April 22, 2015

Testimony before the U.S.- China Economic and Security Review Commission

China's Policy and Strategy for Technology and Innovation

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I. China's innovation policy and the role of the Five-Year Plans in promoting indigenous innovation. How have the Five-Year Plans integrated China's innovation, upgrading, and trade promotion strategies in key economic sectors such as clean energy and telecommunications? How successful have these efforts been?

Building an innovation-driven economy has been highlighted by the Chinese government as one of its major tasks at the current stage of development of the country. Transforming from an imitator to an innovator is the cornerstone of China's innovation policy. China has moved faster than most of its peers in the developing world in establishing the foundations of a world-class innovation system.

The main guiding policy for China's innovation policy is the Outline of Medium and Long Term Plan for S&T Development (2006-2020), whose goals are further detailed in five year plans, such as the current Twelfth Five-Year Plan for Science and Technology Development. In addition, supportive policies for implementing the Outline play a key role in setting up a firm-centered national innovation system in general, and in innovation capacity-building of firms. These policies show an increasing focus on innovation as a means to address societal challenges as well as a focus on building up indigenous innovation by improving university-industry linkages, attracting overseas talents, enhancing intellectual property rights protection, and strengthening international innovation cooperation.

A supplement document of the 12th Five-Year Plan (FYP) issued by the State Council on developing national indigenous innovation capacity (State Council 2013, no. 4) has identified the main objectives and strategies of the 12th FYP in terms of infrastructure (key labs, key projects, key centres, etc), key sectors (agriculture, manufacturing, strategic emerging industries, energy

and transportation), the main drivers of innovation, regional distribution, and improvement of the innovation environment.

According to the document entitled 'Deepening systems reforms to accelerate the implementation of innovation-driven development strategy', issued by the CPC Central Committee and the State Council on March 13, 2015, innovation in China should be demand-oriented, prioritizing talents, following the natural development of scientific research and the market, and adhere to overall innovation which includes technological, institutional as well as management, organisation and business model innovation. It aims to build up a favourable institutional and legal environment for innovation by 2020. This document will be an important guide which is likely to be incorporated into the 13th FYP.

Normally the FYPs do not give very specific policies regarding the promotion strategies of a particular sector, even it is a key economic sector such as clean energy. However, the FYP does identify the key sectors which the country will prioritise in its development. Different ministries which are responsible for the various policies or strategies, eg. innovation, upgrading and trade promotion, should reflect the national strategy in their sectoral development plan in line with the guidance of the Five-Year Plans. Empirical research of government policies finds that many of the innovation policies in China are issued by ministries other than the MOST, for example, NDRC (National Development and Reforms Commission), MOC (Ministry of Commerce), MOF (Ministry of Finance), Customs, central bank, State Intellectual Property Office (SIPO) or even the State Council and CPC Central Committee. Hence the Five-Year Plans have played a pivotal role in pushing forward and coordinating policies, resources and efforts of the various government departments for a national innovation strategy.

The Chinese government has correctly recognised that innovation is a system engineering process, which involves many actors in the economy instead of a simple task for the Ministry of Science and Technology (MOST). There was some lack of coordination in the policies issued by the various departments. In recent years, there were efforts to overcome this problem. The State Council, especially some high level leadership groups, eg. the Central Economic and Finance Leadership Group, and the Central Deepening Reforms Leadership Group, have coordinated these policies (and should be delegated this responsibility more explicitly).

With regard to the development of clean technology, in China, there is a state-led innovation system for clean energy development. China has taken a more "home-based" outside-in technology transfer and indigenous innovation model; while India has taken a more "go-global" active technology acquisition model using overseas R&D lab and cross border M&A (Fu and Zhang, 2011). Although there is strong government support for green technology, the lack of core indigenous technological capability still lingers. In this sector, the solar photo voltaic industry for example, we can be more confident to say that China has developed a strong production capacity instead of technology or innovation capacity. In the telecommunications sector, China's international competitiveness is driven mainly by the private sector (eg. Huawei, Lenovo) and multinational companies except for only a few state owned enterprises (eg. ZTE) (Fu, 2011; Fu, 2015). Similar evidence is also found in a study of the semi-conductor sector in China where there are dual segments in the industry; an export-oriented segment which mainly consists of the foreign-invested firms and a low productive segment which is dominated by domestic, especially state

owned firms (Teece and Chesbrough, 2005). Therefore, it is too early to assess how successful the FYPs have been in promoting China's indigenous innovation capacity. What is clear is that China has been successful in mobilising the resourcing to develop a world class production base in these sectors.

II. Describe China's state-owned and private firms' efforts to innovate and upgrade. Is there a difference between the strategies of private and state-owned Chinese firms? How have these efforts affected Chinese firms' domestic and international competitiveness? What impact, if at all, have these efforts had on the U.S. economy and American competitiveness?

The state-owned and private firms' innovation efforts

Although the state-owned enterprises (SOEs) have been a major force of the Chinese economy, especially before and at the early stage of the reforms from the 1980s, in respect to innovation, the foreign invested enterprises (FIEs) and domestic privately owned firms (POEs) have not only been investing more in R&D than the SOEs, they are also more efficient in innovation and producing more innovative outputs (Chapter 2, Fu, 2015). Moreover, instead of having the SOEs taking a lead in pushing forward the technology frontier among Chinese firms, FIEs and POEs are the leading players in the high-technology, low technology and low-medium technology industries, respectively. That said, SOEs remain a leader in the high-medium technology industries (Chapter 5, Fu, 2015). So the SOEs, POEs and FIEs all have played their roles in China's technology upgrading and innovation. Therefore, instead of a pure market-driven model of innovation or the often assumed 'state-led model of innovation', China's path to innovation follows a multi-driver model led by a mix of players – the state, the private sector and the MNEs, with each of them playing a leading role in different segments of the economy and the innovation system (Chapter 15, Fu, 2015).

In China, state-owned firms (also state universities and research institutes) are currently the major beneficiary of the Five-Year Plans (as they are the main recipients of the government funding under the FYPs). These firms also have much better access to bank loans than the private and foreign-owned firms, especially private small and medium enterprises (SMEs). Reforms of the financial sector started recently in China, including a liberalisation of interest rates. However, reforming the financial sector is a complex task that will take time to accomplish. Moreover, the constraint in access to financial resources by SMEs is a widely recognised problem even in developed economies. Therefore, even with a more liberalised financial sector in China, the government needs to set up targeted SME innovation funds and information support systems to promote the innovation activity of SMEs.

Empirical research finds that Chinese firms that suffer from greater market/institution-related, capability/skills-related or finance/risks-related constraints are more likely to engage with open innovation (eg., collaborate or tap in external resources) in greater depth and breadth to overcome these impediments. The strength of such responses however varies across firms of different ownership types, firm size and technology intensity. Foreign-invested firms appear to respond the most by widening and deepening their openness in innovation. Privately-owned firms have made significant responses to market/institution- and finance/risk-related impediments but not to knowledge/skills-related impediments. However, state-owned firms appear to be least responsive

in terms of using open innovation to overcome the constraints and risks they face. They make no significant adjustments in terms of depth of openness although they increase their width, eg., by adding more partners, to respond to resource and skills constraints (Fu, Xiong and Li, 2013; Fu, 2015).

The state-owned and private firms also appear to have different capacities in regards to absorbing foreign technology. A study of the Chinese semiconductor industry showed that Chinese firms with significant exports (most of which are foreign-invested firms) had higher absorption rates of foreign technology. In contrast, the state-owned enterprises were less capable of absorbing new technologies, relative to other private Chinese firms (Chesbrough and Liang, 2008). This is similar to the findings by Girma et al (2006) on the impact of FDI on the innovation capacity of SOEs. However, the data used in these two studies are somewhat dated in relation to my testimony. With the reforms in SOEs, the situation might have improved to a certain extent.

Impact of innovation on Chinese firms' competitiveness

With regard to the impact of innovation on Chinese firms' domestic and international competitiveness, the majority of empirical research finds a positive association between innovation and Chinese firms' productivity (Liu and Li, 2005; Yang and Yuan, 2014) and their export performance (Guan and Ma, 2003; Lin, 2008). Of course, further empirical evidence is needed using larger and more representative sample and controls for the reverse causality from higher performance to more innovation. Nevertheless, using product level trade data, Wang and Wei (2008) find that improvement in human capital and government policies in the form of tax-favored high-tech zones appear to be the key to the country's evolving export structure. On the other hand, processing trade, foreign invested firms, and government-sponsored high-tech zones all have contributed significantly to raising the unit values of Chinese exports within a given product category.

Impact on the US economy and American competitiveness

As regard to the impact on the US economy, the innovation efforts of Chinese firms, which are significant in cost cutting, have provided US consumers with products that are not just affordable but also of improving quality over time.

So far, the impact of China's innovation efforts on American competitiveness is limited. Direct competition with US firms has been mainly in the labour intensive, low technology sector, which had become relatively small under pressure from imports from other developing countries even before China became a substantial exporter. China has been successful in serving as the final assembler of many high-technology products such as computers, laptops and mobile phones. From the outside, simply looking at the trade data, China is overtaking the US, Japan and South Korea in high-tech product exports. Given the labour division in the global value chain of these products, China's improving capability is now complementary to that of the US and other advanced economies. Because this division of labour and collaboration in the global value chain has enabled those high cost, high technology consumer products to be accessible and affordable to the wider middle-class and even grassroots consumer markets. As a result, American technology giants like Apple are able to reap huge value added.

However, with China moving up the technology ladder and transforming from an imitator to an innovator, there will be competition between China and the US in some industries in the medium and long term (Schott, 2006; Fu, Kaplinsky and Zhang, 2012), the same as the relationship today between the US and Europe and that between the US and Japan.

III. How do Chinese government development plans promote "go-out" strategies related to innovation acquisition? What are the motivations underlying Chinese firms "going out" strategy? Is there a difference between state-owned and private firms strategy?

What impact have these policies had on the U.S. economy and American competitiveness?

The 'go-out' strategy and Chinese firms' motivation to 'go out'

Since 2000, Chinese firms have been encouraged to "go global". While government policies in the early 1990s indicated acquiring advanced technology as one of the objectives of Chinese firms' outward direct investment, policies issued since 2000 after the launch of the "go global" strategy focus more on supporting SMEs and non-state-owned firms to go global. Some specific funding from the fiscal budget has been set up to support the SMEs' go-global activity. Chinese banks are internationalising themselves too to support Chinese MNEs' go global activity, although the loans have to go through the normal commercial loan approval process. Innovation acquisition is not observed to have been promoted using specific policy in the recent wave of the 'go global' phenomenon. Rather, it appears to be driven more by the firms' own strategic choices and location decisions.

Acquiring advanced technology has been a widely recognised objective of those Chinese MNEs investing in advanced economies regardless of ownership (Fu, et al., 2013; Fu, 2015). This type of behaviour of emerging market MNEs in advanced economies is regarded as a natural decision of these firms so as to move up the value chain, from the middle of the Smile Curve to the two ends of it in the Global Factory (Buckley, 2012, Mudumbi, 2012). The significant OFDI projects of Chinese MNEs are a mix of both private firms (eg. Huawei, Lenovo, Sanyi, Geely, Wangxiang, Haier) and SOEs (eg. ZTE, Zoomlion, and some state-owned automobile companies).

According to a survey carried out in Guangdong Province in 2010, the top two objectives for firms that invested in developed countries are 'to explore international markets' and 'to acquire advanced technology and management knowledge'. Over 75 percent of the surveyed firms regarded each of these two as their objectives in developed countries. Of course, SOEs are often argued to be the agents carrying out the state's strategic tasks. The Guangdong survey finds a slight difference in the factors that firms take into account in decision making. While private firms take cost factors into serious consideration in OFDI decision making, SOEs are much less sensitive to this factor and focus more on the learning opportunity (Fu, et al., 2013). Moreover, Chinese MNEs investing in the US appear to have a somewhat different perspective than those investing in Europe. They are going to Europe mainly for knowledge, while they consider the US as a location with opportunities in both knowledge sourcing and market expansion. (Fu, et al., 2013).

The Chinese MNEs 'go global' in a variety of modes. For Chinese firms that aim to acquire innovation abroad, the entry modes include 1) setting up a subsidiary abroad and through the subsidiary's learning and research activities reverse transfer knowledge back to the headquarter, 2) setting up an R&D lab abroad, 3) acquiring firms or a division of a firm abroad which has the technology that the MNE is interested in, and 4) collaborating with foreign firms or universities or research institutions for innovation activities. All these modes are observed among Chinese MNEs, although the actual scale is likely to be smaller than what people normally imagine. For example, the proportion of Chinese firms collaborating with foreign partners is much smaller than that of the OECD countries (OECD, 2013; Fu, 2015).

Impact of China's 'go global strategy'

Overall, it might be too early to assess the impact of China's go global strategy on its innovation capacity. A study of technology-driven MNEs from emerging markets finds that firms with high levels of intangible assets, high profitability and open innovation models are more likely to conduct this type of OFDI. There is high diversity in the impact of go-global OFDI and in several cases the investment has a positive impact on the European subsidiaries. The positive impact in terms of increasing technological capabilities may take several years to realise (Chaminade, 2015). My own research on Guangdong MNEs finds that Chinese firms' OFDI in developed countries positively affects the investing firm's innovation performance. Such a positive impact is enhanced by the focal firm's international experience and the knowledge-seeking motive of overseas direct investment (Fu, Hou and Liu, 2015). Moreover, my case research on Huawei and ZTE's internationalisation shows that they did not only upgrade their technology capabilities, but also their overall capabilities as well. Both of the two new entrants have competed with incumbents by developing resources and capabilities that are especially adapted to the local market. Huawei has accumulated customer knowledge and created a strong customer-priority solution department that is nearly impossible for their western competitors to replicate due to the organisational inertia and bureaucracy in large traditional MNEs (Fu, 2015). Finally, Chinese firms collaborating with foreign universities are more likely to produce innovation of high novelty than when collaborating with domestic universities or than those firms who do not collaborate with universities at all (Fu, 2015).

As regard to the impact of Chinese firms' go global strategy on the US economy, normally inward FDI, regardless of source country, is regarded as a welcomed phenomenon for the host country. It should be the same for Chinese OFDI. However, there are cases in both the US and Europe where OFDI projects by Chinese MNEs are restricted or rejected by host country governments due to concerns over security. It is difficult to make a general conclusion on these cases and it may need to be looked case by case. However, it appears that the objections received by the Chinese MNEs number more than objections to MNEs from other major emerging economies. Lack of trust and communication and some discrimination might exist against Chinese MNEs, especially Chinese SOE MNEs and Chinese MNEs in the high-technology sector. Hence the suspicion on these Chinese MNEs is not well justified (at least for some of them) and they were treated unfairly in respect to their market entry into the US and some other host country markets.

Assuming that Chinese firms can effectively absorb and integrate the knowledge acquired through the 'go global' strategy and develop their innovation capacity, as I discussed earlier, together with

China's continued heavy investment into R&D, China will upgrade to be an innovator, or further ahead, one of the global innovation leaders. How would this affect the US economy? On the one hand, there will be direct competition between the firms in these two countries. On the other hand, the US will have more global knowledge that it can source and a partner of similar capacity with which it can collaborate.

This also depends on whether the US can turn the Chinese technology-driven FDI into an active and dynamic innovator, a normal participant in the US economy which can contribute significantly to the US economy.

To note, these are the likely effects of Chinese firms' OFDI activity. It will be difficult to disentangle these effects between those due to government policy and firms' own decisions.

IV. How, if at all, are China's indigenous innovation and industrial policies impacting global markets and American competitiveness?

The impact of China's indigenous innovation and industrial policies on global markets are exerted through China's increasing competitiveness and hence China's increasing exports in manufacturing products.

For the consumers globally, export growth from a country with reservoirs of surplus unskilled- (and increasingly also semi-skilled and skilled) labour, coupled with sustained productivity growth (Lai, 2004; Fu and Gong, 2011), have provided the world with low-cost products.

For the competitors, some research shows that that Chinese exports crowd out the exports of other Asian countries (high income Asian exporters in particular) mainly in markets for consumer goods (eg., Eichengreen *et al*. (2004), Greenaway et al. (2008), Lall and Albaladejo (2004)). However, Haltmaier et al (2009) find that China's increasing presence in export markets has had a negative effect on exports of some products for some other Asian economies, but not for other products, including those of the electronics industry. Moreover, Ahearne et al (2006) find a 'flying geese' pattern in which China moves into the product space vacated by the Asian Newly Industrialised Economies (NIEs) and a potential for exports of all Asian economies to grow in harmony. With regard to China's impact on the high income countries, Bernard et al (2006) find that firms adjust their product mix in response to trade pressures from low-wage country imports. They also find within-industry resource reallocation towards capital-intensive plants and that firms are more likely to switch to capital- or skill-intensive industries when exposure to low-wage countries is high.

The research on unit prices of manufacturing products in general finds that Chinese exports tended to lower the prices of competitors (eg., Kaplinsky and Santos-Paulino, 2006; Amiti and Freund, 2008). Using the most disaggregated trade data feasible – 8 digits for the EU and the US, and 6 digits for Japan, all for the 1989-2006 period, Fu, Kaplinsky and Zhang (2012) find that imports from middle income countries are in close price competition with those from China and that there has been price competition between China and high-income countries in low-technology products. By contrast, the impact of China's exports on low-income countries is not through price competition but through market expansion. China's WTO entry had a once-for-all shock on the

export prices of high-income countries. The price competition effect of China's exports weakened over the time period from 1989 to 2006, suggesting a gradual change in competition from price to non-price factors such as quality and variety. If sustained, this trajectory will intensify competition with high-income economies in the future.

On the other hand, however, China will change with fast economic and export growth. How might the price effects change in the future? In addition to technology upgrading which was discussed earlier, real wages in China are highly likely to continue to rise as the labour surplus is absorbed. This will result in an increase in the price of China's exports if there is no significant technological innovation to cut the total costs of production. A second possible development is one which, in the context of China's historic trade surplus, sees a growing appreciation in China's exchange rate and hence an increase in China's export price (although in processing trade, higher export prices are to some extent offset by lower import prices). Given the consistent and significant positive association of export prices between Chinese and middle-income countries, this may result in an appreciation in the price of exports of other countries. If the increase in export prices leads to a smaller market share of China's export price, our results suggest that this change also will lead to an appreciation in export prices of medium- and high-technology exports from low-income countries and in resource-based and low-technology exports from high-income countries.

V. How should the United States respond to the challenges and opportunities of China's innovation policy? What are your recommendations for Congressional action related to the topic of your testimony?

First, the US authorities and US businesses should be confident about the dynamism and competitiveness of the US innovation system and the US economy. The US has a world class innovation system, a well developed market system, a world class education system, and well developed institutions that are more transparent and effective than in many of the countries in the world (despite some inefficiency in some parts of decision making and in the economy). The gap in technology and innovation capacities between the US and China remains significant and it will not be easy for China to catch up, especially rapidly because of shortcomings in its education system and economic and institutional systems which need some time to correct. The US should continue to develop its own innovation and S&T leadership. Of course, it also requires a mindset change. In other words, the US need to develop a long term innovation and industry development strategy in the context of global division of labour in a dual- or multi-polar world.

Second, transparency, openness, communications and dialogue matter. In many cases, fears and worries arise from lack of communication, transparency and openness. The worries in the US about China's threat or Chinese firms' threat to the US may not be well founded because what the Chinese government prioritises is developing its own country's prosperity through innovation and industrial upgrading, not competing with other countries. The worries in China that the US will always curb China may likewise not be well founded because the US will welcome sharing the responsibilities of global development with others including China. All this should be communicated to the wider economy and society in both countries using multi-channels. Through this trust will be build up and greater economic and wider engagement between the two countries will be possible. It is the responsibility of the US and Chinese governments to build up the

platforms and channels for a mutual exchange, dialogue, communication and trust in the wider economy and society.

Third, the US should collaborate more with China on innovation. Given the fact that innovation is increasingly a collaborative task and that international collaboration is adopted by more and more firms in today's era of globalisation, United States firms need to have more and more innovation collaboration with their Chinese peers, necessitating less regulation on these kinds of cooperation. Recent research by a joint team of EU and Chinese scholars finds that in 2005, in terms of the total collaborative research with China, the EU was at a slightly higher level than the US in chemistry, and at a similar level in other fields. However, regarding "high quality collaboration", defined as publications in high impact journals, the EU/US ratio increased in almost all fields from 2005 to 2011. In other words, the US needs to have more high quality collaborative research with China (SPI, et al., 2014).

Fourthly, the US should be more active in assisting China in capabilities building especially in areas that the US has concerns. For example, intellectual property rights (IPR) protection has been an area of concern for many years. This is one of the key area that gives rise of disputes and hinders greater collaboration and engagement between firms and research institutes in these two countries. While it is recognized that IPR protection has been improved substantially in China, it is still not enough. The problem is less with the Chinese government's willingness in doing so, but more with knowledge and skills to implement throughout this large country. Therefore, actively providing training and other means of assistance in IPR protection will accelerate the process of problem solving and hence more trade, investment and collaboration with China. Such collaboration and assistance also in including supporting China's greater openness and deeper integration into the global trade, investment and innovation system.

Fifthly, the collaboration between the US and China on innovation policy need not be limited to collaborative research; the collaboration can expand to wider areas along the innovation chain and in the innovation system. For example, in addition to the collaboration in Intellectual Property Rights protection which has already been under discussion for some years, the role of financing, new financial institutions for innovation, especially for entrepreneurial technology start-ups, is likely to be of growing importance in the future. Both United States and China might consider more collaboration in support for private SMEs' innovations in China and the US although there may be different emphasis for firms in each country, eg., more financial support for Chinese SMEs and more market entry for American SMEs.

Finally, global competition for highly skilled talents will be intensified as China is increasingly open up to international talent flows. Migration policy reforms will be an area for close monitoring.

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