the story of the rapidly growing scope and capabilities of Chinese industry. Table 6 shows some summary statistics which may be helpful.

Highlights of Table 3:

- First, we see from the total column that by 2012, China was well on its way to entering into the2-3% range of R&D/GDP intensity occupied by most of the larger

OECD countries, S. Korea, Singapore, and Taiwan. However, as shown in the basic column, the composition of Chinese R&D spending is notably tilted away from basic research, which accounts for about 5% of total R&D spending. In 2012, for the U.S. that proportion was approximately 18%.

- Higher education accounts for nearly 55% of basic R&D. China's research institutions account for 40%. Over the past 20 years, universities have been playing a larger role in China's basic research, while the relative contribution of the research institute sector has diminished.
- At 76.2%, the principal source of R&D spending is enterprise self-raised funds. This proportion exceeds most OECD countries.
- In 2012, government accounted for 21.6% of total R&D spending in Chinese industry. The R&D contribution of the foreign sector was largely through spending within foreign-invested firms, i.e., the enterprise sector.
- Table 3 also shows the government share of R&D spending by province. Unsurprisingly, due to its concentration of universities and research institutes (e.g., the Chinese Academy of Sciences) at 53.7% Beijing shows the highest proportion of government-sourced R&D. Liaoning Province, the seat of a substantial number of state-owned enterprises, received 23% of its R&D spending from the government. At the other end of the spectrum, Zhejiang Province, known for its robust private sector, shows a government funding share of 8.3%.

Significance of Figure 5: Figure 5, trends in Federal R&D, shows federally-funded R&D spending as a share of GDP. While the measure we have used for the Chinese government's share is measured relative to total R&D spending, this figure shows federal R&D as a share of GDP. However, because we know that for the U.S., total R&D spending is in the range of 2.8% of GDP, we can infer that as a share of total R&D spending in the U.S., the government's share is about 29% of the total. Government's share appears to have declined over the past 30 years; particularly that of defense spending.

Highlights from Table 4: While not the only measureable output of R&D activity, the incidence and quality of patenting may be the most important single measure of R&D productivity. This is the case notwithstanding extensive survey literature that indicates that, at least for American firms, with the exception of the drug industry patenting is not the principal means of securing intellectual property.[3] Since China's patent law was established in 1985, the incidence of patenting has surged, so that SIPO now receives more patent applications than any other patent office in the world.

Table 4 documents the distribution of patenting in China's State Intellectual Property Office (SIPO) across three patent types (invention, utility, and design) during 2012. In China, invention patents are typically of substantially higher quality than the alternative utility model and design patents. The former, of 20 years duration, are subject to greater patent review scrutiny than the latter two types, which receive only 10 years of protection. Table 3 also shows the distribution of patenting activity by domestic and foreign patent applicants and patent holders and for domestic patent sources, it shows the type of organizational unit (e.g., enterprise, university, etc.). The lower tier of Table 4 shows some comparative patenting statistics from the U.S. patent office.

Here are some of the highlights from Table 4:

- Only about 1/3 of the patent applications are for invention patents, versus approximately 90% for the U.S. Among these invention patent applications filed with SIPO, approximately 30% are approved.
- Foreign-owned entities within China account for approximately 18% of the invention patent applications and about 33.7% of the patents grants. The vast majority of patents, particularly for Chinese patenting, is concentrated in lower-value utility model and design patents. Because the approval process for utility model and design patents is typically shorter and less rigorous, entities will sometimes file for one of these patent types as a place holder for an invention patent application. Since the review period for invention patents has been shortened and having more than one patent application pending for the same innovation can result in legal complications, this practice has been somewhat curtailed.

[3] See Cohen, Nelson, and Walsh (2000), who find substantial differences across industries in strategies used to secure IP rights. For example, in most industries, secrecy and lead time were cited as more important than patenting as a means of securing intellectual property. The pharmaceutical industry was the only industry listing patents as the most important measure.

Table 4 also reports various data from the USPTO for 2007 and 2014 for granted utility (invention) patents. Among the highlights are:

- In 2012, China granted 217,105 invention patents, of which 143,847 were granted to Chinese applicants. In 2012, the USPTO granted 3000,678 invention patents of which 144,621 were granted to U.S. applicants and 156,057 to foreign applicants, of which 7,236 were Chinese filers.

There has also been a growing body of research concerning patent production functions (i.e. the relationship between inputs to innovation, notably R&D, and patent outcomes), the impact of government patenting incentives on patent quality, and the implications of patent production for firm performance, including productivity and profitability.

- Hu and Jefferson ("Great Wall of Patents", 2007) find a relatively weak link between R&D and patenting, i.e., substantially weaker than counterpart US and EU studies; however, FDI spillovers exhibit a substantial impact on patent production. That R&D is even less important for foreign firms that patent indicates that at least during the earlier 2000 period, most of the intellectual property that foreign firms patented in China was transferred from parent companies.
- Various provincial governments offer incentives/rewards for either filing patents and/or securing patent grants. The research shows that incentives to file patents led to more filings; however, a lower proportion of these were granted. Incentives for securing patent grants seemed to motivate patent applicants to draw the scope of the patent claim more narrowly, thus improving the likelihood of approval while at the same time diminishing the potential value of the patent.
- Recent research by Hu, Zhang, and Zhao (2014) find that: i) a significant portion of the surge has resulted from rapid patent growth in regions and industries that had not previously actively applied for patents; and ii) overall the correlation between patents and R&D and between patents and labor productivity has become weaker over time; particularly for the regions/industries with relatively less patenting activity. This may reflect the establishment of patenting incentives for these regions/industries, thus increasing the incentive to patent and its incidence even as new intellectual property has not been created to the same degree.

4. Comparisons and Weaknesses

In summary, Chinese manufacturing has been steadily closing the productivity gap with U.S. manufacturing. It appears that China has created its own technology frontier, although on average the firms constituting that frontier may, on average, exhibit levels of sales per worker that are about one-half that of the U.S.

China's innovation system has transformed dramatically of the past 20 years. Over this period, China's R&D/GDP ratio has risen from less than 0.6% to more than 2%, putting it in a range similar to that of the U.S. and other OECD countries. However, the growing parity in quantity has not been matched with respect to quality comparisons.

No more than 5% of Chinese R&D is dedicated to basic research. This proportion compares unfavorably with the U.S., which dedicates approximately 18% of its R&D spending to basic research and to other OECD countries which typically dedicate in the range of 20% of R&D spending to basic research.

Only one-quarter of the patent grants issued by SIPO and still in force invention patents; more than three-quarters are utility model or design patents for which the patent review is relatively cursory and the patent duration is 10 years rather than the 20-year duration assigned to invention patents. Moreover, for domestic patents still in force, only about 15% are invention patents. Notwithstanding, the rates of growth of SIPO invention patents and the fraction of those issued to Chinese residents is growing rapidly. Also, from a low based, patents issued to Chinese residents by the USPTO are growing rapidly, surpassing the U.K. in 2014, but still some distance behind S. Korea and Taiwan. Concerning specific R&D performing sectors, the following weaknesses are evident.

In the enterprise sector, researchers find low returns to R&D. Also, at the firm level, there is evidence of a weak correlation between patenting and firm-level productivity growth. Moreover, while provincial governments often extend incentives to firms for patenting, such as for securing patent grants, the incentive for patent grants appears to motivate filers to narrow the claims on their patent applications, hence lowering the quality of the eventually-approved patents.

In the higher education sector, all OECD countries dedicate larger portions of their R&D spending to higher education which performs most of basic research, generally in the vicinity of the share of R&D spending captured by the Chinese universities. Within higher education, researchers often encounter limits to their autonomy insofar as schools and departments operate on a more hierarchical basis, so that grants and rewards may not be well-aligned with merit. Also, university professors often engage extensively with consulting with little research payoff.

Finally, China's research sector, while reporting a robust publication record, tends to be surprisingly weak on patent production. While China's research institutes account for 15% of total R&D spending, that sector accounts for only 7.8% of basic research and 5.5% of total invention patents granted. One development that may alter the relatively weak contribution of China's universities and research institutes to China's patent production, is the implementation of a Chinese version of Bayh-Dole Act, which in China, as it has in the U.S. enables recipients using government-financed research funds (i.e. universities and research institutes) to secure patents and retain the revenue generated by their lease or sale.

Notwithstanding these weaknesses of China's R&D system, one development that bears particular interest is the growth of university-corporate collaborations. One such notable collaboration is that of the Tsinghua Unigroup, which has developed acquisitions-partnerships with chip makers, including the acquisition of Spreadtrum in which Intel subsequently acquired a 20% share. This mode of collaboration may well be the harbinger of the sustained growth and development of China's semi-conductor industry along the trajectory shown in Figure A.1.

5. U.S. Recommendations

The following recommendations are intended to follow from the previous testimony.

While China is substantially reducing the innovation gap with the U.S. with respect to several key measures, in terms of quality, China's measures of the quality of innovation outputs continues to lag substantially behind the U.S. Nevertheless, the quality gap is likely to continue closing over the next several decades.

In light of this substantial narrowing of the U.S.-China innovation gap, the U.S. should seek to retain and develop its comparative global advantage, which is that of basic research, including the robustness of U.S. higher education as the focal point of its basic research activity.

Even if the U.S. sustains and expands its commitment to basic research, the U.S. should anticipate that it is very likely that in many quality dimensions of innovation, China will eventually, e.g. within the next 50 years, if not well before, catch-up with the U.S. If this is managed properly, so that both countries are expanding the international technology frontier, global welfare should substantially gain. From this perspective of likely catch-up, it is very unlikely that in 20-25 years that the U.S. will be able to out-spend China on innovation and defense, much of which involves R&D. More importantly, beyond that, i.e. over a 30-50 year horizon, it is very unlikely that the U.S. will be able to outperform China as the leading global innovator with the leading defense technologies.

In light of this catch-up trajectory, in the near term, the U.S. should seek to engage with China in ways that are possible so as to establish a record of collaboration. Specifically, for example, the U.S. should join the Asia Infrastructure and Investment Bank (AIIB). Also, for the purpose of engaging, and over time, collaborating and integrating with China's rapidly expanding research capabilities, as suggested earlier, the U.S. government should fund U.S. universities, so that they can

The following are copies of the slides that were used for Jefferson's presentation on April 22.

Figure 1. Shows how the labor productivity growth (gLP) of Chinese firms responds to the technology gap with the international frontier (i.e., the U.S.)...the larger the gap the greater gLP.

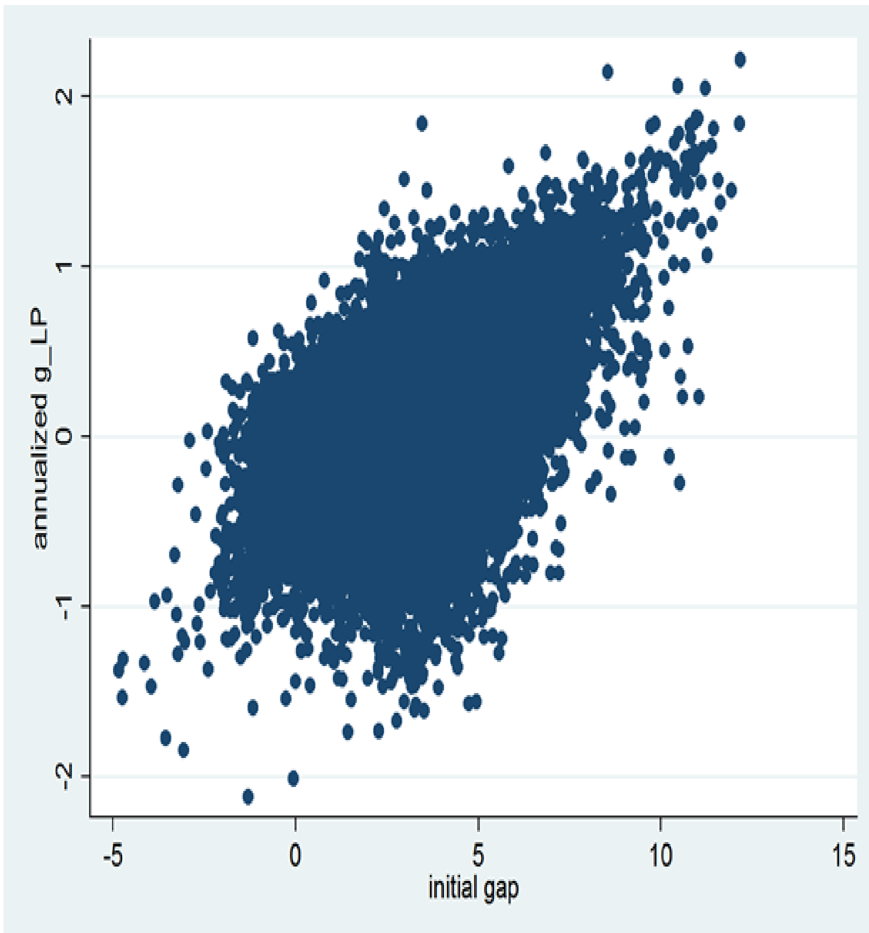


Figure 2. Shows a similar relationship for the rate of growth of catch-up (i.e., gap reduction) relative to the size of the U.S.-China productivity gap –

1. industries to the NW (mostly iron and steel due to relatively slow U.S. LP growth);
2. industries to the SE (petroleum and coal products, chemicals, apparel, computer and electronic products due to relatively high U.S. LP growth.

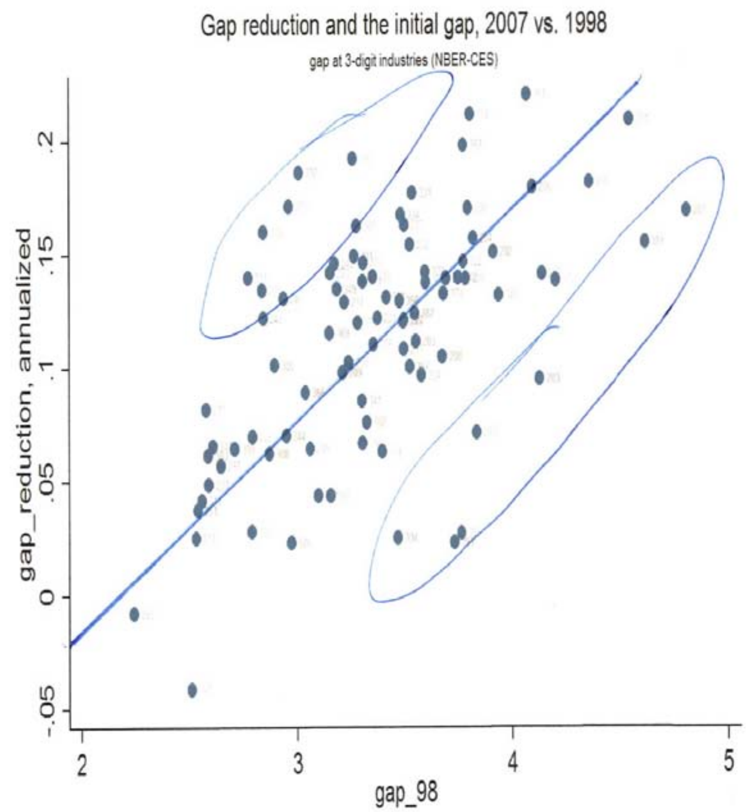


Figure 3. Reversals – 1998-2007 rising capacity utilization in the iron and steel industry; sharp post-2007 decline in capacity utilization…

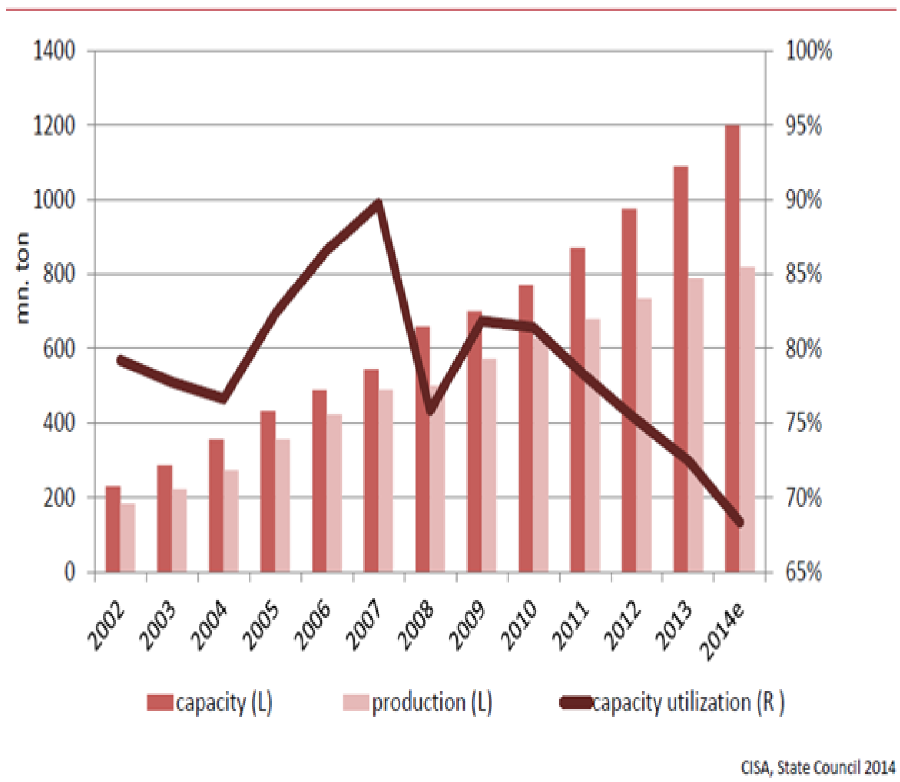


Figure 4. 12th 5-year plan: Ch. 9 (sec. 4) "Drive advantaged enterprises to carry out alliance, x-regional merger and reorganization, and increase industry concentration with an emphasis on…iron and steel (and automobile, cement, machine building…). **The problem…**

(source: Dr. Markus Taube Univ. of Duisburg-Essen)

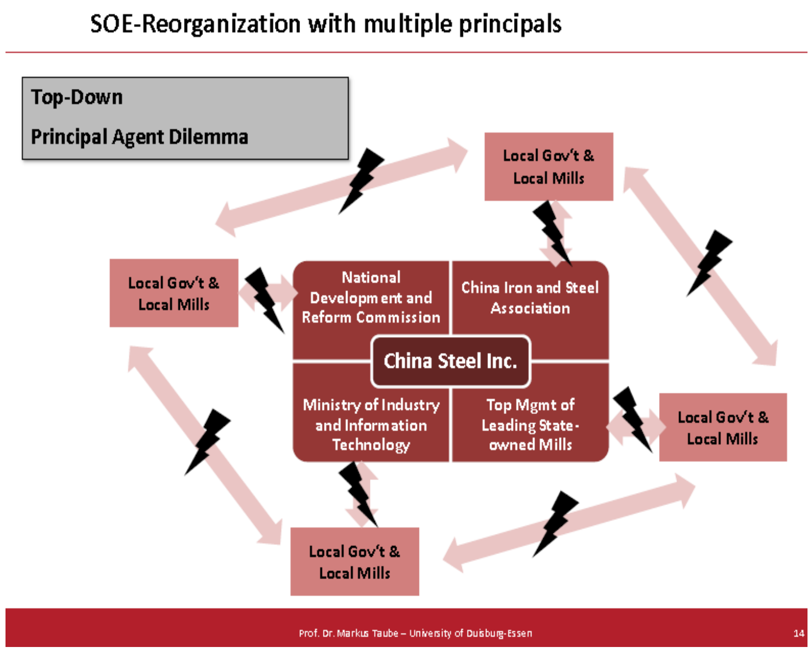


Table 1. Has China developed its own internal frontier?

1. Top decile Chinese firms > U.S. average (3/18) and
top 10 Chinese firms >> U.S. average (15/18)
2. 3-firm comparisons (publicly traded companies):
U.S./China sales/employee advantage = 2.28 (see Table

Table G. Labor productivity by major industry sectors: Industry mean, top decile and top-10-firm average relative to US frontier*

mind2	industry	average LP to frontier ratio		top decile to US frontier ratio			top-10 firms to US frontier ratio			max	
		1998	2007	LP_98	LP_07	VA_share_2y_avg	LP_98	LP_07	VA_share_2y_avg	top1 firm vs US frontier ratio_98	top1 firm vs US frontier ratio_98
0	***Total Manufacturing***	**0.05**	**0.14**	**0.37**	**0.70**	**0.35**	**0.83**	**2.47**	**0.06**		
1	Food and beverage and tobacco products	0.09	0.25	0.55	1.45	0.50	2.20	6.15	0.14	5.24	8.64
2	Textile mills and textile product mills	0.05	0.16	0.37	0.67	0.23	0.84	1.76	0.01	1.51	2.40
3	Apparel and leather and allied products	0.10	0.12	0.66	0.58	0.27	0.99	1.54	0.02	1.67	2.81
4	Paper products	0.04	0.13	0.22	0.45	0.34	0.24	0.97	0.07	0.67	3.62
5	Printing and related support activities	0.08	0.20	0.34	0.77	0.41	0.74	1.20	0.07	2.12	1.86
6	Petroleum and coal products	0.02	0.04	0.07	0.19	0.32	0.07	0.35	0.16	0.10	1.02
7	Chemical products	0.03	0.09	0.19	0.51	0.33	0.60	2.08	0.04	1.07	3.50
8	Plastics and rubber products	0.06	0.14	0.37	0.68	0.28	0.43	1.67	0.03	0.67	8.04
9	Wood products	0.07	0.23	0.49	1.01	0.30	0.56	1.44	0.09	1.28	2.23
10	Nonmetallic mineral products	0.03	0.16	0.22	0.78	0.27	0.54	1.47	0.02	1.25	2.35
11	Primary metals	0.06	0.29	0.49	1.19	0.22	0.65	2.74	0.05	0.97	3.56
12	Fabricated metal products	0.06	0.17	0.41	0.84	0.34	0.60	2.22	0.04	1.27	4.17
13	Machinery	0.03	0.15	0.23	0.68	0.29	0.70	2.53	0.03	1.41	7.61
14	Computer and electronic products	0.08	0.11	0.45	0.52	0.51	1.87	2.17	0.05	3.56	3.64
15	Electrical equipment, appliances, and components	0.07	0.16	0.38	0.72	0.40	0.76	1.90	0.04	1.37	2.56
16	Motor vehicles, bodies and trailers, and parts	0.05	0.20	0.34	0.80	0.45	0.93	3.08	0.13	6.25	9.02
17	Furniture and related products	0.09	0.14	0.43	0.72	0.25	0.36	0.75	0.08	0.82	1.10
18	Miscellaneous manufacturing	0.05	0.07	0.44	0.44	0.27	0.43	0.67	0.04	0.99	1.07

*Note: The sample used in this calculation requires firms, which appeared in 1998, to appear again in 1999; and firms, which appeared in 2007, also existed in 2006. We further dropped firms with VA<=0, L<=1 and VA>=output. For the top 10 firms in each industry, we further limit our sample to LME (large and medium enterprises), and their LP can't exceed 10 times of US average in both 1998 and 2007.

Table 2. What drives the catch-up?

1. Domestic firms with an edge benefit the most from FDI and import competition → separation effect with break out firms…
2. Five (5) of top 8 import sectors are also top 5 mfg. export sectors
3. The computer chips sector is on track…

China's Top 10 Exports

The following export product groups represent the highest dollar value in Chinese globa shipments during 2014. Also shown is the percentage share each export category represe terms of China's overall exports.

1. Electronic equipment: US$571,045,520,000 (24.4% of total exports)
2. Machines, engines, pumps: $400,910,983,000 (17.1%)
3. Furniture, lighting, signs: $93,390,874,000 (4.0%)
4. Knit or crochet clothing: $92,002,609,000 (3.9%)
5. Clothing (not knit or crochet): $81,453,227,000 (3.5%)
6. Medical, technical equipment: $74,020,496,000 (3.2%)
7. Plastics: $66,816,299,000 (2.9%)
8. Vehicles: $64,243,754,000 (2.7%)
9. Gems, precious metals, coins: $63,212,400,000 (2.7%)
10. Iron or steel products: $60,685,405,000 (2.6%)

xx. Computer chips: (2%)

Source: http://www.worldstopexports.com/chinas-top-10-exports/1952

China's top 10 Imports

The following import product groups represent the highest dollar value in World global shipments to China during 2014. Also shown is the percentage share each import categor represents in terms of China's overall imports.

1. Electronic equipment (21.7% of total imports)
2. Oil
3. Machines, engines, pumps (9.2%)
4. Ores, slag, ash
5. Medical, technical equipment (5.4%)
6. Vehicles (4.6%)
7. Plastics (3.8%)
8. Organic chemicals
9. Copper
10. Oil seed

xx. Computer chips (90.5%, $163 billion)**

Source: http://www.worldsrichestcountries.com/top_china_imports.html

**Source International Business Strategies, 2015 estimates reported in the *Wall Street Journal*, http://www.wsj.com/articles/china-looks-to-prop-up-domestic-chip-makers-1422387551

Table 3. China's innovation system…achievements; challenges

numerical catch-up; quality lag

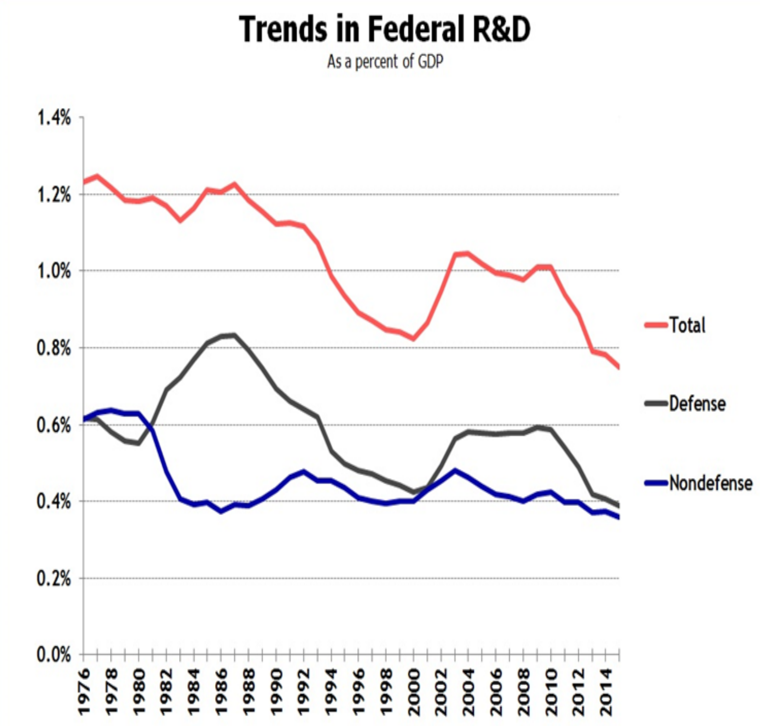
1. China as an "innovative society"…R&D/GDP = 2.0% vs. U.S. 2.8%
2. basic research share…5.0% vs. U.S. 18%
3. government share…21.6% vs. U.S. ~29%

Table 5. Intramural R&D Expenditure by Performing Sector (billion yuan)				
year	total	Basic (%)**	Applied (%)**	Experimental Development (%)**
1995 - Total	**34.87 (0.57%)***	**1.81 (5.2%)**	9.20	23.86
2007 – Total				
2012 - Total	**1029.84 (1.98)***	**49.88 (4.8%)**	**116.20 (11.3)**	**836.76 (83.9)**
Enterprises	**784.22 (76.2%)**	**0.71**	23.89	**759.63 (96.9%)**
Government sector (i.e., Research institutions)	**154.89 (15.0%)**	**19.79 (7.8%)**	**46.93 (30.3%)**	**88.17 (51.9%)**
Higher education	**78.06 (7.6%)**	**27.57 (35.3%)**	**40.27 (51.6%)**	**10.22 (13.1%)**
Private non-profit	**12.67 (1.2%)**	1.81	5.11	5.74
Intramural R&D by Source (billion yuan)				
year	Government	Self-raised by enterprises	Foreign funds	Other funds
2007 – 371.02				
2012 – 1029.84	**222.13 (21.6%)**	**762.50 (74.0%)**	**10.04 (1.0%)**	**35.16 (3.4%)**
Of which				
Beijing - 106.34	**56.60 (53.2%)**	36.86	4.79	8.08
Liaoning – 39.09	**9.00 (23.0%)**	29.64	0.08	0.36
Jiangsu – 128.79	**13.88 (10.8%)**	109.86	0.96	4.09
Zhejiang – 72.29	**6.04 (8.3%)**	64.44	0.31	1.47
*Share of GDP; **share of total R&D expenditure				

Figure 5. A matter of concern…

> U.S. Federal R&D as a share of total R&D - ~29% and declining…less than most large OECD countries.

> Non-defense federal R&D as a share of total ~ 14%



Source: Up to 1994 - National Science Foundation, Survey of Federal Funds for Research and Development; 1995 to Present - AAAS *Research and Development* series. GDP figures are from *Budget of the U.S. Government FY 2015*. FY 2014 and FY 2015 figures are latest estimates. © 2014 AAAS

Table 4. Key points re: patents and publications:

1. China has surpassed the U.S. in total patents filed and granted
2. China has surpassed the U.S. in invention patents granted to domestic filers
3. China has surpassed the U.K. in USPTO patents granted; lags S. Korea and Taiwan
4. Ratio of total patents in force low relative to other countries
5. China ranks 2nd in cited papers; 7th in total citations

Table 7. Comparisons of Patent Production

	Total	Domestic						Foreign
	All SIPO patents	Total	Enterprises	Universities	Research institutes	Government and other organiza-tions	Non-official	All
2012 – China: SPIO								
Invention								
applications	652,777	535,313 (82.0%)	316,414	75,688	29,518	6,807	106,886	117,464 (18.0%)
granted	217,105	143,847 (66.3%)	78,651	33,821	11,248	2,234	17,893	73,258 (33.7%)
In force, of which								
Invention	875,385 (24.9%)	473,187	274,038	96,707	37,639	3,086	61,717	402,198 (45.9%)
Utility model	1,501,044 (42.8%)	1,486,839	973,122	63,650	26,839	10,701	412,527	14,205 (0.9%)
Design	1,132,132 (32.3%)	1,044,997	564,716	17,161	2,671	5,072	455,377	87,135 (7.7%)
Total patents in force	3,508,561	3,005,023 (85.6%)	1,811,876	177,518	67,149	18,859	929,621	503,538 (14.4%)
USPTO, country of origin								
Utility (invention) patents granted	Total	U.S.	Foreign origin	Japan	U.K.	S. Korea	Taiwan	China
2007	157,282	79,526	77,756	33,354	3,291	6,295	6,128	772
2014	300,678	144,621	156,057	53,849	6,487	16,469	11,332	7,236
Citations (Essential Science Indicators, Thomson-Reuters) cumulative (2001-2011)								
Country	India	U.S.	Germany	Japan	U.K.	S. Korea	Taiwan	China
Most cited countries by papers (rank)	11	1	3	4	5	12	18	2
Most cited countries by citations (rank)	16	1	2	4	3	14	Below top 20	7

Comparisons/weaknesses

- All OECD countries dedicate substantially larger portions of R&D to basic research (3-5x)
- Enterprise sector:
  - Declining patent production returns to R&D …also, at the firm level weak correlation between patenting and productivity growth.
  - Local government patenting incentives may be unhelpful, e.g., incentives for patent grants appear to motivate filers to narrow the claims on their patent applications → lower quality
- Higher education sector:
  - All OECD countries dedicate larger portions of higher education which performs most of basic research (2-3x)
  - Limits to autonomy-creativity in higher-ed (hierarchical/muddled incentives).
- Research institute sector:
  - Strong on publications; surprisingly weak on patents
  - 15% of total R&D; 7.8% of basic research; 5.5% of total invention patents granted
- Notable Innovations:
  - Chinese version of Bayh-Dole Act – enables recipients (i.e. universities and research institutes to secure patents for government-funded research)
  - University-corporate collaborations (e.g., Tsinghua Unigroup with acquisitions-partnerships with Chip Makers, including Spreadtrum in which Intel has a 20% share)

U.S. - recommendations

- Increase spending on basic research – retain this comparative advantage as long as possible.
- Anticipate that it is very likely that China will catch-up…i.e.,
  - It is very unlikely that 25 years from now, the U.S. will be able to out-spend China on innovation and defense or…over the following 25 years be able to out-perform China in these areas.
  - To the extent possible seek to establish coordination and/or joint limits on such spending…
- Specifically…
  - Join the AIIB
  - Increase basic research for U.S. universities and Chinese graduate student research engagement.

Annex

Additional tables and figures

Table A1. Chinese-U.S. comparisons 2012-2013: Sales/employee ($1,000)*						
	Chinese		US		US/China	
	NBS all	3-firm	U.S.-BEA all	3-firm	U.S./China all	3-firm comparisons
Footwear	170.9	247.0	524.9	857.7	3.22	3.47
Textiles	85.7	69.0	216.8	193.7	2.53	2.81
Apparel	54.0	300.1	121.2	348.6	2.24	1.16
Paper	127.2	236.6	431.4	331.5	3.39	1.40
Printing	84.0	102.9	180.8	191.8	2.15	1.86
Petroleum	592.9	710.9	7,149.5	2,936.8	12.06	4.13
Chemicals	187.4	232.9	912.1	1,174.4	4.87	5.04
Plastic	101.8	194.6	311.5	305.0	3.06	1.57
Wood	108.1	103.0	207.9	432.3	1.92	4.11
Non-metal	120.1	117.1	255.3	390.8	2.13	3.38
Primary metals	290.0	746.9	779.6	625.4	2.69	0.84
Fabricated metal	115.8	370.1	232.4	554.6	2.01	1.50
Machinery	126.8	305.7	327.1	409.2	2.58	1.34
Computers	120.3	986.4	316.6	963.4	2.63	0.98
Electrical	132.5	225.0	310.1	344.5	2.34	1.53
Motor	168.6	327.6	513.0	707.8	3.04	2.16
Furniture	73.9	95.3	165.0	167.9	2.23	1.76
Telecomm. Equip.	n.a.	229.8	n.a.	475.6	n.a.	2.07
Mean	147.8	311.1	719.2	633.9	3.06	2.28

*Comparisons of the average sales/employee (generally) for 3 publicly-traded companies in China and the U.S. Information for the individual firms was drawn from the internet and/or annual reports.

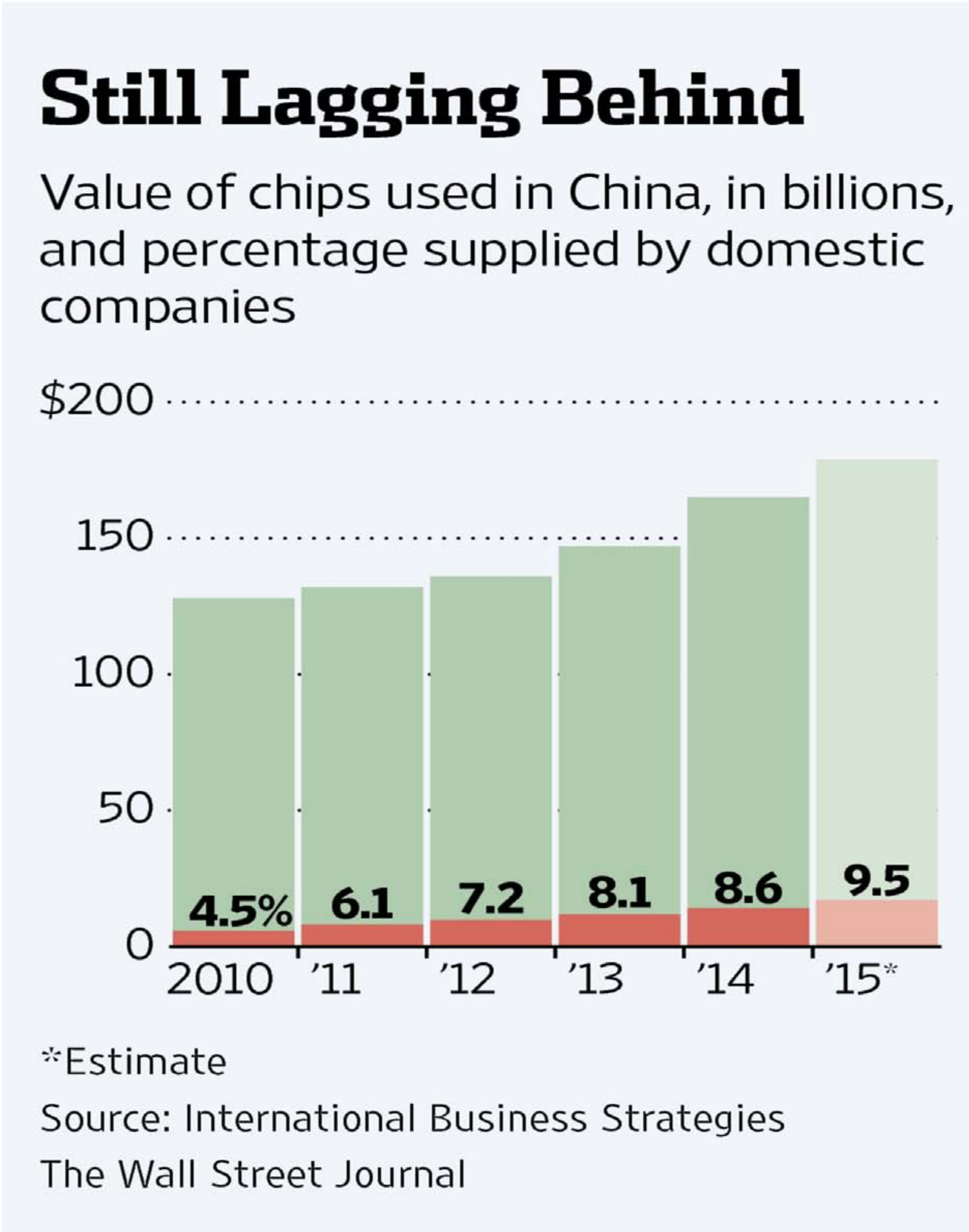

Still Lagging Behind
Value of chips used in China, in billions, and percentage supplied by domestic companies
$200
150
100
50
0
4.5%
6.1
7.2
8.1
8.6
9.5
2010
'11
'12
'13
'14
'15*
*Estimate
Source: International Business Strategies
The Wall Street Journal

Figure A.1

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