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Dieter Ernst, an East-West Center senior fellow, is an authority on global production networks and the internationalization of research and development in high-tech industries, with a focus on standards and intellectual property rights. His research examines corporate innovation strategies and innovation policies in the United States and in China, India, Taiwan, Korea, Malaysia and other emerging economies. The author has served as a member of the United States National Academies "Committee on Global Approaches to Advanced Computing"; senior advisor to the Organisation for Economic Co-operation and Development, Paris; research director of the Berkeley Roundtable on the International Economy at the University of California at Berkeley; professor of international business at the Copenhagen Business School; and scientific advisor to governments, private companies, and international institutions. Related publications include *The Information Technology Agreement, Industrial Development and Innovation—India's and China's Diverse Experiences,* Think Piece prepared for the E15 Expert Group on Trade and Innovation and the International Center for Trade and Sustainable Development (ICTSD), Geneva, March 2014; and *Indigenous Innovation and Globalization: The Challenge for China's Standardization Strategy,* UC Institute on Global Conflict and Cooperation, La Jolla, CA and East-West Center, Honolulu, HI, 2011:123 pages. [Published in Chinese at the University of International Business and Economics Press in Beijing.]

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From Catching-Up to Forging Ahead? China's prospects in semiconductors[1]

by

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Abstract

China's new strategy to upgrade its semiconductor industry (outlined in the *"Guidelines to Promote National Integrated Circuit Industry Development"*, June 24, 2014), seeks to move from catching-up to forging ahead in semiconductors, by strengthening simultaneously China's integrated circuit (IC) design industry and domestic IC foundry services.

This study explores how China's new semiconductor strategy seeks to benefit from **four global transformations in semiconductor markets and technology**: a) the demand pull from mobile devices; b) new opportunities for China's foundries in trailing-node semiconductor technologies; c) changes in the IC foundry industry landscape; and d) a new interest in strategic partnerships and mergers and acquisitions (M&A).

A second contribution of the study is to examine two **Policy Initiatives** of the new strategy: (a) the **IC Industry Support Small Leading Group** to enhance strategy coordination; and (b) **IC Industry Equity Investment Funds** to improve investment allocation, and to enhance firm size and capabilities through strategic partnerships, joint ventures and mergers and acquisitions, involving both foreign firms and domestic firms. The implementation of both policies signals a genuine effort to experiment with a bottom-up, market-led approach to industrial policy. In the Leading Group for instance, experts play an active role in policy formulation and implementation who are well connected in the global semiconductor industry and who know what policies might work in this knowledge-intensive and highly globalized industry.

The use of professional investment fund managers, as opposed to government subsidies or investment, signals the emergence of a *hybrid* model that seeks to combine the logic of equity investment fund management with the objectives of China's IC development strategy. An important, largely unresolved challenge for China's industrial upgrading scenario in semiconductors is the possible impact on exports of China's electronics final products.

The study concludes that, despite movements in the right direction, the new Semiconductor Strategy's capacity for flexible policy adjustments remains limited, and that multi-layered industrial dialogues among key stakeholders in the industry are still at an early stage. To exploit the tailwinds from the market, China needs to experiment further with new more market-driven approaches to industrial policy.

About the author

Dieter Ernst, an East-West Center senior fellow, is an authority on global production networks and the internationalization of research and development in high-tech industries, with a focus on standards and intellectual property rights. His research examines corporate innovation strategies and innovation policies in the United States and in China, India, Taiwan, Korea, Malaysia and other emerging economies. The author has served as a member of the United States National Academies "Committee on Global Approaches to Advanced Computing"; senior advisor to the Organisation for Economic Co-operation and Development, Paris; research director of the Berkeley Roundtable on the International Economy at the University of California at Berkeley; professor of international business at the Copenhagen Business School; and scientific advisor to governments, private companies, and international institutions.

[1] Earlier versions of the paper have been presented at the University of California Institute of Global Conflict and Cooperation (IGCC) conference in San Diego on the Political Economy of China's Technology and Innovation Policies, June 27, 2011; the University of Chicago/Tsinghua University conference on Industrial Co-Development, at the University of Chicago Beijing Center, July 13-16, 2011; the University of Chicago/MIT/ Copenhagen Business School conference on Industrial Co-development with China, Sept 24 and 25, 2012; the Information Technology and Innovation Foundation (ITIF) conference on China's Indigenous Innovation Policy and the Semiconductor Industry , Washington, D.C., December 13, 2012; the 2013 American Association for the Advancement of Science (AAAS) Annual Meeting, 17 February 2013; the East-West Center/University of Frankfurt China conference in Honolulu, April 7, 2014; the US Semiconductor Industry Association (SIA), Washington, D.C., September 18, 2014; and the Peterson Institute for International Economics, Washington, DC , September 19, 2014.

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Overview of topic and why it is important

On the 24th of June 2014, China's government issued the *"Guidelines to Promote National Integrated Circuit Industry Development"* which spells out concrete and ambitious development targets for China's semiconductor industry[1]. This strategy has the support from the top leadership. The goal is to move from catching-up to forging ahead in semiconductors, by strengthening simultaneously China's integrated circuit (IC) design industry and domestic IC foundry services.

This study takes a close look at objectives, strategy and implementation policies of China's new push in semiconductors and examines what this implies for China's prospects in this industry. The following questions are addressed in particular: *In light of the mixed results of earlier support policies in this industry, how realistic are the expectations, outlined in the Guidelines? Does the Semiconductor Strategy signal a resurgence of state-led mercantilist industrial policies? In other words, is the Government just filling Old Wine into New Bottles? Or are there signs of a real shift in strategy and policy implementation that seeks to address global transformations in markets and technology and the rise of private firms in China's semiconductor industry?*

In addressing these questions, the study contributes to the literature three **observations**: *First*, top-down state-led "old industrial policies" simply don't work in a knowledge-intensive and highly globalized industry like semiconductors, where basic parameters that determine how China will fare may change at short notice and in unpredictable ways[2]. Rising complexity of technology, business organization, and competitive dynamics are the root causes for such uncertainty[3]. If China wants to forge ahead in the semiconductor industry, it needs to move towards a bottom-up, market-led approach to "industrial policy". There is ample evidence in the literature that latecomers like China need industrial support policies to catch up and develop a robust industrial ecosystem.[4] But this does not imply old-style top-down industrial policy. In fact, successful catching-up, and even more so forging ahead, requires market-driven approaches to investment finance, and a capacity for flexible policy adjustments based on multi-layered industrial dialogues with private firms.

Second, the rise of private firms in China's semiconductor industry further strengthens the argument for a bottom-up, and gradually more market-led approach to industrial policy. Over the last 60 or so years, China's semiconductor industry has come a long way from a completely government-owned part of the defense technology production system, with SOEs as the only players, towards a gradually more market-led development pattern. The role of SOEs has dramatically declined, and a deep integration into international trade and global networks of production and innovation has transformed decisions on pricing and investment allocation, with private firms as the main drivers[5].

Third, while China's progressive integration into the international economy has unshackled market forces in the semiconductor industry, China's policies to develop this industry still carry the legacy burden of the old-style top-down industrial policy. The result has been an unresolved friction between State and Market, where policy makers and planners prescribe desired outcomes (in terms of growth rates, technology, and "indigenous innovation" products), but fail to take into account the need of industry, and in particular private firms, for global technology sourcing.

The study explores whether China's new policy on semiconductors signals at least incremental movements towards a more bottom-up, market-led approach to "industrial policy". **Part I** demonstrates that China's achievements in semiconductors are overshadowed by persistent weaknesses, despite massive earlier support of the Government. It is argued that China is still playing second fiddle in this industry, because the State's "Indigenous Innovation Policy" collides with the "Global Technology Sourcing" needs of Chinese semiconductor firms. China's indigenous innovation policy focuses on the challenges (licensing costs; cyber-security), but tends to neglect the vast opportunities that result from China's deep integration into the global semiconductor value chain, in terms of learning , the development of innovation capabilities and of best-practice management techniques and institutions. This raises a fundamental question: What changes in policy would be needed to combine the benefits of both innovation strategies – "Indigenous Innovation" and "Global Technology Sourcing"?

Part II of the study reviews what we know about **objectives** and **strategy** that shape China's New Push in Semiconductors. In the leadership's view, the new strategy needs to address both persistent domestic weaknesses and new opportunities resulting from global transformations in semiconductor markets and technology. **Part Two** also takes a closer look at two **Policy Initiatives** to implement the new strategy: (a) the **IC Industry Support Small Leading Group** to enhance strategy coordination; and (b)"market-driven" **IC Industry Equity Investment Funds** to improve investment allocation, and to enhance firm size and capabilities through strategic partnerships, joint ventures and mergers and acquisitions, involving both foreign firms and domestic firms. The implementation of both policies signals a genuine effort to experiment with new and hybrid approaches to industrial policy.

Part Three explores the basic economics that shape China's efforts to upgrade its semiconductor industry. The focus is on global transformations in semiconductor markets and technology which provide a **demand pull from mobile devices for domestic IC design companies**, and **upgrading opportunities for China's IC foundries in trailing-node integrated circuit process technologies** (28nm and above). To exploit the tailwinds from the market, the government is encouraging strategic partnerships and acquisitions, both among domestic firms and with leading global players. An important finding is that, in response to the rising complexity and uncertainty of today's semiconductor industry, the government seems more open to experimentation with new more market-driven approaches to investment finance and flexible, bottom-up policy implementation, based multi-layered industrial dialogues with private firms. It is unclear however to what degree China's semiconductor strategy takes into account its impact on China's critically important exports of electronic final products.

The study concludes with a brief discussion of three factors that could derail China's industrial upgrading scenario in semiconductors (i.e. over-capacity, the Leadership's cyber-security objectives, and new international trade and investment agreements), and lays out implications for future research.

1. Unresolved friction between State and Market explains why China still playing second fiddle in semiconductors

1.1. Current Status - China's achievements are overshadowed by persistent weaknesses

To understand the motivations behind China's new push in semiconductors, it is useful to take stock of China's current status in the semiconductor industry.

Achievements

Achievements are impressive for a country that, before 2000, was considered to be a minnow in this industry. The country's rise as the global electronics factory drastically increased China's demand for semiconductors.

In fact, China is the largest semiconductor market in the world since 2005. In 2013, China's semiconductor consumption market grew by more than 10 % (compared to a worldwide semiconductor market growth of 4.8%). This has increased China's share in world semiconductor consumption to almost 56% (up from less than 19% in 2003). As result, China is by far the most important market for US semiconductor firms.

However, roughly 70% to 75% of all the semiconductors consumed in China (based upon revenue value) are re-exported as components of exported electronic systems that are produced in China, primarily by foreign companies from the US, Korea, Japan and Taiwan[6]. Hence, China's huge and rapidly growing semiconductor market is not reflective of an indigenous demand for semiconductors in China. In fact, buying decisions for integrated circuits (ICs) consumed in China are mostly made in Taiwan, Korea, US (for mobile devices), Japan, Singapore[7].

Another important achievement is the rapid growth of China's IC design industry, from $200m in 2001 to $13.2bn in 2013 (growing by 33% from 2012). As a result, the share of IC design in China's semiconductor industry has increased from 14% in 2010 to 20% in 2013 (PwC, 2014). In fact, IC design has consistently been the fastest growing segment of China's semiconductor industry, and the rate of growth continues to accelerate. For instance, the number of Chinese IC design companies has increased from 518 in 2012 to 683 by the end of 2013. That phenomenal increase of 165 net additional IC design houses during 2013 is by far the largest net increase in the last ten years. It has only been exceeded once in China's semiconductor history in 2002.[8]

There are however serious limitations in terms of scale and product range. The more than 600 Chinese IC design companies that have sprung up may have combined annual sales exceeding NT$400 billion [ca $ 13.2bn] – beating Taiwan's IC design sector – but most of them are "one-generation champions" that are broken up by their founders after going public and lack staying power[9]. With the exception of a few industry leaders (such as Huawei's HiSilion affiliate, ZTE Micro, SPRD, RDA[10], Rockchip, and a few others), most Chinese IC design firms are too small to invest in sophisticated design capabilities and are bound to focus on low-end applications for mature and standardized products.[11]

Important qualitative weaknesses that constrain the growth of China's IC design industry include a narrow focus on consumer products, especially low- and middle-end products such as color TVs, sound systems, clocks, electronic toys, small home appliances and remote controls. As long as China depends on these mature and relatively standardized products, this will constrain China's R&D and capability development in IC design.

As for IC design capabilities, the Government has promoted the development of an 8-core microprocessor that departs from the established design architectures of Intel and AMD. Introduced at the San Francisco IEEE International Solid-State Circuits Conference (ISSCC) in February 2012, China's flagship microprocessor **Godson-3B1500** features 32 nm process technology, which is considerably behind the leading-edge. In addition, the 40-watt Godson CPU is targeted for desktop, laptop or servers, and a modified version (the so-called ShenWei processor SW1600)can be used for supercomputers. However, this type of processor does not address the low energy consumption needs of China's booming mobile devices market.

This neglect of basic market requirements is shared by a related project, the development of an indigenous operating system (OS) to replace Windows and Android for running China's desktop and mobile devices. Led by Ni Guangnan, a former CTO of Lenovo and an Academician of the Chinese Academy of Engineering, the OS Development Alliance, established in March 2014, seeks to benefit from the government ban on the procurement of Windows 8. However, according to Xinhua, the Alliance faces many problems, "including a lack of research funds and too many developers pulling in different directions."[12] And according to interviews conducted by *EETimes* with domestic handset vendors and fabless companies, "it's far from clear how quickly and seriously the Chinese OS will attract local Chinese technology companies whose business is supplying products not only to domestic consumers but to the global marketplace."[13]

More important achievements however are IC designs developed by Spreadtrum and RDA for lower-end smart phones, and IC designs for mid-range tablets, developed by Fuzhou Rockchip[14]. A vital achievement in technology terms is HiSilicon's introduction in late September 2014 of the world's first multi-core networking processor for next-generation wireless communications and routers, and the fact that Taiwan's global foundry leader has accepted to produce this device using 16nm FinFET leading-edge fabrication technology[15].

Overall however China IC design capabilities continue to lag far behind the US, Japan, Taiwan and Korea, in terms of process technology and design line width. In addition, China lacks strong domestic suppliers of EDA tools and software and domestic licensors of IC design-related intellectual property.

Another noteworthy achievement of China's semiconductor industry is a successful diversification into Optical devices (especially LED), sensors and discrete devices, where China now is approaching self-sufficiency. By 2013, a Chinese supplier has entered for the first time the top 10 ranking of packaged LED makers, competing with leading global players, such as Nichia, Osram, and Samsung.

Of particular interest however is the surge of China's semiconductor assembly, packaging and testing (APT) industry, which has become the global market leader. Measured in terms of value added, production revenue, employees and manufacturing floor space, China's APT industry has now moved ahead of Taiwan and Japan (PwC, 2014). The focus on APT clearly stands out as a pragmatic and successful strategic decision. Not only is there a huge market for APT services. And while entry barriers are lower than for front-end IC fabrication, the technological requirements are considerable, providing a cost-effective entry strategy for Chinese firms to build up their management and technological capabilities[16].

Persistent weaknesses

China’s achievements in the semiconductor industry are impressive. Yet, they cannot hide the fact that, despite massive government efforts to build indigenous innovation and production capabilities, China still plays a very limited role in semiconductor production, IC design, and as an innovator. Of particular concern is the large and growing gap between semiconductor consumption and production. From $5.7bn in 1999, this gap has ballooned to a record $108.2 bn in 2013, and it is projected to increase to $ 122bn in 2015. According to Chinese sources, only 8.2% of China’s total semiconductor consumption in 2013 (estimated at $ 145 billion) are supplied by Chinese semiconductor firms[17].

As a result, up to 80% of the semiconductors consumed in China-based electronics manufacturing needs to be imported. As up to 75% of these electronics end products are exported, this requires growing imports of advanced ICs that satisfy the demanding performance requirements of overseas markets. In fact, China’s trade deficit in semiconductors doubled since 2005 to $138 billion in 2011. And in 2012, the value of China's semiconductor imports (US$232.2 billion) even exceeded the amount it spent on crude oil (US$221 billion).

Equally important are qualitative weaknesses. China’s patent applications for semiconductors show that its innovative capacity is improving, but China still has a long way to go to catch up with the US. While China’s share of worldwide semiconductor technology-focused patents increased from 13.4% in 2005 to a peak 21.6% in 2009, it has since declined to 14% in 2012[18].

China continues to lag behind in innovation, especially for advanced semiconductors. The US is way ahead in Multi-Component Semiconductors (MCOs) and Multi-Chip Packages (MCP)[19] – the two semiconductor product groups that are at the heart of the current stalemate of negotiations to expand the Information Technology Agreement (ITA)[20]. And Qualcomm, one of the leading global fabless IC design companies leads in “multimode” wireless communication chips that integrate various wireless standards (including the 4G LTE standard, derived from China’s TD-SCDMA standard).

In short, China’s IC design industry still has a long way to go to catch up with the leading IC design industries in the US, Japan, the EU, Taiwan and Korea. There is no Chinese IC design company in sight that might be able to challenge current global industry leaders. According to a recent industry panel on China’s IC design industry, “the center of gravity for chip design has not shifted to China. Despite a few well-known Chinese companies like HiSilicon and Spreadtrum, the top ten fabless companies are all in the US, Taiwan, or Japan. These companies are spending billions of dollars to invest in new development."[21]

As for wafer fabrication, China continues to play second fiddle. While wafer fabrication has moved to East Asia (primarily Korea and Taiwan)[22], China's 2015 share of total worldwide semiconductor wafer production is projected to remain below 11%. Global IC industry leaders dominate (i.e. Intel, Samsung, Hynix) China's wafer fabrication. For instance, a recent survey of investments in chip fabrication equipment finds that China is the fastest growing market, this is primarily due to the ramp-up of the Samsung NAND Flash Memory fab in Xi'an, which is a $ 6.2 billion project.[23]

Chinese foundries however are lagging two generations behind in process technology and wafer size. In fact, China has made substantial new investments in wafer fabrication plants, but these plants are using older technology and used equipment, which reflects China's focus on LED and other applications that do not require leading-edge semiconductors. Further, as demonstrated in a case study of SMIC, China's leading foundry, Chinese foundries lack process innovation capabilities[24].

And Chinese foundries have a long way to catch up with the leading Taiwanese foundries, which have 60% share of worldwide 2013 foundry revenues versus less than 5% for leading Chinese foundries (PwC, 2014). **Table 1** documents the huge gap in foundry capacity that separates SMIC, China's largest foundry, from the three global foundry industry leaders.

This describes a fundamental challenge for China's new policy to strengthen its semiconductor industry: China's domestic semiconductor manufacturing (i.e. wafer fabrication) technology and capabilities have failed to keep up with the country's IC design capabilities and needs.

Table 1

2013 Foundry Capacity Comparison

Foundry	Capacity / year
TSMC	16,423,625
GLOBALFOUNDRIES	7,326,000
UMC	6,313,500
SMIC	2,682,000

IC Insights -Production capacity figures converted to 8-inch equivalent wafers in order to enable comparison [25]

1.2. Root causes - "Indigenous Innovation Policy" collides with the "Global Technology Sourcing" needs of Chinese semiconductor firms.

The semiconductor industry has been a poster child of China's innovation policy as codified in the **Strategic Emerging Industries (SEI) plan** published in 2012.[25] What explains that, despite massive government efforts to catch up and forge ahead in semiconductors, China still plays a quite limited role in semiconductor fabrication, IC design, and, most importantly, as an innovator?

To explain this puzzle, it is necessary to examine two conflicting innovation strategies which co-exist in China's semiconductor industry, reflecting an unresolved friction between State and Market. On the one hand, there is the government's **indigenous innovation policy** which seeks to correct the failure of the earlier FDI-based export strategy to develop and enhance absorptive capacity and innovation capabilities of Chinese firms. On the other hand are the "**global technology sourcing"** strategies of **Chinese semiconductor firms** which are eager to source core technologies and capabilities from global industry leaders[26].

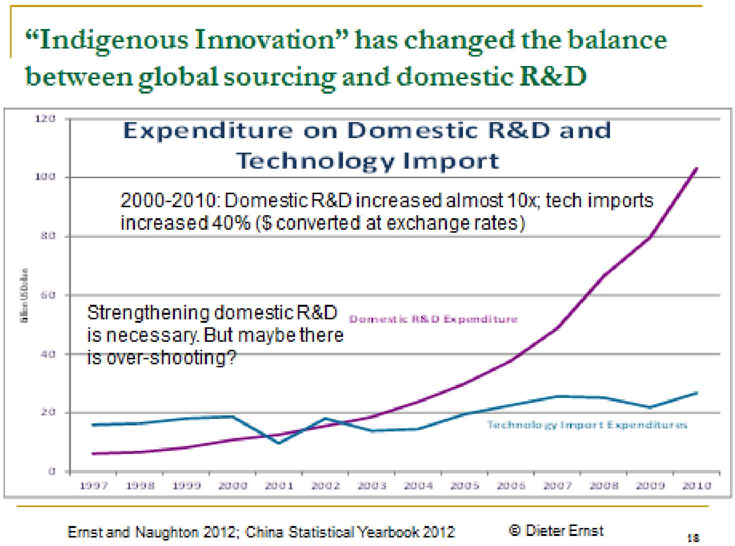
"Indigenous innovation"

Indigenous innovation was adopted as a policy in the **Medium and Long-term Plan for Science and Technology Development 2006-2020** (MLP)[27], as a domestically controlled alternative for developing core technologies that are (asserted to be) unavailable on the international marketplace. It should be stressed that, "indigenous innovation" policies do not advocate technological autarchy. Global technology sourcing and the integration of acquired technologies into new technological solutions are explicitly mentioned in the MLP as types of indigenous innovation.

However, the policy's main objective is to shift the balance from global technology sourcing via FDI to domestic R&D in order to replicate as much as possible the semiconductor value chain in China. An important objective is to leverage control of intellectual property to reduce licensing fees and to extract rent. In the end, the indigenous innovation policy seeks to "change the rules of the game to fit China" to break the technological dominance of the West and to strengthen the country's position in the cybersecurity war[28].

The MLP specifically sets as a target the increase in domestic R&D expenditures relative to expenditure on technology import, which is unlikely to be compatible with aggressive global technology sourcing. Moreover, the strong stress on indigenous innovation undoubtedly discourages firms in practice from deep partnership strategies with foreign firms which are leaders in important core technologies. In any case, the actual outcome, as Figure 1 shows, is that China has dramatically increased domestic outlays for R&D, while expenditures for technology import have grown much more slowly. Between 2000 and 2010, domestic R&D increased by nearly a factor of ten (in dollar terms, converted at exchange rates), while technology import expenditures increased by about 40%. China obviously needs to strengthen domestic R&D, but the current indigenous innovation policy seems to have led to some considerable over-shooting.

Fig.1



While well-intentioned, the indigenous innovation policy fails to take into account the dramatic changes in markets and technology that have transformed the semiconductor industry, both in the global semiconductor value chain, and with the rise of private firms in China.

New Opportunities for Global Technology Sourcing

China's semiconductor industry is deeply integrated into the global semiconductor value chain through markets, FDI and investment. In the **demand chain**, for instance, end users, global brand name companies and electronic manufacturing service providers define performance and cost, while in the **supply chain**, design tool vendors, design services, materials vendors, equipment vendors and semiconductors producers (including foundries) are important sources of technology and capabilities.

The process of dis-integration started decades ago, as the semiconductor industry re-organized around so-called "fabless IC design companies" who sent their designs to be made into silicon-based products at "pure play foundries" (IC contract manufacturers)[29]. While a few of the largest integrated device manufacturers, such as Intel and Samsung, continued to combine IC design and manufacture (and thrive), most firms moved to the disaggregated model. Apart from moving wafer fabrication to Asia (as discussed before), this dis-integration of the semiconductor value chain has also led to the spread of global innovation networks, shifting important segments of electronics system design and IC design to Asia[30] (Ernst, 2009).

This massive process of slicing and dicing the global semiconductor value chain has substantially reduced entry barriers for newcomers like Chinese IC design firms. According to Dr. Leo Li, the CEO of China's leading IC design company Spreadtrum, *"the availability of IC design tools, semiconductor fab services, and open-source smartphone software [Android] allows Chinese firms to circumvent their weak spots and develop their strengths in hardware, IC design, and integration."*[31]

In short, deep integration into the global semiconductor value chain enables Chinese firms to globally source technology and capabilities on a scale never thought possible before. In addition, as the global semiconductor industry critically depends on the China's huge and rapidly growing market, this enhances China's bargaining power in negotiations on global technology sourcing.

Add to this fundamental changes in global end user markets for wireless communication chips which have further transformed the organization of the global semiconductor industry, and have opened up new possibilities of an increasingly fine division of the IC design value chain (Ernst and Naughton, 2012: pages 11-22). One of these possibilities is the much larger space for Chinese firms to introduce new innovative and disruptive business models that foster and reward significant innovation in system and IC design. In fact, global value chain integration has enabled Chinese firms to disrupt the existing competitive order. This happened when MediaTek, a leading chip design company fromTaiwan, a few years ago offered integrated baseband chip sets to Chinese handset producers in Shenzhen for low-cost white good counterfeits of branded handsets**,** the so-called "Shanzhai" handsets[32].

With the introduction of Google's open-source smart phone operating systems Android, this disruption is now repeated, in the form of **"Shanzhai 2.0"** budget smart phones. This enables Chinese IC design firms to concentrate on hardware design first, before developing and catching-up in software design capabilities. At the same time, the availability of mature and inexpensive chip set solutions provided by Taiwan's Mediatek has furthered lowered the entry barriers, giving rise to a renaissance of China's Shanzhai sector, but this time the focus is on incremental innovations in low-cost smart phones.

As a result, a local ecosystem for budget smart phones is emerging that links IC designers, OEMs and Chinese customers The primary focus is on the China market, but increasingly other Asian emerging economies (like India and Malaysia) are becoming important targets[33].

Today, not only is China the biggest market for mobile handsets, with China Mobile being the world's biggest carrier by a margin. Since 2011, China has also emerged as the biggest market for smart phones, ahead of the US, and third generation (3G) mobile telecommunications is finally taking hold. In addition, massive investments are underway to accelerate the build-up of China's 4G network infrastructure. Together, these changes in markets and technology have created new strategic opportunities for Chinese IC design firms to upgrade their product portfolios, process technologies and business models.

China's indigenous innovation policy is still struggling to adjust to these fundamental transformations in technology, as well as in global and domestic markets. In essence, China's indigenous innovation policy focuses on the challenges (licensing costs; cyber-security), but tends to neglect the vast opportunities that result from China's deep integration into the global semiconductor value chain, in terms of learning , the development of innovation capabilities and of best-practice management techniques and institutions.

The view from industry

As documented in an earlier paper (Ernst and Naughton, 2012) some of the Chinese IC design companies which we interviewed emphasized that the indigenous innovation policy provides new opportunities (through government procurement and participation in China's TD-SCDMA standard) to gain market share against established global players. However, there also was a palpable sense of frustration about certain aspects of the Indigenous Innovation policy which these companies felt were constraining their efforts to engage in global technology sourcing.

In fact, many aspects of China's innovation policy collide with the needs of Chinese semiconductor firms. For them, commercial considerations are a primary concern. As late entrants, Chinese semiconductor firms struggle to survive and grow in a highly competitive global market that keeps changing at lightning speed and where technology often has unexpected disruptive effects. China's persistent innovation gap in IC fabrication and IC design implies that Chinese firms continue to need access to core technologies and capabilities from global industry leaders. In fact, Prof. Wei Shaojun, one of the drivers of China's new policy on the Semiconductor industry, emphasizes that collaboration between US and Chinese semiconductor companies is badly needed: "The most advanced technology is in the US, and the most experienced talent is in the US… .But Chinese companies are closer to the end customers and they understand the domestic demands."[34]

Hence, global technology sourcing across the semiconductor value chain is of critical importance if Chinese semiconductor firms want to reap the strategic opportunities that current changes in markets and technology are creating in for instance in wireless communications.

Of particular concern is that, while strategy and vision are developed by the top leadership and the central government, implementation is left to the local governments. Due to misaligned incentives that emphasize GDP growth above everything else, local government officials are generally impatient and always expect big breakthroughs immediately after an investment was made. There is often little understanding that it takes time to move from an idea to a competitive product. In addition, there is a tendency for top-down technology leapfrogging by fiat that neglects the enormousrisks of ramping-up complex technology systems in record time[35]. Furthermore, reflecting a lack of transparency and trust, administrators and government bureaucrats are seeking to design tighter and tighter controls which frequently result in unrealistic deliverables and project schedules[36].

Persistent friction

However, there are additional reasons for the friction between China's innovation policy and the "Global Technology Sourcing" needs of Chinese semiconductor firms. There is no reason to doubt that China's leaders are firmly committed to indigenous innovation as the key to removing poverty and to accelerating China's catching up with the US, EU and Japan. Indigenous innovation is considered essential not only for moving beyond the precarious export-oriented growth model. At stake really is the survival of the system.

But the implementation of this strategic vision is hampered by the fragmentation of China's innovation system that involves diverse stakeholders with conflicting interests. This is hardly surprising. Like most latecomers, China's innovation system is constrained by multiple disconnects between research institutes and universities on the one hand and industry on the other; between 'civilian' and 'defense' industries[37]; between central government and regional governments; and between different models of innovation strategy[38].

Other constraining features of China's indigenous innovation policy include the widely discussed quality problems in education; plagiarism in science and derivative research; a privileged treatment of SOEs in public R&D support and procurement that neglects SMEs; lists of "indigenous innovation" products used for government procurement focus on existing technologies and hence stifle innovation; weak complementary capabilities(for instance in the legal; in patent law; and in standardization); and weak coordination of complex innovation networks.

In the end, it is this friction between the current form of indigenous innovation policy and the global technology sourcing needs of Chines semiconductors firms which defines the dual challenge for China's new policy on semiconductors: Is China adequately accounting for the unintended costs of its "indigenous innovation" policy? And can China combine the benefits of both innovation strategies – "Indigenous Innovation" and "Global Technology Sourcing"?

2. China's New Push in Semiconductors – What do we know about Objectives, Strategy and Policies?

2.1. Background

It is useful to recall that China's strategy to develop the semiconductor industry has experienced many changes in a relatively short period of time. Frequent vacillation between statist and more market-friendly policies reflect a tension between two conflicting objectives: As a latecomer to this industry, China needs to develop and upgrade a robust domestic production and innovation system, while at the same time Chinese firms are eager to reap the benefits of global knowledge sourcing through deep integration into the industry's global value chain. This unresolved friction between State and Market may explain why, despite massive government efforts to build indigenous innovation and production capabilities, China still plays a very limited role in semiconductor production, IC design, and as an innovator.

In fact, until 2000, practically all the semiconductor companies were state-owned enterprises, foreign direct investment was heavily restricted, and decision-making was controlled by the Chinese government. In June 2000, the State Council Rule 18 brought an important shift in policy, focusing on reducing the role of SOEs, encouraging FDI and offering tax incentives[39].

Rule 18 expired in December 2010, and was succeeded by State Council Rule 4, as part of the 12th Five-Year Plan published in February 2011[40]. The new policies, set to expire in 2017, signal an important shift from an emphasis on quantitative growth of production capacity and output value growth to a focus on improving R&D capabilities for advanced technology. Rather than pouring funds indiscriminately into the industry in a "shot-gun" approach, the focus now is on selectively supporting a small group of semiconductor firms with global market share and the capacity for technological innovation. In contrast to rule Rule 18, Rule 4 places much greater emphasis on pragmatic choices, based on a careful selection of what are key bottlenecks and what medium-term goals might be achievable with the current set of accumulated capabilities.

2.2. Objectives

The focus of China's new policy on semiconductors, as codified in the June 2014 *Guidelines*, is on deeply entrenched weaknesses that the new policy needs to address head on:

- A persistent funding gap prevents Chinese IC companies to finance investment and R&D.
- Firm-level innovation capabilities remain weak, and the industry continues to lag far behind the US in its competitiveness and in its capacity to support innovation and China's cyber security.
- There is little coordination between different parts of the IC industry value chain with the result that industry development remains disconnected from market demand.
- Most importantly, the *Guidelines* single out the large and growing gap between semiconductor consumption and production as a critical roadblock to catching-up and forging ahead in this industry.

For China's leadership, the resultant growing pressure on the trade balance defines an important objective of the new policy for semiconductors - to reduce the consumption/production gap through selective import substitution. It is reported that by 2020, the Government's goal is to push the share of Chinese semiconductor companies in China's semiconductor consumption up to as close as possible to 50 percent (Jones, 2014).

Such an ambitious target may not be realistic. However, as China's manufacturing strategy shifts from exports to the domestic market, China may realistically expect to reduce the exported value of its electronic systems manufacture. In turn, this may open up at least some opportunities for reducing the imported content of its semiconductor consumption. There is of course no straightforward causal link. As discussed below in **Part Three** of the paper, much depends on the requirements of the electronics system manufacturers, in terms of performance, price, and timing. Equally important are the technological and management capabilities of China-based fabless companies.

To reduce the production/consumption gap through import substitution, the *Guidelines* describe fairly concrete targets for 2015, 2020 and 2030. In the fast-moving semiconductor industry, projections that extend beyond a few years should of course be treated with a grain of salt. Nevertheless, it is useful to document the expectations of China's leadership.

For 2015, the focus is on strengthening what could be called the **IC design-Foundry nexus**[41]. By leveraging the demand pull from mobile devices (especially budget smart phones) to strengthen the IC design industry, the goal is to turn IC design into an engine of growth for China's IC foundry industry. In turn, the target for IC fabrication is to enable Chinese IC foundry services providers to upgrade from 40nm to 32 nm and 28nm process technology[42]. For IC assembly,packing and testing (APT), the 2015 target is that at least 30% of APT revenue should come from mid- to high-end packing and testing technology.

The target for 2020 is to gradually increase China's local value-added and to upgrade China's position in the global semiconductor value chain. In addition, China should join global industry leaders in IC design for mobile devices, cloud computing, the Internet-of-Everything (IoE) and Big Data. Finally, by 2030, Chinese firms are expected to compete with global industry leaders across key sector of the IC industry supply chain and create disruptive technological breakthroughs.

2.3. Strategy

China's new Strategy to Promote IC Industry Development has both a defensive and a more assertive and self-confident element.

The defensive view

The defensive view holds that China needs to respond to a combination of persistent domestic weaknesses and new threats to China's security and international competitiveness resulting from global transformations[43].

MIIT for instance emphasizes that, despite rapid growth, Chinese IC companies generate low profit margins, and hence have limited means to finance investment. SMIC is mentioned as an example of this financial bottleneck: "In 2013, SMIC realized a record profit of about $ 170 m, but it needs to invest around $ 5bn to produce a month (50,000) of its 12 inch 28nm chips. TSMC, on the other hand, realized a net profit of $ 6.2bn, which allowed it to cover its investments for more than six months." [44]

An equally important concern is that China's IC fabrication technology "remains two generations behind global leaders, and we are still dependent on imported equipment and materials." (ibid.) As documented earlier in this paper, Chinese foundries do indeed lack considerably behind in process technology and wafer size, and they have a long way to go to improve their absorptive capacity and process innovation capabilities. And most Chinese IC design firms are too small to invest in sophisticated design capabilities.

China's new policy on semiconductors seeks to break this vicious cycle, where weak IC design capabilities feed into weak IC fabrication capabilities. According to Tsinghua University's Wei Shaojun, Chinese IC design houses must upgrade in order to secure access to limited foundry capacity. It is worthwhile quoting Dr. Wei's blunt statement: *"As chip production becomes increasingly sophisticated and expensive, the number of customers dedicated chip contractors can fully support will become increasingly limited, giving control of production capacity added importance….Capacity is king…[in the global foundry industry.]… If Chinese chip designers cannot squeeze into the global top 10, they will have trouble securing capacity. ...This predicament is of even greater concern to Chinese authorities than the high value of IC imports."*[45]

Of particular concern for China's leadership is the persistent innovation gap in advanced semiconductors relative to the US, described earlier in this paper. According to MIIT, China continues to remain focused on its role as the "Global Electronics Factory", while remaining weak in high-value added activities in IC fabrication, IC design and software. An equally disturbing domestic weakness is the disconnect between IC design and domestic electronics manufacturing. In terms of policy implementation, MIIT highlights the deeply entrenched inter-agency rivalries which give rise to a lack of coordination among different stakeholders in China's semiconductor industry.

Global transformations, from the perspective of China's government, create competitive pressure for China, but they also provide opportunities. In response to the Global Recession, developed countries have accelerated their structural adjustments, focusing on policies to enhance their international competitiveness. They all seek to expand exports, especially for high-value-added high-tech industries. In the view of China's leadership, the U.S. now has shifted to more aggressive industrial, innovation and trade policies to retain its leadership in the semiconductor industry, which is considered to be one of the main drivers of economic growth.

Chinese technology planners have studied the global ICT industry enough to conclude that this is an industry in transition, if not in turmoil. They observe that, both for IC design and process technology, limitations to the existing technology trajectory are increasing. Traditionally, R&D in the semiconductor industry was based on Moore's Law, i.e. the observation that the number of transistors on a given chip can be doubled every two years[46], and that the resultant "…[a]dvances in semiconductor technology have driven down the constant-quality prices of MPUs and other chips at a rapid rate over the past several decades."[47] Chinese planners realize that today this traditional approach to semiconductor R&D may no longer work - chips may still be getting smaller and faster, but further miniaturization no longer necessarily involves them getting cheaper[48].

At the same time, China's new push in semiconductors realizes that potentially disruptive new technologies transform the parameters of semiconductor demand and supply. Examples mentioned by MIIT include *Cloud Computing*, the *Industrial Internet*, and the *Internet-of-Everything*. China's IC strategy assumes that these internet-based networking technologies require complex multi-component semiconductors (MCOs) in order to integrate systems on chips which consume little energy and which protect against cyber-attacks. China's leadership considers the design and fabrication of these MCOs as an essential prerequisite for forging ahead in the semiconductor industry.

In addition, Chinese technology planners realize that new materials, nanotechnologies and 3D printing will further disrupt existing technology roadmaps. In some sectors of the semiconductor industry value chain, such radical changes in technology are expected to foster the emergence of global oligopolies where a handful of technology leaders control profits and sales, raising the barriers to entry for latecomers like China. Today, for instance, the Big Three in semiconductor fabrication (Intel, Samsung and TSMC) account for around 60% of global capital expenditures for semiconductor facilities, and only these three firms have what it takes to build the next-generation facilities that can produce 450mm wafers with leading-edge process technologies (20nm and below)[49].

The assertive view

In other sectors, however, Chinese technology planners expect that disruptive changes in technology may weaken existing global oligopolies. In the IT industry, this was the case when the spread of mobile Internet-related devices eroded the erstwhile seemingly incontestable leadership positions of Intel and Microsoft in PCs.

In the assertive view, global transformations in markets and technology like the ones discussed before, open up new opportunities for China to forge ahead in semiconductors, while domestic weaknesses call out for and provoke new policies to reduce or at least mitigate these weaknesses.

As for China's persistent domestic weaknesses, MIIT asserts that a BIG Push policy response is required to strengthen the "weak parts of China's supply chain."[50] The Big Push approach ("Make a firm decision and push forward") constitutes a remarkable departure from the traditional focus of China's leadership on incremental policies[51]. Even more remarkable is that the Big Push approach is combined with a commitment to " the decisive role of the market in allocating resources" (p.4) . In a way, it seems that the semiconductor industry is used as an early trial case where the government can see how policies that rely on the "decisive" role of the market might work in practice.

According to MIIT's Miao Wei, in China's new semiconductor strategy, "… [c]ompanies take the lead, with market orientation….Let the market determine the development of products, the technological path, and allow the market to unleash the vitality and innovative capacity of industry…. Make better use of the government to create and environment for fair market competition, and strengthen and improve public service."[52] Specifically, mergers and acquisitions (M&A), both among Chinese companies and with global industry leaders, are now considered to be an important short-cut to strengthen financial resources, as well as management and technological capabilities.

As for global transformations in semiconductor markets and technology, there is a new confidence on the Chinese side that China now has a strong hand to play in international competition. Specifically, Chinese decision-makers in government and industry seem to focus their attention on global transformations in semiconductor markets and technology which provide a demand pull from mobile devices, and a window of opportunity for China's catching-up and forging ahead in trailing-node integrated circuit process technologies (28nm and above)[53].

These global transformations might indeed provide new opportunities for China to move from catching-up to forging ahead in the semiconductor industry. But as discussed in **Part Three**, China would need to move towards a bottom-up, market-led approach to "industrial policy", in order to seize these opportunities.

2.4. Implementation - What is different about the new policies?

Before however, it is necessary to take a closer look at the policies that the Government has introduced to implement the new strategy on the semiconductor industry. In reviewing these policies, it is useful to ask: Is China's government adjusting its support policies for semiconductors, drawing on multi-layered industrial dialogues with private firms, both domestic and foreign? Or will policies again rely heavily on control and micro-managing investment decisions, and thus possibly waste the opportunities provided by global transformations in markets and technology?

Efforts to implement China's new semiconductor industry strategy gathered strength through support from YU Zhengsheng, a prominent member of the current Standing Committee and a former Party Secretary of Shanghai[54]. YU has long been involved in the development of China's electronics industry[55]. YU nominated Vice Premier MA Kai (who was chairman of NDRC from 2003 to 2008) to head China's new policies on IC industry development.

Tax breaks and subsidies continue to play a role. In addition to keeping the tax breaks mentioned in the **State Council Document 4 (2011) document** for IC design houses and foundries, the tax benefits have now been expanded to semiconductor testing firms. This means testing firms now also enjoy savings on corporate income, value-added, and operation taxes.

In addition, the government seeks to create new mechanisms to **improve the efficiency of Government financial support instruments**, especially through the Ex-Im Bank and the China Development Bank. A particular emphasis is placed on debt-financing tools, to be issued especially for SMEs. Priorities include companies seeking to go public; R&D tax credits; and the improvement of loan insurance and credit insurance tools. In addition, the **Guidelines** emphasize efforts to strengthen tax support policies and use Import Tax exemptions for critical equipment, components and materials that are needed for strengthening China's IC industry[56].

Overall however, the government is playing down the role of tax breaks and subsidies in the initiative, as those policies are easily attacked by foreign governments as violating World Trade Organization (WTO) anti-subsidy agreements.

Instead, the government emphasizes the central role to be played by two new policy initiatives[57]:

- An **IC Industry Support Small Leading Group**, chaired by Vice Premier Ma Kai, for ministerial coordination of high-level national strategies
- To improve investment allocation, a set of "market-driven" **regional and national IC Industry Equity Investment Funds** are created "with limited government intervention".

To support these two key policies, the Government (through NDRC) pursues a much more active **anti-monopoly policy** to reduce market abuse by IT companies. If such anti-monopoly policies are well designed, they could enhance the impact of the above two policies to upgrade China's semiconductor industry. Among U.S. IT companies, prominent examples include the pressure on Qualcomm to reduce licensing fees, and investigations of business practices of Google, Apple, Microsoft, Cisco and IBM. In Qualcomm's case, NDRC is expected charge a $ 1.2bn fee for using its dominant position as a supplier of critical MCOs to overcharge licensing fees for Chinese smart phone manufacturers. According to Scott Kennedy, director of the Research Center for Chinese Politics and Business at Indiana University, "…[t]he Chinese government has credibility to pick on Qualcomm because of investigations into the company in other countries. …But it also definitely fits their industrial policy goals if they can squeeze in lower licensing fees or other technology-sharing arrangements."[58] It now looks like Qualcomm will admit guilt and pay cash.[59]

NDRC's **anti-monopoly policy** is controversial – Multinational executives and industry associations believe the NDRC is deliberately targeting foreign companies. In fact, data compiled by the *Financial Times* show that foreign companies or their joint ventures have paid almost 80% of the Rmb3bn ($490m) in anti-monopoly penalties handed down by the NDRC since 2011. However, half of those Rmb 2.4bn in fines for foreign companies was assessed against 10 Japanese auto parts makers who admitted in August 2014 to price collusion. In addition, NDRC argues that its price supervision and anti-monopoly bureau is too inexperienced and understaffed, to organize a conspiracy against foreign companies, although they are now recruiting new staff.

At the same time, there are efforts to strengthen the role of **trade diplomacy**, as a necessary complement of the above industrial support policies for the semiconductor industry. During the current round of negotiations to expand the product list of the **Information Technology Agreement** (the so-called ITA-2), China seems to have experimented (apparently quite successfully) with a combination of delay tactics and a slowly evolving and still precarious strategy of co-shaping the design of an expanded ITA[60].

The IC Industry Support Small Leading Group

On November 29th, 2013, China's Semiconductor Industry Association announced that China's State Council was to establish an **IC Industry Support Small Leading Group**[61] . An important objective of the Leading Group is to reduce inter-agency rivalries in order to improve strategy coordination and to mobilize and consolidate resources. A **Consulting Commission** that reports to the **Leading Group** acts as a Think Tank to assess policy measures, and to suggest solutions and adjustments in policies. An important objective is to speed up government response time and to improve the capacity for flexible response, by navigating around entrenched bureaucratic hurdles and rigid regulations. An additional function of the Leading Group seems to be to mobilize and consolidate public and private resources through Public-Private Partnerships.

Leading Groups have a long tradition in China as a sort of ubiquitous tool to act against or mitigate the silos within the government that bedevil the implementation of strategies laid out by the leadership. To bypass bureaucratic inertia and inter-agency rivals, the State Council occasionally establishes such "leading groups" of high level officials to improve coordination across China's many ministries and other government organizations[62].

In the IT sector, various Leading Groups have been established since the 1980s to issue key strategies and guidelines for the electronics industry[63]. Today's **IC Industry Support Small Leading Group** however differs substantially in terms of organization and governance. An important main difference is the direct involvement of China's top leadership. Vice Premier Ma Kai acts as chair, and prominent local government leaders, like Beijing Vice-Mayor Zhang Gong, play an active role. Participants include key players from four powerful ministries (MIIT,MoST,MoF,NDRC), top industry leaders, and senior academics with an established research and patenting record.

In addition, it seems that the expertise of participants both from industry and research institutes has substantially improved. It is now more common to have experts who have studied and worked abroad and are internationally well connected. Take the example of Dr. Wei Shaojun, who played an active role in drafting China's new IC industry policy. As Dean of the Microelectronics Institute at Tsinghua University, and President of the China IC Design Association, Dr. Wei is well-connected within Leadership circles. Dr. Wei studied and worked in Belgium, and is internationally well connected and respected, as a frequent speaker at the Global Semiconductor Alliance (GSA), and as a key Chinese delegate to the World Semiconductor Council. Chinese experts like Dr. Wei know the international scene well, are familiar with the intricacies of the global semiconductor industry value chain, and thus have a better understanding of what policies might work in this knowledge-intensive and highly globalized industry.

In short, while the institution of a Leading Group is nothing new for China, it nevertheless seems that new wine is now being filled into these old bottles.

Regional and National IC Industry Equity Investment Funds

Arguably the most interesting new policy initiative is the announcement by MIIT and NDRC to establish a **National IC Industry Equity Investment Fund**, endowed with RMB 120bn ($ 19.5bn) over a three to five-year period, to be complemented by a series of **Regional IC Industry Equity Investment Funds.**

Table 2

Initial National Fund: RMB 120bn($19.5bn)/3-5years – Structure & investors

Investor	Amount (RMBbn/%share)
MoF	36 (30%)
China Development Bank	32 (26%)
Beijing E-Town Capital & municipal government	10 (8%)
"Societal funds" (non-governmental)	42 (36%)

Wuhan, Shanghai, Shenzhen to follow the Beijing Fund model

USITO 2014, quoting data from E-Town Capital web site © Dieter Ernst 14

Table 2 provides information on the structure and the investors of the initial National Fund. It is noteworthy that so-called “Societal Funds”, i.e. private equity investment funds, are responsible for 36% of the National Fund.

Potentially, the idea behind the IC Industry Equity Investment Fund could signal an important break with previous policies. According to an industry observer who has requested anonymity, “this is the first time that the Chinese has set up a fund jointly with public investors and asked professional fund management companies to raise, invest and manage the funds, in contrast to direct subsidy or investment in selected projects or companies.” Under the new approach, the investment fund will take stakes in companies proportionate to the amount invested, and the fund manager will insist on a rate of return. The ultimate goal is to leverage the ownership structure to change corporate and industry structures.

However, at this stage, these are declarations of intent, and it may be advisable to take such claims with a grain of salt. One might wonder for instance to what degree the decision to establish an Investment Equity Fund is primarily motivated by an attempt to avoid being accused of violating WTO anti-subsidy agreements. Whether the establishment of an **IC Industry Equity Investment Fund** signals a more professional approach to overcome the critical bottleneck of insufficient long-term investment funds depends to a large degree on the selection of the fund managers and the discretion they will have in allocating funds.

Publicly available knowledge on these questions is limited. We know that the primary purpose of the National Fund is to mobilize private and public funding sources to reduce the investment bottleneck faced by domestic semiconductor firms. According to the **Guidelines,** the **Fund** covers the whole industry value chain (design, manufacturing, R&D, plus commercialization and knowledge-intensive support services). The Fund also is supposed to play a catalytic role in promoting industry consolidation, through M&A among domestic firms and the acquisition of foreign firms which control important technologies or markets.

As for Regional Funds, some information is now in the public domain on the **Beijing IC Industry Equity Investment Fund**. According to USITO, more regional IC Industry support plans have also been released over the summer of 2014, for instance for Anhui Province, Suzhou, Hefei city government, Sichuan province, and Gansu Province. However, none of these announcements provide details on the selection of fund managers and their degree of decision autonomy on allocating funds.

The Beijing IC Industry Equity Investment Fund

A closer look at the **Beijing IC Industry Equity Investment Fund** finds that two fund managers have been selected thus far:

- The main fund and the sub fund #1 for equipment and manufacturing is to be managed by **China Grand Prosperity Investment (CGP);**
- As for the sub fund for IC Design, Packaging and Testing, **Beijing Qingxin Huachuang Investment Management Ltd**. was initially selected as fund manager[64]. However, in June 2014 it was reported that **Hua Capital Management Ltd (HCM)**, a Chinese investment management

company, was chosen to manage the chip design and testing fund under the Beijing government's 30 billion-yuan (HK$37.8 billion) Semiconductor Industry Development Fund[65 66].

While CGP is headquartered in Hong Kong, it is definitely not a global player[67]. But, according to CGP's Chinese web site, they have a long history of managing investment funds in China[68]. Cheng Hairong, the chairman of CGP has over 20 years of experience as an executive director and consultant in establishing and managing listed companies in Hong Kong. Mr. Cheng has knowledge in China finance and investments in life sciences, biotech, energy saving, tourism, trading and finance sectors[69].

CGP seems to have learnt how to walk the fine line between adapting to the requirements of the government, while at the same time making sure that the fund produces enough profits. On the one hand, one could argue that this type of Chinese fund manager just fits nicely with the implementation requirements set by the government. In short, while elements of the market are now introduced, at the same time the government can continue to exercise control. An industry observer who requested anonymity provided a telling example of this hybrid model of Chinese-style fund management. In a meeting with the Beijing Municipal Government, partners of the CGP (China Grand Prosperity Investment Limited Holding Co) fund manager were present, and displayed a "highly deferential behavior" vis-à-vis the government representatives.

Initially, the Beijing subfund for IC Design, Packaging and Testing was supposed to be managed by Beijing Qingxin Huachuang Investment Management Ltd[70]. But very little is known about this fund, and a web search did not produce a company web site.

In June 2014, it was reported that Hua Capital Management Ltd (HCM) would take over the management of the Beijing subfund for IC Design, Packaging and Testing. Hua Capital Management Ltd (HCM) is a private equity firm specializing in buyouts, based in Beijing. Funds managed by HCM include the Shanghai Pudong Science and Technology Investment Co. Ltd, a wholly state-owned limited liability company, established directly under the Pudong New Area government of Shanghai[71].

According to industry observers, the real driving force behind HCM is Chen Datong, who is HCM's chairman as well as Co-Founder and Managing Partner of WestSummit Capital, a leading China-based global growth equity firm focused on helping high growth technology companies access the China market[72]. Another major player is Liu Yue, the deputy chairwoman of HCM, who also has a wealth of experience in China's IC industry. Of particular interest is her role as an early investor in SMIC through Walden Capital, and her continuous involvement with SMIC.

HCM's President, Xisheng (Steven) Zhang, started in 1994 out as a postdoc researcher at UC Berkeley, and then worked in senior management positions in Agilent and Silicon Valley start-up IC design companies, before joining Beijing-based private equity investment company West Summit Capital Management in 2013. Mr. Zhang has over 20 years industry experience in Semiconductors and EDA, and in managing start-up companies in Silicon Valley and in Beijing.

Based on this information, it is possible to conclude that HCM qualifies as a professional fund manager with considerable knowledge of key aspects of the semiconductor industry value chain, especially related to IC design. In the view of USITO, the use of professional investment fund managers, as opposed to government subsidies or investment, "suggest a new approach to industrial policy that focuses on building a strong and sustainable investment environment in China."[73] But a final assessment has to wait until more information is available on how funds will ultimately be deployed.

For instance, while selecting private fund managers might seem to indicate a stronger role for the market, this may actually not be the case if the selected company (i.e. CGP) owes its selection to its close personal connections to the leadership. It is important to establish who makes the key decisions on the allocation of funds, bureaucrats or technocrats with deep industry knowledge.

Another unresolved question is whether the availability of IC Industry equity funds will again lead to a competitive race that pits Beijing against Shanghai, Shenzhen etc, with the result of duplicative investments that will end up giving rise to overcapacity. Furthermore, are there signs that policy decisions are less constrained by elaborate priority lists of "indigenous innovation" products and technologies? If these lists were still important, this would indicate that nothing much has changed.

In any case, the establishment of the Semiconductor Equity Investment Fund does not necessarily imply that China is converging to a US-style market driven policy approach. More likely is the development of a *hybrid* model that seeks to combine the logic of equity investment fund management with the objectives of China's IC development strategy.

3. China's semiconductor industry upgrading scenario – economic reasons for a bottom-up, market-led "industrial policy"

3.1. Perceived Opportunities[74]

China's leadership is very conscious that the US is way ahead in advanced semiconductors and that China has a long way to go to close this gap. At the same time however, the policy documents which define China's new push in semiconductors, also convey a new sense of optimism. Global transformations in semiconductor markets and technology are no longer only perceived as threats. In fact, China's technology planners now seek to identify upgrading scenarios for China's semiconductor industry that could benefit from those global transformations.

Specifically, their attention seems to focus on four global transformations, which are expected to create new opportunities for China to move from catching-up to forging-ahead in semiconductors: a) the demand pull from mobile devices; b) new opportunities for China's foundries in trailing-node semiconductor technologies; c) changes in the IC foundry industry landscape; and) a new interest in strategic partnerships and mergers and acquisitions (M&A).

The following analysis will examine the economic rationale behind each of these four perceived opportunities and what factors might determine China's chances of success. While the opportunities are real, they all involve considerable uncertainty. An important finding is the precarious nature of these opportunities. In other words, basic parameters that determine how China will fare may change at short notice and in unpredictable ways. This implies that flexible policy implementation is required to cope with such uncertainty. If China wants to exploit the above opportunities, it needs to move towards a bottom-up, market-led approach to "industrial policy "guided by the principle of "smart specialization".

3.2. Demand pull for mobile devices as a catalyst for IC design

Chinese decision-makers, both in government and industry, are convinced that, for mobile devices, China is now becoming a lead market, and hence can shape demand and technology trajectories. It is expected that the demand-pull from mobile devices will catalyze an upgrading of China's fabless IC design industry. Chinese IC foundries in turn may be more motivated to invest in capacity expansion and technology upgrading, once demand from local chip design houses increases. Quoting again MIIT's Miao Wei, China's market for mobile devices and for a wide variety of IT equipment is booming and hence should provide "favorable conditions for China to leapfrog ahead of others."[75] As demand for low-end budget smart phones is driving volume growth, it is expected that China can leapfrog into emerging markets for sub-$50 smart phones.

Today, China has four times as many mobile handset subscribers as in the US (almost 1.3bn compared to 327.6m)[76]. China now is the world's largest smart phone market with almost 700m smartphone connections, surpassing the US (197m), Brazil (142m), India (111m), and Indonesia (95m)[77]. Low-cost smartphones designed in China are flooding the market - Android phones designed in China now represent more than 50 percent of the global market[78]. In 2015, Chinese original-equipment manufacturers (OEMs) are expected to design more than half of the world's phones.[79]

Data from the first half of 2014 indicates that smartphone shipments in China will exceed 400 million units in 2014, accounting for 93 percent of total mobile phone shipments in that market[80]. China now is the ultimate prize for global smartphone vendors. In the first quarter of 2014, China contributed 15.8% of Apple's total revenues, due primarily to sales of iPhone devices in China. Most recently, in the second quarter of 2014, China accounted for 37% of global smart phone shipments – some 108.5 million units[81].

Since 2008, the global market share of mobile phones produced in China has almost doubled from 44% to 81% in 2013[82]. In addition, China is now in a position to co-shape international mobile telecom standards. Both TD-SCDMA and TD-LTE standards have fostered the development of technical capabilities of IC design companies based in Greater China (Taiwan's MediaTek, and China's Spreadtrum and RDA) [83]. Global industry leaders (Qualcomm, Nvidia, Marvell, and Intel) are latecomers to China's TD mobile telecom standards, and they are constrained by high fixed costs. But they have other huge advantages, such as superior technology and system integration capacity, and deep pockets due to the high licensing fees they can charge for their technology.

Fig 2 shows that, in the first quarter of 2014, Chinese vendors accounted for a 50% share of the China market.

Fig. 2

There are of course reasons to ask how sustainable will be this shift towards China becoming a lead market in mobile devices. Take Xiaomi, which has been catapulted from practically nothing a few years ago to the third-largest smart phone vendor in China[84] and fifth largest globally. Xiaomi's handsets have achieved almost cult-like status in China, and they are the darling of global media and investors. Yet, as a review of Xiaomi's flagship Mi3 smart phone, concludes: "Xiaomi has promise, but it is far from the world-dominating juggernaught that western media makes it out to be."[85] Its success has been for 3G smartphone only, but not for leading-edge 4G/LTE devices[86].

In fact, China's 4G smartphone market has failed to surge as expected and most Chinese vendors' domestic shipments did not achieve any growth.[87]It is too early to assess whether this slow growth of 4G smartphone demand indicates that the demand pull effect from mobile devices is already being weakened.

Further, Xiaomi continues to depend on foreign companies for core technologies (especially application processors and system platforms). For instance , Xiaomi's latest smartphone, the Mi4, will be available only for China's 3G networks (both for the Chinese TD-SCDMA standard and WCDMA). Like earlier Xiaomi handsets, the Mi4 is based on Qualcomm's Snapdron 801 platform[88], reflecting a long established relationship with Qualcomm.

In addition, if Chinese smartphone makers really want to move from catching-up to forging ahead, they are faced with a very tight global oligopoly in this industry, and hence face severe upgrading barriers. The latest data available for the first quarter of 2014 show that the combined global market share for the two dominant smartphone operating systems (Google's Android and Apple's iOS) has increased to 96.4%, leaving little space for latecomers like Xiaomi to differentiate themselves through alternative operating systems[89].

This of course raises the question whether China now really has a broad enough portfolio of core technologies and the ecosystem required to sustain the move towards becoming a lead market for mobile devices. Or are these expectations a bit premature?

In any case, both the Chinese government and MNCs clearly believe that the shift towards China becoming a lead market in mobile devices is real. As a result, MNCs are all trying to position themselves so that they can sustain market access in the future. It is this perception which seems to drive some of the other global transformations, discussed below, and especially the strategic partnerships between Chinese companies and global industry leaders discussed below under section 3.5.

3.3. The trailing-node upgrading trajectory - New opportunities for China's semiconductor foundries

Part One of the paper described a fundamental challenge for China's new policy to strengthen its semiconductor industry: China's domestic semiconductor manufacturing (i.e. wafer fabrication) technology and capabilities have failed to keep up with the country's IC design capabilities and needs.

This raises the question which of the following propositions might carry greater weight in shaping China's policy responses:

- China's technology gap in wafer fabrication today may matter less, as China's IC design houses can use a great variety of fabs and design services across Asia to tape out their design needs, ranging from top-tier, leading-edge process technology foundries (like Taiwan's TSMC) down to highly specialized niche foundries for analog devices which do not require leading-edge processes.

or

- China's technology lag in wafer fabrication may, in the medium and longer term, substantially constrain efforts to upgrade its design industry, because access to leading-edge foundry capacity may be denied during high growth periods, and because proximity between design and wafer fabrication may still be critical for effective tape-out of leading-edge devices?

A survey of IC design firms in 2013 reported that proximity to foundries is perceived to be more important by Chinese IC design houses than by US design houses, because Chinese firms have weaker technology capacity and hence weaker bargaining power in negotiations with large foundries like TSMC[90].

That broad proposition however needs to be differentiated. Industry observers emphasize that the advantages or disadvantages of proximity to foundries differ, depending on the capability sets and bargaining power of different firms. The pros and cons also differ across product markets and market segments – design houses for instance that focus on analog, mixed-signal designs do not need access to leading-edge process technology, but are well served with trailing-node process technology.

For policy purposes, this paper suggests to be more specific about the precise nature of the policy challenge. One could ask for instance specifically: *As China-based design houses are ramping up 28nm chip orders at TSMC, as reported in August 2014*[91]*, would they be better off if SMIC or any other China-based foundry could have a proven 28nm process technology ready and could provide the full solution (fabrication of the design plus supporting design services that are especially important for latecomers like Chinese IC design firms)?*

China's technology planners who have shaped the *Guidelines* seem to have taken this more focused and pragmatic approach. Based on their research on the global semiconductor industry, the planners expect that significant and stable market for trailing-node semiconductor technology (i.e. 28nm and above) may open up new opportunities for Chinese foundries to gradually gain market share and improve their profit margins in these technologies. The primary beneficiary is expected to be SMIC, which after all is now the fifth largest global foundry.

The underlying economics works roughly as follows: At this stage of the semiconductor cycle, trailing nodes (28 nm and higher) actually carry higher margins than the leading-edge technology nodes below 28nm. This is so because most of the equipment used to produce trailing nodes are either partially or fully depreciated, so trailing nodes don't have the burden of depreciation. According to one observer, "trailing nodes may be returning higher margins, because they are being manufactured in fully depreciated wafer fab facilities."[92]

On the other hand, producing devices at 20nm and below is extremely expensive, resulting from the escalating cost of equipment and tools. There is an intense debate within the industry whether the cost of producing leading-edge devices will decline, and if so, at what pace. But it seems that the current consensus position within the industry is that barriers to such cost reductions will remain substantial for a considerable time.

Thus, second-tier foundries like SMIC may have a limited window of opportunity to compete in trailing node technologies. They may be able to catch up with the leaders in technology and gradually gain share and improve their margin in these trailing nodes. Industry sources report that both SMIC and UMC actually have been gaining market share away from TSMC in these trailing nodes[93].

This window of opportunity however may be closing soon. Once a second-tier foundry like SMIC is adding additional capacity, this will require new facilities with additional depreciation expenses which will reduce margins. And if more foundry capacity would be added, leading to excess capacity, the resultant cost increases would erode profit margins.

SMIC's new management seems to bet that the trailing node upgrading trajectory will work. But the challenge to achieve this goal will be formidable. According to industry observers, SMIC is two generations behind that of Taiwan Semiconductor Manufacturing Co. (TSMC), the world's largest contract chip maker. In the latest *2013 IC Foundries report*, SMIC has retained its position as the fifth largest global IC foundry, and it has grown by 28% in 2013. However, **Table 3** clearly demonstrates that, in terms of foundry capacity, SMIC remains a minnow compared to the three global industry leaders.

Table 3

2013 Foundry Capacity Comparison

Foundry	Capacity / year
TSMC	16,423,625
GLOBALFOUNDRIES	7,326,000
UMC	6,313,500
SMIC	2,682,000

IC Insights -Production capacity figures converted to 8-inch equivalent wafers in order to enable comparison [20]

In addition, SMIC's net profit is not even 1/30th of TSMC's, explaining why without government support China's semiconductor foundry sector lacks the capital needed to ramp up production and compete in the trailing-node processes. While the leading Taiwanese foundries (TSMC, UMC and Powerchip) have a combined 60% share of worldwide 2013 foundry revenues, the combined share of China's SMIC and Grace is less than 5%.

China's technology planners however seem convinced that SMIC may be able to reap latecomer advantages for trailing node technology (28nm), provided of course that appropriate support policies are in place. The underlying economic rationale is aptly summarized by Tsinghua University's Prof. Wei Shaojun: "If the advanced processes …[i.e. below 28nm]…cannot be brought into mass production on schedule, a major shortage of chips using the 28nm process could emerge before 2017. That would give SMIC, which received 28nm orders this year from Qualcomm, a chance to vault to the front of the pack. By 2017, global demand for the 28nm process will be 4 million wafers a month. Right now, capacity hasn't even reached 3 million."[94]

Will SMIC be able to narrow the technology gap?

China-based IC design companies (both domestic and foreign ones) are of critical importance – they account for 40% of SMIC's revenues[95]. To address the real needs of China-based fabless companies, SMIC pursues a flexible approach: “Over 28nm process technology is fungible. In other words, those new 28 nm process lines are also capable of 40nm products.”[96]

According to SMIC’s web site, the company’s 28nm process technology was scheduled to be ready for foundry customers by the end of September 2014. A collaboration, announced in July 2014 , between SMIC and Qualcomm on 28-nm wafer production in China, is expected to accelerate this upgrading process.[97] In addition, SMIC seeks to diversify into potentially profitable specialty foundry niche markets. For instance, SMIC developed an embedded EEPROM platform, which had been adopted by a majority of China's bankcard IC design houses. On microelectromechanical systems (MEMS), SMIC cooperates with Silicon Labs[98], a leading specialist US fabless design company. This cooperation foccuses on manufacturing CMEMS-based MEMS oscillators, designed to allow direct post-processing of high-quality MEMS layers on top of Silicon Labs' RF/mixed-signal CMOS technology. Another joint venture with a US company, Toppan Photomasks Inc, Round Rock/TX seeks to to manufacture on-chip color filters and micro lenses for CMOS image sensors[99].

According to an industry observer who has requested anonymity, SMIC’s strategy has been focused on “stable niche markets (sensors) and generic 180nm+ service, something that TSMC was not interested in…. It was a wise decision on SMIC's part to stop chasing Taiwanese and to seek growth opportunities beyond TSMC dominated leading-edge process markets.”

An emerging division of labor in China’s semiconductor foundry industry

Thus far, China’s trailing-node upgrading strategy for its foundry industry has produced two results: a) an emerging 12-inch wafer fabrication cluster, centered on SMIC; and b) an 8-inch foundry cluster, focused HH Grace. As discussed below in section 3.4., it remains to be seen whether these achievements are sufficient to transform China’s foundry industry into a credible global player.

The 12-inch wafer fabrication cluster, centered on SMIC

China has decided to develop a supply chain focused on 12 in IC manufacturing fabs, centered on SMIC[100]. As part of this target, SMIC seems to focus on 12-inch wafer fabrication facilities with trailing-node process technologies of 28nm and above.

In August 2014, SMIC and Jiangsu Changjiang Electronics Technology Co. Ltd (JCET) announced a joint venture for 12inch bumping and related testing, to be established in Jiangyin National High-Tech Industrial Development Zone in China’s Jiangsu Province. The joint venture can benefit from Jiangyin's unique location and mature industrial environment to quickly set up the 12inch wafer bumping[101] and wafer testing production line (specifically for Circuit Probe (CP) testing)[102]. In addition, the joint venture can also utilize JCET's nearby advanced back-end packaging production line. For SMIC, the JV with JCET will facilitate ramping-up of its 28nm mass production. For China’s IC design industry, this emerging 28nm supply chain will shorten the overall manufacturing cycle time.

The 8-in foundry cluster, focused HH Grace

HH Grace (incorporated through the merger of Shanghai Hua Hong NEC Electronics Company and Grace Semiconductor Manufacturing Corporation) focuses on 8-inch pure-play foundry services covering technology solutions from 1.0µm[103] to 90nm process nodes, focusing on advanced and differentiated technologies including eNVM (embedded Non-Volatile Memory), power management IC, power discrete, RF, CMOS image sensors as well as standard logic and mixed-signal.

With three 8-inch wafer fabrication facilities in Zhangjiang and Jinqiao of Shanghai, HHGrace offers production capacity over 124,000 8-inch wafers per month. HHGrace is also seeking to upgrade its capacity to provide foundry solutions for MEMS[104] solutions through a strategic partnership with Shanghai Quality Sensor Technology Corporation ("QST"), a Chinese company producing high-end magnetic sensors and MEMS sensors.[105] As SMIC is also diversifying into the MEMS market niche, there is reason to be concerned about a lurching threat of over-capacity[106].

3.4. Changes in the IC foundry industry landscape

Whether China might succeed in its trailing-node strategy, depends on the impact of significant recent changes in the IC foundry industry landscape. It is an open question at this stage how the new global foundry landscape might affect China's efforts to upgrade its semiconductor industry. It is unclear in particular whether the emerging new global foundry landscape will create new entry possibilities for SMIC and other Chinese foundries.

Apple acts as a catalyst

As is so often the case in this industry, Apple acted as a catalyst for change. In response to acrimonious and unresolved patent wars, Apple switched from Samsung to TSMC as the sole supplier of Apple's next-generation application processors. As a result, the global foundry landscape is changing beyond recognition.

For a while, it looked like Apple would be TSMC's only relevant customer for 20nm, providing it with quite some bargaining power as a *monopsonist*. As long as TSMC would remain the only meaningful foundry supplier of 20nm process technology, this would imply that prices for 20nm foundry services would be negotiated between a *monopsonist* (Apple) and a *monopolist* (TSMC).

If such a market structure would prevail, Chinese IC design firms would find it quite difficult to gain access to TSMC foundry services. As lower-tier customers, Chinese IC design firms are likely to be charged higher prices. But higher chip fabrication cost is arguably not the main concern. The main barrier to using TSMC's foundry capacity is what the industry calls MOQ, i.e. "minimum-order-quantity". Chinese IC design firms clearly are vastly disadvantaged relative to Apple, and may well end up having to wait for a long time to get its chips fabricated ("taped-out" in industry parlance).

Already in the second quarter of 2014, it became clear that Chinese IC design firms are unlikely to have secure access to TSMC's foundry services. TSMC announced that its production capacity is almost fully booked for the fourth quarter of 2014. TSMC's nearly sold-out wafer production has placed most IC design houses in a dilemma as to whether they should queue up at TSMC for capacity. Since lead times for wafers usually extend to 4-6 months during peak business cycles, IC design houses may receive deliveries only in the first half of 2015 for wafer orders placed in the fourth quarter of 2014. Hence, Chinese fabless IC design companies would suffer, given that time-to-market is of critical importance for success.

As timely and cost-effective access to TSMC's capacity will become even more difficult, this would in principle provide new opportunities for SMIC and other Chinese foundries to gain business from Chinese fabless design companies, provided of course SMIC will succeed in accelerating its upgrading to 28nm process technologies. On the positive side, there are indications that SMIC's focus on trailing node technologies has already pushed down prices and MOQs. This is important for Chinese fabless companies, as it may facilitate timely and cost-effective access to foundry capacity in China. Most importantly, Chinese fabless companies will have to struggle less with TSMC's demanding MOQ requirements.

Intensifying competition in the leading-edge foundry business

In the meantime, however, Apple's Big Bang move to drop Samsung as its foundry supplier, has now set in motion a chain of events that are likely to change further the global foundry landscape. But at this stage there is no way to predict possible outcomes. Nor is it possible to anticipate how all of this will affect China's efforts to upgrade its foundry industry.

For Samsung, the loss of Apple's foundry contracts is a massive setback. But Samsung is fighting back, and the company now seeks to compete head on with TSMC in the pure play global foundry business for leading-edge integrated circuits. Foundry work remains an important segment for Samsung, and the company has announced to invest $14.7 bn into a new, cutting-edge wafer fab that will use leading-edge wafer size and process technologies in order to attract foundry contracts from fabless IC design companies[107].

Samsung now has become the fourth largest IC foundry, behind TSMC, Global Foundries and UMC[108]. In 2013, Samsung had a 15% increase in its foundry sales and was less than $10 million behind the third-largest IC foundry in the world—UMC. According to *IC Insights*, "Samsung has the ability (i.e., leading-edge capacity and a huge capital spending budget) and desire to become a major force in the IC foundry business. It is estimated that the company's dedicated IC foundry capacity reached 150,000 300mm wafers per month in the fourth quarter of 2013. Using an average-revenue-per-wafer figure of $3,000, it is estimated that Samsung's IC foundry business segment has the potential to produce annual sales of about $5.4 billion."[109]

Another potentially transformative event is the decision of IBM to get rid of its semiconductor fabrication. Since the beginning of 2014, there was intense speculation about who would acquire IBM's semiconductor assets. For some observers, it seemed "… quite logical that a sale of IBM's chip manufacturing would be to China."[110] In the end, IBM's foundry operations were transferred to Global Foundries, as announced on October 21, 2014[111]. In a quite unusual arrangement, IBM pays Global Foundries $1.5 billion, simply to get rid of its unprofitable chip manufacturing business. In a statement, IBM seeks to justify this embarrassing retreat, stating that the move would save it billions of dollars IBM would otherwise have to spend to keep upgrading its facilities for the next generation of chip technology[112].

The deal involves two IBM fabs: a) East Fishkill,N.Y. with a 15,000 wafers per month capacity, that has just ramped up the 22nm process used to make IBM's Power 8 processors and where 14nm technology is under development; and b) Burlington, Vermont, with 45,000 wafers per month capacity – a specialty fab for analogue devices, much of it for the defense industry.

There are still considerable regulatory hurdles, not only because of the defense-related products, but also because Global Foundries is primarily owned by the government of Abu Dhabi, and hence requires approval of the deal by CFIUS (the Committee on Foreign Investment in the U.S.). But if the deal would go through, it would not only expand Global Foundries' capacity by more than 10%, but it also would add more than 10,000 IBM semiconductor patents. IBM, after all has been one of the founding fathers of semiconductor technology. IBM's semiconductor patent portfolio thus will be quite valuable, especially those patents which cover IBM's 22nm and especially its 14nm technologies.

It is unclear to what degree the IBM'Global Foundries deal will affect China's plans to upgrade its semiconductor foundry industry. Taiwan's UMC most likely will be negatively affected. In light of the earlier speculations that China might be the recipient of IBM's foundry assets, it is worthwhile asking: Why did China not acquire the IBM semiconductor business? Were there US national security considerations involved? Or were there doubts whether SMIC would have the level of competency needed for ongoing support of IBM mainline of business?

Another important player in this transformation of the global foundry landscape is Intel. By establishing its own rapidly growing Custom Foundry group, Intel demonstrated that it intends to play an active role at the top end of the global foundry industry. Intel is actively recruiting worldwide top foundry service specialists. With locations in the US, Canada, and India, Intel's strategy is to provide "select customers strategic access to our leading edge process technology and manufacturing services…[, as well as]… turnkey services … [such as]… ASIC design services, specialty IP, wafer manufacturing, packaging and testing." [113] A first step was a 12-year agreement, signed in February 2013, with Altera, a leading US fabless chip design company. As part of recently announced strategic partnerships with two Chinese fabless companies (Rockchip and Spreadtrum), Intel is expected to add these two Chinese companies as foundry customers.[114]

There are persistent rumors that Apple may select Intel to fabricate some of its most recent application processors[115]. In the end, intensifying competition in the global foundry business is all driven by wafer price negotiations – all the leading fabless companies are searching for ways to escape the high prices charged by TSMC.

From China's perspective, what matters is that the industry clearly is in turmoil, due to intensifying competition among a small band of foundries that are able to offer high-volume leading-edge foundry production over the next five years. This leading group of foundries includes TSMC, Global Foundries, UMC, Samsung and Intel, but China's SMIC is not part of this exclusive club. These five leading-edge technology foundry leaders are fierce competitors – their main goal is to put pressure on TSMC to reduce its foundry service prices for leading-edge semiconductors. In fact, it is now expected that pricing will likely come under pressure, and that this may even be the case for leading-edge devices.

As a result, a recent forecast of growth patterns in foundry sales expects the 2014 leading-edge 28nm-and-below foundry market to be about $5.1bn, a 72% increase in size as compared to 2013[116]. The report concludes:" Not only is the vast majority of pure-play foundry growth coming from leading-edge production, most of the profits that will be realized come from the finer feature sizes as well."

For China, one possible impact of the emerging new global foundry landscape may well be to reduce the scope of its "trailing node upgrading" strategy. In the end, it is unclear at this stage whether the emerging global foundry landscape will support China's upgrading efforts in this industry, and how all of this will affect China's new push in semiconductors. This provides yet another example of the deeply entrenched uncertainty that characterizes the dynamics of semiconductor industry development.

3.5. A new interest in strategic partnerships and mergers and acquisitions.

As described in **Part Two** of the paper, strategic partnerships, joint ventures, and mergers and acquisitions (M&A) are an important ingredient of China's new policy on semiconductors. Two objectives are driving these efforts: On the one hand, M&A among domestic firms are expected to create new opportunities for economies of scale and scope, and for creating synergies among firms with different specialization patterns and capabilities. A second objective is to gain access to cutting-edge technology and best-practice management techniques through strategic partnerships and joint ventures with leading global semiconductor firms.

Domestic M&A: Spreadtrum and RDA

On July 19, 2014, Tsinghua Unigroup announced that it was arrangi ng for a merger between Spreadtrum and RDA.[117] The main goal is to create a credible competitor in the IC design market for low-end budget smart phones, not only against Taiwan's MediaTek, but also against the emerging challenge from Qualcomm.[118] Since 51 percent of Tsinghua Unigroup is owned by Tsinghua Holdings, a 100 percent state-owned limited liability corporation funded by Tsinghua University, the Spreadtrum/RDA merger is expected to deliver a new, state-owned, consolidated entity that might be able to generate sufficient economies of scale and scope.

In addition, there is the promise of significant potential synergies between these two companies that started out with very different business models[119].

RDA is proud of its local roots, initially providing low-cost RF(radio frequency)circuits, especially to Chinese *Shanhzai* handset vendors. RDA's strategy relies on access to cheap, well-trained local engineering talent for chip design. These engineers have graduated from Chinese universities, and RDA willingly takes on the task of providing them with real-world design experience. Through intensive use of domestic engineering talent, RDA engages in exceptionally rapid cycles of prototyping and new product development. RDA chips don't need leading-edge process technology, and hence can rely on foundries with older technology. This low-key and pragmatic business model has allowed for rapid catch-up in capabilities and a sustained growth in market share at the low end of the end market.

Spreadtrum on the other hand followed the path initially blazed by Taiwan's MediaTek, providing a turnkey platform that combines baseband and RF chips, along with the relevant associated software solutions. Dr. Leo Li, Chairman, CEO and President of Spreadtrum Communications, Inc., has more than 23 years of experience in the wireless communications industry, and has worked for instance for Broadcom, Rockwell Semiconductors and Ericcson. Since Dr. Li joined Spreadtrum in May 2008, the company has followed a remarkable strategy of technology leapfrogging into trailing-node process technology. This strategy has enabled it to offer feature-rich phones and move rapidly into low-end smartphones. A key milestone came in October 2010, when Spreadtrum engineers successfully prototyped a 2.5G integrated chip solution using 40 nm process technology, which provided the basis for a 95% increase in sales in 2011.

Spreadtrum's focus on trailing-node process technology culminated on June 23, 2014, in the introduction a quad-core smartphone platform (the "SC883XG"), designed with advanced 28nm process technology, that integrates diverse Third Generation mobile telecommunications standards, including China's TD-SCDMA standard.[120] Spreadtrum's adoption of more advanced semiconductor process technology delivers higher performance and lower power consumption, providing handset makers with a cost-effective solution for mid- to high-end handset models.

On paper at least, the merger between Spreadtrum and RDA offers significant potential synergies. As one Chinese semiconductor industry observer explained, "Spreadtrum is weak in everything except TD-SCDMA, while RDA is strong in RF. Both are weak in application processors. … Spreadtrum's integrated circuit R&D is weak, but … [the company is] …strong in software. Meanwhile, RDA is very strong in IC R&D, but has no real software development." [121]

A similar assessment is offered by a US-based industry observer: "If you wanted to create a China-based company that could (with a lot of work and a lot of money) someday rival Qualcomm, Spreadtrum and RDA are the two companies that I would pick." [122] Whether this merger will work however remains an open question. Forcing together two companies with very different cultures has triggered raw emotions and turmoil among RDA employees who object to it. RDA's Chairman and CEO Vincent Tai, who reportedly resisted the Tsinghua Unigroup's acquisition plan, was fired by the RDA board in late 2013[123]. This apparently has created quite some bad blood in the company.

Global partnerships and M&A

China's efforts to realize partnerships and M&A with leading global semiconductor firms are facilitated by two recent developments: First, as the cost of moving to leading-edge multi-component semiconductors (MCOs) and process technologies keeps rising, the semiconductor industry experiences a growing pressure to consolidate size and market power through partnerships and M&A[124]. At the same time, China's emerging role as a lead market for mobile devices acts as a powerful magnet to global industry leaders, both in the semiconductor and in the mobile device industry, to secure long-term access to the China market.

As a result of these two developments, the interest and willingness of foreign firms to engage with Chinese firms now seems to have substantially increased. To some degree this reflects a perception in the headquarters of global firms that the balance of power is shifting, providing China with greater bargaining power. In fact, the leading global players, and especially US firms, are all now experimenting with strategic partnerships and M&A with Chinese IC design companies and foundries[125]. China's technology planners believe that, if handled correctly, the new interest by global industry leaders in strategic partnerships could create new opportunities for Chinese firms to engage in global technology sourcing.

Important examples of this new round of US-Chinese partnerships in semiconductors include, but are not restricted to the following recently announced agreements.

Global partnerships in the Foundry Industry

Qualcomm/SMIC

On July 2nd, 2014, Qualcomm and SMIC announced that they are working together on 28nm wafer production for Qualcomm's latest Snapdragon processors in China[126]. Qualcomm, the leading base band cellular processor company states that it will offer support to accelerate the development of SMIC's 28nm process technology.[127]

If Qualcomm would stick to its commitment to share critical knowhow, this agreement would be a big win for SMIC, enabling China's leading foundry to implement its trailing-node upgrading strategy that depends on the advancement of its 28nm technology.

But what is in it for Qualcomm? Some observers argue that without the NDRC antitrust pressure on Qualcomm, it is debatable whether Qualcomm would have found SMIC to be its best choice.

However, it is useful to consider that a combination of the following three motivations may have been instrumental in Qualcomm's decision. The catalyst most likely has been indeed the pressure exerted by NDRC. As Qualcomm had been singled out by the Chinese antitrust authority, appeasing the Chinese government by contracting some 28nm production to SMIC might clear the air between the parties. In addition, it is also very lucrative business. Second, there is a general shortage of 28nm production capacity, so Qualcomm may not have had much of a choice but to resort to second-tier production capacity available at SMIC. But SMIC is not Qualcomm's only option. On October 14, 2014, UMC announced that it has received orders from Qualcomm 28nm chips for Fourth Generation LTE smartphones, with shipments to begin in the fourth quarter of 2014[128]. Again this indicates how unpredictable these global transformations are, and hence how precarious key assumptions are which underlie China's industrial upgrading scenario for semiconductors.

Third, Qualcomm like other leading fabless design companies may seek to use diversification of foundry suppliers not only to get better pricing at SMIC, but also to induce price reductions by TSMC. Fourth, as Qualcomm seeks to outmaneuver Taiwan's MediaTek and China's Spreadtrum in the low end of the smartphone market, a strategic partnership with China-based SMIC might enhance the chances to gain design-ins from Chinese smartphone vendors. This motivation has gained further urgency, as Spreadtrum has recently received a $ 1.5bn investment from Intel (further discussed below).

An additional motivation for Qualcomm's decision to link up with SMIC might reflect a more fundamental shift in the semiconductor industry. As indicated earlier in this paper, there is an intense debate within the industry whether the cost of producing leading-edge devices will decline, and if so, at what pace. The Global Five (TSMC, Global Foundries, UMC, Samsung and Intel) are betting on a speedy transition to leading-edge process technologies, starting with 20nm devices. However, another equally influential group contends that barriers to such cost reductions will remain substantial for a considerable time.

Take for instance Zvi Or-Bach, a respected industry figure[129], who argues that "dimensional scaling beyond 28nm would not provide reduction of SoC [=system-on-chip] cost and, accordingly, 28 nm could the preferred node for many years."[130] The Global Semiconductor Alliance (GSA) in fact has established a 3D-IC Packaging Working Group, reflecting the importance of this potentially disruptive move towards 3D-IC based on 28nm process technology.[131]

Qualcomm apparently has decided to support this approach. At the 2014 Design Automation Conference (DAC), Qualcomm declared: “"One of the biggest problems is cost. We are very cost sensitive. Moore 's Law has been great. Now, although we are still scaling down, it's not cost-economic anymore. It's creating a big problem for us." [132]

In other words, Qualcomm needs to find production partners for monolithic 3D chips. As TSMC is not taking the lead in 3D chips, Qualcomm may bet that SMIC, after establishing a good relationship with Qualcomm in 28nm, will continue to upgrade its foundry capacities into monolithic 3D chips. According to SMIC's web site, "SMIC will also extend its technology offerings on 3DIC and RF front-end wafer manufacturing in support of Qualcomm as its Snapdragon product portfolio continues to expand."[133] Or-Bach argues that, while SMIC lags behind TSMC in leading-edge nodes, this does not disqualify SMIC to use the Qualcomm deal to develop a strong position in 28nm. If it is true that the value of the more advanced nodes is diminishing, then the SMIC-Qualcomm deal might suggest that "SMIC is positioning itself to lead in the next generation technology driver - monolithic 3D, using the most effective node for years to come. If the rest of the foundries will ignore it, they may find themselves trailing behind SMIC in few years, in what by then could become THE technology driver. "[134]

Global partnerships in IC design

Global partnerships and M&A also are gathering momentum in China's IC design industry. Among partnerships initiated by US firms, of particular interest are Intel's investments in two Chinese fabless companies, Rockchip (for tablet ICs) and Spreadtrum (for smart phone ICs).

Intel/Rockchip

In May 2014, Intel announced that it has entered a strategic agreement with Fuzhou Rockchip Electronics Co., a Chinese fabless IC design company focused on IC design for Android tablets[135], to accelerate and expand the portfolio of Intel-Based Solutions for tablets.

This deal had well calculated commercial and technological features. For Intel, it could certainly accelerate time-to-market for its tablet-related processors. There may also be a substantial public relations component, as Intel can now claim "We have a Chinese Partner".

A unique feature of the Android tablet market is that China-based IC design houses like Rockchip, Allwinner Technology and Actions Semiconductor have become the main suppliers of tablet chips. The reason for this is not technological superiority, but the simple fact that leading international smart phone chip design companies have neglected this market. For them, the tablet chip market was unattractive, because global demand for tablets is only about one-fifth of the smartphone market, and prices for tablet chips are only about one-third of those for smart phone chips[136].

The success of Chinese tablet chip designers has been a wake-up call for companies like Intel which now aims to ship 25 million tablet processors in the second half of 2014. [137] For Intel, the link with Rockchip is expected to provide it with Rockchip's ecosystem in China, including Rockchip's software support and existing back-end component and market channel relationships[138]. An important motivation for Rockchip apparently is the intensifying competition between tablet chip design based on ARM processors, which has caused Rockchip's profits to fall and narrowed its options to differentiate itself from competing design houses.

In short, the Intel/Rockchip partnership may well have positive effects on the upgrading of China's IC design industry, provided of course that both companies find ways to establish effective mechanisms for technology transfer and absorption.

Intel/Spreadtrum

On September 24, 2014, Intel announced that it will pay $1.5bn for a 20% stake in two Chinese mobile IC design companies (Spreadtrum Communications and RDA Microelectronics) through a deal with Tsinghua Unigroup, the government-affiliated private equity firm which owns the two mobile chipmakers. This deal is quite complex, and many essential data points have not yet been made public. For instance, how much for the $ 1.5 billion was paid in cash? What are the contractual arrangements for sharing intellectual property? And does this involve an IC fabrication deal for Intel's Custom Foundry group?

In principle, this deal could provide a boost to China's efforts to upgrade its IC design industry. If RDA and Spreadtrum would be able to absorb Intel's technology, this deal could empower these two companies to compete head-on against Qualcomm and Taiwan's MediaTek. At the same time, Chinese smart phone vendors might also benefit, as they now would have an alternative to costly Qualcomm chipsets.

As for Intel's motivations, the company's web site states that "..[t]he purpose of the agreements is to expand the product offerings and adoption of Intel-based mobile devices in China and worldwide."[139] Since a new CEO tool over at Intel in 2013, the company has pursued an array of deals and strategies to ensure its chip technology gets into more smartphones and tablets[140]. Reflecting Brian Krzanich's background in semiconductor fabrication, Intel "… has opened the chipmaker's prized, cutting-edge factories to paying customers."[141]

But apart from access to the thriving China market, Intel's main motivation clearly is to overcome its persistent weakness in the smartphone chip industry, which is being dominated by ARM, Qualcomm and MediaTek. As Intel's design philosophy is shaped by the needs of the PC market, it neglected the alternative design approach in the mobile IC design industry, which is based on system-on-chip design that provides "turnkey solutions". Intel now seems to recognize that it could benefit from partnering with Spreadtrum and RDA. After all, these two Chinese companies have been early adapters of "turnkey solutions", and they have learnt to sell an integrated device template to smart phone vendors, who in turn have benefited through lower production costs and faster turnaround times.

By the same token, the partnership with Intel could help both Spreadtrum and RDA to reduce their dependence on ARM processors. As long as they remain "me-too ARM IC designers", their profit margins will be limited, as ARM captures the largest share of the value-added. According to industry observers, "…[w]ith Intel's architecture and tech support, … [Spreadtrum and RDA]…will jump to the forefront and give Qualcomm, MediaTek and [other apps processor companies] a serious run for the money."[142]

Finally, partnering with two leading Chinese mobile IC design companies, could also provide Intel with new customers for its Custom Foundry Group. At this stage, this is mere speculation, as the Intel-Tsinghua Unigroup agreement does not provide much details. Intel's300mm wafer fabrication line in Dalian, which was opened at great fanfare in 2010 to produce 65nm chipsets for PCs and servers, is significantly under-utilized. This by itself would provide a powerful motivation for Intel to include foundry services in the agreement with Tsinghua Unigroup.

Mergers and acquisitions initiated from the Chinese side

Proposed acquisition of OmniVison Technologies

In August 2014, US camera sensor-maker OmniVision Technologies,a leading developer of advanced digital imaging solutions, has received a take-over bid from Hua Capital Management Ltd (HCM), a Beijing-based investment management company[143]. As indicated in **Part Two** of the paper, HCM was chosen in June to manage the sub fund for chip design and testing under the Beijing government's 30 billion-yuan (HK$37.8 billion) Semiconductor Industry Development Fund. Omnivision's stock price climbed by 14 per cent to just over $28 on the news. The company's board of directors said it was evaluating HCM's proposal. And on September 19, HCM has hired Bank of America to provide funding for its US$1.7 billion bid for US camera sensor-maker OmniVision Technologies[144].

The proposed acquisition of OmniVision is the first example of how China's *Guidelines* are being used to acquire a foreign company, with the intention of "making that company Chinese." In fact, Omnivision has strong Chinese roots, hence the chances of success are considerable. In fact, OmniVision was co-founded by Hong Xiaoying, a Chinese immigrant and current chief executive, and the company has Chinese and Taiwanese managers among its senior ranks. The company had sales of US$1.45 billion last year, but has hardly grown from 2013. The company however has attractive technology with a wide range of applications, such as cars, mobile devices and security equipment. In 2012, Omnivision was second placed among the top-three vendors of CMOS image sensors that comprised Sony, Omnivision and Samsung with 21, 19 and 18 per cent of the $6.9 billion market, respectively. Omnivision has supplied Apple with back-side illuminated CMOS image sensors for its iPhone and has a design center and testing facility in Shanghai, China.

If that acquisition would go through, it could give a significant boost to China's plans to upgrade its IC industry. The deal also would seem to address some of the Leadership's security concerns. It is of course an open question whether this deal will receive regulatory approval in the US, from CNIFUS and other relevant agencies, as the deal may well raise security concerns in the US. According to USITO, the OmniVision deal may be less significant technologically, but it may well be an early herald of bigger more substantial foreign acquisitions down the road[145].

Acquisition of Broadcom division?

On June 24, 2014, it was reported that the Chinese government was planning to take over Broadcom's mobile baseband unit[146]. These rumors however have not yet been confirmed. The rumors probably emerged in response to an earlier announcement by Broadcom that it is considering selling or shutting down its cellular baseband business. After that statement, industry sources reported that other companies such as Qualcomm, Intel, and Taiwan's MediaTek were not interested in acquiring the business unit because Broadcom's product lines are not complementary to their businesses.

From China's perspective, an acquisition of Broadcom's mobile baseband unit would carry significant promises. Broadcom's activities, which include a strong portfolio 3G and 4G chips as well as modem IP, could help Chinese handset vendors which are planning to build up their own in-house chipset platforms. China's technology planners expect that the acquisition of Broadcom's business unit by the Chinese government might enhance the semiconductor supply chain, and it may also reduce China's huge demand-supply gap of ICs.

Broadcom's main goal is to expand its sales in China by making chips that support a wider range of handsets. Of particular interest are those handsets which run on the network of the world's largest telecom carrier, China Mobile Inc., using the Chinese Standards for 3-G and 4-G mobile communications[147]. Broadcom's strategy is shaped by the assumption that demand will continue to rise for low-cost smartphones that work on China Mobile's third-generation network.

An acquisition of parts of Broadcom's mobile communications chip business thus might fit well with Broadcom's general strategy. In contrast to many US IT firms, Broadcom publicly states that it welcomes the recent spending by the Chinese government to bolster the domestic chip production and design industry. The underlying rationale is that this might help to strengthen Broadcom's already quite close cooperation with Chinese companies such as Spreadtrum and SMIC. Broadcom also acknowledges that it is in talks with Tsinghua Unigroup, the government-related fund that has acquired both Spreadtrum and RDA.

At this stage, it is unclear why China's government has not proceeded to acquire Broadcom's mobile baseband unit. Many theories are circulating in the investment community, highlighting possible constraints, in terms of timing, sharing of intellectual property, and lack of trust.

There is no doubt that, if well managed, the strategic acquisition of foreign IC design houses could help to address important weaknesses (there are aplenty!) of China's still precariously weak IC design industry. And even if strategic acquisitions would face regulatory hurdles in the US, there are arguably other opportunities for China to implement global knowledge sourcing strategies. For instance, ex-Nokia teams in Finland and around the world (including in China) could be used as sources of critically important intangible knowledge. The same may be true for engineers and engineering teams from the former RIM/Blackberry, from the down-sized IC division of Infineon, and other such once important global companies.

China also may want to consider other opportunities, such as cooperating with leading centers of excellence like IMEC (in Belgium), the Holst Center (in the Netherlands), and other centers of excellence, for instance in Nordic countries.

In the end, China's push to upgrade its IC design industry through M&A raises of course a fundamental question: Does China have the managers who could make these extremely demanding acquisitions and cooperation agreements work? And are management approaches in place which could cope with the negative side effects of internationalizing the work force of Chinese IC design companies, as manifested for instance in the substantial gaps in remuneration between domestic and foreign engineers and managers?

China's growing role in semiconductor mergers and acquisitions

The Thomson Reuters data base on mergers and acquisitions (M&A) in the semiconductor machinery and semiconductor and related device manufacturing industries (NAICS codes 333295 and 334413) provides some proxy indicators of China's growing role in semiconductor mergers and acquisitions[148]. The afore-mentioned illustrative examples thus may well be quite representative.

First, M&A deals in which Chinese firms were targets, display a rising trend – out of 225 such M&A deals between January 1, 2005 and September 30, 2014, almost 30% (65 deals) occurred in 2013 and the first nine months of 2014. Of those 225 M&A deals,72% (161 deals) were transactions where Chinese firms were both the target and the acquirer[149].

Second, China's importance as an acquiring nation is on the rise – of the 196 deals that involved China as the acquiring nation between 2005 and end September 2014, 30% (59 deals) were closed in 2013 and the first nine months of 2014.

China also has gained in importance both as an acquirer nation and as a target nation in the semiconductor industry. As an acquirer nation, China now is number 4 (with 198 deals), after the dominant US (901 deals), South Korea (402), and Japan (231). And as a target for semiconductor M&A, China is now number 3 (with 227 deals), following the leading US (847 deals) and South Korea (416), but ahead of Japan (210 deals).

Future research would need to deepen the analysis to include detailed case studies of deals, focusing especially on the role of top acquirers (for semiconductor firms, as well as investor groups and government agencies.) Of equal importance will be case studies of the role of Chinese firms, both as acquirers and as acquisition targets, and the impact of these deals on technology transfer, and the development of absorptive capacity and innovation capabilities of the companies involved in these deals.

3.6. How will China's push in semiconductors affect its exports of electronic final products?

An important challenge for China's industrial upgrading scenario in semiconductors is the possible impact on exports of China's electronics final products. Unfortunately, there is little discussion of this critical issue in the publicly available Chinese policy documents.

China's exports of electronic final products are of huge value and central to the country's trade and development. For 2013, the UN COMTRADE data base reports China's ICT (=information and communication technology) exports (not including IT services and software) as $599.7 billion, which is roughly 27% of China's total goods exports[150]. In other words, almost a third of China's total goods exports are ICT products that are powered by semiconductors[151]. China thus relies on semiconductors as an essential input of a large share of the products it exports.

As China still lacks a fully developed semiconductor industry, China depends on semiconductor imports as an enabler of its exports of electronic final products. For 2013, again according to UN COMTRADE data, China's ICT exports are reported as roughly 2.3 times the value of China's 2013 semiconductor imports ($261.3 billion).

Some observers in the U.S. suggest that China's new push to expand and upgrade its semiconductor industry may actually undermine downstream users, i.e. China-based semiconductor-consuming producers of electronic final products, and hence may erode China's export surpluses in the ICT industry[152]. It is argued that, in case China-based semiconductor consuming ICT goods vendors only had access to locally produced chips, this might severely limit the quantity, type and quality of chips they can design into their final goods, and hence might constrain performance features of those final goods, and increase their cost. If these IC consuming companies were foreign firms, this could motivate them to move to locations outside of China where they would have unrestricted access to all the chips they need.

To succeed in global competition, semiconductor-consuming ICT goods vendors based in China would need fast and unrestricted access to all chips that are available in the global market. In this scenario, China's new semiconductor policies may only be able to change buying patterns if chips designed and fabricated in China are superior in performance and price relative to competing products. The policy conclusion drawn from this argument is that China's new policies on semiconductors can only work if they allow for "free and open markets and a level competitive playing field in all markets."

Chinese technology planners view these arguments with considerable skepticism. From a Chinese perspective, these arguments neglect the needs of a country that is a latecomer to this industry. In this view, China first needs to develop gradually a more integrated local industrial value chain and firm-level capabilities, before it can fully reap the benefits of a more open, more transparent, and less discriminatory market for semiconductors. Chinese technology planner acknowledge that, in the short run, global technology sourcing (through imports of semiconductors, but also through joint ventures, strategic partnerships or M&A) is necessary to accelerate catching-up. They seem to be convinced, however, that forging ahead would require the development of a domestic semiconductor industry value chain, as well as relevant technology and management capabilities of Chinese firms.

Based on the findings of this paper, it is appropriate to highlight two caveats that should inform assessments of China's policies to upgrade its semiconductor industry. The first caveat is that China's new push in semiconductors should take into account the need of down-stream, semiconductor-consuming industries. Moving to self-sufficiency in semiconductors not only is unnecessary. It simply would not work, and it would defeat its purpose, as it would undermine the competitiveness of downstream semiconductor-consuming industries. For China's new policy on semiconductors to succeed, planners and policy makers need to step back and explore possible unintended negative consequences for downstream user industries.

The second even more important caveat is that, thus far, there is little research on possible impacts of China's new semiconductor policy on down-stream user industries. China needs in-depth empirical research on how to balance the needs of the semiconductor and its user industries. As will be argued below, the only way to collect the necessary information is to move towards a bottom-up, market-led approach to "industrial policy", and close interaction between the government and private firms through multi-level industrial dialogues and public-private partnerships. In order to do justice to the conflicting needs of stakeholders across the industrial value chain, China clearly needs a substantially enhanced capacity for flexible policy implementation.

3.7. Rising uncertainty requires flexible policy implementation

The analysis of China's semiconductor industry upgrading scenario has shown that global transformations in the semiconductor industry may facilitate China's efforts to move from catching-up to forging-ahead in semiconductors. A second important finding however is the precarious nature of these opportunities – basic parameters that determine how China will fare may change at short notice and in unpredictable ways. Rising complexity of technology, business organization, and competitive dynamics are the root causes for such uncertainty.

Today, innovation in semiconductors depends increasingly on science and on interactions of multiple and very diverse stakeholders through geographically dispersed innovation networks that extend the boundaries of industries and nations.[153] For semiconductors, competition is centered on the increasingly demanding performance features for electronic systems. Whether one looks at laptops, smart phones, mobile base stations, medical equipment or car electronics, these electronic systems all need to become lighter, thinner, shorter, smaller, faster, and cheaper, as well as having more functions and using less power. To cope with these demanding performance requirements, engineers have pushed modular design and system integration, with the result that major building blocks of a mobile handset are now integrated on a chip.

Design teams also need to cope with the accelerating pace of technical change. Essential performance features are expected to double every two years, time to market is critical, and product life cycles are rapidly shrinking to a few months. Only those companies thrive that succeed in bringing new products to the relevant markets ahead of their competitors. Of critical importance is that a firm can build specialized capabilities quicker and at lower cost than its competitors[154] .

Arguably, the most important manifestation of rising technological complexity is the convergence of ICT infrastructures for the Internet, wireless, and mobile communications, and cloud computing that culminates in ubiquitous networks (or the "Internet of Everything")[155].

The root cause for these increasingly demanding requirements for technology development is the emergence of a "winner-takes-all" competition model, described by Intel's Andy Grove[156]. In the fast moving ICT industry, success or failure is defined by return on investment and speed to market, and every business function, including R&D and standard development, is measured by these criteria.

Intensifying technology-based competition has provoked fundamental changes in business organizations. No firm, not even a global market leader like Intel or Qualcomm, can mobilize all the diverse resources, capabilities, and repositories of knowledge internally.

Corporations have responded with a progressive modularization of all stages of the value chain and its dispersion across boundaries of firms, countries, and sectors through multi-layered corporate networks of production and innovation. The complexity of these global networks is mind-boggling. According to Peter Marsh, the *Financial Times'* manufacturing editor, "…[e]very day 30m tones of materials valued at roughly $80 billion are shifted around the world in the process of creating some 1 billion types of finished products."[157]

While the proliferation of global production networks goes back to the late 1970s, a more recent development is the rapid expansion of global innovation networks (GINs), driven by the relentless slicing and dicing of engineering, product development, and research (Ernst 2009). Empirical research documents that this has further increased the complexity of global corporate networks. GINs now involve multiple actors and firms that differ substantially in size, business model, market power, and nationality of ownership, giving rise to a variety of networking strategies and network architectures.

The flagship companies that control key resources and core technologies, and hence shape these networks, are still overwhelmingly from the United States, the European Union, and Japan. However, there are also now network flagships from emerging economies, especially from Asia. Huawei, China's leading telecommunications equipment vendor, and the second largest vendor worldwide, provides an example of a Chinese GIN that can illustrate the considerable organizational complexity involved in such networks[158].

In short, rising complexity and uncertainty is the defining characteristic of today's global semiconductor industry. For China's policy to upgrade its semiconductor industry, flexible policy implementation is required to cope with this rising complexity and uncertainty.

Uncertainty implies that it is always preferable to have built-in redundancy and freedom to choose among alternatives rather than seeking to impose from the top the "one best way" of doing things[159]. First, rising complexity drastically reduces the time available for policy formulation and implementation, which makes it practically impossible to get solutions right the first time. There may have to be many policy iterations, based on trial and error, and an extended dialogue with all stakeholders to find out what works and what doesn't.

Second, rising complexity makes it difficult to predict possible outcomes of any particular policy measure, especially unexpected negative side effects, of which there is an almost endless variety. In fact, a small change in one policy variable can have far-reaching and often quite unexpected disruptive effects on many other policy variables and outcomes. To cope with this complexity challenge requires a capacity for flexible adjustments in policies meant for instance to strengthen the absorptive capacity and R&D investment of Chinese firms.

And, third, it is next to impossible to predict the full consequence of interactions among an increasingly diverse population of both domestic and international stakeholders in China's semiconductor industry. Given the diversity of competing stakeholders, the results of a particular industrial support policy depends much more on negotiations, gaming, and compromises than on the logical clarity and technical elegance of that policy (Ernst: 2014).

Prioritization is no longer the exclusive role of the state planner. The focus of policy-making thus needs to shift from the selection of priority sectors, technologies and areas for public investment to the facilitation of "smart specialization", defined as *"an interactive process in which the private sector is* *discovering and producing information about new activities and the government provides …* [incentives and removes regulatory constraints] *….for the search to happen, assesses potential and empowers those actors most capable of realizing the potentials."*[160]

Conclusions

To assess the findings of this study, it is useful to highlight that policies to develop the semiconductor industry in China have experienced many changes over a relatively short period of time. In the broad view of things, a progressive integration into international trade and global networks of production and innovation has transformed the industry, with private firms emerging as major sources of growth, pricing decisions and investment allocation.

At the same time however, China's policies to develop the semiconductor industry still carry the legacy burden of the old top-down policy approaches. This study documents that China's new policy to upgrade its semiconductor industry, as described in the *"Guidelines to Promote National Integrated Circuit Industry Development"*, does not represent a radical break with a deeply embedded statist tradition. It retains many aspects of the "old industrial policy" doctrine, placing final control over whatever changes might occur in the hands of the government, and, in the final instance, the top leadership.

Within these boundaries, however, the study detects important changes in the direction of bottom-up, market-led approach to industrial policy. The study highlights a shift in the composition and governance of the **IC Industry Support Small Leading Group**. It is now more common to have experts play an active role in policy formulation and implementation who have intimate knowledge both of the international industry and the national policy circles.

Equally important are potentially quite important shifts in the allocation of investments funds. A closer look at the **Beijing IC Industry Equity Investment Fund** finds that the use of professional investment fund managers, as opposed to government subsidies or investment, signals a new approach to industrial policy that focuses on building a strong and sustainable investment environment in China. This does not imply that China's approach to investment funding will converge any time soon to a U.S.-style model of investment finance. More likely is the development of a *hybrid* model that seeks to combine the logic of equity investment fund management with the objectives of China's IC development strategy.

The study also highlights additional examples of at least incremental movements towards a more bottom-up, market led approach to industrial policy. For instance, China's technology planners no longer view global transformations in markets and technology merely as threats. In this more assertive view, global transformations are viewed as opportunities for China to forge ahead in semiconductors. The study has analyzed in quite some detail how China's new semiconductor strategy seeks to identify upgrading opportunities for China's semiconductor industry that could benefit from four global transformations: a) the demand pull from mobile devices; b) new opportunities for China's foundries in trailing-node semiconductor technologies; c) changes in the IC foundry industry landscape; and) a new interest in strategic partnerships and mergers and acquisitions (M&A).

An important, largely unresolved challenge for China's industrial upgrading scenario in semiconductors is the possible impact on exports of China's electronics final products. Research for this study did not find much discussion of this critical issue in the publicly available Chinese policy documents. Despite movements in the right direction, is would seem fair to state that the new Semiconductor Strategy's capacity for flexible policy adjustments remains limited, and that multi-layered industrial dialogues among key stakeholders in the industry are still at an early stage.

Finally, a defining characteristic of China's new Semiconductor Strategy is a persistent tension and frequent vacillation between more statist and more bottom-up industrial policies. To some degree this reflects China's latecomer status in this industry. But, given the tremendous progress that China has realized in this industry, it is time to shift the focus of attention to domestic impediments that are still constraining progress to a "new industrial policy" approach, which of course would need to reflect and address the specific needs of China's evolving economy.

What could derail the industrial upgrading scenario?

Finally, it is time now to address three larger issues, which might well derail China's industrial upgrading scenario for semiconductors. A detailed analysis is beyond the scope of this paper. Instead, an attempt is made to raise some specific questions for future research.

Threat of overcapacity

The **first question** addresses the ever present threat of **overcapacity**: Will China's push to upgrade its semiconductor foundry industry create overcapacity like in the solar PV industry and wind power? As is typical for China, the implementation of the semiconductor policy is left to the local governments. As Lieberthal demonstrates, "…[t]he last three decades of reforms…have greatly empowered the leaders… in every province, municipality, and township to act in entrepreneurial ways to grow the GDP of their locality every year."[161] Each locality is quite inward looking, and much less concerned about national issues.

This has negative consequences. Most importantly, local governments have become masters in producing over-capacity, due to misaligned incentives that are focused exclusively on the region's GDP growth. In addition, local protectionist policies reduce the scope for scale economies and economies of scope. "Even with a very large national market, many plants produce at suboptimal scale, and many investment decisions are made on the basis of political criteria." (Lieberthal (2011): p.26)

This raises the question: Why should this be different for the semiconductor foundry industry? Some observers argue that, unlike in the PV industry, technological barriers and the huge minimum investment burdens may prevent over-investment in the IC foundry industry. Future research needs to assess how realistic this argument is.

Cyber- Security

The **second question** asks: Will the **Leadership's cyber-security objectives** derail the Industrial Upgrading scenario?

China's policy on information security seeks to protect China-based information systems against perceived threats to national and public security[162]. The underlying strategic rationale provides an example of Susan Shirk's description of China as a "fragile superpower."[163]

There is a widespread concern among China's leadership, especially in the military and the Ministry of Public Security (MPS), that China is exposed to nontraditional and asymmetric threats to national security. Information technology is viewed as a double-edged sword. China's resurgence both as an economic and military power challenges incumbent global and regional leaders. China's leadership believes that Western IT systems use product backdoors, system loopholes, and Trojan horses to steal China's national secrets, and to slow down China's rise as a global economic power.[164]

China's leaders also fear that persistent leadership in IT provides ample opportunities for "Western powers" to use export controls, control over technical standards, and high licensing fees to stifle China's development and force reliance on Western technology. As a latecomer to the global race in information and communications technology, China has weak capabilities in information system management, and there is a general lack of knowledge and institutions that are capable of protecting China's critical information systems.

To counter these threats, the **China State Informatization Leaders Group (SILG)**, a high-level Chinese leadership body, developed in 2003 **China's Five-Year National Cyber Security Strategy**(SILG Document 27) to address threats to information systems and networks through an indigenous national assurance system under firm domestic control. Apparently this confidential document contains a comprehensive strategy, with its priorities reaching just about every aspect of information security technology.

In response to Edward Snowden disclosure of U.S. National Security Agency (NSA) global surveillance practices in China and elsewhere[165], China's concern with cyber-security receives prominent attention in the **"Guidelines to Promote National Integrated Circuit Industry Development"**. The Guidelines argue that, in order the Security and Reliability of ICT products and services in China, it is necessary to

a. "Promote the wide use and government procurement of "safe and reliable" software and hardware, including IC.
b. Encourage telecommunications, internet and end---product companies to make procurement decisions based on safety and reliability of products
c. Form industry standards system and develop safe and reliable capabilities in emerging industries (IoT, Big Data, cloud computing)" [166]

This raises the following questions for future research: Is the drumbeat on security used primarily as a tactic to mobilize support for aggressive investment funding?[167] Or is this focus on security an overriding concern for China's leadership that will cast aside many of the afore-mentioned economic considerations? How serious in fact are potentially short-term negative impacts? For instance, according to some observers, much of the Chinese government is in gridlock, as no one dares to start new initiatives in light of the renewed focus on Security (under the guise of the anti-corruption campaign). And, longer term, what would be the fate of China's semiconductor industry, if security concerns would really sideline China's commercial and industrial interests, and if China would indeed move back to creating its own self-reliant system of semiconductor and information and communication technologies?

Trade and Investment Agreements

Finally, a **third question** for future research would need to examine how new international and investment agreements might affect China's efforts to upgrade its semiconductor industry. A defining characteristic of today's international trading system is that plurilateral trade agreements are gaining in importance relative to the gridlocked Doha round of multilateral trade negotiations[168]. Examples are the WTO Government Procurement Agreement (GPA), the Information Technology Agreement (ITA), the Trans-Pacific Partnership Agreement (TPP) and the Transatlantic Trade and Investment Agreement (TTIA).

Of immediate interest is the **Information Technology Agreement (ITA)**[169]. By reducing barriers to trade that have not been adequately addressed in the gridlocked Doha round, the ITA is widely expected to facilitate the diffusion of innovation in the critically important information and communications technology (ICT) industry[170].

Proponents of ITA emphasize that developing countries, and especially Emerging Economies, could reap significant gains from trade for innovation from the ITA, as tariff reduction will lower import prices, improve market access for exporters, and enhance competition[171]. China benefitted substantially from the first round of ITA trade liberalization. During 2013, ITA members in Geneva were negotiating a possible substantial expansion of the list of products covered by ITA, the so-called ITA-2 round. Since November 2013, these negotiations have stalled. The real sticking point remained advanced semiconductors, the so-called MCOs (i.e. multi-component semiconductors), where China was adamant "that it will not accept tariff cuts."[172]

Throughout the 2013 ITA-2 negotiations, China has used a combination of delay tactics and a slowly evolving strategy of co-shaping the design of an expanded ITA-2. This reflects China's over-riding concern to upgrade its semiconductor industry through innovation and the development of generic technology platforms like MCOs. However, ITA-2 without China would be an oxymoron. Not only is China the world biggest smartphone market,[173] it is also by far the most important market for US semiconductor firms.[174] As John Neuffer, senior vice-president of global policy at the Information Technology Industry Council (ITIC) points out, "China has got to be part of this. They are too big a player. You can't have an outcome without the Chinese."[175]

In short, without China, ITA-2 negotiations are likely to remain stalled. Bold action is required to avoid zero-sum game or even negative-sum game outcomes and resultant trade conflicts. Thus far, progress has been incremental. China has enough resources to cope with the current stalemate of ITA-2 negotiations. But longer-term, China needs progress in ITA-2 negotiations as much as the US. Without some sort of compromise on these trade negotiations, it will be difficult for China to proceed with its strategy of upgrading its semiconductor industry. If China would remain on the sidelines of an expanded ITA-2 agreement, this could have substantial negative impacts on China's prospects in semiconductors.

In the end, there is hope that pragmatism will continue to prevail. As Brandeis University's Peter Petri observes, "China is not averse to intervening, but it has done that against the background of a lot of liberalization. It's paying off."[176]

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[1] USITO, 2014, *"Guidelines to Promote National Integrated Circuit Industry Development"* (unauthorized translation of document published by the Ministry of Industry and Information Technology, the national Development and Reform Commission, the Ministry of Finance, and the Department of Science and Technology, June 24, United States Information Technology Office, Beijing.

[2] A growing literature on "new" industrial policies argues that, under conditions of uncertainty, "..*[t]he right model for industrial policy is not that of an autonomous government applying … taxes or subsidies, but of strategic collaboration between the private sector and the government with the aim of uncovering where the most significant obstacles to restructuring lie and what type of interventions are most likely to remove them. …[T]he analysis of industrial policy needs to focus not on the policy outcomes—which are inherently unknowable ex ante—but on getting the policy process right."* (Rodrik. D., 2004, Industrial Policy for the Twenty-First Century, Research Working paper 04-047, John F. Kennedy School of Government, Harvard University, November: p.3). See also Foray, D., 2014, *Smart Specialisation. Opportunities and Challenges for Regional Innovation Policy*, Routledge, London and New York.

[3] See, for instance, Ernst, D., 2005, "Complexity and Internationalisation of Innovation: Why is Chip Design Moving to Asia?", *International Journal of Innovation management*, special issue in honor of Keith Pavitt, 9 (1), March: pp.47-73.

[4] Classic sources include Kim, L., 1997, *Imitation to Innovation. The Dynamics of Korea's Technological Learning*, Harvard Business School Press, Boston/Mass.; Nelson, R.R. , 2005,*Technology, Institutions, and Economic Growth*, Cambridge: Harvard University Press. See also Stiglitz, J.E. and B.C. Greenwald, 2014, *Creating a Learning Society. A New Approach to Growth, Development and Social Progress*, Columbia University Press.

[5] See Ernst, D. and B. Naughton, 2008, "China's emerging industrial economy. Insights from the IT industry", chapter 3 in: C.A. McNally (ed), *China's Emergent Political Economy. Capitalism in the dragon's lair*, Routledge and East-West Center Studies, London and New York. China's semiconductor firm fits the pattern observed by Nick Lardy: "Private firms have become the main source of economic growth… and the major contributor to China's growing and now large role as a global trader."(Lardy, N., 2014, *Markets over Mao. The Rise of Private Business in China*, *Peterson Institute for International Economics*, Washington, D.C., September: page 4.)

[6] These foreign companies are either contract manufacturers (the so-called electronic manufacturing service providers) like Taiwan's Foxconn, or global brand name companies with China-based factories, like Samsung. (PwC, 2014, *A Decade of Unprecedented Growth. China's Impact on the Semiconductor Industry 2014 Update*, http://www.pwc.com/gx/en/technology/chinas-impact-on-semiconductor-industry/2014-section-1.jhtml)

[7] In 2013, almost 17% of semiconductors consumed in China were purchased outside and transshipped/ consigned into China for consumption (PwC, 2014).

[8] Data are from the China Center of Information Industry Development (CCID) Consulting and the China Semiconductor Industry Association (CSIA), as quoted by PwC's Ed Pausa, in email to the author, dated July 6, 2014.

[9] Wang, Hsiao-Wen, 2014, "China's Semiconductor Grab – TSMC, MediaTek in the Bull's Eye", CommonWealth Magazine, 21 August 2014, http://english.cw.com.tw/article.do?action=show&id=14830

[10] As discussed later, SPRD and RDA have been merged in…

[11] For instance, the combined revenues of the top ten Chinese IC design companies of $ 1.57 B is much lower than the individual results posted by each of the top five global fabless companies (China's Fabless Profile, *EE Times Confidential Special Report 2011*). According to MIIT research, the total combined revenue of China's 500 or so IC design companies equals around 60 to 70% of the revenue of Qualcomm. USITO, 2014, Interview with, Miao Wei, MIIT, Director of Department of Informatization, on the background, significance and key points from the "Guidelines" June 25: p.3.) According to industry sources, 223 Chinese fabless companies lost money in 2013, and many of the fabless companies have fewer than 50 people.

[12] "Chinese OS expected to debut in October", *Xinhuanet*, August 24, 2014, http://news.xinhuanet.com/english/china/2014-08/24/c_133580158.htm

[13] Yoshida, Y., 2014, "China Launching its Own OS, Seriously?", *EETimes*, August 25, 2014, http://www.eetimes.com/document.asp?doc_id=1323638

[14] See **Part Three** below for details.

[15] Shilov, A., 2014, "TSMC builds world's first 32-core networking chip using 16nm Fin FET process",*Kitguru*, September 25, http://www.kitguru.net/components/cpu/anton-shilov/tsmc-builds-worlds-first-32-core-networking-chip-using-16nm-finfet-process-technology/

[16] China's successful catching-up and forging ahead in semiconductor assembly, test and packaging supports Ken Lieberthal's important observation: "*"Pragmatism has been a hallmark of China's reforms over the past 30 years, as Chinese leaders have not flinched from a realistic view of their challenges. They typically experiment with various approaches before deciding on the best ways to address major concerns."* (Lieberthal, K., 2011, *Managing the China Challenge. How to Achieve Corporate Success in the People's Republic*, Brookings Institution Press, Washington, D.C.: p.7.)

[17] CCID and CSIA data quoted in Jones, H., 2014, "China Wants to be No.1", EETimes, August 20

[18] *Derwent Worldwide Patent* data quoted in PwC, 2014

[19] NRC 2012, *The New Global Ecosystem in Advanced Computing*

[20] For details on China's position in ITA, see Ernst, D., 2014, *The Information Technology Agreement, Industrial Development and Innovation - India's and China's Diverse Experiences*, Think Piece prepared for the E15 Expert Group on Trade and Innovation and the International Center for Trade and Sustainable Development (ICTSD), Geneva, http://e15initiative.org/wp-content/uploads/2014/03/Dieter-Ernst.pdf

[21] Limin He, Corporate vice president of Cadence, a leading provider of computer-aided IC design tools, as quoted in " China Fabless Semiconductor Panel: Don't pack your Bags Just Yet", http://community.cadence.com/cadence_blogs_8/b/ii/archive/2014/06/18/china-fabless-semiconductor-panel-don-t-pack-your-bags-just-yet.

[22] According to SEMI, the global industry association serving the manufacturing supply chain for the micro- and nano-electronics industries, Asia's share in worldwide wafer fabrication capacity is now 54%, and is expected to increase to more than 66% in 2015. See SEMI – *World Fab Watch2014*, http://www.semi.org/en/Store/MarketInformation/fabdatabase/ctr_027237 . Capacity comparisons are in equivalent 8-inch wafers.

[23] *SEMI Forecasts Back-to-Back Years of Double-Digit Growth in Chip Equipment Spending*, July 7, 2014, http://www.semi.org/node/50436

[24] Shih, W., 2009, *Semiconductor Manufacturing International Corporation (SMIC): 'Reverse* BOT', HBS SMIC Case study, http://www.hbs.edu/faculty/Pages/item.aspx?num=36733
[25]国务院关于印发"十二五"国家战略性新兴产业发展规划的通知 [The State Council Notification on the Long-term Development Plan for Strategic Emerging Industries during the 12th Five Year Plan], 国发〔2012〕28号. July 7, 2012.
[26] As analyzed in Ernst, D. and B. Naughton, 2012, *Global Technology Sourcing in China's Integrated Circuit Design Industry: A Conceptual Framework and Preliminary Findings*, East-West Center Working Papers, Economics Series, No. 131.
[27] See http://www.gov.cn/jrzg/2006-02/09/content_183787.htm, and http://www.gov.cn/english/2006-02/09/content_184426.htm . For details, see Ernst, 2011, chapter 2.
[28] "*We will strive to catch up with and overtake advanced countries in … new-generation mobile communications, integrated circuits, big data, advanced manufacturing, …, and to guide the development of emerging industries."* PM LI Keqiang*, Government Work Report March 2014* which specifically mentions "integrated circuits" in the context of "using innovation to support and lead economic structural improvement and upgrading."

[29] For the economics of global vertical disintegration in IC design, see Ernst, D., 2005, "Complexity and Internationalization of Innovation: Why is Chip Design Moving to Asia?", *International Journal of Innovation Management*: and Ernst, D., 2005, "Limits to Modularity - Reflections on Recent Developments in Chip Design", *Industry and Innovation*.
[30] Ernst, D., 2009, A *New Geography of Knowledge in the Electronics Industry? Asia's Role in Global Innovation Networks*, East-West Center Policy Studies # 54.
provides a detailed analysis of the spread of global corporate networks of production and innovation in the electronics industry.
[31] Interview, June 22, 2012.
[32] Shanzhai (山寨) refers to Chinese imitation and pirated brands and goods, particularly for low-cost handsets. Literally "mountain village" or "mountain stronghold", the term refers to the mountain stockades of regional warlords or bandits, far away from official control.
[33] For details, see **Part 3.2.** of the paper (Demand pull for mobile devices as a catalyst).
[34] Prof. Wei Shaojun, as quoted in "China Fabless Semiconductor Panel: Don't pack your Bags Just Yet", http://community.cadence.com/cadence_blogs_8/b/ii/archive/2014/06/18/china-fabless-semiconductor-panel-don-t-pack-your-bags-just-yet. Dr. Wei, who is Dean of the Microelectronics Institute at Tsinghua University, and President of the China IC Design Association, has played an active role in drafting China's new IC industry policy.
[35] The collision between two high-speed trains in Wenzhou on 23 July 2011, the third-deadliest HSR accident in history, provided an example of the high risks of top-down technology leapfrogging. (Rabinovitch, S., 2011, "Crash threatens China's high-speed ambitions", *Financial Times*, July 24.
[36] An important insight of innovation theory is that, in general, catching-up in hi-tech industries like semiconductors takes time, in order to develop the necessary skills, as well as the critically important intangible knowledge and a great variety of complementary soft innovation capabilities that are necessary to develop a strong absorptive capacity. See, for instance, Kim Linsu, 1997; Ernst, 2002, and Ernst, 2009).
[37] See for instance Walsh, K., 2011, *The Chinese Defense Innovation System*, presentation at IGCC Chinese Defense Industry Conference, June 30-July 1.
[38] Creating university-industry linkages has been the focus of much of Chinese attempts to reform its innovation system. More recently, attempts are under way to address the other disconnects, but so far with mixed results. See for instance chapter 2 in Ernst, D., 2011, Indigenous *Innovation and Globalization: The Challenge for China's Standardization* Strategy, UC Institute on Global Conflict and Cooperation; La Jolla, CA and East-West Center, Honolulu, HI., 123 pages http://www.EastWestCenter.org/pubs/3904 [Published in Chinese at the University of International Business and Economics Press in Beijing, 自主创新与全球化：中国标准化战略所面临的挑战].

[39] Simon, D., 2001, "The Microelectronics Industry Crosses a Critical Threshold", *The China Business Review*, 28(6):pages 8-20.

[40] *State Council Document 4 on Issuing Several Policies on Further Encouraging the Development of the Software and Integrated Circuit Industries* (28 January 2011).
[41] See detailed discussion below in **Part Three** of the paper.
[42] A single nanometer (nm) is one million times smaller than a millimeter. Since integrated circuits, such as computer processors, contain microscopic components, nanometers are useful for measuring their size. In fact, different eras of processors are defined in nanometers, in which the number defines the distance between transistors and other components within the CPU. The smaller the number, the more transistors that can be placed within the same area, allowing for faster, more efficient processor designs. (http://www.techterms.com/definition/nanometer)
[43] See MIIT Vice-Minister YANG Xueshan, keynote speech at the third Science and Technology Committee Annual Meeting in Beijing, August 19, 2014, http://www.miit.gov.cn/n11293472/n11293832/n11293907/n11368223/16113093.html . See also USITO, 2014, *China IC Industry Support Guidelines – Summary and Analysis*, September 1, Beijing.
[44] USITO, 2014, Interview with, Miao Wei, MIIT, Director of Department of Informatization, on the background, significance and key points from the "Guidelines" June 25:p.3.
[45] Wei Shaojun, quoted in Wang, Hsiao-Wen, 2014, "China's Semiconductor Grab – TSMC, MediaTek in the Bull's Eye", CommonWealth Magazine, 21 August 2014, http://english.cw.com.tw/article.do?action=show&id=14830
[46] Moore, Gordon E. (1965). "Cramming more components onto integrated circuits" (PDF). Electronics Magazine. p. 4. http://www.cs.utexas.edu/~fussell/courses/cs352h/papers/moore.pdf
[47] Byrne, David M.; Oliner, Stephen D.; Sichel, Daniel E. (2013-03). "Is the Information Technology Revolution Over?", *Finance and Economics Discussion Series Divisions of Research & Statistics and Monetary Affairs Federal Reserve Board*. Washington, D.C.: Federal Reserve Board Finance and Economics Discussion Series (FEDS), http://www.federalreserve.gov/pubs/feds/2013/201336/201336pap.pdf
[48] "Chip-makers are betting that Moore's Law won't matter in the internet of things", June 10, 2014, http://qz.com/218514/chip-makers-are-betting-that-moores-law-wont-matter-in-the-internet-of-things/
[49] G.Dan Hutcheson, VLSI Research, quoted on 450mm wafer transition, in Izumiya, W., 2014, "450mm wafer transition won't happen till 2020 at the earliest", *The Semiconducctor Industry News, June 5,* https://www.semiconportal.com/en/archive/news/news-by-sin/140605-sin-izumiya-may-vlsi.html
[50] USITO, 2014, Interview with, Miao Wei, MIIT, Director of Department of Informatization, on the background, significance and key points from the "Guidelines" June 25:p.3.
[51] The established view is that, in the words of a senior banker at HSBC, "…[t]he Chinese authorities don't like the 'big bang' approach. That's why they test something – and if it works – they do more of it." (Justin Chan, co-head of markets for Asia-Pacific at HSBC, quoted in Noble, J., 2014, "Grand global ambitions for currency sow domestic risks". FT Special Report *The Future of the Renminbi*, September 30: page 2.)
[52] USITO, 2014, Interview with, Miao Wei, MIIT, Director of Department of Informatization, on the background, significance and key points from the "Guidelines" June 25:p.4.
[53] For details, see **Part Three** of this paper.
[54] http://en.wikipedia.org/wiki/Yu_Zhengsheng
[55] YU started working as a technician in several radio factories in Hebei Province (1968–1975) before he joined the Research Institute for the Promotion and Application of Electronic Technology under the Fourth Ministry of Machine-Building Industry, where he served as a technician, engineer, and assistant chief engineer (1975– 1982). He was promoted to deputy director in 1982, after which he was transferred to the Ministry of Electronics Industry (MEI) where he served as head of the Department of Microcomputer Management, and later the MEI deputy director of planning (1982–84). Today, he is a strong promoter of China's IC industry's development. http://www.brookings.edu/about/centers/china/top-future-leaders/yu_zhengsheng.
[56] If implemented, these policies are of quite some interest to current negotiations to expand the Information Technology Agreement (ITA). For instance, suppose China can use selective import tax exemption, what does this imply for China's interest in ITA-2? Can import tax exemptions provide access to lower-cost critical inputs, so that import reductions via ITA-2 would be unnecessary?
[57] The following quotes are from USITO's unauthorized translation of the ***"Guidelines to Promote National Integrated Circuit Industry Development"***.

[58] Mozur, P., 2014, “Using Cash and Pressure, China Builds its Chip Industry”, *The New York Times*, October 26

[59] Chang, G.G., 2014, “Qualcomm In Quicksand, Its China Problem Not Fixable”, July 27, http://www.forbes.com/sites/gordonchang/2014/07/27/qualcomm-in-quicksand-its-china-problem-not-fixable/ . The article quotes the following statement of Qualcomm’s CEO: “We just believe whatever the resolution may be, will likely include some form of payment.”

[60] See detailed analysis of China’s approach to current ITA-2 negotiations, in Ernst, D., 2014, *The Information Technology Agreement, Industrial Development and Innovation - India’s and China’s Diverse Experiences,Think Piece prepared for the E15 Expert Group on Trade and Innovation and the International Center for Trade and Sustainable Development (ICTSD), Geneva,* *http://e15initiative.org/wp-content/uploads/2014/03/Dieter-Ernst.pdf*.

[61]http://www.csia.net.cn/Article/ShowInfo.asp?InfoID=38790 and http://www.csia.net.cn/Article/ShowInfo.asp?InfoID=38789 .

[62] Leading groups have been extensively used since the early 1980s to foster the reform of China’s Science and Technology system, see Saich, Tony. “Reform of China's Science and Technology Organizational System.” *Science and Technology in Post-Mao China*. Ed. D.F. Simon and M. Goldman. Council on East Asian Studies, Harvard University, 1989, 69-88.

[63] In 1982, the State Council funded a permanent Leading Group called the “Leading Group for Electronics, Computers, and Large-Scale Integrated Circuits”. In 1984, the group’s name was changed to the “State Council Leading Group for the Revitalization of Electronics [Industry]”. The following year, the Leading Group published a document called “The Strategy for the Development of China’s Electronics and Information Industries” which laid out strategies for the 7th five year plan. For details, see Simon, D., 1988, *Technological Innovation in China: The Case of the Shanghai Semiconductor Industry*. Massachusetts: Ballinger Publishing.

[64] http://usito.org/news/beijing-picks-investment-firms-manage-beijing-ic-support-fund

[65] “Hua Capital hires Bank of America for OmniVision deal”, *South China Morning Post*, September 19, 2014, http://www.scmp.com/business/companies/article/1595559/hua-capital-hires-bank-america-omnivision-deal

[66] There is no information available in the public domain on what role (if any) **Beijing Qingxin Huachuang Investment Management Ltd**. is supposed to play.

[67] An informal inquiry, conducted by the author in spring 2014 among fund managers in a leading global bank, showed that none of the interviewees knew CGP.

[68] http://www.prosperityinvestment.hk/index.php?lang=tc

[69] CGP’s business philosophy is summed up in the following statement of its chairman: “*Following the economic recovery of the United States of America, it started to reduce the scale of debt purchase in 2014 which affected the international fund flow. This may lead to the withdrawal of fund from various countries including China and Hong Kong which in turn causes the instability of the stock market and the economy of these countries. However, this “tight funding” situation may be an opportunity for the Group to identify potential investment at a lower investment cost. All in all, we will continue our investments in both China and Hong Kong with caution.”* Message from the Chairman of CGP, Annual report 2013, http://www.prosperityinvestment.hk/vtuploads/201404/LTN201404161316.pdf

[70] http://usito.org/news/beijing-picks-investment-firms-manage-beijing-ic-support-fund

[71] As discussed below, Hua Capital Management Ltd (HCM) is also managing China’s acquisition of the US IC design company OmniVision.

[72] Chen Datong got his BS, MS, PhD from Tsinghua University, and worked as a Post-Doctoral research fellow at Stanford University. Dr. Chen has more than 20 years of investment and operations experience in the technology and semiconductor industry,and he owns 34 US and European patents. Prior to WestSummit, Datong was a Venture Partner at Northern Light Venture Capital, a leading technology VC fund, where he led investments in the semiconductor industry. Datong was the Co-Founder and CTO of Spreadtrum Communications, and hence has deep insider knowledge of that company. Prior to Spreadtrum, Dr. Chen was the Co-Founder and Senior VP for Omnivision, again providing him with insider knowledge for the acquition of that company, discussed below. Datong serves on the Board of Directors for two other important Chinese IC design companies, GigaDevice and VeriSilicon.

[73] USITO, 2014, *China IC Industry Support Guidelines – Summary and Analysis*, 1 September: p.6.

[74] The following analysis is based on interviews with observers and insiders of China's semiconductor industry. Where publicly available, key policy documents have been consulted which shape China's new push in semiconductors.
[75] USITO 2014 interview with Miao Wei: p.3.
[76] China data are for December 20, 2013, http://www.reuters.com/article/2013/12/20/china-mobilesubscribers-idUSL4N0J51ZN20131220 , while US data are from "U.S. Wireless Quick Facts". http://www.ctia.org/your-wireless-life/how-wireless-works/wireless-quick-facts .
[77] GSMA, 2014, *Smartphone forecasts and assumptions, 2007-2020*, http://www.gsma.com/newsroom/smartphones-account-two-thirds-worlds-mobile-market-2020/
[78] Data are from the Canalysis Country Market Tracker, October 2014, http://www.canalys.com/what-we-do/country-market-trackers . Examples include Chinese budget smart phones designed by Lenovo, Huawei, ZTE, and Xiaomi.
[79] Mansfield, I., 2014, "Chinese phone manufacturers expected to take half the market in 2015," *Cellular News*, March 10, , cellular-news.com. The term original-equipment manufacturer (OEM)is used here to refer to the company that acquires a product or component and reuses or incorporates it into a new product with its own brand name. For details, see Ernst, D., 2004, "Global Production Networks in East Asia's Electronics Industry and Upgrading Perspectives in Malaysia", in Shahid Yusuf, M. Anjum Altaf and Kaoru Nabeshima (eds.), *Global Production Networking and Technological Change in East Asia*, The World Bank and Oxford University Press, 2004.
[80] Goldstein, P., 2014, "Gartner, CCS Insight: Smartphone growth in 2014 will be fueled by low-cost models", http://www.fiercewireless.com/story/gartner-ccs-insight-smartphone-growth-2014-will-be-fueled-low-cost-models/2014-10-15
[81] Canalysis, 2014, "Xiaomi becomes China's top smart phone vendor", 4 August, http://www.canalys.com/newsroom/xiaomi-becomes-china%E2%80%99s-top-smart-phone-vendor
[82] PwC 2014, quoting data from CSIA, MIIT and Gartner.
[83] For an analysis of China's TD-SCDMA standard, see Ernst, 2011, chapter 5.
[84] Note however that, according to Canalysis, "… Xiaomi has risen from being a niche player to become the leading smart phone vendor in the world's largest market, overtaking Samsung in volume terms in Q2. Xiaomi took a 14% share in China, on the back of 240% year-on-year growth. http://www.canalys.com/newsroom/xiaomi-becomes-china%E2%80%99s-top-smart-phone-vendor . While these data need to be taken with a grain of salt, the often quite substantial differences in market share estimates of different consulting firms indicate the fluidity and unpredictability of the rapidly evolving smart phone market.
[85] Sambandaraksa,D., 2014, "Living with the Xiaomi MI3", *Telecom Asia*, September 10, http://www.telecomasia.net/blog/content/living-xiaomi-mi3?section=INSIGHT&utm_source=silverpop&utm_medium=newsletter&utm_content=&utm_campaign=telecomasia
[86] *Foreward Concepts Wireless Newsletter*, August 14, 2014: p.1.
[87] Chen, A. and L. Lin, 2014, "China 4G smartphone demand fails to surge: CoolPad, Lenovo, Xiaomi unlikely to achieve 2014 targets", *DigiTimes*, 1 October.
[88] *Foreward Concepts Wireless Newsletter*, August 14, 2014: p.2.
[89] Data are from the IDC Worldwide Quarterly Mobile Phone Tracker, August 17, 2014, http://www.idc.com/search/other/perform_.do?sortBy=RELEVANCY&_xpn=false&cg=5_1321&srchIn=ALLRESEARCH&src=&athrT=10&lang=English&cmpT=10&page=1&hitsPerPage=50
[90] Anderson, E. et al, 2013, *Measuring the U.S.-China Innovation Gap: Initial Findings of the UCSD-Tsinghua Innovation Metrics Survey Project*, STI Policy Brief # 14, December, http://www-igcc.ucsd.edu/assets/001/505418.pdf
[91] On August 4, 2014, TSMC reported that it has received 28nm chip orders from more than 10 China-based IC design houses and design service providers (Chao, C. and S. Shen, 2014, "China-based IC design houses ramping 28nm chip orders at TSMC", *DigiTimes*, August 4). The companies mentioned in the announcement comprise all ;eading China's IC design firms, i.e. HiSilicon, Spreadtrum, Rockchip, Allwiner, RDA and Datang.
[92] Ed Pausa, PwC, email to the author, August 18, 2014.

[93] Li, M., 2014, "Chinese Fabless Industry to Outgrow Semiconductor Sector by Significant Margin", *The Wall Street Transcript*, May 26; 4 pages

[94] Wei Shaojun, quoted in Wang, Hsiao-Wen, 2014, "China's Semiconductor Grab – TSMC, MediaTek in the Bull's Eye", CommonWealth Magazine, 21 August 2014, http://english.cw.com.tw/article.do?action=show&id=14830.

[95] *SMIC Investor Fact Sheet*, 2014, http://www.smics.com/eng/investors/ir_sheet.php

[96] Tzu-Yin Chiu, CEO of Semiconductor Manufacturing International Corp. (SMIC), quoted in Yoshida, Y., 2014, "Will SMIC Narrow Tech Gap". EETimes, March 27: page 3.

[97] For a detailed discussion, see below (**3.5. A new interest in strategic partnerships and mergers and acquisitions)**.

[98] Silicon Labs is a fabless company in Austin/Tx, designing high-performance, analog-intensive, mixed-signal semiconductors. http://www.silabs.com/about/pages/default.aspx

[99] SMIC's new R&D and manufacturing center seeks to develop proprietary MEMS process technology, as well as manufacturing capabilities for silicon-based sensors, and trailing-node wafer process technologies.

[100] Yoshida, J., 2014, "China erects first 12in IC manufacturing supply chain", *EETimes*, August 11

[101] "Wafer bumping" is replacing wire bonding as the interconnection of choice for a growing number of components. The broad term "wafer bumping" is defined as the process by which solder, in the form of bumps or balls, is applied to the device at the wafer level. The use of wafer bumping is driven either by performance, form factor or array interconnect requirements. The ability to properly design the device for bumping will have direct bearing on manufacturability, reliability, and cost savings from wafer fabrication through component assembly. (see Patterson, D.S., 2001, "The back-end process: Step 7 – Solder bumping step by step", *Solid State Technology*, Volume 44, issue 7, 1 July, http://electroiq.com/blog/2001/07/the-back-end-process-step-7-solder-bumping-step-by-step/

[102] According to Wikipedia, wafer testing is a step performed during semiconductor device fabrication. During this step, performed before a wafer is sent to die preparation, all individual integrated circuits that are present on the wafer are tested for functional defects by applying special test patterns to them. The wafer testing is performed by a piece of test equipment called a wafer prober. The process of wafer testing can be referred to in several ways: Wafer Sort (WS), Wafer Final Test (WFT), Electronic Die Sort (EDS) and Circuit Probe (CP) are probably the most common

[103] µm= micrometer

[104] Micro-Electro-Mechanical Systems, or MEMS, are defined as miniaturized mechanical and electro-mechanical elements (i.e., devices and structures) that are made using the techniques of microfabrication. The critical physical dimensions of MEMS devices can vary from well below one micron on the lower end of the dimensional spectrum, all the way to several millimeters. Likewise, the types of MEMS devices can vary from relatively simple structures having no moving elements, to extremely complex electromechanical systems with multiple moving elements under the control of integrated microelectronics. The one main criterion of MEMS is that there are at least some elements having some sort of mechanical functionality whether or not these elements can move. https://www.mems-exchange.org/MEMS/what-is.html

[105] QST holds worldwide and exclusive license of Honeywell's AMR magnetic sensor technology. In addition, QST holds patents in a number of CMOS integrated multi-axis motion sensors.

[106] See further discussion on threat of over-capacity in the Conclusions of this paper.

[107] IC Insights, 2014*, Samsung Invests Big to Maintain Leadership, Support New Markets*, IC Insights Research Bulletin, October 15.

[108] "Foundry Ranking by Capacity 2013-2014, http://anysilicon.com/foundry-ranking-capacity-2013-2014/

[109] The 2014 McClean Report, http://www.icinsights.com/news/bulletins/Top-13-Foundries-Account-For-91-Of-Total-Foundry-Sales-In-2013/ . With annual sales of about $5.4 billion, Samsung would be ahead of the 2013 sales of Global Foundries, the current Number 2 in the IC Foundry ranking.

[110] "IBM fabs for sale – the semiconductor shockwave", *Electronics Weekly*, 10 February 2014 http://www.electronicsweekly.com/news/business/viewpoints/ibm-fabs-sale-semiconductor-shock-2014-02/#sthash.p1E0hyzx.dpuf

[111] Merritt, R., 2014, "IBM strikes historic fab deal with GlobalFoundries", *EETAsia,* October 21.

[112] Waters, R., 2014, "IBM's troubles with cloud send profits tumbling.", FT, 21 October: front page. According to industry insiders, IBM management was under quite some pressure from Warren Buffett, IBM's biggest shareholder, whose stake has been drastically reduced by IBM losses.

[113] See the web site of Intel's Custom Foundry Group, http://www.intel.com/content/www/us/en/jobs/campaigns/foundry-jobs.html.

[114] For details of Intel's deals with Rockchip and Spreadtrum, see section 3.5. below.

[115] Nenni, D., 2014, "The Apple Samsung TSMC Intel 14nm Mashup!", October 4, https://www.semiwiki.com/forum/content/3898-apple-samsung-tsmc-intel-14nm-mashup.html

[116] IC Insights, 2014, *Leading-Edge IC Foundry Market Forecast to Increase 72% in 2014*, *IC Insights Research Bulletin*, September 25.

[117] The process of merging Spreadtrum and RDA was actually quite complex. On December 23, 2013, Tsinghua Unigroup announced the US$1.7 billion acqusition of Spreadtrum, "as contemplated by the previously announced agreement and plan of merger, dated as of July 12, 2013 (the "Merger Agreement"), between Tsinghua Unigroup and Spreadtrum". (http://www.spreadtrum.com/en/news/press-releases/tsinghua-unigroup-completes-acquisition-of-spreadtrum-for-us31.00-per-ads). And on July 19, 2014, Tsinghua Unigroup announced the "approximately US$907 million merger of RDA Microelectronics with an affiliate of Tsinghua Unigroup (the "Merger") as contemplated by the previously announced agreement and plan of merger, dated November 11, 2013 and amended on December 20, 2013 (the "Merger Agreement"), between Tsinghua Unigroup and RDA." http://ir.rdamicro.com/releasedetail.cfm?ReleaseID=860768 . Most likely, this complicated process was necessary to get the necessary pre-clearance from the NDRC, the responsible Chinese government agency.

[118] Bushell-Embling, D., 2014, "Qualcomm bringing LTE-A to low-cost phones". *Telecom Asia*, September 11.

[119] For details, see Ernst and Naughton, 2012: chapter IV.

[120] Spreadtrums' SC883XG platform integrates current best practice 3G mobile standards of the 3GPP international standard development organization that draws on Europe's GSM standard and includes China's TD-SCDMA standard.

[121] Anonymous Chinese industry observer, quoted in Yoshida, J., 2014, "Battle of Spreadtrum/RDA Merger", *EETimes,* March 21

[122] Email to the author by Will Strauss, president of Forward Concepts (Tempe, Arizona), August 22, 2014.

[123] Mr. Vincent Tai is RDA's co-founder and has been chairman of RDA's board of directors and chief executive officer since RDA's inception in 2004.

[124] During the first half of 2014, a wave of mergers and acquisitions has hit the semiconductor industry, as chipmakers try to gain scale, cut operating expenses, and grow their cross-selling opportunities by consolidating. Important deals include: Qualcomm's acquisition of Cambridge Silicon Radio (CSR); Infineon's acquisition of International Rectifier; Cirrus Logic's purchase of Wolfson Electronics; the merger between RF Micro Devices and TriQuint Semiconductor; Avago's purchase of LSI Corp; and Microchip's acquisition of Bluetooth chipmaker ISSC.

[125] Very little information on these efforts is in the public domain, but rumors abound.

[126] While Qualcomm refuses to provide details, the deal most likely is for Qualcomm's Snapdragon 210 processor, a low-cost chip for 4G LTE budget smart phones that features multimode 3G/LTE and LTE Dual SIM support. (Bushell-Embling, D., 2014, "Qualcomm bringing LTE-A to low-cost phones". *Telecom Asia*, September 11)

[127] Yoshida, J., 2014, "Is SMIC-Qualcomm 28nm deal one-sided?", *EETimes,* July 7

[128] Lien, J. and S.Shen, 2014, "UMC lands 28nm LTE chip orders from Qualcomm, say sources", *DigiTimes*, 14 October. According to industry sources, these chips are to be used for the production of iPhone 6 smart phones, which seems to indicate that UMC is expected to continue to receive more follow-up 0rders from Qualcomm.

[129] Zvi Or-Bach has more than 20 years of experience in the IC design industry, and holds over 100 issued patents, primarily in the field of 3D integrated circuits and semi-custom chip architectures. http://www.monolithic3d.com/zvi-bio.html

[130] Or-Bach, Z., 2014, comments on Yoshida, J., 2014, "China's SMIC-Qualcomm 28-nm Deal: Why Now?", *EETimes,* July 3*.* On the underlying technological transformations, see also Or-Bach, Z., 2014, "Qualcomm Calls for Monolithic 3D IC", *EETimes*, June 17.

[131]According to GSA, "…[a]s geometries continue to shrink and 2D scaling becomes increasingly difficult, 3D-IC packaging becomes a natural alternative to continued advances in ever smaller footprints; it is the convergence of

performance, power, and functionality. Many of the benefits of 3D-IC packaging, such as increasing complexity while simultaneously improving performance, reducing power consumption, and decreasing footprints are proven and readily understood. Other benefits such as improving time-to-market, lowering risk, and lowering cost will be conquered as 3D-IC packaging becomes a commercially viable solution across many application domains." http://www.gsaglobal.org/working-groups/3d-ic-packaging/

[132] Quoted in Or-Bach, Z., 2014, "Qualcomm Calls for Monolithic 3D IC", *EETimes*, June 17.

[133] http://www.smics.com/attachment/201407181552332_en.pdf

[134] Or-Bach, Z., 2014, comments on Yoshida, J., 2014, "China's SMIC-Qualcomm 28-nm Deal: Why Now?", *EETimes,* July 3.

[135] Founded in 2001, Fuzhou Rockchip Electronics Co. develops System-on Chip solutions for Android Tablet, Android TV box(Smart TV), E-Book, WIFI/ Bluetooth audio solution.The company has combined its Video/Audio and Android experience to produce semiconductor (IC) solutions for leading global contract manufacturers and brand name companies. Rockchip is headquartered in Fuzhou, where most design and development is taking place, and has three additional branches in Beijing, Shanghai and Shenzhen, focusing mostly on software and marketing, www.rock-chips.com

[136] Chao, C. and A. Hwang, 2014, "International smartphone chip vendors enhance development of tablet chips." *Digitimes*, October 21.

[137] Chen, M. and J. Tsai, 2014, "Intel aims to ship 25 million tablet processors in the second half of 2014", *Digitimes*, August 26.

[138] Lin, E., 2014, "Intel, Rockchip look to expand the x86 presence in tablet AP market", *Digitimes*, 22 September.

[139] http://newsroom.intel.com/community/intel_newsroom/blog/2014/09/25/intel-and-tsinghua-unigroup-collaborate-to-accelerate-development-and-adoption-of-intel-based-mobile-devices

[140] Intel's investment in Spreadtrum and RDA comes less than six months after Intel reached an agreement with Chinese chip maker Rockchip to make inexpensive tablet chips with Intel's architecture and branding. For details, see below.

[141] Shih, G. and N. Randewich, 2014, "Intel to invest up to $1.5 billion in two Chinese mobile chipmakers", http://www.reuters.com/article/2014/09/26/us-spreadtrum-m-a-intel-idUSKCN0HK29R20140926

[142] Yoshida, J., 2014, "4 Reasons for Intel's $ 1.5 Billion Bet in China", *EETimes*, September 26

[143] Omnivision Announces Receipt of Non-Binding Acquisition Proposal, http://www.reuters.com/article/2014/08/14/ovti-acquire-proposal-idUSnPn63Cqkl+88+PRN20140814

[144] "Hua Capital hires Bank of America for OmniVision deal", *South China Morning Post*, September 19, 2014, http://www.scmp.com/business/companies/article/1595559/hua-capital-hires-bank-america-omnivision-deal

[145] USITO email to the author, dated October 23, 2014.

[146] "China govt to bid for Broadcom cellular unit – report", June 25, 2014, http://www.telecompaper.com/news/china-govt-to-bid-for-broadcom-cellular-unit-report--1021572

[147] Murphy, C. and P. Mozur, 2014, "Broadcom Aims to Sell Chips Supporting All Chinese Telecom Carriers", *The Wall Street Journal*, March 20.

[148] I am grateful to Ed Pausa at PwC for sharing his analysis of the Thomson Reuter database.

[149] There were 64 other transactions where the acquirer was from a different nation including the US (16), Hong Kong (10), Singapore (5), and Japan (4), et al.

[150] I am grateful to Falan Yinug of the U.S. Semiconductor Industry Association (SIA), for sharing these data.

[151] Other industries, like car and aircraft, are also large consumers of semiconductors. Hence, the role of semiconductors for China's total goods exports is significantly higher.

[152] The following arguments are based on written comments from SIA emailed to the author, dated September 26, 2014.

[153] For detailed analysis, see Ernst, D., 2005, "Complexity and Internationalisation of Innovation: Why Is Chip Design Moving to Asia?" In *International Journal of Innovation Management*, special issue in honor of Keith Pavitt (Peter Augsdoerfer, Jonathan Sapsed, and James Utterback, guest editors) 9(1) (March): 47–73. See also Ernst, D., 2009, *A New Geography of Knowledge in the Electronics Industry? Asia's Role in Global Innovation Networks*, Policy Studies, no. 54 (Honolulu: East-West Center, August).

[154] Kogut, B. and U.Zander (1993). "Knowledge of the Firm and the Evolutionary-Theory of the Multinational Corporation", *Journal of International Business Studies* **24** (4): 625–645.

[155] For an analysis of the increasing complexity and diversity of global innovation networks, see Ernst, D., 2014, *Trade and Innovation in Global Networks – Regional Policy Implications*, East-West Center Working papers, Economics Series, No.137, May, chapter two.

[156] Grove, A., 1996, *Only the Paranoid Survive*, Doubleday

[157] P. Marsh, "Marvel of the World Brings Both Benefit and Risk," *Financial Times,* June 11, 2010, 7. For a detailed case study of the multi-layered global production networks in Asia's ICT industry, see Ernst 2004.Yusuf OUP

[158] The company has pursued a two-pronged strategy (Ernst and Naughton: 2007): it is building a variety of linkages and alliances with leading global industry players and universities, while concurrently establishing its own global innovation network of more than 25 R&D centers worldwide. Huawei's own GIN now includes, in addition to at least eight R&D centers in China, five major overseas R&D centers in the United States, and at least ten R&D centers in Europe (Ernst, 2014: chapter Two). The choice of these locations reflects Huawei's objective to be close to major global centers of excellence and to learn from incumbent industry leaders: Plano, Texas, is one of the leading U.S. telecom clusters initially centered on Motorola; Kista, Stockholm, plays the same role for Ericsson and, to some degree, Nokia; and the link to British Telecom was Huawei's entry ticket into the exclusive club of leading global telecom operators.

[159] Jordan, L.S. and K. Koinis, 2014, *Flexible Implementation: A Key to Asia's Transformation*, *East-West Center Policy Studies series*, No.70, March.

[160] OECD, 2013, *Innovation-driven Growth in Regions: The Role of Smart Specialisation. Preliminary Version,* OECD, Paris. For the underlying concept of "smart specialization", see Foray, D., 2014, *Smart Specialisation: Opportunities and Challenges for Regional Innovation Policy Opportunities and Challenges for Regional Innovation Policy*, Routledge.

[161] Lieberthal, K, 2011, *Managing the China Challenge. How to Achieve Corporate Success in the People's Republic*, Brookings Institution Press, Washington, D.C.: page 21.

[162] The following draws on chapter two in Ernst, D., 2011, Indigenous *Innovation and Globalization: The Challenge for China's Standardization* Strategy, UC Institute on Global Conflict and Cooperation; La Jolla, CA and East-West Center, Honolulu, HI., 123 pages http://www.EastWestCenter.org/pubs/3904 [Published in Chinese at the University of International Business and Economics Press in Beijing, 自主创新与全球化：中国标准化战略所面临的挑战].

[163] Shirk, S.L., 2007, China: *Fragile Superpower: How China's Internal Politics Could Derail Its Peaceful Rise*, Oxford University Press, Oxford etc.

[164] A *backdoor* is a secret or undocumented means of getting into a computer system. Many programs have backdoors placed by the programmer to allow them to gain access to troubleshoot or change the program. Some backdoors are placed by hackers once they gain access to allow themselves an easier way in next time or in case their original entrance is discovered. A *loophole* is a weakness or exception that allows a system, such as a law or security, to be circumvented or otherwise avoided. Loopholes are searched for and used strategically in a variety of circumstances, including taxes, elections, politics, the criminal justice system, or in breaches of security. The *Trojan horse*, in the context of computing and software, describes a class of computer threats (malware) that appears to perform a desirable function but in fact performs undisclosed malicious functions that allow unauthorized access to the host machine, giving them the ability to save their files on the user's computer or even watch the user's screen and control the computer. Trojan viruses can be easily and unwillingly downloaded.

[165] A study on the damage to America's ICT industry caused by NSA global surveillance practices concludes: " The recent revelations about the extent to which the National Security Agency (NSA) and other U.S. law enforcement and national security agencies have used provisions in the Foreign Intelligence Surveillance Act (FISA) and USA PATRIOT Act to obtain electronic data from third-parties will likely have an immediate and lasting impact on the competitiveness of the U.S. cloud computing industry if foreign customers decide the risks of storing data with a U.S. company outweigh the benefits." (Castro, D., 2013, *How Much Will PRISM Cost the U.S. Cloud Computing Industry?*, http://www2.itif.org/2013-cloud-computing-costs.pdf .)

[166] Quoted from USITO, 2014, *USITO Summary and Analysis – China IC Industry Support Measures*, September 1: p.5

[167] After all, security concerns as a tactic to mobilize support for investment in R&D have been used in other countries before, the US included.

[168] In contrast to multilateral WTO agreements, where all WTO members are party to the agreement, a plurilateral agreement implies that WTO member countries have a choice to agree to new rules on a voluntary basis.

[169] ITA went into effect in April 1997 with 29 World Trade Organization (WTO) Member countries. Unlike other plurilateral agreements, ITA provides "most favored nation" (MFN) treatment to all WTO Members, even if those countries have not joined the agreement. Today, ITA has 78 WTO Members—36 are non-Organisation for Economic Co-operation and Development (OECD) member countries, and 35 of them are developing countries. They include significant players in the electronics industry (China, Taiwan, Malaysia, Thailand, and Vietnam), and other countries, such as India, Egypt, Indonesia, Philippines, and Turkey, which have the potential to become players. In its current form, ITA provides zero tariffs for 217 electronics products. The main product groups covered are computers, semiconductors, semiconductor manufacturing and test equipment, telecommunications equipment, software, and scientific instruments. (For details, see WTO. 2012. *15 Years of the Information Technology Agreement, Trade, Innovation and Global Production Networks*. World Trade Organization, Geneva)

[170] From a global welfare perspective, trade expansion could reinforce the diffusion of innovation, as argued in Curtis, J. 2013. "Trade and Innovation: Challenges and Policy Options." Background paper for Expert Group 6 meeting, ICTSD, Geneva, 6–7 June.

[171] For an optimistic scenario, see for instance Ezell, S. J. 2012. *Boosting Exports, Jobs and Economic Growth by Expanding the ITA.* Information Technology and Innovation Foundation (ITIF), Washington, DC, March, pp 8–9. For a comparative analysis of India's and China's experience with ITA, see Ernst, D., 2014, *The Information Technology Agreement, Industrial Development and Innovation: India's and China's Diverse Experiences*, Think piece prepared for E15 Expert Group on Trade and Innovation, http://e15initiative.org/wp-content/uploads/2014/03/Dieter-Ernst.pdf

[172] "ITA Expansion Talks Suspended Again; No Timeline for Resumption Set.". *Inside US Trade*. 21 Nov, 2013. http://insidetrade.com/Inside-US-Trade/Inside-U.S.-Trade-11/22/2013/ita-expansion-talks-suspended-again-no-timeline-for-resumption-set/menu-id-172.html .

[173] Ernst , D. and Naughton, B. J. 2012. "Global Technology Sourcing in China's Integrated Circuit Design Industry: A Conceptual Framework and Preliminary Findings." East-West Center Working Paper No. 131, Aug.

[174] PWC. 2013. "China's Impact on the Semiconductor Industry, 2014 Update." http://www.pwc.com/gx/en/technology/chinas-impact-on-semiconductor-industry/index.jhtml.

[175] Donnan, S. 2013. "Negotiators Nervously Eye China's Resistance in IT Trade Talks." *Financial Times*. 19 Nov, http://www.ft.com/intl/cms/s/0/9456096e-5112-11e3-b499-00144feabdc0.html#axzz2srbBkrjM.

[176] Email to the author from Peter Petri, 28 Jan 2014.