The Economics of Sharing the Supply Base

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Abstract

For mass-consumed products, innovation increasingly makes market shares uncertain, plants costly, and product life short. Under *outsourcing,* rival firms (like Apple, HP) use plants of the same contractors (like Foxconn) to fill the orders received. Under *offshoring*, sharing supply chains across industries (like smart phones, electronic games) enhances the 'economy of co-location' at large trading countries (like China). Over their overlapping generations of products, firms find gradual reductions in both the risks of idled facilities, also the ability to relocate jobs. Thus, the innovation-driven *offshore outsourcing* constitutes a formidable obstacle against Obama to 're-shore' Apple's orders from China to America.

1. Motivation

This study focuses on a popular but counterintuitive practice. Successful firms[1] launch new products[2], by *sharing supply base*[3], which is indispensable to their success[4], with their rivals[5].

[1] Like Apple, the firm with the world's largest market capitalization.
[2] Such as smart phones and tablet computers.
[3] Such as Foxconn – one of the world's top ten employers.
[4] For example, Jobs 'pushed people to bring products out before they were ready', by Wozniak, the co-founder of Apple right in the beginning (Gibbs, 2014). When Jobs said 'I want a glass screen, and I want it *perfect* in six weeks' and sent message to Foxconn, an Apple officer observed, 'If Mr. Jobs wants perfect, there is nowhere else to go' (Duhigg and Bradsher, 2012).

The issue here matters not only to intellectual curiosity, but also international policy, as seen from the following paraphrased dialog (Isaacson, 2011).

Jobs to Obama, in a requested meeting, early 2011:

"700,000 in China now work on products of Apple";

Obama to Jobs, in an anticipated inquiry:

"What does it take to bring these jobs home?"

Jobs to Obama, proffering his pet project:

"Get 30,000 manufacturing engineers by any means; issue green cards if needed."

This study contends, Jobs' plan was wrong. He took Apple from Amelio[6], who just brought him back to Apple, but continued Amelio's policy and carried it to its limit, in outsourcing everything, against his own predilection of wall-to-wall control (Isaacson, ibid.). Judging from his proposal to Obama, one must wonder whether he succeeded under that policy at Apple, yet incredibly *knowing not what he was doing*. In any case, it will be shown that, supervisory engineers form a necessary, rather than a sufficient condition for his proposal.

Section 2 casts the paradoxical behavior of the firm in commonsense terms. Section 3 reviews briefly the familiar trade literature, where offshore outsourcing is approached in an a-temporal framework[7]. That provides context for the current study, with a dynamics driven by waves of new goods under a General Purpose Technology[8]. Like the a-temporal theory, the current study highlights the subject in parsimonious models with a tractable structure and assumptions motivated by available information. The purpose is to shed insight for policy making[9], and yield testable results to compare alternative explanations of reality. For this purpose, Section 4 presents the key elements of a theory in a list of assumptions. They combine into an analytic model to assure self-consistency of the logic behind the study. Following this is Section 5. It explains the causal

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5 Like HP and Nokia.

6 Then, the CEO of Apple, brought in due to his record of turning failed companies around.

7 For example, those surveyed in Helpman (2011).

8 See Helpman and Trajtenberg (1998).

9 An example is Jobs' proposal to President Obama for returning the manufacture of Apple's products from China to America (Isaacson, 2011).

relationship among technology, outsourcing and offshoring, also how empirical information helps to assess the current policy debates. As conclusion, Section 6 explains the challenges in testing the theory with empirical data. This is true for the present study, just like for the new, new trade theory. For now, one can at most show the consistence between the implications of the theory and available information.

2. A Common-Sense View

From the dialogue reported by Isaacson (ibid.), Jobs regarded those 700,000 as workers in his own plants. They are not. They worked on orders from Jobs under contract, no different from a waiter serves a patron at a restaurant. The waiter cannot be ordered to set up a table anywhere on the moment's fancy, unlike a servant in the patron's household. For a special occasion, the patron might rent the venue with the staff, but that will be on far costlier terms. Apple did not produce its products at its *own* plants in America or China, or anywhere else, because Jobs could not be sure to have popular products all the time, and afford such a larger labor force on a full time basis. After all, at NeXT, his creations were not commercial successes[10].

In fact, a major portion of those 700,000 Chinese workers was at Foxconn, and Apple's orders never accounted for more than half of the capacity of the latter. Foxconn was a *shared supply base*, working at that time also for Nokia of Finland, Sony of Japan and such American rivals of Apple, like Dell and HP, each made its orders as received from the market. Unless Nokia, Sony, Dell and HP would all abandon China, with its well-functioning clusters of suppliers, Apple would not be able to move its production from China to America, with or without accompanied by the tested-and-true management service of Foxconn. This would be true whether or not America had on hand those 30,000 manufacturing engineers.

Sturgeon (1998) provided the in-depth documentation of the major outsourcing of Apple under Amelio, selling its plant in Colorado to SCI, another contract manufacturer.

[10] *Sharing the supply base* is not limited to the modern industry of consumer electronics. Cheng (1996) describes in detail how the athletic footwear industry had gravitated to the same pattern, with the Taiwanese firm Pou-Chen playing the same role of Foxconn. Nor has such a practice much to do with modern East Asian businesses. The Globe theater in the Elizabethan era was shared by Shakespeare with his peer (rival) playwrights like Jonson since the former could not be sure to have enough masterpieces at all times to fully utilize the fine stage he partially owned. The economics decides the issue.

Presumably, by making certain concessions in the sales price of the plant, Apple secured a commitment from SCI. Within three years after the sales, Apple could exercise the option to request the use of that sold plant in Colorado to produce its output, even though at that time, both Apple and SCI had other plants offshore. This fact shows the reason of the sale has to be *sharing the supply base* at SCI, and not the *low production cost* outside America[11].

To place this major outsourcing (and plant sale) in its full strategic context, Apple was near a financial collapse. However, this was not because there were no promising projects for new products. Instead, it was because there were not enough well developed products realizing their full potentials. Far from giving up, or simply retrenching production for cash, the delegation of manufacturing activities to SCI (with its network of plant facilities) is actually a turn-around plan, getting several goals in one strike. By refocusing managerial attention on product development, the proceeds from plant sales can fully develop selected projects into highly profit products, and then mass-produce them with the far larger network of productive capacities of the contract manufacturer.

Ironically, the full potential of this master stroke was only realized under the incomparable charisma of Jobs, at the expense of Amelio himself.

Moreover, it is reported that what transpired above was not an isolated case. Sturgeon ibid observed that Apple was no pioneer in such outsourcing, but only a follower of the practice of its American peers in the industry. Nor is such outsourcing a sign of American exceptionalism, Van Liemt (2007) noted from his interviews, the European firms followed the American example.

3. The Present Study and the Trade Literature Briefly Reviewed

The current study deals with the changes in how goods are produced – by whom: in house or on contract; at where: at home or abroad; what is the consequence of the 'change over time'; whether such changes could or should be 'reversed in time' with government initiative.

[11] Had the low cost of offshore production was the cause for the plant sale, either Apple could always use its own overseas facilities, so it would not make price concession to trade for the commitment of SCI, or the commitment of SCI bargained for would be the overseas SCI facilities, and not at the Colorado plant.

These are questions relate to outsourcing and offshoring, topics also at the center of the new, new trade theory, with an extensive literature as well as collections of cited empirical documentation, though in all this literature, the focus is who is doing what for 'productive tasks', at a particular instant, in a 'timeless' framework and researched for their own purposes.

This trade literature provides at least convenient frameworks for the present study. At the heart of this literature are sorting theorems, classifying any heterogeneous firm being studied in a *snapshot* at any instant, specifically, the Lamy-Shiraishi matrix, for example.

Table 1 The 1987 entry for Apple in the Lamy-Shiraishi matrix

(Manufacturer, location; time)		At *where*	
		At home	Off shore
By *whom*	In house	Apple, America; 1987	
	On contract		

For the intertemporal focus in this inquiry, one may consider:

(a) From static analysis to comparative statics. By juxtaposing two snapshots at the time he was at Intel, and now he is in retirement, the observation of Grove (2010) can be presented in the following table.

Table 2 The concern of Grove, shown in the Lamy-Shiraishi matrix

(Manufacturers, location; time)		At *where*	
		At home	Off shore
By *whom*	In house	Scaling-up tasks; previously	Scaling-up tasks; today
	On contract		Scaling-up tasks; today

Grove observed that while scaling worked well in Silicon Valley, not many jobs were created there lately, as American firms found it less costly and more profitable to do manufacturing and even engineering overseas. What Grove worried was not only jobs

were lost, but also the economy broke the chain of experience that is essential in technological evolution, and would lose the growth potential.

(b) From comparative statics to causal dynamics and policy design. The developmental trajectory of a particular firm (say, Apple), describes how its products are produced: at various locations and by various manufacturers. The following Lamy-Shiraishi matrix indicates clearly what is contemplated in the Jobs-Obama dialog is the reversal of a two-step transition, each driven by a separate economic force, and presumably a separate hurdle to overcome.

Table 3 Apple's 2-stage trajectory in the Lamy-Shiraishi matrix

(Manufacturer, location; time)		At *where*	
		At home	Off shore
By *whom*	In house	(a) Apple, America; 1987	
	On contract	(b) SCI, America; 1997	(c) Foxccon, China; 2007

Outsourcing: cell (a) to cell (b); offshoring: cell (b) to cell (c)

In addition, it has a similar logical structure in analysis, which may help exposition, especially those readers familiar with the trade literature. In particular, there is pre-commitment, ex ante, followed by discovery of reality, and then consequential actions, ex post, before receiving payoffs, The uncertainty to be resolved concerns productivity of a firm for the new, new trade theory, and market preference in the present study. This will be seen in Figure 1, next section.

However, at present, no easy means is known yet to utilize the contributions of this literature to resolve questions like those grappled with in this study.

The discussion of such methodological issues in detail is in the hope that other professionals may come up with better solutions to bridge the gap between available analytic tools and urgent policy questions today.

To be specific, the well-known study of Antras and Helpman (2004) will be examined as an example of the new, new trade literature. In their parsimonious model, firms studied are heterogeneous only in their productivity; their self-discovery of the truth explains much about their decisions on *how* and *where* should their outputs be produced.

There is a specific pair of universal functions, $\Psi = (U, F)$: a utility function *U for all households*; a production function *F for all firms*, except for the firm-specific productivity index, θ.

There are also five types of 'fixed costs', Φ, common for all firms[12]: to *engage or not* in contract production (the *outsourcing* question), to *go abroad or not* (the *offshoring* question); to *enter the market or not*. Having paid for market entry, *ex ante*, firms discover how productive they really are, then decide, *ex post*, *how* to produce the products - *where*: *at home* or *abroad*; *by whom*: *in house*, or *on contract*.

The *sorting theorem* maps (Ψ, Φ) into an ordered quadruplet of *productivity thresholds*, $\Theta(\Psi, \Phi) = (\theta^0, \theta^1, \theta^2, \theta^3)$, that partition the half-line for productivity, $[0, \infty)$, into five intervals: $[0, \theta^0), [\theta^0, \theta^1), [\theta^1, \theta^2), [\theta^2, \theta^3), [\theta^3, \infty)$. These stand for the five options, namely, 'Exit', or the four choices for production, which depending on the magnitudes of fixed costs, f_k^l,[13] the *productivity thresholds*, may be ranked as: 'At home, on contract', 'At home, in house', 'Offshore, on contract', and 'Offshore, in house', in rising order of productivity. At any *t*, *every* viable firm is classified in a snapshot, by its own productivity $\theta(t)$ after self-discovery, into one of the four cells, within the matrix of Lamy and Shiraishi (2007).

Although in the trade literature, a broad collection of empirical inquiries has been cited, the purpose there is only to draw *qualitative* insights for theoretic research. No published result is known yet to develop quantitative estimates and calibrate those *universal function forms* and *magnitudes of fixed costs* underlying the sorting theorems.

Instead, insight from a more general literature is found to be crucial to the current research, which is applicable to some industries (like athletic footwear and consumer electronics, both important in the America-China trade, and in the latter case being the focus of the Jobs-Obama dialog):

- The theory of General Purpose Technology[14] which serves as the ultimate source of market uncertainty, driving the current analysis

[12] For the Northern firms being studied, $\Phi = (f_E, (f_k^l : l = N, S; k = V, O))$, with *E* for entry, *N* for at home, *S* for offshore; *V* for in house, *O* for on contract).
[13] See footnote12.
[14] See for example, Helpman and Trajtenberg (1998).

- The thesis of learning-by-trading[15] which apparently explains much of the economic growth of China, the World's Workplace, that yields in turn the economy of co-location, making offshoring so difficult to reverse.

4. A tractable model with simple assumptions

This explorative study concentrate on three propositions:

- Technology is the major cause for *outsourcing*
- The onset of significant outsourcing brings forth *offshoring*
- The trend for *offshore outsourcing* is difficult to reverse

The first proposition will be demonstrated in this section with an analytic model; the second will be illustrated using a paradigm case in history; the third follows logically, taking noted of the economic forces driving outsourcing and offshoring.

4.1 Outsourcing for the sake of sharing the supply base

It is assumed that *new products* arrive in over-lapping vintages, each with a distinct *technology*, and a representative vintage, v_t, at instant t, is studied, one at a time.

There are two types of decision makers maximizing their value of net revenue stream:

- Several, say two symmetrical but competing innovators (denoted as 'lead firms') launch *new* products under their own brands, to produce outputs with the *same* current technology and their own *specific* design, carried out
  either, *in house*: they conduct both *product definition* and *product fabrication*,
  or, *on contract*: they specialize on *product definition*, but not *product fabrication*,
  where their payoff is the expected present value of the *net profit* stream.
- Contract manufacturers fabricate for the lead firms at a market decided fee, φ, where their payoff is the expected present value of the *fee-over-cost* stream.

One now adopts the following:

[15] See for example, Coe and Helpman (1995).

Assumptions.

A1. Goods from any technology vintage t have a stochastic product life, to be displaced by disruptive innovation in any interval of length $\Delta > 0$, with probability, $\rho\Delta > 0$, as $\lim\Delta \downarrow 0$.

A2. For vintage v_t, there are *two* lead firms, symmetric to each other *ex ante*, until a popularity contest[16], whence:

- w, the winning firm in the contest becomes the temporary monopolist
- r, the rejected firm re-designs goods for an *interval* of length $T(t) > 0$, and returns, transforming the market into a symmetric Cournot duopoly, over the rest of product life.

A3. Contract manufacturers form an industry in which all identical firms break even, offering a unit manufacturing discount when it is necessary to deter entry.

A4. For lead firms, the initial decision of resource allocation is as follows:

- Operation starts by partitioning 1 unit of financial resources into:
  $\theta \in [0, 1)$ for plant and equipment; $1 - \theta$ for R&D and marketing.
  If production is *on contract*, $\theta = 0$.
- Contract manufacturers raise own capital on the market for plant investment.

A5. The industry demand for the product may be written as:

$$q = q_w + q_r = a(1 - \theta) - p, \quad a(.) \text{ being continuously differentiable}$$

where p and q are, respectively, the unit price and the industry output for vintage v_t. Products q_w and q_r of firms w and r, are perfect substitutes under duopoly.

$$\mathrm{d}a/\mathrm{d}(1 - \theta) > 0.$$

a is the 'choke price', at where the industry demand falls to zero, and

$1 - \theta$ is the *common* spending level of each lead firm to promote goods of vintage v_t.

A6. The marginal manufacturing cost is constant over all outputs, and takes the value:

$c(\theta^0)$ for production *in house* by the lead firm,
$c(.)$ being continuously differentiable

$(1 + \mu)\, c(\theta^*)$ for production *on contract* by the contract manufacturer,

where

[16] Say, taking tentative orders at a trade fair, on the basis of proto-types in exhibition.

$\mu > 0$ reflects the difficulty in producing output designed by others,

$\mathrm{d}c/\mathrm{d}\theta < 0$ depicts the fact that marginal cost is lower at costlier plants,

θ^0 is the cost of the plant chosen by a lead firm producing, *in house,*

θ^* is the cost of the plant chosen by the contract manufacturer.

A7. When output q is produced *on contract*, φ is both the *marginal cost* for the *lead firms* and the *unit revenue* for the *contract manufacturer*, subject to a possible discount.

The market determinants for the fee of contract manufacturing service, include:

(i) the lead firms' output decisions, q_w and q_r, and

(ii) the contract manufacturer's choice of plant, θ^*, and any discount per unit on contract fee, $\delta \geq 0$, for entry-deterrence.

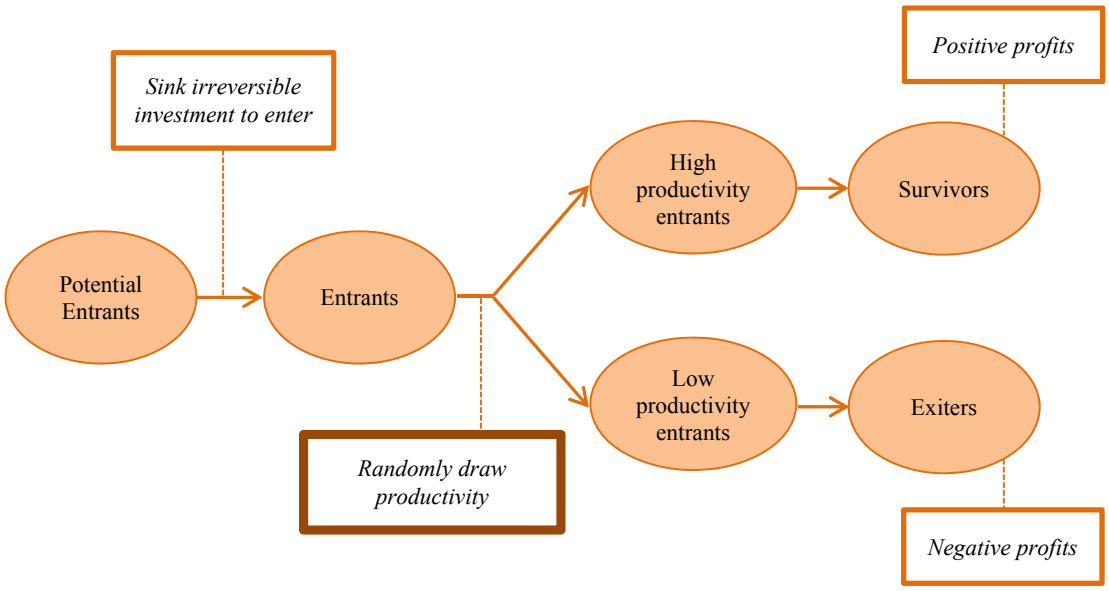
A8. Technological advance shortens the *redesign interval* from vintage to vintage: $\mathrm{d}T(t)/\mathrm{d}t < 0$.

The *pre-commitment, ex ante – self-discovery – adjustment, ex post* time line is shown in Figure 1b, in a form adapted from Greenaway and Knellor (2007), for readers familiar with the treatment in the new, new trade theory, displayed as Figure 1a. The goal of the latter is a timeless comparison across firms, at a particular instant, while the purpose of the current study is the intertemporal transition, across product vintages.

At this point, the focus of attention is the emergence of outsourcing, where major offshoring occurs at a subsequent point of time, as a consequence: the factual documentation comes from Sturgeon (1999), in Section 2; the causal observation follows the observation of Michael Marks, the former CEO of Flextronics, a keen rival of Foxconn at one time (O'Brien, 2001), in Section 5.

From the view of policy assessment, this two-stage transitions outsourcing-then-offshoring is likely to matter. With each stage driven by a separate economic force acting upon fiercely competing lead firms, at the edge of survival, logic suggests such trend may be more complex for designers of policy intervention in 're-shoring', aimed at reversing the *fait accompli*.

a. Outsourcing and offshoring ─ The new, new trade theory



b. Outsourcing ─ The present case

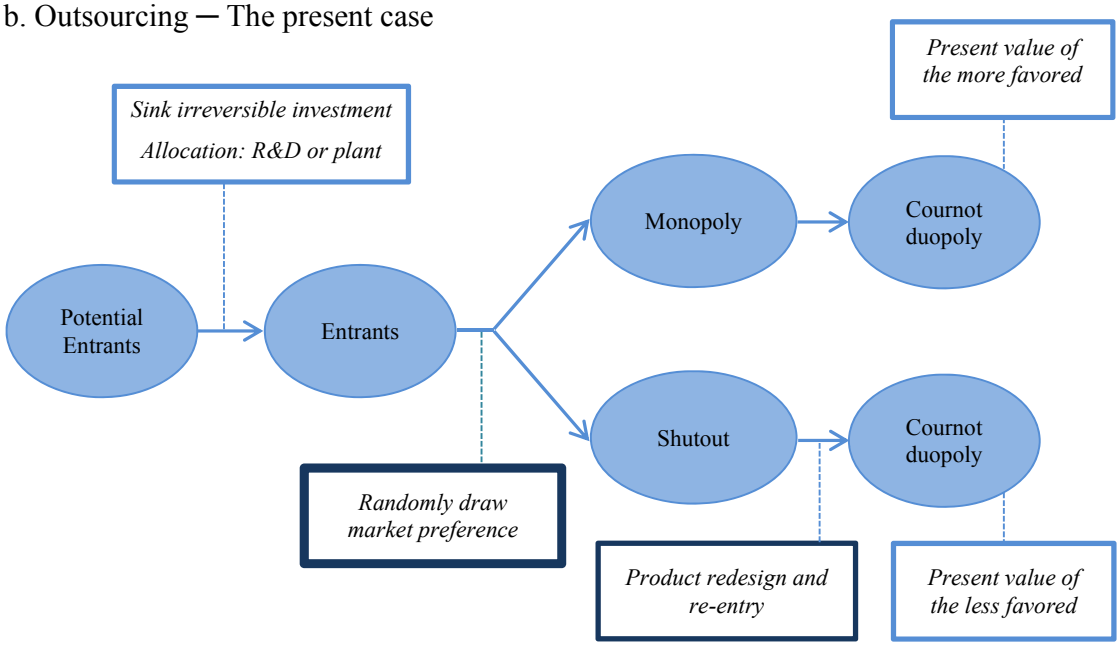


Figure 1 Outsourcing – Two alternative views

4.2 Technology advance causes lead firms to outsource for sharing the supply base

It is a *fact* that many lead firms fabricate products *on contract*, now, and not *in house,* as before (Van Liemt, 2007). What needs to be shown is the driving force is technology.

To study outsourcing, one focuses on the *transitional instant*, t^*, when *both* lead firms for the particular technology are indifferent over the alternatives for fabrication: *in house* or *on contract*[17].

Lemma 1.

For fabricating in house,

- at whatever θ,

a monopolist has,

$$p^M(\theta) = [a(1-\theta) + c(\theta)]/2 \quad \text{for price}$$
$$(1)\quad q^M(\theta) = [a(1-\theta) - c(\theta)]/2 \quad \text{for output}$$
$$\pi^M(\theta) = [a(1-\theta) - c(\theta)]^2/4 \quad \text{for profit,}$$

a duopolist has,

$$p^D(\theta) = [a(1-\theta) + 2c(\theta)]/3 \quad \text{for price}$$
$$(2)\quad q^D(\theta) = [a(1-\theta) - c(\theta)]/3 \quad \text{for output}$$
$$\pi^D(\theta) = [a(1-\theta) - c(\theta)]^2/9 \quad \text{for profit,}$$

and the industrial output is

$$Q^M(\theta) = [a(1-\theta) - c(\theta)]/2 \quad \text{under monopoly}$$
$$(3)$$
$$Q^D(\theta) = 2\,[a(1-\theta) - c(\theta)]/3 \quad \text{under duopoly;}$$

- lead firms in initial resource allocation implement a choice[18],

$$(4)\quad \theta \in Arg\ max_{[0,1]}\,[a(1-\theta) - c(\theta)],$$

with possible multiple solutions. To avoid diverting attention to unlikely events, adopt

[17] But they always make the *same* choice as assumed for convenience.

[18] For any pair of continuously differentiable functions $(a(1-\theta), c(\theta))$ over the closed unit interval, $[0, 1]$, there must be at least one maximum for $[a(1-\theta) - c(\theta)]$, with or without the following pair of conditions: $a(1-\theta) > c(\theta) > 0$; $a'(1-\theta) > 0, c'(\theta) < 0$, for all θ. With that pair, one can readily find graphically, all those θ values where $a(1-\theta) - c(\theta)$ is a maximum.

Assumption A9. Facing multiplicity, both firms would always select the same choice:

(5) $\theta^0 = Min_\theta \{Arg\ max_{[0,1]} [a(1-\theta) - c(\theta)]\}$,

and define the maxima for π^M and π^D, respectively, as,

$$\pi^M(\theta^0) = \pi^*, \quad \pi^D(\theta^0) = (4/9)\,\pi^0.$$

A Numerical Example.

$a(1-\theta) = 1/2 + (1/2)(1-\theta)$, $c(\theta) = (1/6) + (3/8)[(4/3) - \theta]^2$.

Figure 2 illustrates graphically the case: $\theta^0 = Arg\ max_\theta [a(1-\theta) - c(\theta)] = 2/3$.

$a(1-\theta^0) = a(1-2/3) = 2/3$; $c(\theta^0) = c(2/3) = 1/3$;

so that:

$a(1-2/3) - c(2/3) = 1/3$; $\pi^M = (1/3)^2/4 = 1/36$; $\pi^D = (1/3)^2/9 = 1/81$.

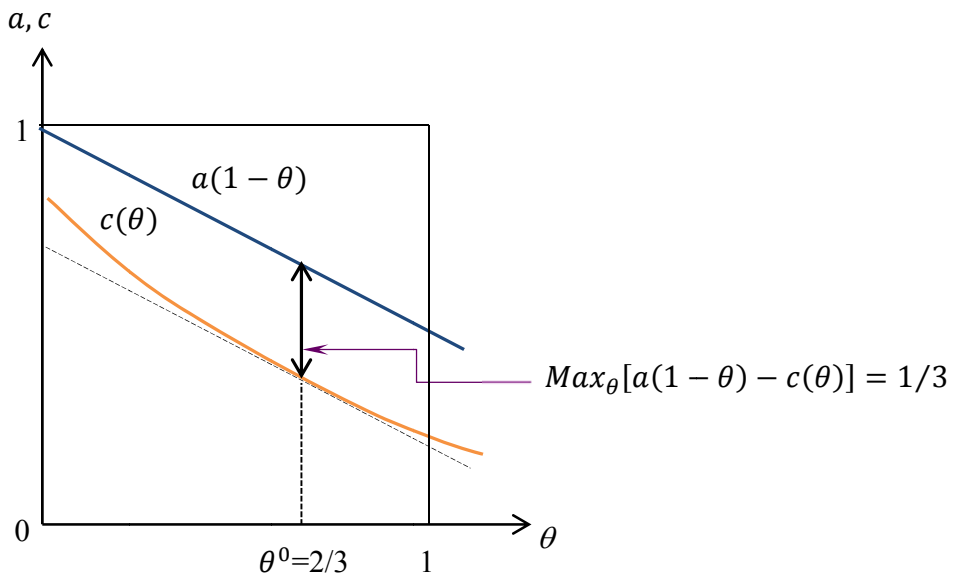


Figure 2 Illustration for a numerical example

From Figure 1, θ, the *initial common choice* of both firms[19] decides the plant, θ^0, the marginal cost $c(\theta^0)$ over the product life, and q_M, the monopoly output where the marginal revenue equals $c(\theta^0)$, and so on.

One can then tabulate the expected value of the net profit stream for the lead firms:

[19] That is before knowing whose product design wins the market favor.

Table 4 The computed expected value of the expected net profit stream

	The winner of market favor	The loser of market favor
The monopoly phase: $[0,T]$	$(1-e^{-\rho T})\pi^0/\rho$	0
The duopoly phase: (T,∞)	$(4/9)e^{-\rho T}\,\pi^0/\rho$	$(4/9)e^{-\rho T}\,\pi^0/\rho$
Sum	$\Pi' = [1-(5/9)e^{-\rho T}]\pi^0/\rho$	$\Pi'' = (4/9)e^{-\rho T}\,\pi^0/\rho$
The *ex ante* value: $(0,\infty)$	$\Pi^\circ = (\Pi' + \Pi'')/2 = \pi^0\,[1-(1/9)e^{-\rho T}]/2\rho$	

Using Assumption A1, one can deduce Figure 3.

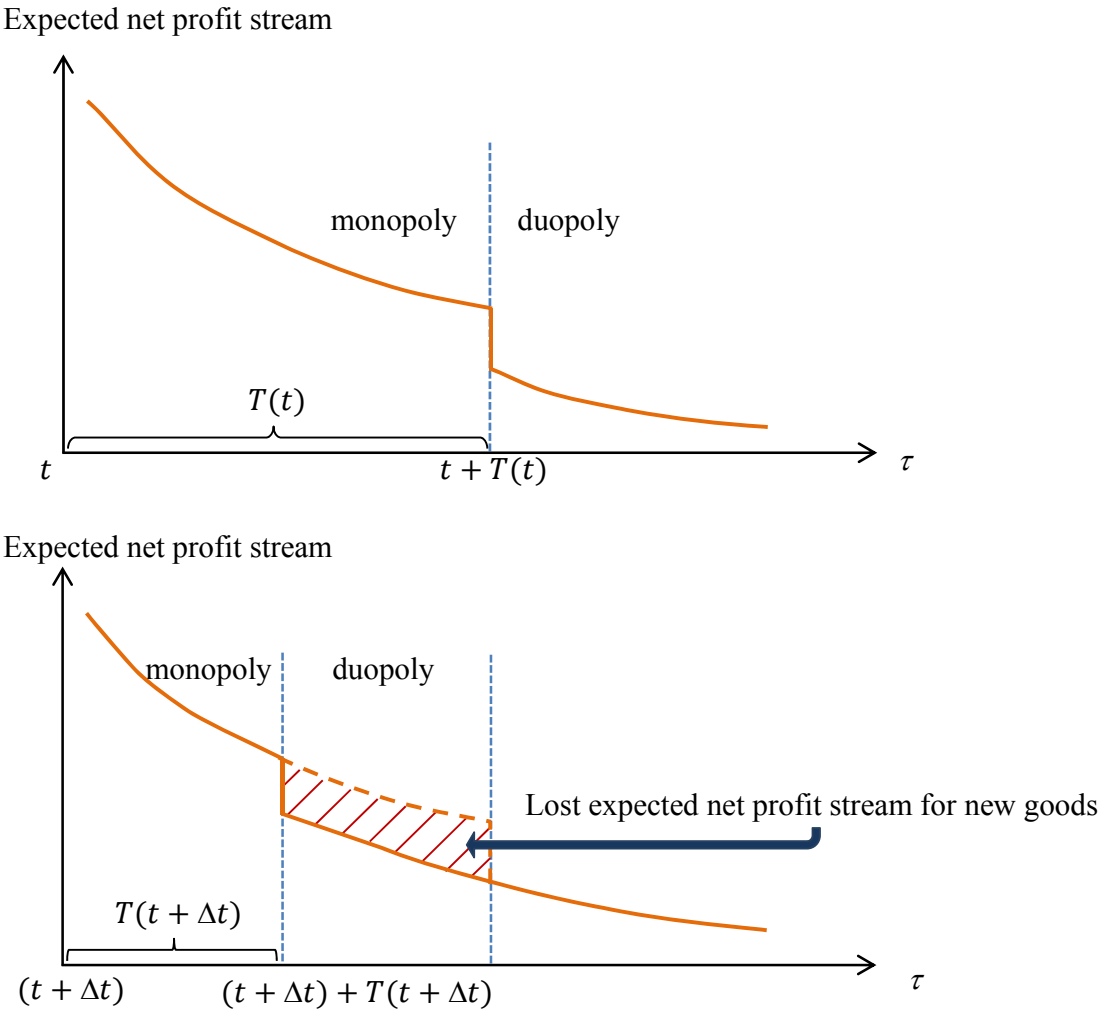


Figure 3 Technology progress threatens new goods

This supplies the background observed by Sturgeon (1999), in 1996 the industrial norm in electronics industry has shifted away from production *in house* to *on contract.*

Characterization of the transitional vintage, t^*

By the definition of a transitional vintage, the following four conditions must be met:

(i) Indifference of the lead firms over whether the output is produced *in house* or *on contract*, given φ^0 as the unit manufacturing fee being charged.

(ii) φ^0 is the optimal rate of fee to charge for the contract manufacturer, whatever plant θ^* it chooses for production.

(iii) *Financial viability* of the contract manufacturer: the value of expected stream of net revenue is *no less* than the value of investment in plants.

(iv) *No new entry* into the industry of contract manufacturing: the value of expected stream of net revenue is *no more* than the value of investment in plants.

Lemma 2

By Assumptions A6 and A7 and (5), Condition (i) is satisfied at the manufacturing fee:

(6) $\varphi^0 = a(1) - [a(1-\theta^0) - c(\theta^0)]$.

Proof.

By routine calculation, analogous to the derivation of Table 4, one obtains that for a lead firm which producing on contract, the present value of the expected profit stream is,

$$\{[a(1) - \varphi^0]^2/4\}\,[1 - (1/9)e^{-\rho T}]/2\rho,$$

which must be equal to the present value of the expected profit stream, when producing *in house*:

$$\Pi^0 = \{[a(1-\theta^0) - c(\theta^0)]^2/4\}\,[1 - (1/9)e^{-\rho T}]/2\rho.$$

Compare the last two expressions and simplify, one obtains (6).

Next, denote the expected net value stream of the contract manufacturer as Π^C.

One now can study conditions (ii), (iii), (iv) about contract manufacturing, for t^*: by charging the optimal fee rate, φ, and selecting the optimal plant, θ^*, contract manufacturing breaks even.

Lemma 3

By Assumptions A4, A5, A6 and A7, the break-even condition for contract manufacturing is:

(7) $0 = \Pi^C = Max_\theta\{-\theta + Max_\varphi\,[\varphi - (1+\mu)c(\theta)]\,[a(1) - \varphi]P[T(t)]/2\}$,

in which a term, 'the present value factor':

$$P[T(t)] = \left[1 + e^{-\rho T(t)}/3\right]/\rho > 0,$$

is used to simplify expressions.

Proof.

By Assumptions A1, A2 and A7, using Lemma 1, and substituting φ for $c(\theta)$ as the marginal cost for the lead firms to produce on contract, one has the expected value of the stream of industry demand for manufacturing service as:

$\left[\left(1 - e^{-\rho T(t)}\right)/\rho\right][a(1) - \varphi]/2$ under monopoly, over the interval, $[0, T]$,

$\left[(4/3)e^{-\rho T(t)}/\rho\right][a(1) - \varphi]/2$ under duopoly[20], over the interval (T, ∞).

The above two terms sum up to:

$$\left\{\left[1 + e^{-\rho T(t)}/3\right]/\rho\right\}[a(1) - \varphi]/2 = P[T(t)]\,[a(1) - \varphi]/2.$$

Now the contract manufacturer has,

- The expected value of net revenue, $[\varphi - (1+\mu)c(\theta)]P[T(t)]\,[a(1) - \varphi]/2$, the fee-over-cost margin per output unit[21] is, $[\varphi - (1+\mu)c(\theta)]$, where the parameter μ signifies the difficulty to fabricate products designed by others.
- The expected equivalent output units over the horizon, $[a(1) - \varphi]P[T(t)]/2$

For any given value of θ, hence, $c(\theta)$, one can solve for the maximized value:

$$Max_\varphi\,\{[\varphi - (1+\mu)c(\theta)]\,[a(1) - \varphi]\}P[T(t)]/2,$$

and thus under the optimal plant choice, θ^*, the break-even condition of the contract manufacturer becomes (7).

Now, note in the above expression, $\{.\}$ is a parabolic form of φ. This yields:

[20] Specifically, at each instant, the sum before discount is twice as much as the demand for each duopolist, $2 \cdot \{[a(1) - \varphi]/3\} = (4/3)\{[a(1) - \varphi]/2\}$.

[21] The value of the contractor's marginal cost is computed under Assumption A6.

Lemma 4

(8) $\varphi^* = Arg\ max_{\varphi}\{[\varphi - (1+\mu)c(\theta)][a(1) - \varphi]\} = [a(1) + (1+\mu)c(\theta)]/2,$

and,

(9) $Max_{\varphi}\ [\varphi - (1+\mu)c(\theta)]\ [a(1) - \varphi]P[T(t)]/2$

$$= P[T(t)]\{a(1)^2 - [(1+\mu)c(\theta)]^2\}/8$$

$$= P[T(t)]\pi^C(\theta),$$

say, with,

(10) $\pi^C(\theta) = a(1)^2/8 - [(1+\mu)^2/8]c(\theta)^2,$

which is continuously differentiable, and strictly increasing, by Assumption A6, also bounded above by $a(1)^2/8$.

One can also further get from (6) and (8),

(11) $c(\theta^*) = [2\varphi^* - a(1)]/(1+\mu)$

Finally, θ, the cost of plant raised on the financial market must be applied against the maximum expected value of the fee-over-cost stream, as in (7).

Taking note that the multiplicative term $P[T(t)]$ is a function of the vintage index, t, it is now possible to study the relationship between the evaluation and choice of plant θ^*, as well as the determination of the transition instant, t^*.

Proposition 1 (*Production on contract, at the transitional vintage,* t^*)

At the transitional vintage t^*, the three conditions (i) – (iv) must hold, providing the necessary conditions to determine the four magnitudes, $(\varphi^*, c(\theta^*), \theta^*, t^*)$, that characterize the contract manufacturing.

Proof.

Specifically,

First, by Lemma 2, the indifference condition of the lead firms, decides the equilibrium manufacturing fee φ^* in (6).

Second, by Lemma 4, the fee-setting rule for a contract manufacturer, which ties its marginal cost, $(1+\mu)\ c(\theta^*)$, hence also $c(\theta^*)$, to the fee it sets through its optimization operation, as in (10).

Third, what is left is the final step to characterize the transition instant, t^*, by the breaking-even condition of the contract manufacturer, which takes the form:

(12) $0 = \Pi^C = Max_\theta\{-\theta + P[T(t^*)]\pi^C(\theta)\}$,

where $\pi^C(\theta)$ is characterized by (10) above.

In general, this is a situation representable in the Figure 4, with two equally eligible solutions for θ^*, which completes the proof of this proposition.

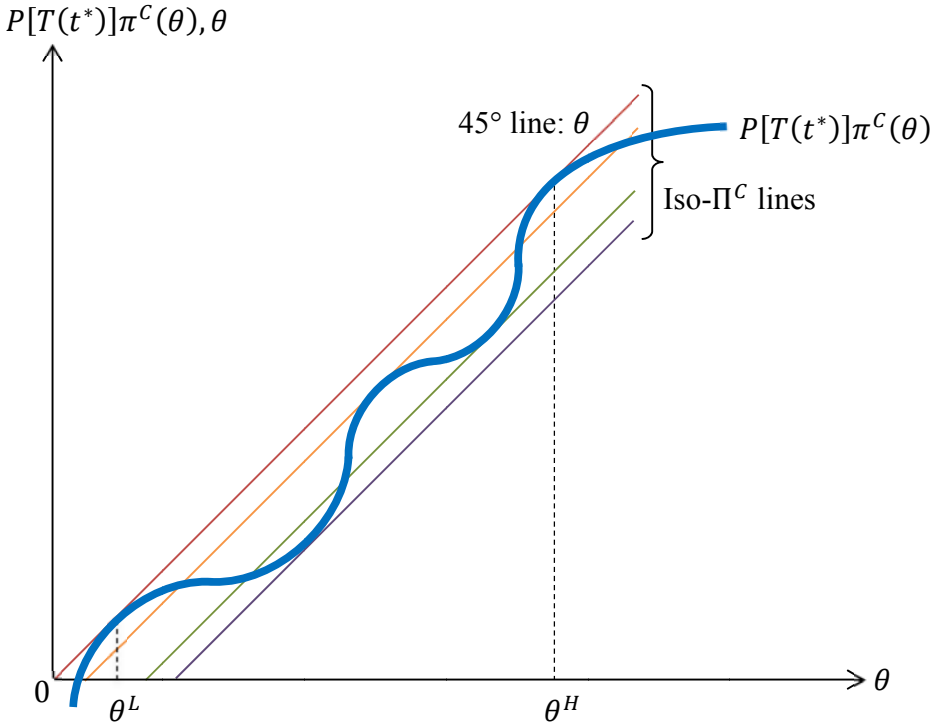


Figure 4 The contract manufacturing industry at break-even equilibrium

The *asset valuation principle*[22]:

(11) $0 = \partial\{-\theta + P[T(t^*)]\pi^C(\theta)\}/\partial\theta$

$= -1 + P[T(t^*)]\,\partial\pi^C(\theta)/\partial\theta$.

(By differentiating the term,{.}, on the right-hand side of (10) with respect to θ)

Equivalently,

(12) $1/P[T(t^*)] = \partial\pi^C(\theta)/\partial\theta$,

[22] This means the value of the asset equals the expected marginal contribution of the stream of capital service in saving the use of the variable productive inputs (say, labor) throughout the product life.

which relates the plant investment, θ^*, to the transition time, t^*.

One can now combine conditions (iii) and (iv) into their replacement:

(v) *The breaking-even condition for contract manufacturing*

Now substitute the optimum values, θ^* and φ^* into (12) and rearrange, one has:

(13) $1/P[T(t^*)] = \pi^C(\theta^*)/\theta^*$,

which satisfies (v), and completes the proof of the proposition.

The above relation again relates θ^* to t^*.

Thus, combining (12) with (13), one can solve both θ^* and t^* (See Figure 4):

(14) $\partial\pi^C(\theta)/\partial\theta = \rho/\left[1 + e^{-\rho T(t)}/3\right] = \pi^C(\theta^*)/\theta^*$.

Combining both members at the two ends of (14), one obtains,

Corollary 1 (*The unit elasticity rule for transitional instant* t^*)

At t^*,

(15) $\partial ln\pi^C/\partial ln\theta = 1$.

As it will be illustrated below in the completion of the numerical example, this will determine the 'interval for redesign' for the transitional vintage, $T(t^*)$. In combination with the time profile of technological advance, $T(t^*)$. In principle, such information may, reveal the calendar date for transition, t^*.

Remark.

At the root of the phenomenon of sharing the supply base, there must be some 'valuable facility' to be shared, which takes the form of a plant in the paradigm case of Apple selling its plant to SCI, in outsourcing. A plant has 'asset value' on the market means, by its use it reduces the (marginal) cost in production; the asset valuation principle means it commands the price of reducing cost over all expected equivalent units through its economic life. Thus, an asset with value θ must reduce the unit production cost for its owner, hence, $c'(\theta) < 0$, is fundamental to the problem studied. But this means one cannot exclude – in fact, must expect – that the function $\pi^C(\theta)$, hence $P[T(t)]\pi^C(\theta)$ also, is not everywhere concave over its range, $[0, 1]$. Thus, its shape as in Figure 4 is to be expected. In the numerical example, it is a quartic function of θ:

$$P[T(t)]\{1-(1+\mu)^2[{c_0}^2+2c_0\,c_1(c_2-\theta)^2+{c_1}^2(c_2-\theta)^4]\}/8,$$

$$\mu=1/5,\ \ c_0=1/6,\ \ c_1=3/8,\ \ \ c_2=4/3.$$

Thus to characterize the transitional instant θ^* in general, one needs an intuitive, but set-theoretic, approach in Figure 5.

The viability of fabrication on contract

Note now the purpose to focus on the transition vintage t^* in outsourcing is to trace the cause for outsourcing as technological advance, not cost comparisons, nor factor abundance across the nations; the importance of such causation is to highlight the challenge in bringing jobs from Asia to America, against the tide.

One now adopts a set-theoretic argument. Reproduce Figure 4 as Figure 5 and define:

$S=\{(\theta,v)\colon v\le P[T(t^*)]\pi^C(\theta)\}$, the attainable set, and $[S]$, its convex hull,

$Int(S)$, its interior.

This means with redesign interval $T(t^*)$, and the equivalent present value factor being

$$P[T(t^*)]=\left[1+e^{-\rho T(t^*)}/3\right]/\rho>0,$$

all optimal attainable actions of the contract manufacturer break even, and the model is at its equilibrium.

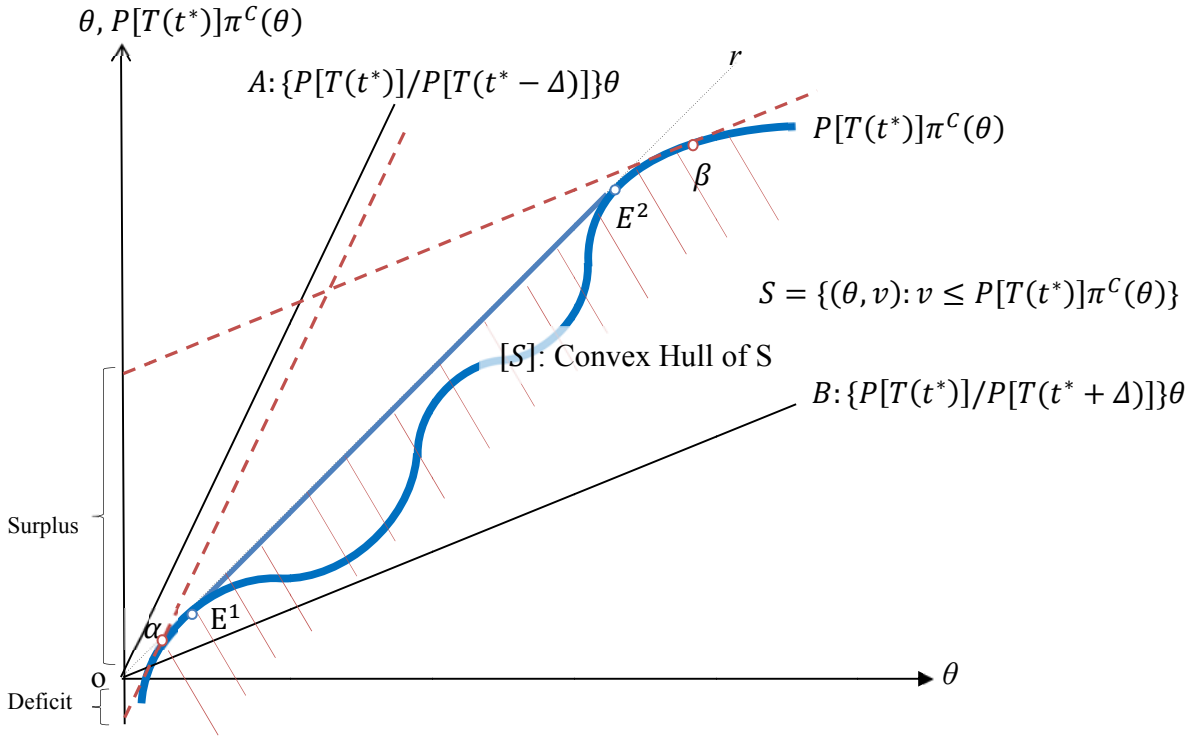


Figure 5 Technological Advance makes Contract Manufacturing Viable

One can now state:

Proposition 2 (Existence and Uniqueness of the transition vintage, t^*)

Proof.

Since origin $o \notin [S]$, which is convex by construction, there *exists* at least one support line of $[S]$, namely, the ray or through origin o separates the two[23].

Moreover, by Corollary 1, at whatever optimal pair, (θ, π^C), which need not be unique, along or, $P[T(t^*)]$, and hence, t^*, the transitional instant is *unique*[24], completes the proof.

[23] Formally, a convex set (like $[S]$) has at least a support that is closest to another (like the *point o*) separated from it.

[24] Formally, as both sets are in two dimensional space, and one is a point, there can be at most two supports through that point (zero distance), and only one with positive slope.

What happens at $t \neq t^*$ is tabulated in Table 4 below.

Table 4 Viability analysis of the Contract Manufacturing Industry

	$t < t^*$	$t > t^*$
Redesign interval	$T(t) > T(t^*)$	$T(t) < T(t^*)$
Equivalent present value factor	$P[T(t)] < P[T(t^*)]$	$P[T(t)] > P[T(t^*)]$
Break-even ray through o	A: $\{P[T(t^*)]/P[T(t)]\}\theta$	B: $\{P[T(t^*)]/P[T(t)]\}\theta$
Result	$A \cap S = \emptyset$	$B \cap Int(S) \neq \emptyset$
What vertical shift supports S	Downshift of A reaching α	Upshift of B reaching β
About contract manufacturing	There is always deficit	There can be surplus
Contract manufacturing	Not viable	Entry needs deterrence

One now can summarize such information as:

Proposition 3

Technological progress shortens redesign interval, penalizes production *in house*:

1. Before t^*, lead firms fabricate *in house*; contract manufacturing is not viable;

2. At t^*, contract manufacturing breaks even; lead firms are *indifferent* between two choices for fabrication: *in house* or *on contract*;

3. After t^*, lead firms fabricate *on contract*, receiving discount on manufacturing fee: δ; contract manufacturer breaking-even, after offering discount for entry deterrence, that raises output and plant investment.

Corollary 3

Throughout the post-transition period, all the following six trends continue:

- The increase of the value of the plant, θ
- The reduction of the marginal production cost, c, due to discount
- The expansion of the industry output, Q^M and Q^D
- The decline of unit product price, p^M and p^D
- The rising competitive pressure for lead firms in shortened monopoly, T
- The rising competitive pressure for contract manufacturing in reduced margin, φ

Numerical Example (Continued)

Assuming in addition, μ = 1/5, and θ = 1/3.

Now,

$$a(1) = 1, c(\theta) = (1/6) + (3/8)[(4/3) - \theta]^2$$

$$a(1) - (1+\mu)c(\theta) = 1 - (6/5)\{(1/6) + (3/8)[(4/3) - \theta]^2\}$$

$$= (4/5) - (9/20)[(4/3) - \theta]^2$$

$$\pi^C(\theta) = 2\{1 - [1 - (3/4)\theta]^2\}^2/25.$$

By (15),

$$1 = dln\pi^C(\theta)/dln\theta = -4\theta\,[\theta - (4/3)]/\{(4/3)^2 - [\theta - (4/3)]^2\}$$

$$= 4[3\theta - 4]/(3\theta - 8),$$

so that by routine computation, one can obtain the solutions,

$$\theta^* = 8/9,\ \ \pi^C(\theta^*) = 128/2025,\quad \pi^C(\theta^*)/\theta^* = 16/225 = 1/P(T)\,,$$

or,

$$1/P[T(t)] = 1/\left(3 + e^{-T/3}\right) = 16/225,$$

or,

$$e^T = (1/11.0625)^3.$$

5. Offshoring and Outsourcing

From the conceptual point of view, offshoring is relatively straightforward and has much less to be analyzed than outsourcing; but for political economy, it is far more significant. Jobs and Obama would never be bothered with such issues, if there had been no massive movement of jobs from the developed North to the developing South, making China the world's largest manufacturer and exporter. But in this globalized era, the major occurrence of these two - outsourcing and offshoring - are separated in time, yet linked with causality, and both driven by technological innovations, in different mechanisms. To begin with, it is this complexity, rather than either merely their conceptual intricacy or quantitative magnitude that makes it compelling to carry out this study.

5. 1. Impact of technology on outsourcing – disruptive innovations

- Production *in house* or *on contract*

Sharing the supply base is not the motivation of *all* the outsourcing and offshoring, but *a significant portion* of them, including those causing much of today's policy debates. Both Van Liemt, (ibid.) and Chue and Lim (2005) report results of interviews with many business leaders that reveal the latter's concerns: the *increased uncertainty* in marketing their new products means the shortening of *expected* product lives. There is much less chance to earn back the investment in plants. It discourages them *to own* expensive equipment, outright, *or*, to *hire* workers, full time.

- Rivalry in market *but* complementary in production

Sharing the supply base transforms the relationship among the lead firms in the same industry. Apple, HP, Dell and Nokia are rivals on the market, but also *incipient* mutual complements in patronizing Foxconn, since for anyone to survive (even if not all can thrive), the existence of firms like Foxconn has become nearly indispensable. Against the Jobs-Obama plan, the challenges now are interlocked: Apple cannot move alone without Foxconn, Foxconn cannot move with Apple only, without also moving a large cohort of HP, Dell and Nokia. Given any adjustment cost, the lumpiness of moving altogether to America already makes the proposition nearly impossible.

5.2 Impact of technology and outsourcing on offshoring

- The impact of technology on the economies of scope through co-location

As remarked by Michael Marks, former CEO of Flextronics (O'Brien, 2001), *digitization* made the great difference. Many electronics products today, from personal digital assistants to inkjet printers are made with the same 'DNAs', from connectors to circuit board, processors, plastic and rubber. This standardization of inputs makes the service of electronics manufacturing a 'commodity', with intense competition and thin profit margin. It provides opportunities for the *economies of scale* in supplying inputs upstream, at the same time makes the *economies of scope* through co-location crucial for contract manufacturers to situate themselves in those countries with the institutions and the size to play host for them, and certainly not *anywhere* in the 'developing South', just with low factor cost.

By the nature of this process, for researchers, documentation via well-prepared data sets is simply out of the question for fast moving and momentous events in locations with the real world's least transparent political economies, perhaps within the next a couple of decades. Veracity of information depends upon sifting over news items for mutually independent sources with concordant content, that remain consistent by economic logic.

- The impact of outsourcing on the economy of scope

Now one can show how the practice of *outsourcing* has done much to facilitate *off-shoring* to those particular locations that offer economy of scope. Perhaps with the possible exception of Samsung of Korea today (and certainly not Apple), few multinationals can cover, *in house*, the full range of electronic products from television sets, to smart phones, tablet computers, servers, electronic games, etc. which require a host of various supplies, parts, components, etc. But this can be dealt with by using a contract manufacturer, with production base in China, for instance, to realize the full economy of scope.

- The co-evolution of business practice and political economy

Sturgeon and Lee (2005) documented inside the contract manufacturing industry, the competition between two groups, one in North America (including SCI, which Apple initially dealt with in 1996) and the other mostly in Taiwan (including Apple's present main contractor, Foxconn, with 90% of its million-person employees in China) took around a decade before most of the business gravitated to the latter. This process suggests (i) mostly lead firms in America and Europe started outsourcing with locally-based contract manufacturers, and in the lengthy adjustment process, in which firms with relationship-specific investments in each other do not switch partners overnight (Grossman and Hart, 1986), (ii) the strength of the economy of co-location, eventually wins out for China, and (iii) the comparative advantage in 'business methods' of Taiwanese firms for contract execution is an endurable element in the picture.

Since Jobs and Obama focused on Apple's production in China, one would like to examine how has China developed its relative strength. Chen (2008) reported that observing the success of the Kaoshiung Export Processing Zone (KEPZ) of Taiwan, Zhou Enlai, the Chinese premier, showed interest to emulate such a strategy for attracting foreign capital, generating trade and profit. This was the root of the reversal of the former

Chinese policy of isolation in 1978-79 and the founding of Special Economic Zones like Shenzhen as experiment.

Yao (2011a, 2011b) documented how China's Seventh Five Year Plan over 1986-1991 set priorities to develop the coastal provinces and adopted the strategy of 'Great international circulation' to serve foreign firms as export platforms. The latter initiative gave rise to a large sector of processing trade in China, yielding huge trade surpluses instead of having a serious deficit. He further credited Taiwanese firms, such as Foxconn, the world's largest contract manufacturer, as playing a huge role, which corroborates the observation of Steinfeld (2010).

Such development enabled China to manufacture and export electronics products, not only making Chinese trade 'special', but also gaining much technology transfer from abroad, under the Chinese policy deign, in the views of Rodrik (2006).

In the saga, of the emerging deep Sino-American economic interactions today, Taiwan has played a key role twice, to link the world's top two economies: once related to China's rise as the World's Workshop through the *offshoring* movement, and the other in the actual practice of *outsourcing*. This is so, even though Taiwan is neither the home of important lead firms, like America, nor the host of actual manufacturing, like China.

The very presence of Taiwan's dual role is actually the empirical evidence of the phenomenon of sharing supply base, which dominates much of world trade today.

As illustrated by the Apple-SCI case and in the report of Van Liemt (2007), China was not a predominant host for contract manufacturing, then as now. It gains its present prominence certainly not because the falling of Chinese factor prices relative to others. Quite the contrary is true. What makes the difference is likely *co-location*, a potential advantage of large countries, like China, but also India. Though India started its Kandia Export Zone in 1965: as early as Taiwan and a dozen years before China. Yet, China now plays a role India does not. But as both Chen and Yao show, the personal involvement of Chinese leaders with powers more centralized than India makes the difference. With Taiwan's success as a template, zoning as an institution is backed with serious resources.

While China is the world' largest exporting country in the world, Foxconn is the largest exporting firm for China. Lauded by Chue and Lim (2005) for its superior 'business models', with court record showing that its Chinese rival BYD hired away it

employees, and secured its operating manuals, with contested legitimacy (Li, 2012), and regarded as irreplaceably efficient by its client[25]. It replaced Flextronics as the world's largest contract manufacturer in 2004 (Pick, 2006) and holds that position for the last ten years whereas Flextronics was at the top for two years only.

One ought identify where are the strengths of Foxconn, equivalently, what does the market favor it for. Here, the astute observation of Pick, ibid, are telling:

- It serves fewer but more promising clients than its peers, to gain a more stable clientele
- It commits to its client more relationship-specific investment to limit the client's intention to switch partners
- It focuses more than its peers on China, gaining economies of scale and scope in that economy
- It competes hard to assemble and design for clients, gaining the right of preparing the Approved Vendor List (AVL), so as to become a monopsonist over its suppliers, thus reducing input cost and driving up profit margin

All these winning strategies make sense only if it operates in its own chosen line of business of contract manufacturing. Historically, it started as a supplier of plastic television knobs, but next shifted to become a supplier of the ubiquitous connectors in electronics, and then went upstream to assemble a giant tool-making team, so as ready to produce to clients' specifications quick (Xu, 2008).

In real life, in contrast to the simplified model in this study, the market uncertainty confronts not only the lead firms, but also the contract manufacturers. Foxconn's advantage is to contain the adjustment costs as the market shares of clients shift.

These winning strategies make sense, only when its business centers on the management of *shared*-supply base. Descriptively, thus the irreplaceability of Foxconn to its clients implies the indispensability of supply base sharing by the industries it serves.

Normatively, the above analysis confirms the incipient complementarity among contract manufacturer and most (if not all) their clients, under such a practice. As a

[25] As testified by employees of Apple when Jobs need last minute adjustment for i-phones (Duhigg and Bradsher, 2012).

matter of fact, during 2012, Apple was the largest client of Foxconn, but its business was only 39% of the latter (Barclays Capital, 2012:11).

6. Between Theory and Evidence

Helpman (2006) observed about the empirical testability, over the literature surveyed there. Significantly, he pointed out the lack of 'available data sets' which require 'firm level data', concerning 'different types of products'. Such difficulties pertain to the central subject of sorting firms on the twin questions of producing *at where* cum *by whom*. It is also mentioned how theory helps the identification of data that needs collection to improve empirical analysis.

As discussed earlier, on outsourcing and offshoring, the new, new trade literature characterize at an instant, the behavior of all firms studied like a 'snapshot'. This study, in comparison, focuses on different though related questions: how certain class of firms[26] which are important in life[27] behaved differently over time and whether such changes *can* and *should* be influenced with policy. The nature of the questions being addressed, and 'the change of times' itself[28], make firm-level information even more important for this study than for the new, new trade theory. Relevant and urgent policy issues, as what confronted Jobs and Obama, are being debated, with or without the participation of economists, and whether all 'desirable information' is, or even can ever be, collected.

On the one hand, unlike the days before 2006[29], far fewer large firms, both 'lead firms' and 'the contract manufacturers', battle each other fiercely. Information vital to researchers can be also sensitive to the survival of these firms themselves[30]. Conscious effort by the government or academics to collect such data tends to be challenging.

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[26] Especially those under the influence of the general purpose technology, such as the electronics firms.

[27] These may be firms active over the period in question, such as Apple, or the new dominant firms, like Google, replacing the old ones, like Nokia, RIM.

[28] Again to an important degree, due to the consequence of the prevailing general purpose technology, namely microelectronics, such as Moore's Law.

[29] That is to say, among the lead firms, when RIM competed against Nokia at a rather leisurely pace, rather than with both of them being unceremoniously swept away by Apple as well as Samsung.

[30] The sensitivity of the situation is such for firms sharing the same supply base (say Foxconn) that they request workers of their common contract manufacturers to produce everything except one last part to assemble in the last moment to confuse possible leakers (Hill and Jones, 2012).

On the other hand, the rise of giant 'lead firms' like Apple, which has the highest market valuation and their contract manufacturers like Foxconn, which has been estimated to involve 40% of the consumer electronics in the world all by itself (Duhigg and Bradsher, 2012) may change the nature of information necessary. Internal information of such firms seems somewhat relevant to world trade; how much cross-firm data sets including their far smaller peers in an industry can add information remains to be demonstrated.

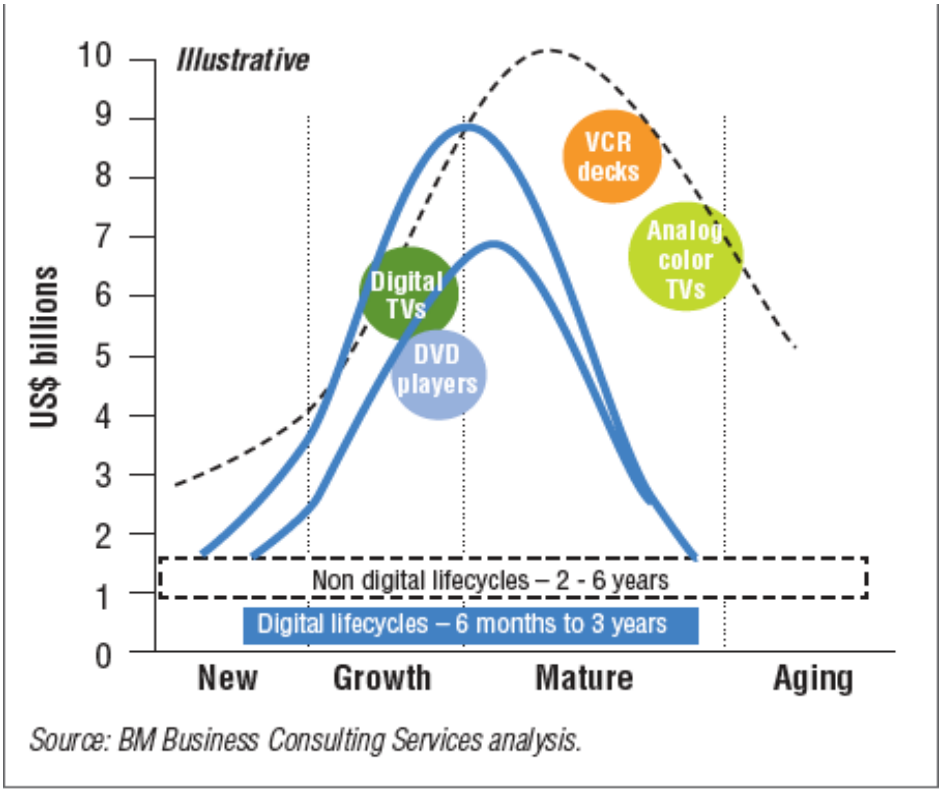
Analytically, the often-heard shortening of the prospective economic life of products, may mean either more rival firms competing for dominance at any time, or more rapid market entry by competitors, or most likely, the lowering of barriers separating industries: the smart phone has taken away market shares from watches, alarm clocks, dedicate cameras and stand-alone GPS navigation guiding devices.The last case is directly the consequences of the presence of the General Purpose Technology.

Fragmentary evidence is available either in qualitative form, as stated in Chue and Lim (2005), see Figure 6, or the quantitative information from Hewlett-Packard is available, as seen in Figure 7.[31]

Although the information is 25 years old, this information shows nicely that the most profitable periods of Hewlett-Packard outputs have gradually shortened over time. It fits the fact that in 1996, outsourcing is already an established practice as said by Sturgeon (1999). [32]

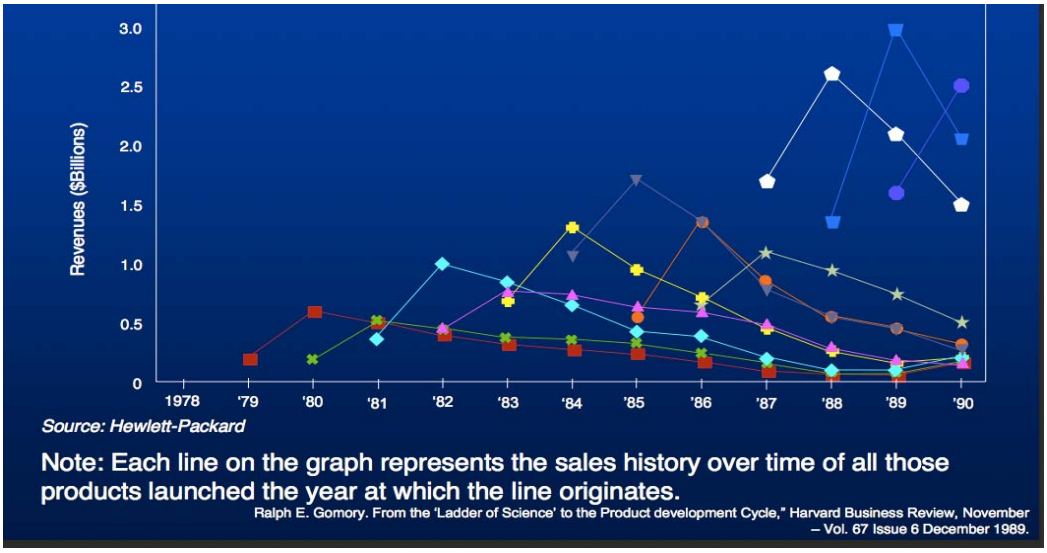
[31] Figure 7 reproduces with permission a slide in a Cornell lecture by Donald P. Greenberg, on line. Although it is not in the Gomory article at the Harvard Business Review as annotated, it is understood that this was given by Gomory, possibly in a presentation of his Harvard Business Review article.

[32] Such data should meet Helpman's standard. It took more than two decades to appear in print, and there seems no similar information in the public domain.



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

Figure 6 Life Cycle of Digital and Non-digital Products



Reproduced from Greenberg (2013), slide 40

Figure 7 Life cycles of products of Hewlett-Packard

At the same time, differences among products emphasized by Helpman (2006), are important. Why contract manufacturing plays key roles for athlete footwear (with little connection to electronics), but not hard disk drives (HDDs) is a challenge for researchers. Likewise, one might suspect, information from data-rich, in-depth industry studies such as Cheng (1996) and McKendrick et al. (2000)[33]. Whether or not readily amenable to econometric methods like panel studies, they appear valuable to policy analysis.

Finally, at the methodological level, the 'pre-commitment' – 'self-discovery' – 'adjustment' trilogy that underlies both the new, new trade theory and the present study is itself only an approximation to reality. Real life is a continuous process where action leads to more information and information prompts more action, ad infinitum. How to get the most information early and commits to the least sunk cost irreversibly leads to dynamic games involving the adaptive control process[34]. The real life relevance is seen in the Hewlett-Packard decision to ship products from Chongqing, China to Duisburg, Germany by rail, which is cheaper than airfreight but far faster than ocean shipping. This shorter time-to-market allows for early production response to the most recent market development (Bradsher, 2013).

[33] Respectively, these studies are on athlete footwear and hard disk drives.

[34] The topic was surveyed earlier by Bellman (1962) and the multi-player version is considered by Vrabie, et al (2013).

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