The World Economy

The World Economy (2013)
doi: 10.1111/twec.12045

Chinese Electronics Export; Taiwanese Contract Manufacturing – The Win–Win Outcome along the Evolving Global Value Chain

An-Chi Tung[1] *and Henry Wan, Jr.*[2]
[1]*Economic Institute, Academia Sinica, Taipei, Taiwan and* [2]*Department of Economics, Cornell University, Ithaca, NY, USA*

1. INTRODUCTION

CHINA's arrival as the world's top exporter is one of the current developments that attracted the most attention worldwide. What seems even more remarkable about Chinese export concerns its high-tech content than its volume. Within China's merchandise export, office and telecom equipment (SITC 75, 76 and 776) – among the high-tech trade – rose from only 5 per cent in 1990 to 28.5 per cent in 2010. The last figure is not only the largest in Chinese major export items, but also more than the sum of the next four categories – clothing, chemical, textiles and agricultural products. For this category, China's world market share went from 1 per cent in 1990 to 27.8 per cent in 2010. The last figure is not only the largest in the world, but also more than the sum of the next four economies (not including Hong Kong)[1] – USA, Japan, Korea and Taiwan (see Figure 1).

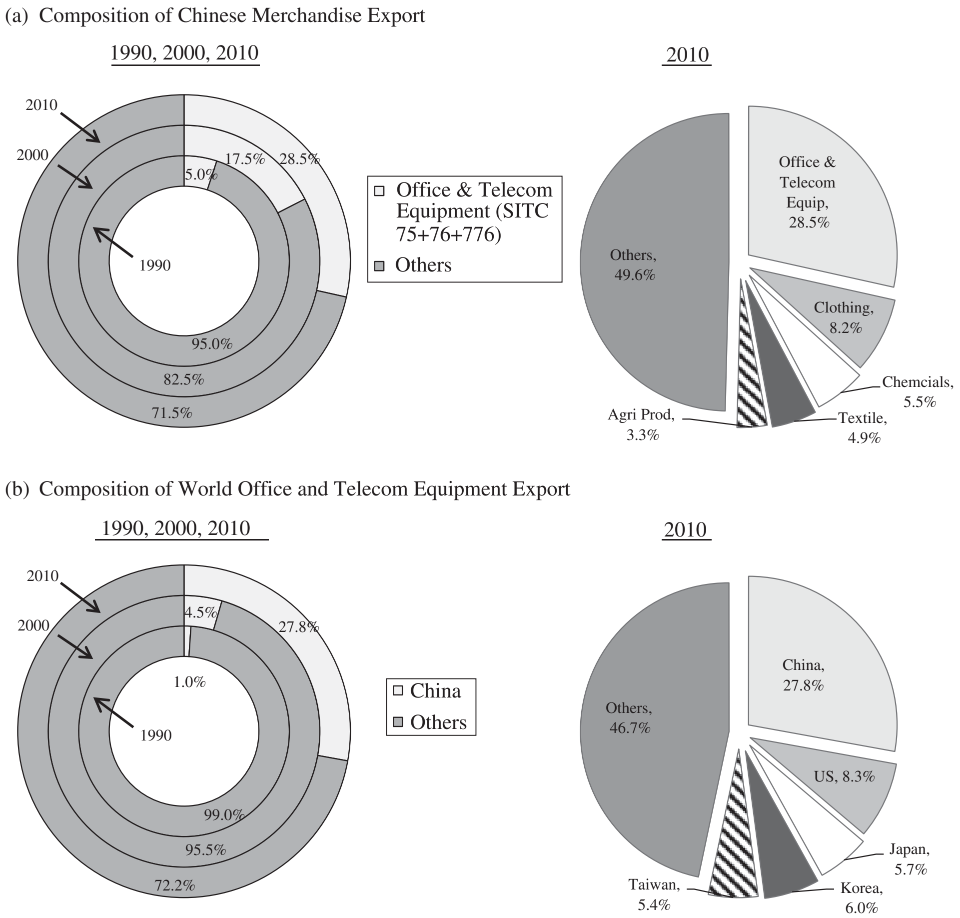
Over a period of 20 years, this 28-fold expansion of the Chinese share in the world export market – when happening to what is currently the most valuable category of the Chinese export – is surely related to the emergence of China as the world's top exporter, ahead of Germany and the US. At the same time, the importance of this category, office and telecom equipment, is also seen by the fact that even the total export value of China, as the world's top exporter, is still a shade smaller than the total export of this category, in the entire trading world during 2010.

It is a *post hoc, ergo propter hoc* fallacy to regard such a record as natural for China, because of its low wage and large population: first, no country with an even lower wage and

We gratefully acknowledge the helpful discussion with Simone Clemhout and valuable comments from two anonymous reviewers. Also, the first author thanks the National Science Council for financial support (98-2410-H0001-033).

[1] Although total export of office and telecom equipment from Hong Kong is large in the world market (10 per cent in 2010), almost all are 're-exports' (98.9 per cent in 2010), and a major portion of which go to China (65.2 per cent in 2010, as calculated from UN Comtrade databank). Therefore, Hong Kong is included in 'others' in Figure 1 to avoid double counting.

FIGURE 1
Chinese Export of Office and Telecom Equipment



Source: WTO Statistics Databank.

a large population shares the same export composition or volume; second, given its large population, its relative low wage, and an outward-oriented trade regime for nearly 30 years, Chinese export has reached its current content and volume only recently.

However, in this era of ‘task-trading’ (Grossman and Rossi-Hansberg, 2008), the Chinese export record does not quite convey what it used to mean. Presently, 70 per cent of the Chinese export of electronic appliances is ‘process trade’, based on expensive, imported components. In the mid-2000s, 90 per cent of the products in such categories are produced by foreign-managed firms (Steinfeld, 2010). Consider an Apple i-pod that the US imported at a unit cost, $144.40 from a Taiwanese factory in China, 3 per cent was to an American chip designer, 2 per cent for memory chips imported from Korea, 3 per cent for profit of the Taiwanese firm, 14 per cent for a display module imported from Japan, and another 51 per cent for a Japanese hard-disk drive producer, who made components in China from imported Japanese parts (Dedrick et al., 2010). The value-added earned by China is far below the dollar value of the Chinese export, and represents little of the cutting-edge technology in those goods.[2]

Thus, in addition to both the rising volume and the high-tech connection, the third unusual aspect of Chinese export is the unprecedented emphasis on its process trade.

Whatever interpretation one may entertain, for studies of trade and development, the phenomenon of China's export expansion is still remarkable and deserves explanation, and not to be dismissed offhand as some random outcome. The growth of Chinese export resembles a shadow cast not only by the Chinese economy alone, but also by an aggregate of all economies along the global value chain – an *ad hoc* grouping more massive and less understood than China – with China as merely its last link. To a significant extent, the recent rise of the Chinese role in world trade has to be viewed as part of the growth of the global value chain (Lamy and Shiraishi, 2011), apart from the Chinese imports needed purely for the rising domestic consumption. Furthermore, the expanding Chinese role in the supply chain is, in turn, the outcome of the technological advances of the present day.

Beyond the explanation of various past events, *ex post*, one needs a firm understanding of the causal mechanisms at work for the assessment of various issues in future world trade and development, *ex ante*, for example whether there will be any near-term displacement of China's role in world trade, with the rising of Chinese labour cost. Deep understanding may be achieved by both following closely the chronology of the evolving global value chain, and extending economic analysis to a set of interrelated key notions, such as the shortening of the product life cycle, the emphasis by firms on the time-to-market, the scaling-up operations, modularised production, and so on. These terms frequently play significant roles in business (or production engineering) reports on supply chains and in the context of a related issue – the current economic interactions between China and Taiwan.

The global importance of Taiwan is to help making China even more important than its considerable size: in 2011, at merely 48 per cent of America by total GDP, and only 8 per cent larger than India in population, China leads the world in industrial sector value-added of $3.41 trillion (i.e. 118 per cent of America or 752 per cent of India) and merchandise export of $1.9 trillion (i.e. 128 per cent of America or 640 per cent of India).[3] Such a feat is accomplished in factories, many under Taiwanese management, like Foxconn, or implementing Taiwanese business methods, like BYD. Such strengths as superior time-to-market and effective scaling-up for new products, via modularised production, are critically important to electronics. They were also traditional advantages of Taiwan's low-tech sectors like clothing (Shieh, 1992).

For illustration, one may start with a counter-intuitive observation: with far lower costs, China is exporting now most of the products Taiwan used to sell. Yet, for a surprisingly long period now, Taiwan has suffered neither a sweeping de-industrialisation, nor the falling of input prices towards the Chinese levels, as one might expect.

For example, Taiwan has retained its role in supplying 94 per cent of notebook computers worldwide by 2010, of which 96 per cent is on contract, all produced offshore (most in China), but with significant portions of high-valued tasks like R&D done at home (MIC, 2011). Regarding exports, this led to a sizeable reduction in Taiwan's export of electronics

[2] One measure of the importance of a particular trade concerns the bargaining power aspect: how disruptive the cessation of such trade will bring, as in the 1973 Arab oil boycott.
[3] Industrial value-added of the United States is calculated from the Bureau of Economic Analysis, and the rest are from WDI figures.

data processing and office equipment (SITC division 75) to the world between 2000 and 2010, after a huge growth in the 1980s and 1990s. Yet, WTO statistics indicate that this decrease is more than compensated by the increase in the exports of telecommunications equipment (SITC division 76) and integrated circuits and electronics components (SITC group 776). It turns out that Taiwan exports more of office and telecom equipment to the world in recent years, and also more of these to China.

Regarding employment, in the specific case of Hon Hai-Foxconn Group, its massive employment expansion in low-wage China is accompanied in Taiwan, not by concurrent one-to-one job losses, but the creation of high-pay jobs in developing industrial robots. This employment pattern is parallel to what prevails in the hard-disk drive industry (Gourevitch et al., 2000).

Contract manufacturing provides much net revenue from abroad for Taiwanese firms like Foxconn. Having such firms is potentially helpful than otherwise, to a Taiwan facing a declining balance of payment surplus. It also helps Taiwan as the ‘Krupps of computer wars’, no matter that Apple wins and Nokia loses.[4]

The short explanation of this win–win outcome suggests that this may be due to the conjunction of two facts. First, based on the strength of their specific given conditions, both China and Taiwan are now serving crucial but different roles in the same global supply chain. It has been observed that based upon the importance of ‘time-to-market’, Taiwan had played a critical role in shaping the global value chain into the American (or ‘open’) rather than the Japanese (or ‘closed’) network form, before China’s major expansion in trade.[5] Taking advantage of the agglomerative externalities provided by the surging Chinese export, Taiwanese firms then outcompeted their rival contract manufacturers, by shifting their supply bases to China from elsewhere. An example is the Hon Hai-Foxconn Group of Taiwan, which has become both the largest contract manufacturer in the entire world and the largest exporter for China; its sizable worldwide employment stood at 800,000 in 2010, when total employment in the computer industry was 166,000 in the USA and 1.5 million in Asia, according to Grove (2010).

Second, underlying much of such development is the fact that the major technological progress in recent decades takes the specific form of rapid and continuous miniaturisation, known as Moore’s Law.

Before proceeding to various details later, the next section offers a chronological summary broadly representative of the observed development.

2. A CHRONOLOGY OF THE EVOLVING GLOBAL VALUE CHAIN

Chronology can be a powerful tool in clarifying causality, when combined with selective, first-hand evidences at the microlevel. Over recent decades, on the demand side, the US market is both a major destination for consumption goods (Lamy and Shiraishi, 2011) and the locus of origin for the world’s retail revolution (Feenstra and Hamilton, 2006) in which chain stores market standardised products with barcodes, and so on, to serve mass consumption; on the supply side, American R&D has also formed the principal driving force for the general-purpose technology (Helpman and Trajtenberg, 1998) of the microelectronics revolution.

---

[4] This is an advantage for Taiwan, which has no access to the IMF and World Bank in times of crises.
[5] The difference between an ‘open’ system and a ‘closed’ system is elaborated in the next section.

For the chronology of the evolving global value chain, useful milestones might be chosen from events pertaining to the major American firms supplying branded goods ('lead firms'), concerning (i) who their major rivals are, (ii) how they source their main supply and (iii) where their products are made or assembled. A working hypothesis here is that, by and large, within the last four decades, the evolution of the global value chain has gone through three phases, separated by two significant transitions.

In the initial phase, the US lost the consumer electronics market to Japanese competition. There are two alternative forms of 'global value chain', operated by the Americans and the Japanese. American suppliers of high-tech products either manufacture some of their products by themselves at home or outsource low-skill tasks to their foreign affiliates in Asia and Latin America, in 'open' networks, where subcontractors can work for multiple clients. In contrast, subcontractors from less-developed economies as 'captive suppliers' perform low-skill tasks for their exclusive Japanese clients in 'closed' networks to serve the local markets.

During the intermediate phase, American firms turn over their manufacturing activities to contract manufacturers for implementation. The latter includes both (i) the electronics manufacturing services (EMS) firms in North America, which carry out all manufacturing activities and logistics for a broad range of products, or farm out some actual manufacturing to China, Southeast Asia and Latin America and (ii) the original design manufacturers (ODM) in Taiwan, which undertake certain levels of product design in addition to logistics and manufacturing, for personal computers and mobile phones (Sturgeon and Lee, 2005). Instead of competing against American firms in final product markets, Japanese firms supply their former rivals instead with high-value components upstream, such as memory chips and displays.

In the current phase, on the one hand, the division of labour has continued between American suppliers of branded products who specialise in R&D and Japanese firms – now joined by their Korean counterparts – in high-value components. On the other hand, for both desktop and laptop personal computers and mobile phones, Taiwanese firms have dominated their American EMS rivals in contract manufacturing and concentrated most of the actual production activities in China, rather than in Southeast Asia and Latin America. In personal computer and mobile phone markets, some Taiwanese firms have entered with their own branded products, just as Korean firms have in the mobile phone market.

Between the initial and the intermediate phases lies the *early* transition, from the middle 1980s to the early 1990s, where the American lead firms and the Taiwanese contract manufacturers are the active agents for transition, at the expense of the former's Japanese rivals.

What American lead firms seek in outsourcing manufacturing activities is the flexibility of an open network: to scale up production after a successful pilot run, without investing in fixed equipment with the sunk cost. Thus, trial-and-error remains affordable in innovation even with shortened product lives. To wit, Sturgeon (1998) documented how Apple adopted the shared supply chain selling its plant to the contract manufacturer SCI System to be shared with its own rivals! This proves to be what it takes against their Japanese challengers in their closed networks.

A presumably unintended benefit is that in an open network, the product designs outsourced by diverse clients can be combined and altered by Taiwanese engineers with structured designed methods (Borrus, 1997). About such 'modularised operation' of the Taiwanese firms, an officer of a Singaporean computer firm interviewed by Callon (1995, p. 8) deserves to be cited:

> their design capability exceeds anything in the United States . . . For years, they have been building design cells. So when they need a new design, they pull together the appropriate cells, make some small changes and they have a new design.

When coupled with the flexibility of decision-making for small Taiwanese firms, such design capability constitutes the competitive advantage in the 'time-to-market'. To Taiwanese firms in interviews (Callon, 1995), this factor is even more important than the cost advantage, when used against their Japanese rivals.

Between the intermediate and the current phases lies the late transition, around the early 2000s, where the Taiwanese contract manufacturers and Chinese local governments are the active agents for transition at the expense of both the US EMS firms and the producers in Southeast Asia and Latin America.

According to Tao and Yang (2008), tax reforms in China put great pressure on the local government to seek revenue by granting favours to foreign firms, especially in the acquisition of industrial land. Thus, the readiness of Taiwanese contract manufacturers, like the Hon Hai-Foxconn Group, to locate their production base in China forms an advantage in dominating the American contract manufacturers (Pick, 2006). By now, the Hon Hai-Foxconn Group has a 50 per cent share of the EMS business in the world (iSuppli, 2010).

At the same time, the clustering externalities offered by China also persuaded Taiwanese firms to shift their production from locations such as Mexico (Ancelovici and McCaffrey, 2005). The ready availability of various parts and supplies nearby saves time.

Some conclusions can now be reached, from the above chronology:

1. The current growth patterns of both China and Taiwan are significantly influenced by the operation of the system of global value chain, in which the industry of contract manufacturing plays an essential part.
2. The rise of both the global value chain and contract manufacturing was mainly initiated by American firms that allow themselves to specialise in innovation and marketing and reap high value-added, accordingly; by their respective competitive strength, both Taiwan and China have succeeded in playing important and rewarding roles in this evolving development.

3. THE UNDERLYING TECHNOLOGICAL AND ECONOMIC FORCES AT WORK

After providing the chronological narratives of the last section, it is time to return to several notions, where the underlying technological foundation and economic causation are to be elaborated:

- Moore's Law ushers in innovations causing the shortening of the replacement cycle of buyers in the merchandise trade. See Chue and Lim (2005).
- With more frequent replacement, contract manufacturing arises to separate fabrication from R&D and marketing. See Sturgeon (1998) and Van Liemt (2007).
- Venders of merchandise compete in markets that favour competitors who excel on the time-to-market. See Callon (1995), Borrus (1997), and Naughton (1997).
- Experience in product design within open networks gives advantage to Taiwanese contract manufacturers over their rivals. See Callon (1995), Sturgeon and Lee (2005) and Pick (2006).
- Clustering externalities make China the 'Workshop of the World'. See Ancelovici and McCaffrey (2005).

Each of these steps will be discussed in relation to their chronological timing and with economic analysis, in the following sections. Additional consequences are covered as concluding remarks.

4. MOORE'S LAW JUSTIFIES THE SPEEDING UP OF REPLACEMENT

By Moore's Law, the transistor density on an integrated circuit increases geometrically. This agrees broadly with observations over the decades as shown in Figure 2 (Jovanovic and Rousseau, 2005). Instead of being a tide that lifts all boats, this accelerating development of miniaturisation ushers in a continuous flood of disruptive innovations in ever faster tempo and causes a wide range of creative destruction of existing goods with the emergence of their superior successors. For example, cell phones offer greater mobility over landline communication. Smart phones combine further functions of internet connection and a single lens that doubles as digital camera, succeeded by those with two lenses, which support video conferences. Tablet computers then come with a vast array of novel applications to their users.

In business literature, like Chue and Lim (2005), it is said that such microelectronic revolution brings along shorter product lives, which, in turn, narrows the window for profits for consumer electronics companies, as shown in Figure 3. In economic terms, the length of a replacement cycle is an equilibrium outcome reflecting the interaction between the buyers and sellers of the product, based on cost and benefit considerations. The shortening of the replacement cycle must therefore be treated as the response mechanism to stimulus. By economic reasoning, one can track the effects on production and trade to their technological causes.

For insight, consider a parable of replacement decision, where consumers face the cost and benefit over a binary choice: buying a new device in every New Year Season or every other one. Saving an extra purchase over the two-year interval means forsaking the enjoyment over the second year of a device, including all new improvements appearing in the first. Obviously, when progress takes place at any constant pace of improvement, more frequent replacement is appropriate under some situations but not others. Focus now on any break-even situation. One can show that the fact that technological progress is accelerating geometrically under Moore's Law would turn the scale for the more frequent replacement. Additionally, so far, such discussions presume a constant replacement cost over time. The usually observed decline in unit cost for electronic products, as a result of improved technology, would further reinforce the decision for early replacement, and hence, a shorter product cycle.

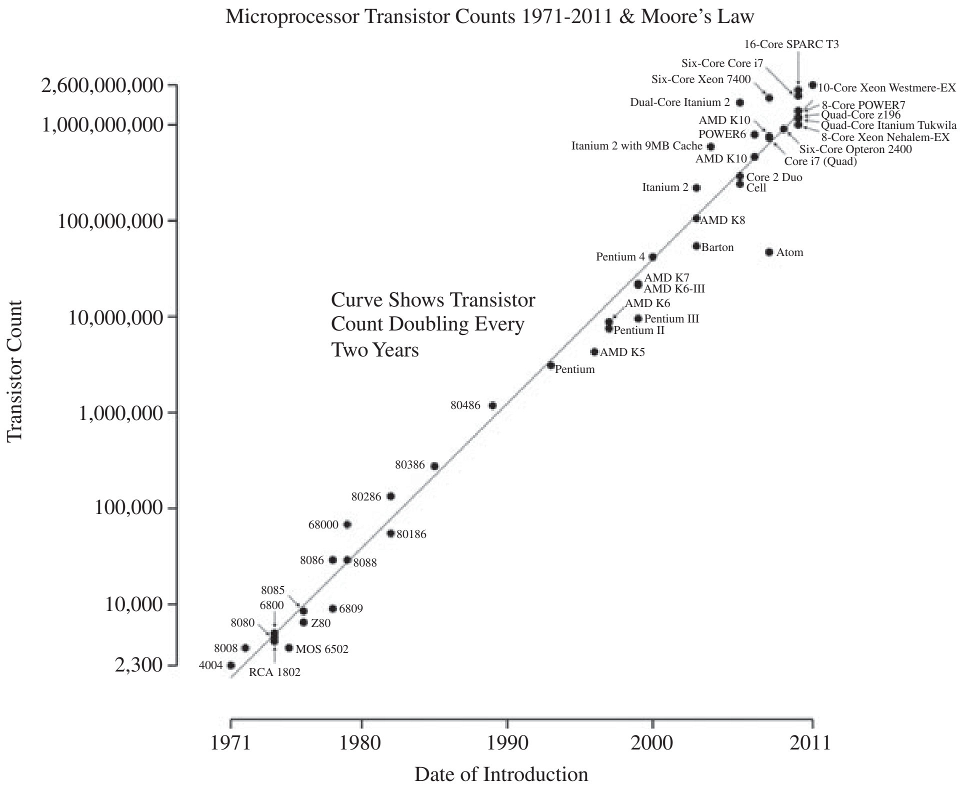
By Moore's Law, miniaturisation proceeds with constant acceleration rate. It is known that the product life has shortened over time. To decide whether there is any economic rationale behind this observation, a model is constructed based upon the following,

Assumptions

- The benefit of the innovation arrived at time t is Ae^{bt}, where A, $b > 0$.
- The device has a physical life of four periods.
- The buyer faces the binary choice of replacing the device in two ways:
  - i. Every period: at the end of period 1, 2 and 3.
  - ii. Every other period: at the end of period 2.
- The incremental replacement cost at the end of periods 1 and 3 is constant C.
- Each new device embodies the benefit of all innovations up to that time.

Let the decision be made at the end of period s, the above information implies the following diagram (Figure 4), where B is the benefit for option (i) over (ii).

FIGURE 2
Moore's Law



Source: Reproduced from http://upload.wikimedia.org/wikipedia/commons/thumb/0/00/Transistor_Count_and_Moore%27s_Law_-_2011.svg/2000px-Transistor_Count_and_Moore%27s_Law_-_2011.svg.png

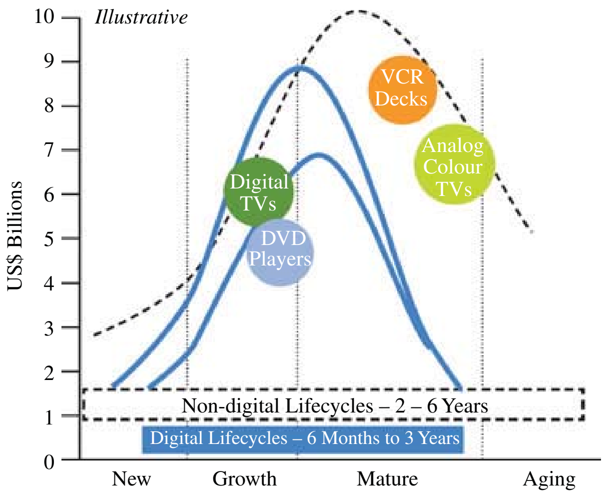
To sum up, this section explains the dynamics in the general theme: on the supply side, Moore's Law allows design engineers to incorporate new features and applications in electronic products at an ever faster pace; on the demand side, excited by the prospect of enjoying novel conveniences early, consumers switch to new gadgets in shorter cycles, in spite of the higher cost of ever quicker replacement. With the market enforcing the consumers' writ, firms must adapt to the continuously shortening product cycles to survive and thrive.

5. THE ADVANTAGE REGARDING THE TIME-TO-MARKET

Now consider the effect of a shortened product life on vending firms in the market in the choice of the production technique. In the current context, this concerns the decision to produce a product either by technique (i) in a customised version with artisanal skill or (ii) by methods that only approximate the absolute ideal. For insight, one considers a simple example[6] where

[6] This is actually a specialisation of a general treatment in Appendix A.

FIGURE 3
Shorter Product Lifecycles Narrow the Window for Profits



Source: Reproduced from Chue and Lim (2005), p. 3.

every choice has implications on three aspects for the product, each represented by a distinct parameter:

1. The market appeal, a, identified as the 'choke price' of a linear demand with the slope equalled to -1 (by normalisation),
2. A constant marginal cost, c, and
3. The delivery date, d.

For the current illustration, each parameter takes two alternative values, representing respectively, customised or volume production and denoted respectively by single or double prime signs:

$a' > a''$, (Other things being equal, customisation has superior appeal)
$c' > c''$, (Other things being equal, volume production is less expensive)
$0 < d'' < d' < T$ (Other things being equal, volume production means earlier delivery)

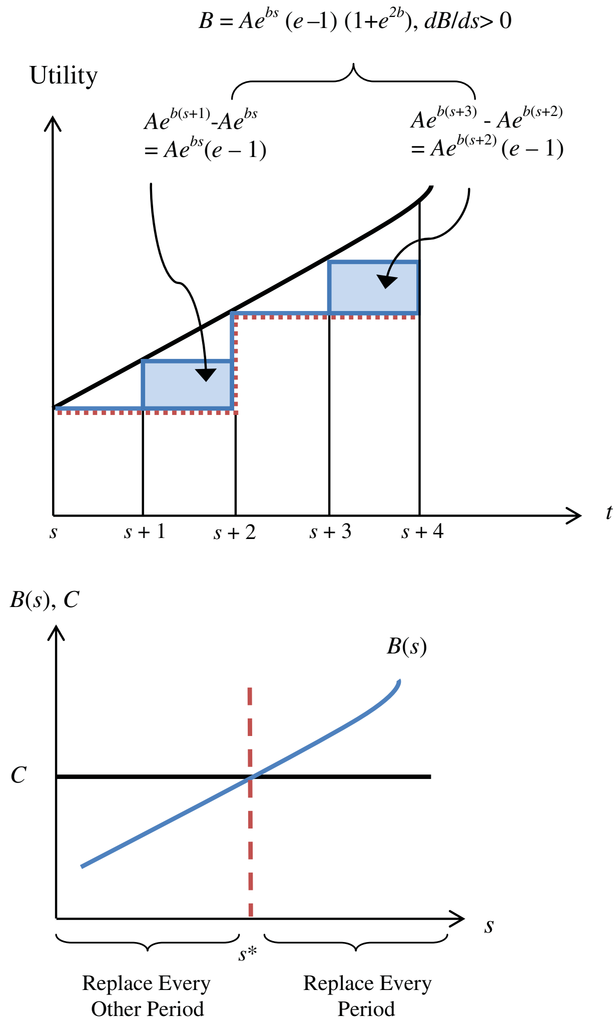
with T being the arrival date of that disruptively innovative product of the next generation, which marks the termination date for the product currently planned, whichever production technique is adopted.

The expected gross profit is $\Pi = (T - d)\ \pi = \ (T - d)\ (a - c)^2/4$, with π as the instant gross profit.

For simplicity, in Figure 5, a numerical example is deployed to illustrate, graphically, how the shortening of the product cycle – seen in the last section – tends to make firms to favour production methods approximating the quality of the ideal item, according to the brevity of the time-to-market.

Start at the instant for planning at time 0, a reduction of the product cycle means an earlier arrival of the next disruptive innovation, in the shift of T to some value, $T^{\circ} < T$. Obviously, depending on the specific circumstances, there are

FIGURE 4
Moore's Law Quickens Replacement



$U(T)$, the set of cases where 'seeking the ideal' may be chosen when the product cycle is T, and $V(T)$, the set of cases where 'using approximate solution' may be chosen.

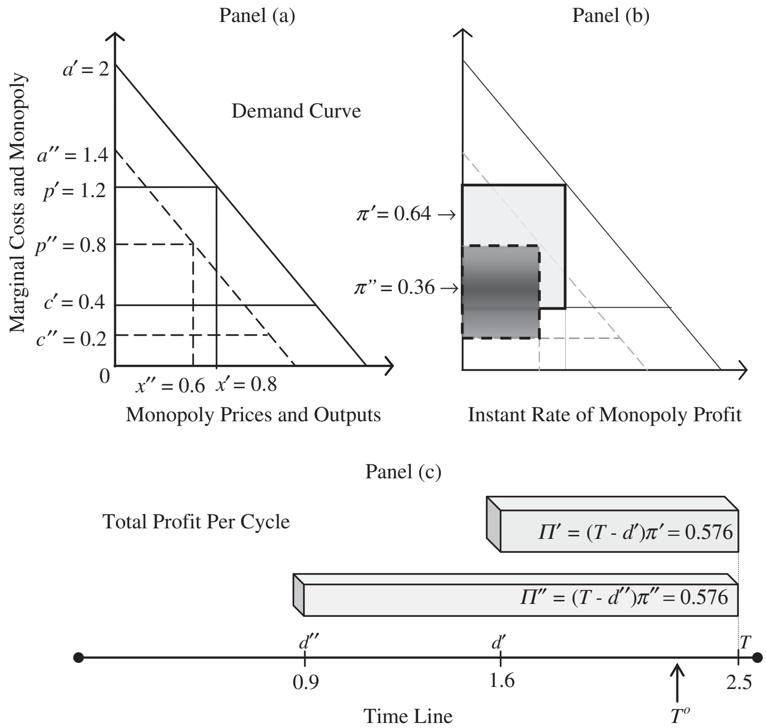
Focus now the set of break-even cases between two technologies, with product cycle equal to T:

$$W(T) = U(T) \cap V(T).$$

From the graphic demonstration in Figure 5, the shortening product life implies an unequal proportional shrinkage in profitability: $(T - T^\circ)/(T - d') > (T - T^\circ)/(T - d'')$, which tips the balance in favour of quicker time-to-market, or symbolically,

$$W(T) \subset V(T^\circ).$$

FIGURE 5
Profit and Time-to-market



To sum up, this section focuses on the comparative statics of how firms adapt to the shortened product cycle. Specify now the payoff of firms in terms of the criteria: 'faster, better and cheaper'. By a comparative static exercise, time-to-market is shown to gain relative importance in the multi-dimensional trade-offs for entrepreneurs.

Steve Jobs' action at Apple served as a paradigm case. Against his obsession over end-to-end control for perfection (seeking 'better'), he saved overhead costs by outsourcing everything after his return to Apple in 1997 (seeking 'cheaper') (Isaacson, 2011, p. 547), but made sure that during 2007, in the last minute switch to gorilla glass for the i-phone screens, he had Foxconn from Taiwan as contract manufacturer with its reputation on time-to-market to pull all stops to accomplish quickly his goal (seeking 'faster') in China, with location advantages explained below (Duhigg and Bradsher, 2012).

6. UNCERTAINTY AND SHORT PRODUCT LIFE CALL FOR CONTRACT MANUFACTURING

Up to this point, for the sake of simplicity, both the fixed cost F and the risk in innovation δ are left out of the picture or assumed to be the same for various choices and hence omitted in the discussion. To explain the rise of contract manufacturing, one needs to extend the analysis and brings both fixed cost and risk in innovation into consideration.

For a firm engaging in launching a product, when the product life is T, by producing the output with own facilities, the expected present value of reward may be written as:

$$(1-\delta)\Pi(T) - F \geq 0, \quad \Pi'(T) > 0 \quad \text{(Discount rate is assumed zero for simplicity)},$$

where there is a chance δ of failure in the innovative project, and the prospect of earning gross profit $\Pi(T)$ under the best possible technology, while the fixed cost F must be paid under all circumstances. Therefore, as the product life is reduced beyond some critical point, firms would either leave the market altogether or operate by subcontracting out all manufacturing activities, as in the earlier mentioned example of Apple selling its plant to the subcontractor SCI Systems (Sturgeon, 1998).

Outsourcing production, of course, is not a new practice, usually carried out by firms in developed countries to take advantage of lower input prices, and not to get out of manufacturing altogether, to save commitment to fixed equipment. It has been a long business tradition that 'captive subcontractors' depend on a few clients as their sole, or principal, source of income. Competition for orders keeps the subcontractors' profit margin negligible, making it impossible to fund R&D, accumulate intellectual property, and gain independence.

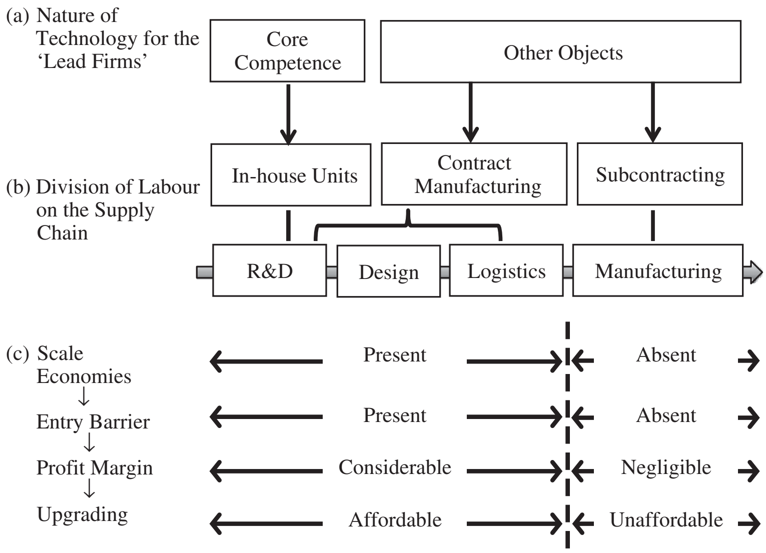
What makes the difference with the introduction of contract manufacturing industry is summarised in Figure 6. By serving many clients in an open network, the subcontractors naturally extend their activities to logistics, and sometimes into certain level of product design, as in the case of Taiwanese subcontractors. The advantage is to modify parts in certain ways so that the same parts can meet the demands of many clients to save not only production costs by scale economy, but also the time delay in delivery. That is to say, production is rearranged by modularisation to approximate what is achievable in customised production.

Again, the principle of modularised production has its own history. For example, Meyers (1986) noted that in supplying ready-to-wear ladies' garments, an American store, The Limited, had produced pants, shirts and shorts in Hong Kong, Sri Lanka and Mauritius, respectively, to market in record time. Nonetheless, it is the pressure for time-to-market that raised the importance of modularisation to its new heights and extended its application from fabrication to design.

Borrus (1997) credited the reversal of fortune for American electronics firms and against their Japanese competitors as due to American affiliation with overseas Chinese (OC) associates on account of the time-to-market. As mentioned earlier, interviews of Callon (1995) show the trump card of the OC subcontractors is modularised design by combining and adapting elements from their collections of macro-cell designs. Such a collection, in turn, is made possible by serving diverse clients under the American (open) network. Again as mentioned, the advantage of an open network is pronounced in the presence of fixed equipment and the risk in innovation, while such risk increases when product life shortens with the replacement cycle, under Moore's Law.

To recapitulate, it is natural that brevity in time-to-market is always a strength under R&D rivalry. When product cycle shortens with technological advance, the last section shows that even for firms with independent demand rather than oligopolistic competition, they would favour techniques with brief time-to-market. Although every firm prefers to have short time-to-market, it is the ODMs in open networks who would improve their competitive strength over time, bringing victory to themselves and firms affiliated with them, like the American electronics firms.

FIGURE 6
Function Decides Form; Form Ordains Performance



Sections 4 and 5 imply that under Moore's Law, time-to-market gains relative importance in decision making. Thus, given their comparative advantage, Taiwanese businesses achieve dominance over time.

In contract manufacturing, co-location of suppliers is important. China's advantage is its size, and by now, good infrastructure. That explains why Taiwanese contract manufacturing eventually gravitates to China.

7. THE GROWING ADVANTAGES FOR THE CROSS-TAIWAN STRAIT ASSOCIATION

In contract manufacturing, Taiwanese firms are late-comers in comparison with their North American peers. As a production site for contract manufacturing, Mainland China was far from being the unique candidate, especially in earlier years. Ethnic affinity across the Taiwan Strait is a factor which does not intensify over time and also partly offset by geopolitical concerns, on the part of Taiwan, especially under Tenghui Lee's presidential tenure.

On the other hand, Taiwan's advantage in contract manufacturing is its design experience. The accumulation of past designs under an open network is a growing advantage over time. The advantage of Mainland China is partly due to relatively low input cost, a factor that does not grow over time, but also partly due to clustering externality, a factor that gains weight by China's increasing export activities. Both factors are relevant to the consideration of time-to-market, which is rated as more important than cost advantage from the interviews by Callon (1995).

Two facts mentioned earlier – the gradual ascendancy of Taiwanese contract manufacturers over their North American rivals (Sturgeon and Lee, 2005) and the successive shift of Taiwanese investment to China from locations such as Mexico – are both consistent with the above reasoning.

8. SOME CONCLUDING OBSERVATIONS

In this explorative study, an effort is made to show the technological basis of the rise of global value chain and the rise of Factory Asia, with China as its last station.

It is found that Moore's Law is instrumental in the emergence of the contract manufacturing industry, the consumers' choice of frequent product replacement, the producers' choice of technique in favour of ready delivery than customised production and the various patterns of international production and trade.

In such discussions, economic analysis has been extended to study the length of replacement cycle, the advantage of swift time-to-market and the value of collections of designs.

The roles of design and logistics in production economics are suggested. The central role of time-to-market is emphasised. Its implications can be seen by considering the economic positions of both Taiwan and Mainland China in the world economy. In an era defined by the continued waves of innovation in electronics, it is by their experience in design that Taiwanese firms helped their American clients against their Japanese rivals and kept the global value chain in open network form, on account of speedy delivery. It is with that same strength Taiwanese firms succeeded to dominate the contract manufacturing industry and serve the catalyst role for Chinese participation in high-tech exports.

Taking this framework as a basis, one can further make speculative predictions regarding the future evolutions of the global value chain, keeping in mind such facts that so far the nearly monopolistic hold of Microsoft and Intel over operative systems and central processing units, respectively, remain intact, for decades. But that must be a project for the future.

APPENDIX A

The numerical example is a special case of the following,

General Model. Let payoff be

$$\Pi = f(v;T),$$

where $v = (v_1, v_2, \ldots, v_N)$ is an N-vector of characteristics for a project, with $v_1 = d$, standing for the date of delivery (time-to-market), $(v_2, \ldots, v_N) = w$ standing for 'other' characteristics and T standing for the termination date, then $T - d$ is the product life.

Assumption.

$$\textit{For some} \quad g(.), f(v;T) = (T-d)g(w).$$

Proposition. (Shortened product life favours early delivery).

For two projects:

$$v^0 = (d^0, w^0) \text{ and } v^1 = (d^1, w^1),$$

where

$$f(v^0;T) = (T - d^0)g(w^0) = (T - d^0)g(w^0) = f(v^1;T),$$

$$d^0 < d^1,$$

then for all $\Delta \in (0, T)$,

$$[(T - \Delta) - d^0]g(w^0) > [(T - \Delta) - d^1]g(w^1).$$

Proof. Routine computation.

Remark. In the special example, $N = 3$, $v_2 = a$, $v_3 = c$.

REFERENCES

Ancelovici, M. and S. J. McCaffrey (2005), 'From NAFTA to China? Production Shifts and their Implications for Taiwanese Firms', in S. Berger and R. Lester (eds.), *Global Taiwan: Building Competitive Strengths in a New International Economy* (Armonk, NY: M.E. Sharpe), 166–93.

Borrus, M. (1997), 'Left for Dead: Asian Production Networks and the Revival of US Electronics', in B. Naughton (ed.), *The China Circle: Economics and Technology in the PRC, Taiwan, and Hong Kong* (Washington, DC: The Brookings Institution), 139–63.

Callon, S. (1995), 'Different Paths: The Rise of Taiwan and Singapore in the Global Personal Computer Industry', Working Paper no. 105 (Stanford, CA: Asia/Pacific Research Center, Institute for International Studies, Stanford University).

Chue, Y. C. and T. C. Lim (2005), *Sink, Swim or Soar: Services Hold the Key* (Somers, NY: IBM Business Consulting Services). Available at: http://www-935.ibm.com/services/uk/igs/pdf/esr-g510-6163-sink-swim-or-soar.pdf (accessed 31 March 2012).

Dedrick, J., K. L. Kraemer and G. Linden (2010), 'Who Profits From Innovation in Global Value Chains? A Study of the iPod And Notebook PCs', *Industrial and Corporate Change*, **19**, 1, 81–116.

Duhigg, C. and K. Bradsher (2012), 'How the US Lost Out on iPhone Work', *New York Times*, 23 January.

Feenstra, R. C. and G. G. Hamilton (2006), *Emergent Economies, Divergent Paths: Economic Organization and International Trade in South Korea and Taiwan* (New York: Cambridge University Press).

Gourevitch, P., R. Bohn and D. McKendrick (2000), 'Globalization of Production: Insights from the Hard Disk Drive Industry', *World Development*, **28**, 2, 301–17.

Grossman, G. and E. Rossi-Hansberg (2008), 'Trading Tasks: A Simple Theory of Offshoring', *American Economic Review*, **98**, 5, 1978–97.

Grove, A. (2010), 'How America Can Create Jobs', *Business Week*, 1 July.

Helpman, E. and M. Trajtenberg (1998) 'A Time to Sow and a Time to Reap: Growth Based on General Purpose Technologies', in E. Helpman (ed.), *General Purpose Technology and Economic Growth* (Cambridge, MA: MIT Press), 55–84.

Isaacson, W. (2011), *Steve Jobs* (New York: Simon & Schuster).

iSuppli (2010), 'Foxconn Rides Partnership with Apple to Take 50 Percent of EMS Market in 2011', Press Release, 27 July. Available at: http://www.isuppli.com/Manufacturing-and-Pricing/News/Pages/Foxconn-Rides-Partnership-with-Apple-to-Take-50-Percent-of-EMS-Market-in-2011.aspx (accessed 31 March 2012).

Jovanovic, B. and P. L. Rousseau (2005), 'General Purpose Technologies', in P. Aghion and S. Durlauf (eds.), *Handbook of Economic Growth (Volume 1)* (New York: Elsevier), 1181–224.

Lamy, P. and T. Shiraishi (2011), *Trade Patterns and Global Value Chains in East Asia: From Trade in Goods to Trade in Tasks* (Geneva: IDE-JETRO and WTO).

Lee, K. Y. (2000), *From Third World to First: The Singapore Story* (New York: HarperCollins).
Meyers, W. H. (1986), 'Rag Trade Revolutionary', *New York Time Magazine*, 8 June. Available at: http://search.proquest.com/docview/425924663?accountid=13877 (accessed 31 March 2012).
MIC (2011), *Information Industry Yearbook 2011* (Taipei: Institute for Information Industry).
Naughton, B. (ed.) (1997), *The China Circle: Economics and Technology in the PRC, Taiwan, and Hong Kong* (Washington, DC: The Brookings Institution).
Pick, A. (2006), 'Foxconn's Strategic Coup: How Does Terry Gou Build Success?' EMS/ODM Service, Report Preview Q2-2006.
Shieh, G.-S. (1992), *"Boss" Island: Subcontracting Networks and Micro-entrepreneurship in Taiwan's Development* (New York: Peter Land).
Steinfeld, E. (2010), *Playing Our Game: Why China's Rise Doesn't Threaten the West* (New York: Oxford University Press).
Sturgeon, T. (1998), 'Network-Led Development and the Rise of Turn-key Production Networks: Technological Change and the Outsourcing of Electronics Manufacturing', IPC Globalization Papers (Cambridge, MA: MIT Industrial Performance Center).
Sturgeon, T. and J.-R. Lee (2005), 'Industry Co-evolution: A Comparison of Taiwan and North American Electronics Contract Manufacturers', in S. Berger and R. K. Lester (eds.), *Global Taiwan, Building Competitive Strengths in a New International Economy* (Armonk, NY: M. E. Sharpe), 33–75.
Tao, R. and D. Yang (2008), 'The Revenue Imperative and the Role of Local Government in China's Transition and Growth', paper for the conference on China's Reforms (University of Chicago), July 2008.
Van Liemt, G. (2007). 'Subcontracting in Electronics: From Contract Manufacturers to Providers of Electronic Manufacturing Services (EMS)', Sectoral Activity Programme Working Paper WP 249 (Geneva: International Labor Office). Available at: http://www.ilo.org/public/english/dialogue/sector/papers/tem-mee/wp249.pdf (accessed 31 March 2012).