China's evolving role in Apple's global value chain

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Abstract
Using Apple's 2015 published list of supplier companies and their subsidiaries, this paper analyses how one of the world's most significant lead technology companies and its network of core and non-core suppliers have become increasingly embedded in China's ICT global value chain. By mapping both the global networks and the networks within China of Apple's supply chain, this paper provides insights into the significance for China and for Chinese companies of its increased integration in the ICT GVC. By examining the geography of outsourcing and offshoring by Apple's suppliers, it distinguishes between locations where intellectual property is being generated and consumed and refers to the particular challenges faced by a latecomer country like China in achieving the best balance between technology autonomy and benefiting from GVC integration.

Apple China ICT Global Value Chain core and non-core component suppliers assembly-related functions

Introduction

The centre of gravity of the global value chain (GVC) and to some extent of innovation in the information and communications technology (ICT) sector has been shifting away from more developed regions of the world to less developed regions in Asia and particularly to China. Much of this relocation has involved increased fragmentation of production through outsourcing non-core functions to other companies and in many cases to offshoring an increasing range of activities to lower cost locations. Asia's importance also increases as markets in Asia become more significant and also as the capabilities of supplier companies within Asia improves. Some scholars see this integration of emerging regions in a positive light, with local supplier companies improving their capabilities and in some cases becoming significant competitors of lead companies from the more developed regions. Others suggest that participation in the supply chains of lead technology companies results in a subservient relationship which can prevent supplier companies from becoming more innovative and independent. To examine the role of mainland China and mainland Chinese companies this paper examines the increasingly important role of China in Apple's ICT global value/supply chain, primarily as one of the major centres of production of sophisticated electronic equipment such as PCs, laptops, tablet computers and smartphones. More specifically it examines the national composition of companies involved in more and less sophisticated parts of Apple's supply chain, the extent have Chinese companies become involved and the range of functions are they responsible for.

The paper will use the terms 'supply chain' and 'value chain' interchangeably, as the supply chain is related to the value chain, but it is more connected to industry and engineering and involves activities such as procurement and logistics. Value chain analysis examines how companies organize and locate different functions and activities to benefit from the comparative advantage of different regions (Porter, 1985; WTO, 2013). By analysing Apple's supply chain,

both globally and in China, it will examine how one of the world's most significant ICT companies has been exploiting the comparative advantage of China in recent years to increase its competitiveness globally. The key question to be explored is the extent to which China has benefitted from increased involvement in Apple's supply chain. To what extent have Chinese companies become involved in Apple's supply chain and what range of functions are they responsible for? The paper firstly traces the evolution of Asia's ICT value chain and looks in particular at China's growing role within it. It will then examine the geography of Apple's supply chain, both globally and within China mapping of Apple's core component, non-core component and assembly-related suppliers both globally and within China. Finally, it finally draws some conclusions about the implications of China's increasing integration in both Apple's supply chain and in the ICT GVC more generally.

China's ICT GVC

China's share of global ICT exports grew from 2.1% in 1996 to 30% in 2012, making it the world's leading exporter of ICT products (Ezell and Atkinson, 2014). China's own domestic market for ICT products and services has also grown significantly, with important implications for the new shift from over-reliance on an export model towards promoting domestic consumption in the post-crisis period. This has also had implications for foreign investor companies in China, which see China's growing domestic market of great significance for their own development, but are experiencing growing competition from Chinese technology companies supported by China's government giving preference to local companies, products and services particularly in the public procurement market (Grimes and Sun, 2014).

To some extent China's early involvement in the ICT sector was closely related to its dependence on foreign technology and foreign direct investment (FDI) to develop this sector. With the significant progress made by its own companies in recent years, and with the determination of the Chinese state to achieve technological autonomy in targeted sectors such as telecommunications, recent Chinese policy has shifted in the direction of indigenous innovation, and the promotion of domestic technology standards. Yet national statistics reveal very high levels of foreign involvement in both importing and exporting of high technology goods, with a continued high level of dependence on export processing of intermediate goods (OECD, 2012). The increasing focus, however, by both Chinese and foreign companies on the growing domestic market for high technology products is contributing to significant growth in the local ICT sector (Ezell and Atkinson, 2014).

Despite this changing business environment, which many would regard as a natural evolution in a huge and increasingly economically significant country, many global lead companies continue to see China as an important production location and market, even though the policy environment may reflect what Breznitz and Murphree (2011) term 'structured uncertainty'. Chen and Lombaerde (2013) suggest that weak protection of intellectual property in China, because of the immature state of the legal system, may make it difficult for Chinese firms to access western technology, and while increased productivity in low- and middle-technology areas could be achieved, moving further up the value chain was not guaranteed. Notwithstanding China's impressive performance in technology catch-up in recent years, and the fact that a small number of significant Chinese technology companies such as Huawei, Xiaomi, Lenovo and ZTE, have

developed international brands, non-Chinese global lead technology companies continue to dominate the technology sector, mainly because of their continued control over key intellectual property in areas like semiconductors and software architecture.

Fragmentation of GVCs has been facilitated by the modularization of technology production, allowing core and non-core functions to be located in the most appropriate regions (Sturgeon and Kawakami, 2010). Modularity of both product and the industry itself has facilitated outsourcing/offshoring models resulting in the geographical separation of centres of the production and consumption of intellectual property. While China has increasingly benefited from this changing geography, there is growing concern among policymakers of the dangers of 'lock-in' to lower value added functions such as assembly, or what is referred to as the 'modularity trap' (Sturgeon and Kawakami, 2010). Ernst (2014) argues that in the case of Taiwan's PC industry participation in global production networks (GPNs) impeded rather than fostered innovation because the dominant supplier companies Microsoft and Intel, who reaped most of the benefits, controlled the architecture.

By examining the geography of Apple's supply chain, both globally, and within China, this paper seeks to add to existing research on GVCs and globalization. To explain the rationale underlying the geography of Apple's supply chain, we examine in detail which functions have been located inside or outside China. What does the geography of Apple's supplier networks tell us about the origins and destination of the key generators of intellectual property responsible for different parts of the value chain? We would expect that a greater proportion of core component suppliers such as semiconductor companies will be found outside China, while an increasing number of non-core supplier companies will be located in China. If China is to benefit from having an increasing proportion of Apple's supply chain and its associated ecosystem located within the country, there should be a growing substitution by Chinese companies of non-Chinese suppliers over time, and to some extent the supplier functions should increase in sophistication from non-core to core components, reflecting a process of upgrading of local capabilities.

Theoretical framework

Governance, which is seen as a top-down process, is one of the building blocks of the GVC framework and explores how lead companies with a strong market presence exercise power in the coordination of supplier companies within the GVC (Gereffi et al., 2005). In the context of China, power exercised by a lead company may be partly constrained by state policies in relation to foreign investors (Cooke, 2013). Within the far-flung value chains, facilitated by modularization in electronics, lead companies set performance criteria in areas of price, quality, speed of response and delivery standards for their suppliers. With much of the outsourcing and offshoring involving a significant shift in the locus of production to Asia, and particularly to China, this framework has also paid attention to the upgrading challenges facing late developer country their firms and technology sector. While scholars have pointed to the benefits for emerging economies of integration in GVCs, they also highlight the pitfalls of the low value added modularity trap, with Sturgeon and Kawakami (2010) suggesting in 2010 that China's handset sector had already fallen into this trap because of its high dependence on external sources of technology.

Mudambi (2008) argues that the global geography of economic activity is influenced by how a firm organizes and controls various parts of the value chain and where it locates different activities. Because firms in emerging markets are gradually catching up in their competencies and also firms from advanced markets are contributing to spillovers through relocating advanced activities in lower cost locations, a wider dispersal of functions is creating opportunities for adding value in these locations (Xu and Sheng, 2012). Higher value-added activities at both ends of the value chain are usually concentrated in more advanced regions, while those in the middle dealing mainly with production and assembly tend to be in emerging market locations. Firms that control the higher ends of the value chain strip out standardized activities to be offshored and maintain their market leadership through high levels of R&D and innovation. Over time, firms which carry out these lower value-added functions seek to move up the value chain by developing their own brands and marketing expertise. In Apple's case, by decoupling intangible and tangible functions, it exercises control over R&D intensive activities at one end of the chain and marketing and brand activities at the other, while outsourcing manufacturing, assembly and testing, and exercising considerable control in coordinating the value chain (Mudambi, 2008).

By tracking the ecosystem developed by Apple in China, this paper seeks to evaluate the extent to which Chinese companies have succeeded in upgrading their involvement in Apple's supply chain. While Apple is only one of many global technology companies with a significant involvement in East Asia's and particularly China's ICT GVC, it is particularly suitable as a case study for understanding how such companies from more developed regions exploit the comparative advantages of China and its implications for China's own developing ICT sector. Apple is a leading technology company with an extensive global supply chain consisting in 2015 of 198 companies, many of which are also major global technology companies, whose 759 subsidiaries are involved in supplying Apple with components, or like Foxconn, are primarily involved in assembly of products. 336 of these subsidiaries are located in China and another 115 are in Taiwan, with only 84 located either in Europe or the US. Hence Apple's global supply chain provides an excellent case study of both the global spread and the major concentrations of supplier companies in China.

Methodology

The starting point for this study is Apple's list of supplier companies which provides the name and location of each supplier. This list facilitates an analysis of the geography of supplier companies both globally and within China and the identification of significant clusters of Apple suppliers in Chinese locations. Extensive web searching was used to identify the key components supplied by these companies, allowing us to relate supplier companies to a threefold classification of companies. While much of the supply chain is likely to remain relatively stable from year to year, Apple may also drop existing suppliers or pick new ones. Insights from more than 60 hours of interviews with foreign technology companies in Shanghai since 2009 informed our discussion about the Chinese market, the changing policy context, technological capabilities of Chinese competitors, intellectual property issues, and dealings with local companies.

The bill of materials (BOM), which provides a comprehensive list of raw materials, components and assembly operations required to manufacture a product, is a useful framework for

distinguishing between different types of supplier companies. Based on the BOM for various Apple products a threefold classification of core, non-core and assembly related suppliers is used with high cost components being classified as 'core', and lower cost components as 'non-core'. In the case of the iPhone 6, the BOM is $196 with the display being the most expensive component at $45 (Jones, 2014). Core components include the display, printed circuit board (PCB), integrated circuit (IC)/discrete devices, optical modules, electroacoustic components, internal memory and hard disk/CD-ROM. Non-core components include connector, function and structure components, peripheral devices, battery, and passive devices, while the third assembly category includes foundry, original design manufacturing (ODM), original equipment manufacturing (OEM), packaging and printing, and others. The connector/function/structure group includes electronic connectors, electronic functional components and electronic structural components.

The next step was to match product components to Apple suppliers in order to specify their position in the GVC, which was carried out through an extensive search of supplier websites. In the case of displays, for example, the key companies in Apple's list of suppliers included Japan Display Inc, LG Display Co. Ltd., Sharp Corporation and another 21 companies. Hon Hai Precision Industry Co. Ltd (Foxconn), Pegatron, Flextronics International Ltd and six other companies provided foundry and ODM/OEM services to Apple. The result was a database of supplier companies in Apple's GVC classified into three groups in which particular companies were connected with particular components based on their value added. By specifying the country of origin and the country of location of each subsidiary, and specifying the city and provincial location of subsidiaries located in China, it was possible to track both the global spread of Apple's GVC and the particular role played by China within that GVC. The firm-level database allows an analysis of the role of different company types within Apple's GVC, with the location of supplier companies illustrating the spatial structure of Apple's GVC. Figure 1 illustrates the smiling curve of Apple's GVC, with a range of core, non-core and assembly-related functions disaggregated at different points along the curve and in different global locations.

Figure 1

To illustrate the global distribution of component suppliers, use is made of Social Network Analysis (SNA) with country of origin and country of location being the key nodes in the network. Social Network Analysis provides a useful way of mapping relations between participants in a global network, which in our case are supplier companies in Apple's GVC (Otte and Rousseau, 2002). The linkages between locations and their direction illustrate the countries of origin and location, while the significance of a particular country in the network is reflected not only by the number of suppliers originating in it, but also the number of connections between it and other locations. This mapping exercise provides insights into the overall spatial structure of Apple's supplier network for three types of supplier companies, indicating the strength of connections between different locations and the direction of outsourcing relationships between country of origin and destination. Location quotients are used to identify the key concentrations of subsidiary suppliers in China and to compare the distributions of the three categories of subsidiaries, allowing us to identify any locations with either over- or under-representation of types of supplier subsidiaries.

China's role in Apple's GVC

Turning to the Apple case study, Table 1 shows that the 2015 list of suppliers comprised 198 companies and 759 subsidiaries, 336 (44.2%) of which were located in China. 48% of companies and 47% of subsidiaries were core component suppliers, while 37.8% of companies and 38.4% of subsidiaries supplied non-core components; 14.1% of companies and 14.6% of subsidiaries were in the assembly category. While the general trend is for more high value-added activities to be located outside China, this is not true for each of the core component categories. Thus, while there appears to be a tendency to locate core component suppliers outside China, for various reasons including IP protection, the fact that much of the final assembly of Apple products takes place in China creates a need for a range of both core and non-core component suppliers to locate some activities in China. This may well reflect a gradual evolution of the ICT GVC, with an increasing shift of higher value added activities closer to the key location of production, but it is also likely to be influenced by cost factors.

Table 1

Although all of the companies and their subsidiaries originated in only 16 countries, the subsidiaries are widely distributed in 30 countries, with China being the most significant location having 44.2% of the total. The much smaller number of locations from which supplier companies originate as opposed to where supplier subsidiaries are located, suggests a differentiation between the relative concentration of intellectual property generation in more developed regions, and the much wider spread of locations in which this IP is exploited. The data also suggests, however, a gradual shift away from more developed regions in order to exploit the comparative advantage of a wider range of locations within the ICT GVC. With China having 44.2% of all supplier subsidiaries, it appears to have attracted a critical mass of global ICT supplier companies.

Only three countries of origin accounted for 80.2% of the 759 supplier subsidiaries: 32.7% were Japanese, 28.5% were US, and 19.0% were Taiwanese. Of the remainder, 6.5% were European and 7.5% were Asian, of which only 3.95% were Chinese. Only eight (2.2%) of the core component subsidiaries were Chinese. An obvious consequence of the fact that much of the intellectual property for Apple's products originates in a small number of developed regions is that much of the value added arising from these products mainly benefits these countries of origin, while the direct benefits to China remain low despite having a significant part of Apple's value chain located in it (Dedrick et al., 2009). Thus, while Huawei is exceptional in having developed its own processor, Chinese mobile firms, including the relatively successful Xiaomi, find it very difficult to become global brands because of legal challenges over intellectual property in developed regions.

Analysis of the country of origin and country location of Apple's supplier subsidiaries clearly indicates the central role of China in the ICT GVC as a production centre. It also reveals considerable dependence of GVC activities in China on external sources of technology and intellectual property resulting from the outsourcing arrangements of foreign companies in developed regions. Yet, we have few insights into the detailed working of this outsourcing and

offshoring process, namely, into which firms move which particular functions from which countries to which particular locations. Using Social Network Analysis (SNA), it is possible to provide some of the specifics about the relations between the origin of Apple supplier companies and where they locate their subsidiaries.

Figure 2 maps the relationship between country of origin and country location of the 356 core component supplier subsidiaries. The US, with 40.0% of subsidiaries, is the most significant country of origin, mainly because of its strength in the semiconductor industry, with its main destination linkages being the US itself and China, and a wide range of other destinations in both developed and less developed countries. This reflects the diffusion of US foreign investment over time, initially to more developed regions such as Western Europe, later to Eastern European countries and later again to Asia and Latin America. The distribution of location countries most likely reflects strategic decisions in relation to intellectual property conditions in different locations, but also the increasing need to be close to the growing centre of gravity of production in China, which has been strongly influenced by cost factors. This geography of intellectual property in the key area of mobile phone technology reflects the on-going strategy of companies like Apple to benefit from the comparative advantage of China as a location for more basic functions, while ensuring that the key intellectual property is developed in regions with higher levels of IP protection.

Figure 2

Interviews with foreign technology companies in Shanghai in 2014 indicated that the decision of IBM and other major technology companies in China to share key intellectual property with Chinese partners may herald a new stage in the role of foreign companies in China, but also reflects China's strong leverage because of its market size which major companies cannot ignore. While a variety of views were expressed about threats to IP faced by foreign technology companies in China, a number of interviewees emphasised that many foreign companies, even with operations in China for ten years or more, were still trying to negotiate strong cultural differences in business practices, which had implications for building trust within partnerships. While many claim that foreign technology companies continue to have leadership over Chinese companies, they acknowledge considerable convergence in the past decade and also stress significant differences in how Chinese companies recognise value and what returns they expect from creating value. In the area of chip fabrication in which Taiwanese companies such as the Taiwan Semiconductor Manufacturing company (TSCM), play a dominant role and which in recent years has been significantly relocated to the Chinese mainland, some technology company interviewees suggested that Taiwanese companies were playing an important role in helping local Chinese companies catch up with technology developments in this area.

In all there were 51 US core component companies and 216 subsidiaries supplying Apple and 72 (32.8%) of the subsidiaries were in China. Many of the US supplier companies are well known integrated circuit brands, such as AMD, Analog Devices, Broadcom, Fairchild Semiconductor, Intel, Nvidia, Skyworks, and Texas Instruments. The role played by European nodes in the network of core component suppliers is also striking, with the Netherlands, Switzerland and Austria with a strong background in semiconductors having connections with quite a few network countries. German company Infineon, which supplies Apple with baseband chips, does

so from outside China despite having a plant in China, as does the German semiconductor company Robert Bosch. The Dutch semiconductor company NXP which has nine supplier subsidiaries, two of which are in China, is in the process of merging with US company Freescale Semiconductor, which is also an Apple supplier. ST Microelectronics, headquartered in Switzerland has 11 supplier subsidiaries, one of which is in China.

Although many of these major global brands in key technology components continue to dominate the mobile phone industry, the scale of development of the Chinese market is impacting on the changing geography of competitiveness, which is forcing some of these companies to merge with others in order to preserve their leadership position in the GVC. A recent interview with one of these supplier companies in Shanghai revealed some concern about being a market leader in a particular area of technology in China, since the mobile chip company Qualcomm, which makes around half of its total revenue in China, had recently been fined USD975 million for abusing its monopoly position in the market. Interviewees in other technology companies, however, tended to agree that Qualcomm had been overplaying its position in the Chinese market in relation to royalty fees.

Following the US and the European nodes comes Japan accounting for 98 or 27.5% of core subsidiaries, 33 of which were in China. There is also a tendency for companies to locate at least one of their subsidiaries in China, which may allow for some aspects of production and testing of products to be carried out locally and facilitate just-in-time delivery to final assembly locations.

The third most significant country of origin of subsidiaries numercially is Taiwan, with 39 core component subsidiaries, 27 of which are in China. There were 16 PCB subsidiaries, nine optical and eight display suppliers, and three each in ICs and electroacoustic components. Unlike both the US and the European nodes, Taiwan's strongest link is with China. Two major Korean companies, Samsung and LG dominated the Korean contribution accounting for 31 of the 43 subsidiaries. Among these were Samsung's two display subsidiaries, eight integrated circuit and seven passive device subsidiaries, and LG had six display subsidiaries, four optical and four battery subsidiaries. Despite the intense rivalry between Samsung and Apple, and despite major legal battles over intellectual property infringement, Samsung continues to be one of Apple's most significant supplier companies.

Figure 3 illustrates the network of non-core supplier component companies. Japan was the primary country of origin of non-core subsidiaries, and 23.3% of these were located in Japan, suggesting a strong tendency to locate in the home country. Thus while Japan's second major location for non-core components is China, there is a wide dispersion of subsidiaries throughout Asia and on a smaller scale in Europe. Despite the large number of non-core suppliers, the fact that more than 80% of subsidiaries originated in three countries, reflects considerable concentration in the generation of intellectual property, even for non-core components. It is striking that to date so few Chinese companies have made any significant inroads into the dominant role played by Japanese companies in these areas of technology.

Figure 3

The pattern of US non-core component supplier locations shows the strongest connection with China, but with many linkages throughout low cost locations in Asia. Taiwan's linkages are primarily with China, followed by Taiwan itself and with a few other low cost locations. While Japan is the key node in which non-core subsidiaries originate and disperse to other locations, China is the primary node to which non-core subsidiaries move from many different locations, with Taiwan, Japan and the US being the key countries of origin. The fact that more than 50% of non-core supplier subsidiaries were located in China, even if few of them were Chinese companies, compared with only 30% of core component suppliers, suggests a time lag in the shift of elements of the ICT GVC to China, presumably with the intention of preventing significant leakage of key intellectual property. Despite the apparent general reluctance of Japanese suppliers of non-core components and particularly those supplying passive devices to locate in China, there appears to be a general push over time to increase the level of sophistication of functions in China where much of the ICT production is located.

Figure 4 looks at the origin and location of the 111 supplier companies in the assembly category, which includes, foundry, ODM/OEM, packaging and printing and others, and not surprisingly, 69.3% of this third category was in China. In 2014, the quarterly contract value for Foxconn was USD 18bn and USD 3.6bn for Pegatron, with both companies getting more than 41% of their revenue from Apple (Satarino and Burrows, 2014). Also while having only one of its five subsidiaries in China, TSMC was the sole foundry supplier to Apple, and Taiwanese companies also contributed strongly in packaging and printing. Table 2 lists the final assembly locations for Apple products in China and shows the dominant role of Foxconn in this sector. The fact that almost 70% of subsidiaries in this third category associated with final assembly are located in China reflects its significant comparative advantage as a major location for assembly, testing, and chip fabrication.

Figure 4

Table 2

Of the 198 companies in Apple's supply chain, 14 were Chinese and 29 of the 759 subsidiaries were Chinese. Of the 14 Chinese companies, five were core component suppliers and eight of the 29 subsidiaries were core component suppliers. Among the core Chinese companies, there was one display, two printed circuit board (PCB) companies with three subsidiaries, and two electroacoustic component companies with four subsidiaries. This suggests a small beginning for Chinese companies in supplying core components to Apple and a possibly greater potential for involvement over time. Among the more numerous non-core companies, there were five connector companies with 10 subsidiaries three battery companies with six subsidiaries, and one packaging and printing company in the third grouping of assembly-related suppliers. Although the overall contribution of Chinese companies to Apple's supply chain is modest, the fact that even a small number of Chinese companies have become Apple suppliers in the face of global competition is a significant development.

Apple's supplier subsidiaries in China

Although 44.2% of the 759 subsidiaries are in China, the proportion varies by country of origin, from 79.3% of Taiwanese to only 26.5% of Japanese, which accounted for the highest number of subsidiaries overall (Table 3). Even the US with the second largest number of subsidiaries had 32.8% in China. The proportion also varies according to type of subsidiary, from 31.1% of core components, 50.3% of non-core and 69.3% of assembly, and again this varies according to country of origin. The high proportion of Taiwanese operations in China is not surprising, since Taiwanese companies led the relocation of the ICT sector to China and plays a dominant role in final assembly. While the usual pattern is for a higher proportion of non-core subsidiaries to be located in China relative to core component subsidiaries, this is reversed in the case of Korea, although the numbers involved are small.

Table 3

With the growing shift of the production, assembly and testing and consumption of electronic products to China, it has become increasingly difficult to keep key component suppliers at a distance from production and assembly locations. The practice by foreign companies in China of purchasing semiconductor chips outside China and having them transhipped there for production illustrates the caution exercised by some companies in relation to protecting intellectual property (PWC, 2015). Yet China's new semiconductor strategy is partly based on the hope that with a 700 million market for smartphones, the demand pull of the mobile sector will help to upgrade the local industry, and already Huawei has proved itself to be the exception to the rule by developing its own microprocessor.

While the assembly category was the most likely to be located in China, it was the smallest grouping with 77 subsidiaries, but some of these facilities which include Foxconn's major assembly operations employed in some cases hundreds of thousands of workers. The 336 subsidiaries were distributed widely in 57 different cities, but the main concentrations were along the eastern seaboard, particularly around long-established ICT-industry centres in Shanghai-Suzhou and Shenzhen-Dongguan (Table 4). 42 of the 57 cities accounted for less than one percent of subsidiaries. Outside the main concentrations 20.2% of subsidiaries were located in an additional 33 cities. The shift away from the major concentrations along the eastern seaboard has been in progress for some time, with Foxconn, in particular moving major operations away from Shenzhen to inland cities with lower costs and closer to the labour supply.

Table 4

Table 4 illustrates the location quotients of the major concentrations and outliers of different types of subsidiaries, while also showing details for cities having 3% or more of all subsidiaries. Shanghai together with the neighbouring province of Jiangsu account for more than 42% of all subsidiaries, with the overall profile showing a slight over-representation of core and non-core subsidiaries and an under-representation of assembly. Within this grouping there is some variation with Shanghai and Kunshan having higher LQs for assembly. In Kunshan, both Foxconn and Pegatron have plants, with Foxconn producing iPods and Pegatron iPhones, while Foxconn, Inventec, Pegatron and Quanta Computer (all Taiwanese ODMs/OEMs) assemble a range of Apple products in Shanghai.

Guangdong province had 37.7% of subsidiaries, which together with the Shanghai-Jiangsu province concentration accounted for almost 80% of all subsidiaries in China. The two key cities in Guangdong were Dongguan with 14.6% and Shenzhen with 11.6% of subsidiaries. There was no dramatic difference in the ratio of core and non-core suppliers between the two major concentrations, which probably reflects the need to have a wide range of suppliers relatively close to final assembly locations. Although Shenzhen's LQ for assembly was 1.4, which reflects its on-going importance as an assembly centre, overall Guangdong's importance in assembly with 36% of all assembly subsidiaries appears to have diminished somewhat, with the shift to the interior of China reflected in an assembly location quotient of 1.3 for Other Provinces.

Among the outlier assembly locations are operations such as Foxconn's iPad plant in Chengdu (Sichuan province), employing 20,000 and Foxconn's iPhone plant, employing 79,000 and Pegatron's iPad plant in Taiyuan (Shanxi province) (Barboza and Brabsher, 2012). Foxconn's largest iPhone assembly plant, accounting for 70% of production and employing 200,000 is in Zhengzhou in Henan province, where it comprises about 60% of the province's industrial output. Having obtained considerable labour subsidies and tax incentives from the local government, Foxconn relocated some of its assembly activity from Shenzhen to Henan (Chang, 2015). Chan et al (2013) note Apple's increased ability to pressure Foxconn to accept lower margins while at the same time acceding to Apple's demands for technical changes and large orders.

Conclusions

The conceptual framework of the GVC to date based on top down governance and bottom up upgrading, while retaining broad validity, requires some nuancing in relation to the specificities of that part of the ICT GVC located in China. The exercise of power by lead companies and suppliers of key components is being constrained by a powerful state with significant leverage from a very attractive market. Bottom up upgrading needs to be contextualized in a broader global framework in which all technology companies are vying with each other to maintain innovation leadership. While previous research has highlighted the extent to which China's ICT export sector is dominated by foreign companies, few have provided evidence of the extent to which the supplier networks of key technology companies such as Apple are also dominated by foreign companies.

The findings show that to date, Apple has been reluctant to involve many Chinese companies in its supply chain, with the majority of suppliers, even many of those located in China itself, being foreign companies. Apple's choice of supplier companies reflects their ability to deliver the highest quality in good time and at the negotiated price, but may also reflect elements of trust related to business culture, suggested by some of our technology company interviews in Shanghai. While Apple needs a certain degree of stability and confidence in the ability of suppliers to guarantee the supply of components in good time, it has also shown itself quite ready to switch suppliers when the need arises. Although the input by Chinese companies into Apple's GVC is quite modest, a start has been made, not only in non-core components but also in some core components, and this can be built on over time. China's policy of indigenous innovation may create some challenges in achieving the best balance between increasing technology

autonomy and control over intellectual property on the one hand and obtaining the benefits from integration in global technology development on the other. Catching up in some key technology areas such as semiconductors, however, is proving quite challenging for China.

While the analysis of Apple's supplier company networks reveals an ongoing significant separation between the geography of intellectual property generation and the geography of its consumption as the centre of gravity of ICT production has increasingly shifted to China, our analysis also suggests caution towards what some scholars have already suggested as a radical change in the global geography of IP generation towards Asia. Despite a significant shift in the centre of gravity of the supply chain to East Asia and assembly to China, Chinese supplier companies have yet to make significant inroads as suppliers of key components or as major assemblers of Apple products.

It is likely that Foxconn, as the major contract manufacturer for Apple, has some say in the choice of suppliers in areas closer to assembly operations, but it also has been subject to some pressure from Apple through its willingness to award some of its contracts to Pegatron. While the level of revenue reaped by Apple from its global operations is much greater than in competitor companies, the ability to capture such high revenues reflects in a real way Apple's overall influence in effectively coordinating a far-flung GVC. In some cases, Apple's dominant role in the GVC is ameliorated by the fact that in key areas it is quite dependent on a few supplier companies, such as Foxconn in assembly, and TSCM and Samsung in chip fabrication. Apple's dependence on Samsung as a key supplier continues despite the difficult relationship between both companies, and the fact that they are major competitors. It should also be remembered that although Apple is a major client of many of its suppliers, in quite a few cases it is only one among a number of customers, and the lower their dependence on Apple, the less power it can exercise over them.

As a foreign company operating within China, even for the most part indirectly through its supplier companies and particularly Foxconn, Apple's power is also constrained by China's state policy, with its recent focus on promoting indigenous innovation, which would involve some pressure to provide opportunities for Chinese companies in exchange for market access. A major reason why foreign companies in China are under significant pressure to play according to government directives is the size and growth of the local market, which they need, and can only access by being cooperative, thus restricting their own agenda.

The competitive role that China plays as the key location for much of Apple's final assembly results from many factors, but particularly the scale, flexibility and responsiveness of key supplier companies, particularly its major contract manufacturer Foxconn, and also its major chip manufacturer TSCM, also a Taiwanese company. Apple faces huge challenges in effectively coordinating its far-flung supply chain, both globally and within China, to ensure that products are delivered to the market in the huge volumes required and in good time in the case of new product launches. Thus while considerable power is exercised by a lead company in the supply chain, circumstances are constantly changing and they may impact on the level of power a lead company can exercise

It is possible that companies in emerging economies like China, because of their particular advantages dealing with their very large local market, could disrupt the linear model of development by gaining significant market dominance despite lacking key technology leadership. Local Chinese success stories such as Xiaomi reflect typically incremental innovation in business models, but because there is an underlying absence of cutting edge technology in key areas like processors, such companies face major challenges in developing global brands. However, rather than seeing upgrading as a key challenge only for companies in emerging economies, it should be noted that all technology companies, even those with a long established record of technology leadership must undergo a continuous process of innovation to maintain their leadership. It may be possible for local Chinese brands to dominate the local market for a period, but such dominance is unlikely to be sustained without authentic innovative developments. Some elements of upgrading that derive from involvement in a technology GVC may not be clearly visible such as the broad base of managerial and other skills transferred through interaction with global operators. Company interviews in Shanghai reveal significant flows at the managerial level of people who had spent some years working for FIEs moving on and establishing their own operations, often with linkages back to the previous business networks in which they were involved. Such a flow of skills is vital both for Chinese companies to benefit from the presence of FIEs and for FIEs to be able to expand their market opportunities.

It would appear that shifts in the location of production of ICT products away from the dominant concentrations in the urban coastal eastern regions to the interior are very much about the changing geography of competitiveness within China in terms of costs, labour availability and also regional development incentives. In some respects the most significant aspects of the spatial distribution of Apple's GVC are both the global shifts and the regional patterns which appear to reflect on-going strengths in innovation and IP ownership and control, but also only a very gradual shift of key functions to China itself. This pattern appears to reflect more the objective of the lead company and its foreign-dominated supplier base to exploit China's competitive advantage and burgeoning market without yielding too much to potential competitor Chinese companies. It is likely, however, that China will continue to exert significant influence on foreign companies involved in China to provide greater access to intellectual property in exchange for market access.

The geography of Apple's supplier networks indicate the extent to which ICT functions within the Chinese mainland continue to be significantly dependent on receiving significant IP input through outsourcing from firms in the US, Japan, Korea, Taiwan and elsewhere. While these maps reflect a significant shift in the centre of gravity of supplier companies from the west to East Asia, they also reflect the considerable ground to be made up by China in growing its influence in the ICT GVC as a supplier of core components.

The presence of so many of Apple supplier companies in China, who also probably supply other major technology companies, rather than suggesting that they create barriers for the participation of local companies, may indeed, by creating a highly sophisticated ecosystem, with global standards of components and manufacturing processes, facilitating significant evolution in the

technology standards of local companies. In many respects the challenges facing China partly result from some degree of isolation from involvement in global technology standards. The lack of progress in the semiconductor sector is a good illustration of this. Thus, while having key global technology companies and their subsidiaries locating in China is not likely to result in any direct exchange of key intellectual property to local companies, some advantages are likely to result by the presence of a largescale ICT ecosystem of foreign supplier companies in the country. Just as Taiwanese supplier companies have made incremental progress in acquiring more sophisticated capabilities by being involved in such an ecosystem, it is also likely that Chinese companies will improve their competitive ability to both supply and even compete.

China's policy makers face considerable challenges in achieving the right balance between pressurizing foreign companies to share intellectual property and ensuring that its own technology sector benefits to the greatest extent possible from its involvement in the ICT GVC. Seeking to extract more intellectual property from foreign supplier companies located in China may slow up the spatial shift of more core component activity to China. While the paper indicates that Chinese mainland companies have made only modest gains in their involvement as suppliers for Apple's GVC, some mainland companies such as Huawei and Xiaomi have achieved a certain measure of success both in the Chinese market and in less developed countries. This success may reflect a possible disruption in the traditional model, dominated by non-Chinese companies and based on retaining technological leadership, by one which allows local companies to gain considerable market dominance by means of familiarity with the market and superior customer support. Huawei's success, however, is also related to its determination to develop its own technology in processors, memory chips and even operating systems.

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Figures

Figure 1 Apple's smiling curve and GVC (Mudambi, 2007, 2008; Sun and Grimes, 2015)

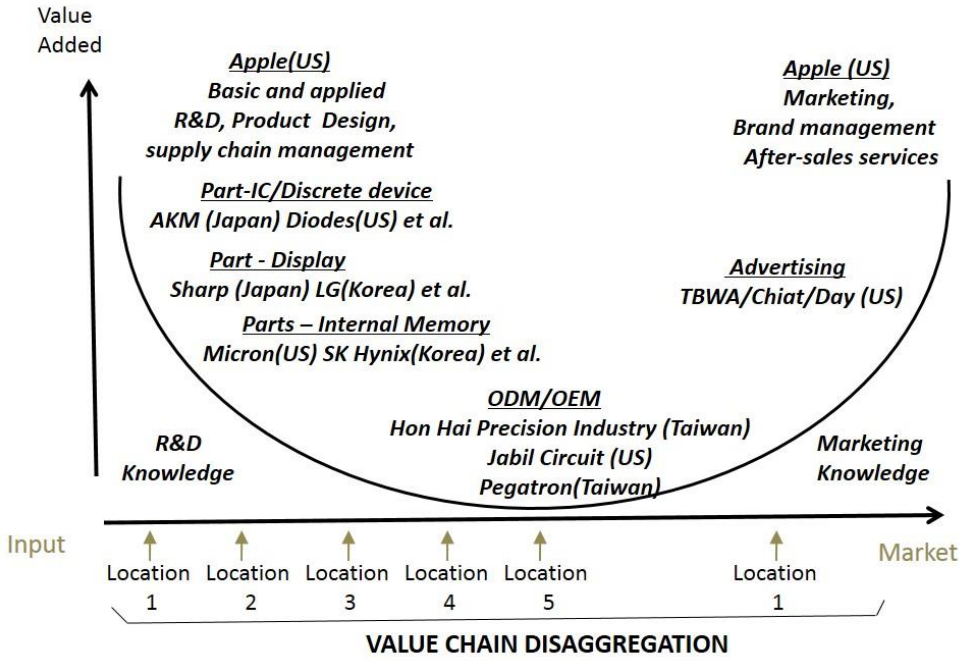
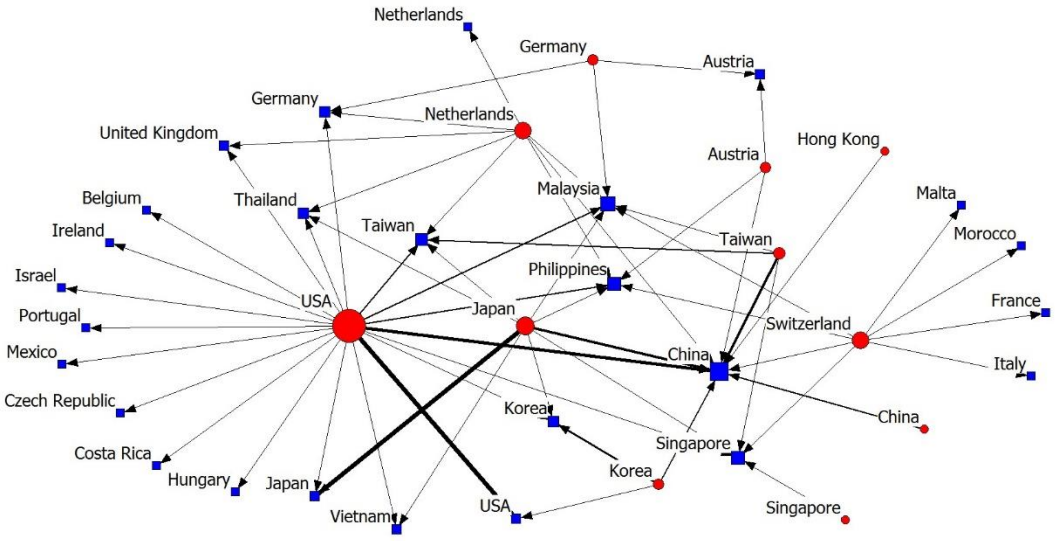
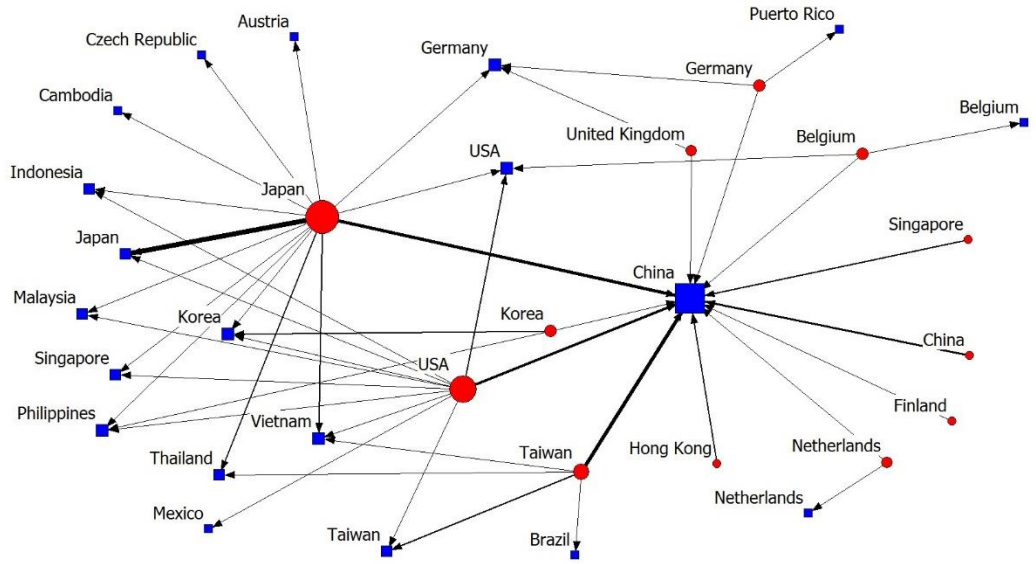


Figure 2 Origin-location network of core component supplier subsidiaries



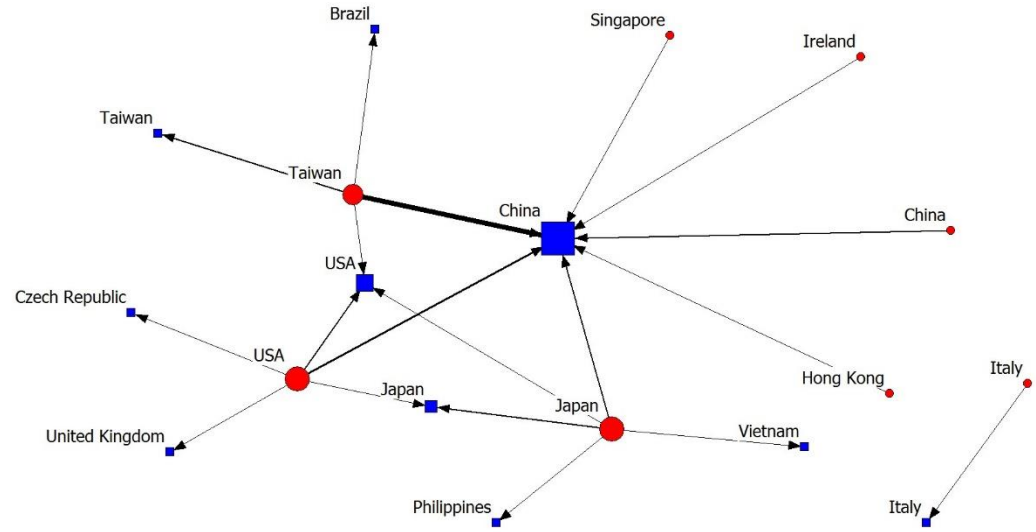
Key: The red circles represent countries of origin and the blue boxes represent location countries. The size of circles and boxes reflect means the indegree or outdegree of each country; the width of links indicates numbers of subsidiary connections between countries; the arrows indicate the direction of origin to location.

Figure 3 Origin-location network of non-core component supplier subsidiaries



Key: see Figure 2

Figure 4 Origin-location network of assembly supplier subsidiaries



Key: see Figure 2

Tables

Table 1 Supplier companies and subsidiaries by type and number of subsidiaries by type in China

Type	**No**	**Subsids**	**China**	
		Core		**% in China**
Display	24	76	32	42.1
PCB	16	40	20	50.0
ICs	35	189	33	17.5
Optical	8	17	8	47.1
Electroac	7	18	13	72.2
Int Mem	3	11	3	27.3
Hard D CD	2	5	3	60.0
Total	95	356	112	31.1
		Non-core		
Connector	50	152	91	59.9
Per Dev	10	27	21	77.8
Battery	7	29	12	41.4
Pass dev	8	84	23	27.4
Total	75	292	147	50.3
		Assembly		
Foundry	9	54	43	79.6
PckPrnt	11	36	24	66.7
Others	8	21	10	47.6
Total	28	111	77	
Total	198	759	336	44.2

Table 2 Final assembly locations of Apple products in China

City	Province	Company	Product
Shenzhen	Guangdong	BYD	accessories
		Foxconn	iPad
		Foxconn	iPhone
		Foxconn	Mac
		Foxconn	iPod
Shanghai		Foxconn	accessories
		Foxconn	iPad
		Pagatron	iPhone
		Inventec Corp	iPod
		Quanta Computer	Mac
Taiyuan	Shanxi	Foxconn	iPhone
		Pegatron	iPad
Kunshan	Jiangsu	Pegatron	iPhone
Changshu	Jiangsu	Quanta Computer	iPod
Chengdu	Sichuan	Foxconn	iPad

Table 3 Subsidiaries in China by country of origin

Country of origin	Core	% in China	Non-core	% in China	Assembly	% in China	Total Subsidiaries	% in China
US	141	22.7	51	52.9	24	50	216	32.8
Europe	33	12.1	14	42.9	4	75	51	25.5
Japan	98	23.5	133	27.8	18	33.3	249	26.5
Taiwan	39	69.2	52	82.7	54	83.3	145	79.3
Korea	32	40.6	11	27.3			43	37.2
Hong Kong	4	100	6	100	4	100	14	100
Singapore	1		9	100	2	100	12	91.6
China	8	100	16	100	5	100	29	100
Total	356		292		111		759	44.2

Table 4 Location quotients for major concentrations of subsidiaries in China

Province	**City**	**% Total**	**Core**	**Non-core**	**Assembly**	**LQ Core**	**LQ Non-C**	**LQ Assembly**
	Shanghai	13.4	9.9	13.6	18.2	0.7	1.0	1.4
Jiangsu								
	Wuxi	5.4	9.0	4.1	2.6	1.7	0.7	0.5
	Suzhou	9.5	13.5	8.8	5.2	1.4	0.9	0.5
	Kunshan	8.4	4.5	10.2	10.4	0.5	1.2	1.2
Total Jiangsu		28.7	33.3	29.9	19.4	1.2	1.0	0.7
Guangdong								
	Dongguan	14.6	11.7	17.7	13.0	0.8	1.2	0.9
	Guangzhou	3.6	6.3	2.7	1.3	1.7	0.7	0.4
	Shenzhen	11.6	7.2	12.2	16.9	0.6	1	1.4
Total Guangdong		37.7	31.5	40.8	36.3	0.8	1.1	1.0
Other Provinces		20.2	25.2	15.6	26.0	1.2	0.8	1.3
Total		100	100	100	100			