

The development and future of Factory Asia¹

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1. INTRODUCTION

Like a gigantic, impossibly complex but wonderfully efficient factory, East Asia churns out a vast array of manufactured goods with world-beating price-quality ratios. But this is not a series of national efforts. Manufacturing processes that used to be performed in single factories (mostly in Japan and Korea) have been fractionalised and dispersed across the region – creating what Baldwin (2006) called ‘Factory Asia’.

This paper looks at the underlying interconnected processes that have led to the development of Factory Asia – namely the fractionalization of the manufacturing process into stages and the dispersion of these stages around Asia. It does so by developing the TOSP (tasks, occupations, stages, products) framework that was informally introduced in Baldwin (2012a). The TOSP framework views the production of goods as the performance of a range of tasks that are organised into occupations (collection of tasks) and stages (collections of occupations). Typically offshoring occurs at the level of stages rather than tasks or occupation.

This framework is then used to examine the likely effects of improving ICT on the future of Factory Asia. Two dimensions are distinguished: fractionalisation of the production process (slicing up the value chain), and their spatial dispersion (offshoring stages).

A key premise of this paper is that it is a trap to think of Factory Asia from the perspective of traditional trade theory. It is tempting to think of the fractionalisation as simply a further step in the century’s long march from autarky to free trade. After all, the fast-lane of Factory Asia involves the offshoring of low-skill intensive stage to nations that are abundant in low-skill labour while knowledge-intensive stages remain in nations that are well-endowed with knowledge workers. A natural, but incorrect, way to think of this is as nations’ shifting resources to their comparative advantage sectors.

As this misthinking is pervasive, the rest of the introduction is devoted to contrast the old globalisation paradigm – which views the process as driven by the steady lowering of trade costs – with an alternative narrative that views globalisation as two processes rather than one.

1.1. Globalisation as two unbundlings

Globalisation is often viewed as linear – a progressive integration of national economies driven by lower technical and manmade trade costs. In trade economists’ jargon, globalisation is basically the move from autarky to free trade done slowly. The sharp trends in Figure 1 suggest that this is a mistake.

Globalisation was associated with an agglomeration of economic activity in what used to be called the industrialised nations. From 1820 to 1988, the G7’s share of global output rose from 22% to 67%. Since then, the share has plummeted and is now back to the level it first attained in 1900. About the same time, the world saw a massive shift in manufacturing activity from G7 nations to a handful of developing nations that have come to be called

¹ This paper was written for the ADB’s project “The Future of Factory Asia”. Our contribution draws heavily on the authors’ earlier works to inform policy and help direct future research.

Emerging Economies. In the two decades from 1970 to 1990, the G7's manufacturing share dropped from 71% to 65%. The subsequent two decades saw it plummet to 50%. The share shifts, however, were not generalised. Only seven nations saw their share of manufacturing rise by more than ½ of one percentage point (China, Korea, India, Indonesia, Thailand, Turkey and Poland). Plainly we are in a new phase of globalisation – a phase that is distinct from earlier phases. There are many names for this new globalisation paradigm – the global value chain (GVC) revolution, fragmentation, trade in tasks, etc.

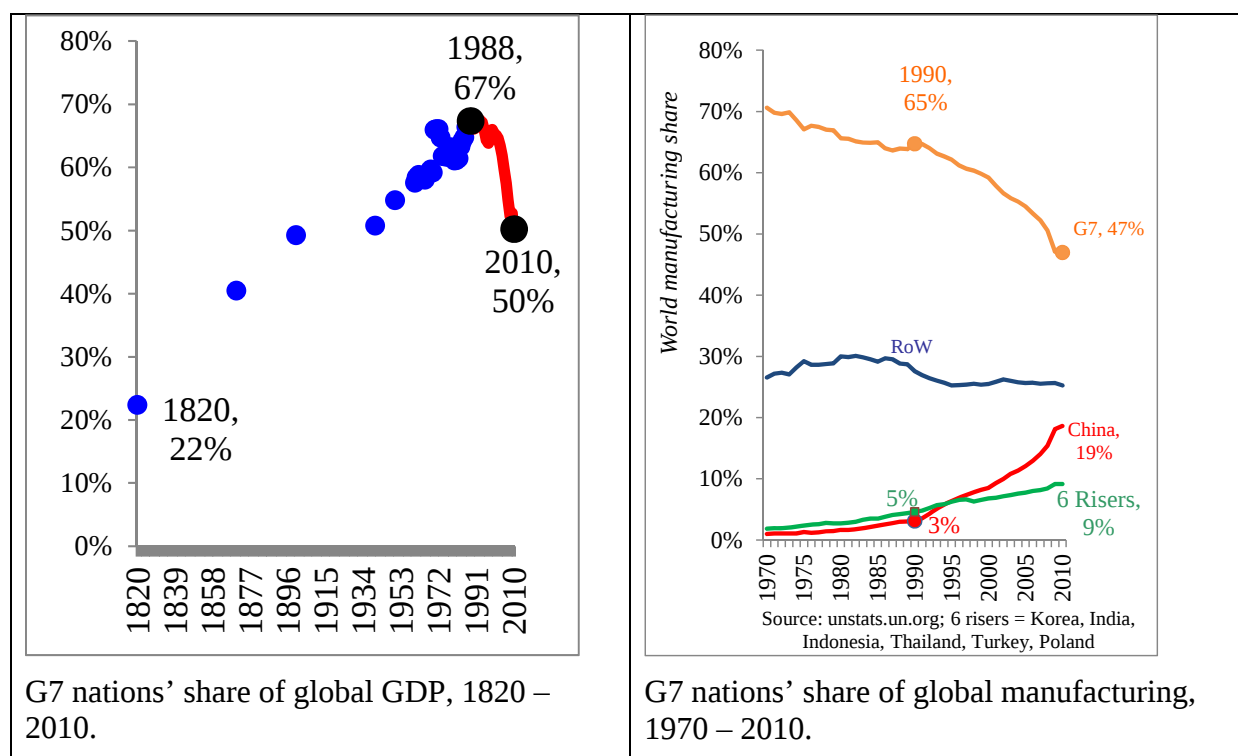


Figure 1: Globalisation: One process or two?

Source: Authors' elaboration of data from unstats.un.org and Maddison's database.

On the back of this prima facie evidence, it would seem we need two processes to explain globalisation's main outlines, not one. Falling trade cost won't cover it. In a 2006 paper for the Finnish Prime Minister's office, Baldwin (2006a) characterises this as globalisation's two great unbundlings. The first unbundling – up to the mid or late 1980s – is the traditional, linear process driven by lower trade costs. The second unbundling was driven by better Information and Communication Technology (ICT). The 1st unbundling allowed consumption and production to be separated by great distances but production stages remained bundled in factories and industrial districts. The ICT revolution sparked the 2nd unbundling by unbundling the factories. Improved ICT made it economical for stages of production formerly performed in rich-nation factory to be unbundled and dispersed to low-wage nations.

The development of Factory Asia was one of the first manifestations of the 2nd unbundling, although a similar development occurred in North America and Europe.

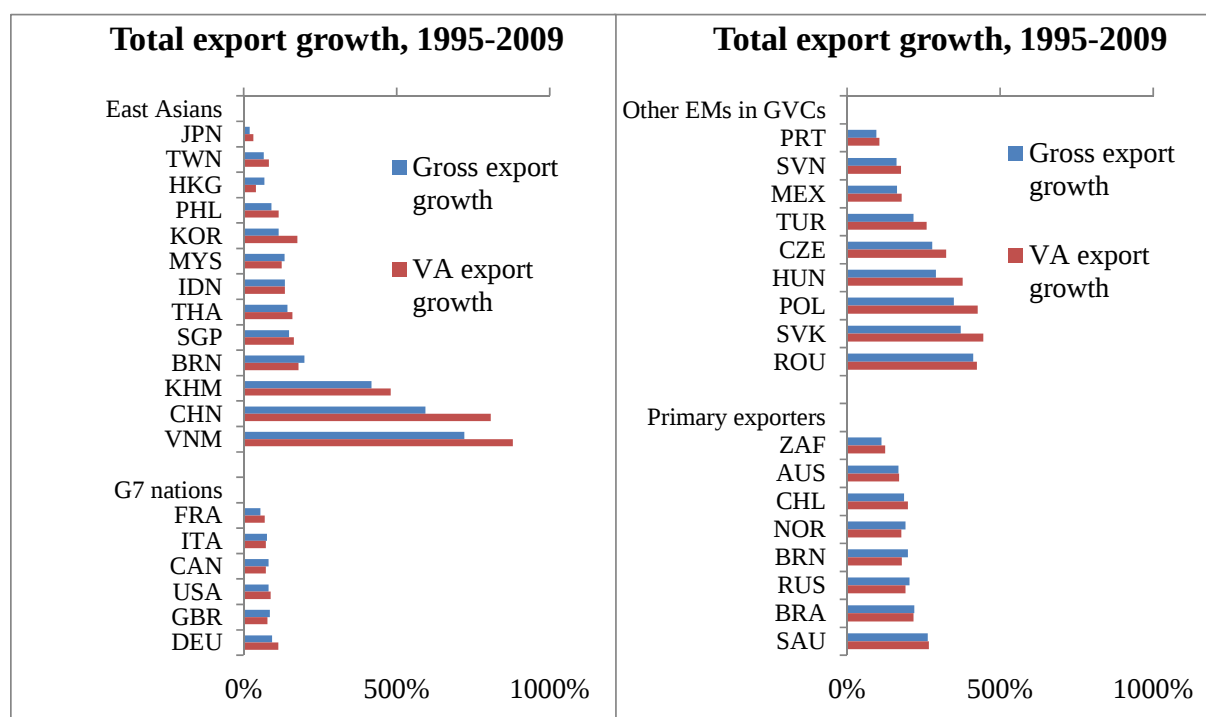
2. FACTS: THE DEVELOPMENT OF FACTORY ASIA

One of the most striking features of Factory Asia is the very rapid growth of exports from emerging East Asian economies – measured in either gross or value added terms. By ‘gross exports’ we mean the standard, customs-based numbers. By value-added exports, we mean the domestic value added contained in a nation’s gross exports. The difference is that the value added figures net out the foreign value added embedded in gross exports. For example, if Mexico exports a car that contains a US engine, the gross export is the value of the whole car; the value-added export is just the value that was added in Mexico.

As Figure 2 shows, the growth has been quite uneven. In general, emerging markets have seen higher growth with China, Cambodia, and Vietnam showing spectacular growth (although from very low bases in the latter two cases).

For comparison, we include the export growth figures for the G7 and a handful of emerging markets that are known to be active in outsourcing and GVCs. A point we will explore more below is that there seems to be a connection between the magnitude of the growth and size of the gap between gross and value-added exports (a rough measure of supply-chain trade).

Figure 2: Total export growth, 1995-2009, various nations, gross and value-added.



Source: TiVa database with authors’ calculations.

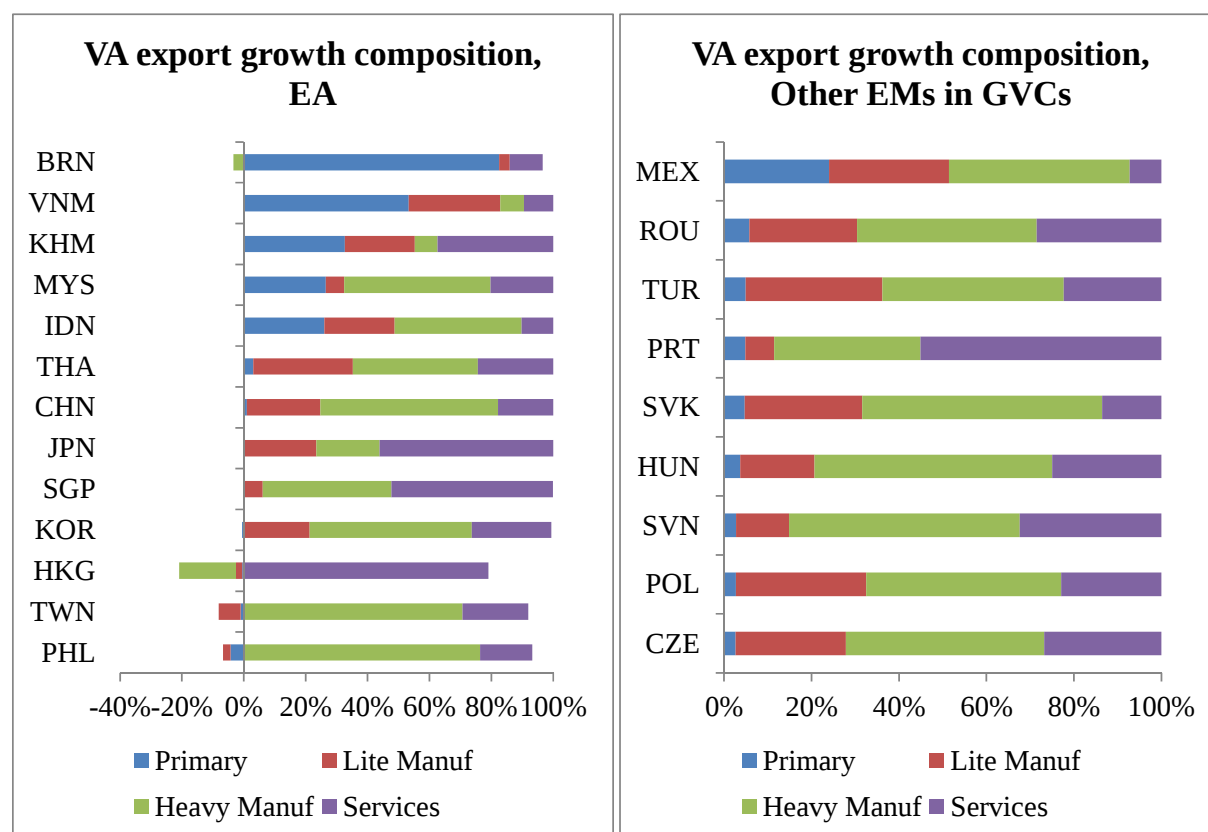
The commonality of emerging markets’ rapid export growth hides an important distinction. Some of these nations – like Brazil and Russia – are achieve high export growth on the back of the booming demand for commodities. Others are doing it via manufactured goods.

To provide hints as to the sources of the growth, 3 shows the growth decomposition by broad sector – focusing on primary exports, light manufactured exports, heavy manufactured exports, and service exports. The left panel shows a wide diversity among East Asian (EA) nations . Some nations – such as Brunei, Vietnam, and Cambodia have seen their natural resource based exports account for substantial fractions of their total export growth. For most,

however, the key driver was manufactured exports. Only in Hong Kong, Singapore and Japan have service exports played a large role in VA export growth.

The role of commodity exports has been smaller in the emerging markets involved in Factory North America (Mexico), and Factory Europe (Poland, Turkey, etc.). The commonality is that manufacturing exports account for the lion's share of the growth – often 2/3rd or more.

Figure 3: Decomposition of VA export growth by broad sector, 1995-2009.



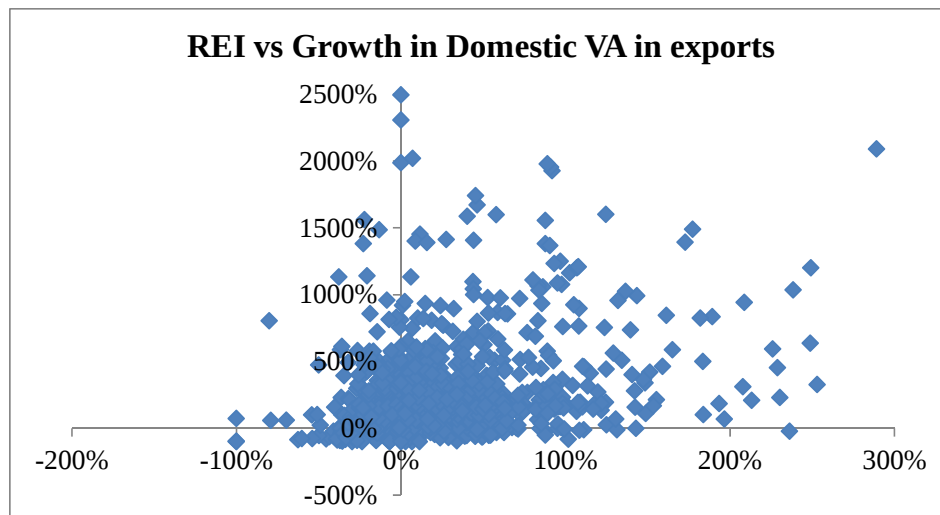
Source: TiVa database with authors' calculations.

2.1. Connection to supply-chain trade

A property of fast growers that rely on manufacturers is that they seem to be linking-up to global supply chains to a much larger extent. This section presents prima facie evidence that this link is indeed important for many of the East Asian nations.

The measure of supply-chain trade involvement we use is the share of re-exported intermediates (REI), that is, imported intermediates that are re-exported either as parts and components, or embedded in final goods. Our aim is to explore the connection between increases in this measure of SCT and increases in the domestic value-added contained in exports. In both cases, we look at the percentage increase from 1995 to 2009 (which is the full span of the TiVa database). The first look at the raw data is not encouraging. 4 shows the scatter plot of the change in 57 nation's SCT measure in 18 different sectors against the same nations' growth of domestic value added in exports in the same sectors. The overall correlation is unclear.

Figure 4: Growth in supply-chain participation and domestic value added in exports (VA export growth on y-axis, REI growth on x-axis).



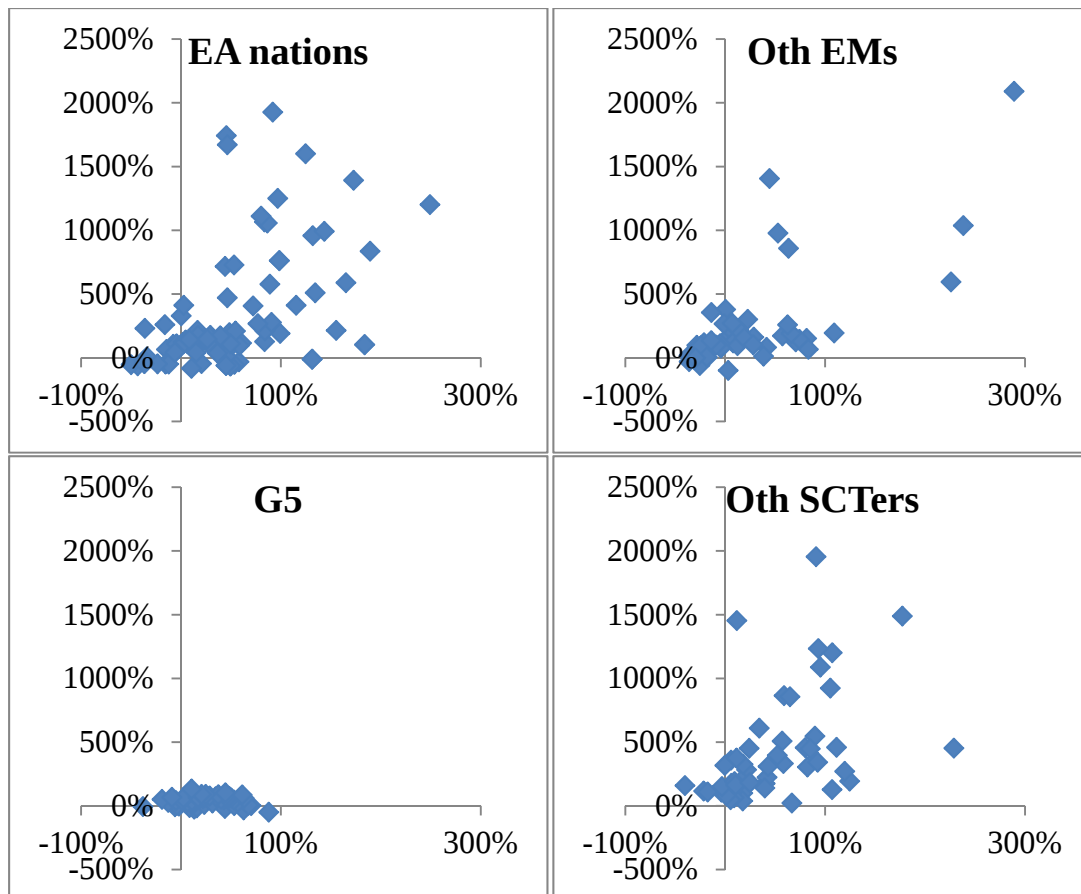
Source: TiVa database with authors' calculations.

The 2nd unbundling logic, however, suggests that the correlation should differ greatly for 'headquarter economies' and 'factories economies' – as well as across sectors (since production unbundling has not happen equally in all sectors). Once we separate the East Asia nations from the others, a positive relationship looks much more plausible. Indeed, Figure 5 shows that a positive link seems to hold for other nations involved in supply-chain trade (those in Factory North America and Factory Europe). The link is completely missing for G5 nations – the Headquarter economies, and driven by outliers in the large economies outside of Asia for other emerging markets (other EMs).

When we look at sectors – pooling across of nations – the positive association is clear in some sectors but not in others (Figure). It is particularly clear in the machinery sectors, Electrical and optical equipment, transportation equipment, and Machinery and equipment not elsewhere classified.

The last cut of the data highlights the growth correlation between supply-chain participation and VA export growth by country group and by sector (Figure). Here a couple points stand out. First, China and Vietnam are frequently outliers – with big positive growth in both measures. Second, East Asian nations seem to systematically have more positive links between the two measures than the other nations. This, however, is less true in the classic outsourcing sectors such as textiles and machinery of various sorts. Indeed in transportation, the correlation of the East Asian nation and other factory economies (Other SCTers) is not at all clear.

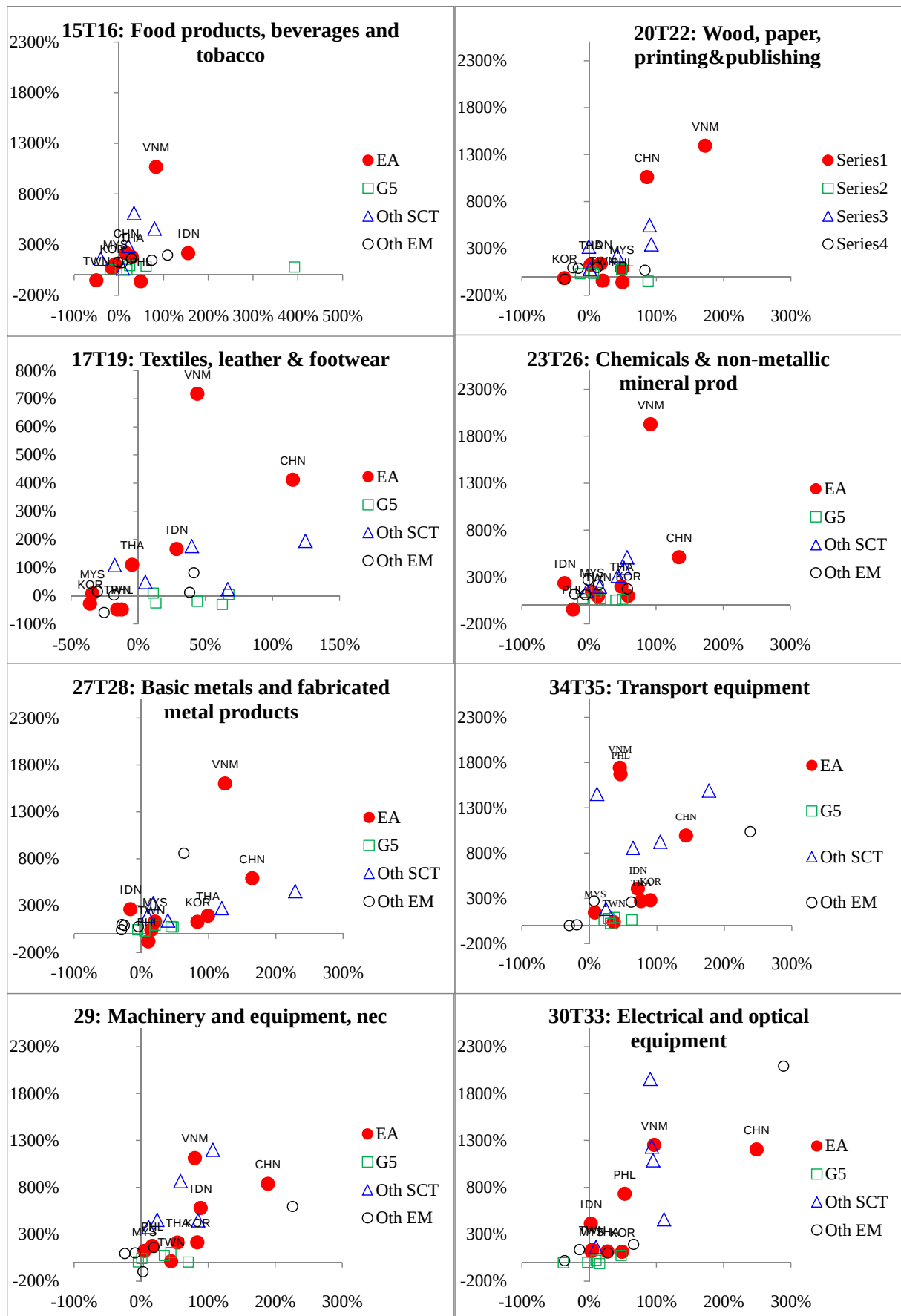
Figure 5: Supply chain participation and value-added exports, by nation groups (VA export growth on y-axis, REI growth on x-axis).



Source: TiVa database with authors' calculations.

Note: EA nations are: VNM, IDN, THA, CHN, MYS, PHL, TWN, KOR; G5 nations are: JPN, FRA, USA, DEU, GBR; Other SCRs are: SVK, POL, TUR, MEX, HUN; and Other EMs are: BRA, CAN, ZAF, IND, RUS.

Figure 6: Supply chain participation and value-added exports, all nations by sector (VA export growth on y-axis, REI growth on x-axis).



Source: TiVa database with authors' calculations.

2.2. Evolution of Factory Asia

Data for the early days of Factory Asia are difficult to come by. One rough indicator that does reach back to the 1960s is a simple intra-industry trade index (IIT) (Bruhart 2009). The idea here is that two-way trade in similar products that is either North-South, or South-South is likely to be largely supply-chain trade, i.e. two-way trade in parts and components. Plainly this is a crude measure, but it is transparent, widely understood and available for most nations going back to the early 1960s.

Figure 8 shows the measures for Japan (left panel) and China (right panel). The first salient point is that Japan's exchange with the Tiger3 nations (Korea, Hong Kong and Singapore) has been growing steadily since the 1960s. In the early days, much of this was in microelectronics (Grunwald and Flamm 1985). The big turning point came in the mid-1980s. The IIT numbers with China, the ASEAN nations, and the South3 (India, Nepal and Sri Lanka) all took off around 1986 – more or less all at the same time. The IIT numbers climbed steeply till the early 1990s with all partners but then levelled off for the South3. IIT with China and ASEAN, however, continued to soar.

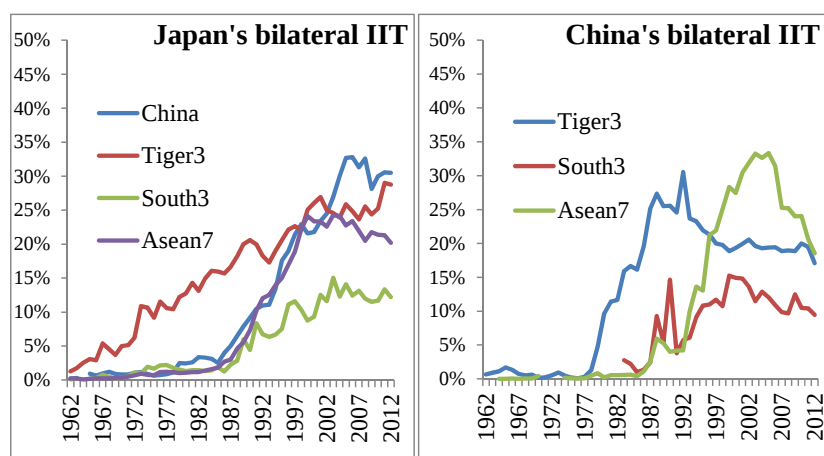


Figure 8: Japan's and China's bilateral IIT, 1962 – 2012.

Source: Authors calculations on Comtrade data.

The right panel shows the same calculations for China. Here we see that the IIT break-through was postponed until the late 1970s, but was again first with the Tiger3. China's IIT with South3 and ASEAN took off at approximately the same point as did Japan's.

Turning to the South two-way trade, Figure 9 shows the paths of Japan's and Korea's IIT with all 7 ASEANs. Japan's IIT with three of the big ASEANs – Malaysia, Thailand and the Philippines – took off at about the same time, i.e. mid- to late-1980s. The sharp rise in IIT with Indonesia and Vietnam came a decade later. For Indonesia (which is still a big commodity exporter), the rise was much less marked than for the others. Laos and Cambodia have not really joined the Japanese supply chains according to this indicator. For Korea, the timing is similar but the engagement is muted compared to Japan.

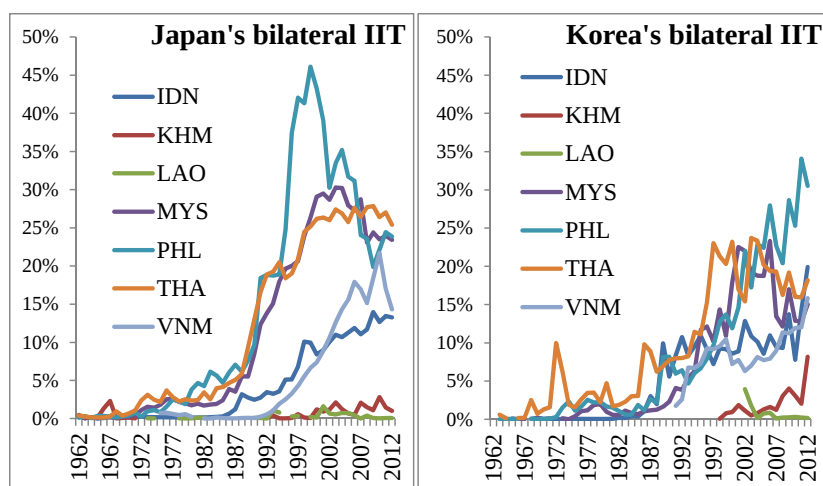


Figure 9: Japan's and Korea's bilateral IIT with ASEANs, 1962 – 2012.

Source: Authors calculations on Comtrade data.

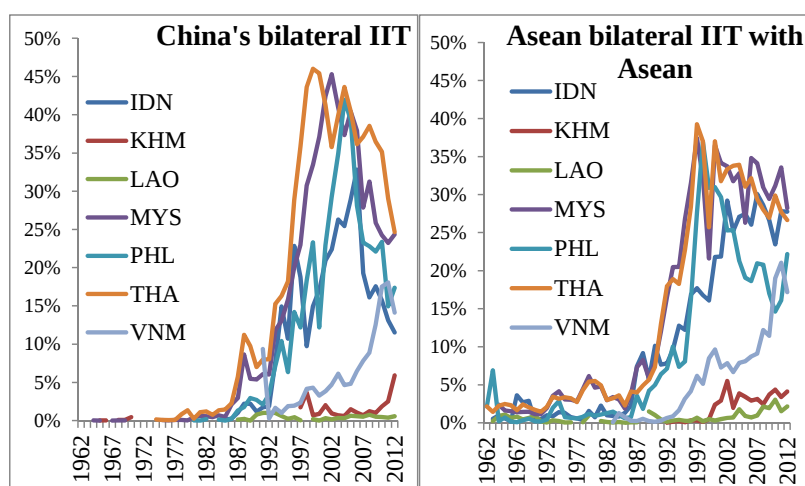


Figure 10: China's and each ASEAN's bilateral IIT with ASEANs, 1962 – 2012.

Source: Authors calculations on Comtrade data.

To round out the picture, Figure 10 shows the IIT proxy for Factory Asia participation for China with each ASEAN and for each ASEAN with the others. What we see is that China's bilateral IIT with Thailand and Malaysia jumped in the mid-1980s, but it did not start until the early 1990s with Indonesia and the Philippines. The IIT measure slopes up from the later 1990s for Vietnam but does not really take off until the early 2000s. Cambodia's IIT with China has taken off only in the 2010s. As for the ASEANs among themselves, we see a similar timing. The 'big four' ASEANs, Thailand, Malaysia, Indonesia and the Philippines, see their IIT scores jump in the mid-1980s. Vietnam's jump is delayed till the late 1990s with a significant acceleration in the 2000s.

More direct evidence comes from the IDE-JETRO international input-output table. This shows the country of origin of imported manufactured goods purchased by the manufacturing sector of each East Asian economy. **Error! Reference source not found.** has three panels corresponding to the shape of Factory Asia in 1985, 1990 and 2000.

Table 1: Widening and deepening of the Asian Manufacturing Matrix, 1985, 1990, 2000.

(Share of manufactured inputs bought by column nation's manufacturing sector from the row nation; numbers less than 2% are zeroed out; own-nation purchases are also zeroed out)

1985	China	Indonesia	Malaysia	Philippines	Thailand	Singapore	Taiwan	Korea	Japan
Indonesia						8%			
Malaysia						16%			
Philippines						0%			
Thailand						0%			
China				2%		14%			
Taiwan						3%			
Korea									
Singapore		3%	7%						
Japan	3%	12%	14%	4%	9%	12%	7%	8%	
RoW		15%	19%	19%	14%	11%	10%	16%	8%
1990	China	Indonesia	Malaysia	Philippines	Thailand	Singapore	Taiwan	Korea	Japan
Indonesia									
Malaysia						5%			
Philippines									
Thailand									
China						3%			
Taiwan			3%	4%	3%	3%			
Korea				2%		2%			
Singapore			7%	2%	3%				
Japan		8%	10%	8%	14%	18%	10%	8%	
RoW	8%	23%	20%	21%	22%	44%	17%	13%	5%
2000	China	Indonesia	Malaysia	Philippines	Thailand	Singapore	Taiwan	Korea	Japan
Indonesia						2%			
Malaysia				3%	4%	12%	2%		
Philippines									
Thailand			4%	3%		3%			
China		2%	3%		4%	5%	2%		
Taiwan			5%	5%	3%	3%			
Korea	2%	3%	4%	8%	3%	4%	4%		
Singapore			13%	6%	4%				
Japan	2%	7%	15%	20%	16%	19%	14%	7%	
RoW	4%	16%	20%	20%	17%	38%	15%	11%	4%

Notes: The columns would sum to 100% if we had included each nation's supply of inputs to its own manufactured sector (a number that is often greater than 50%) and if we had not zeroed out the low numbers (less than 2%). RoW equals Rest of World.

Source: IDE-JETRO, Asian input-output matrix (7 sectors) for 1985, 1990 and 2000; see, for example, www.ide.go.jp/English/Publish/Books/Sds/082.html.

The top panel shows the situation in 1985 when Factory Asia was very simple. With the exception of Singapore, East Asian nations sourced their imported manufactured inputs from Japan and the rest of the world – all the rows are dominated by zeros except those of the Japan and the rest of the world (mainly the US and Europe). By 1990 (second panel), it was more complex: 'Triangle trade' still dominated the picture with the low-wage nations (first 5 columns) buying inputs from Japan and the rest of the world but providing no inputs in return. Now, however, Japan is not the only headquarter economy. Taiwan, Korea, and Hong Kong experienced their own hollowing-out phases and new triangle trade appears. This new triangle trade involves the shipment of parts from the new HQ economies to the 'factory economies' (China and the advanced ASEANs, Indonesia, Malaysia, the Philippines and Thailand). This can be seen from the emergence of new non-zero entries in the rows for Taiwan, Korea and Singapore.

By 2000, Factory Asia was really complex. Firms based in the 'factory economies' began to source parts from other factory economies rather than from the HQ economy alone. In particular, Thailand, Malaysia and China became important suppliers of parts to other 'factory economies' including each other. In short, the input-output matrix went from simple triangle trade to a much more complex situation where the 'factory economies' were both makers and buyers of parts and components.

This rise of China's position in the Matrix between 1990 and 2000 is especially noteworthy. At the beginning of the decade, it neither bought nor sold much manufactured inputs in East Asia. By the end of the decade, we see many entries for the Chinese column (which shows its purchase pattern) and the Chinese row (which shows which nations depend a lot on inputs from China). The flourishing of intra-ASEAN trade is also clear from the comparison of 1990 and 2000.

The message of **Error! Reference source not found.** is clear. By 2000, the competitiveness of manufacturing firms in East Asia depended in a serious way on the smooth functioning of regional trade. A disruption of trade between, say, Malaysia and China, could cause serious problems for Japanese and Korean firms trying to sell in the US.

3. ECONOMICS OF SUPPLY-CHAIN UNBUNDLING

Globalisation's 2nd unbundling shifted the locus of globalisation from sectors to stages of production. This requires an analytic focus on supply chains. The economics of this change is best looked at by decomposing it into two phenomena: fractionalisation and dispersion.

- Fractionalisation concerns the unbundling supply chains into finer stages of production.
- Dispersion concerns the geographic unbundling of stages.

The two are linked in so far as the organisation of stages may be crafted with dispersion, i.e. offshoring, in mind. This section considers them in turn and their interlinks.

3.1. Supply chain unbundling: The functional dimension

A prime assumption behind our conceptualisation of Factory Asia is that the ICT revolution triggered the 2nd unbundling and this resulted in Factory Asia. The main avenue of investigation is thus to understand how ICT improvements fostered production unbundling. Here we start with fractionalisation, putting off issues of dispersion (offshoring) temporarily.

The TOSP framework

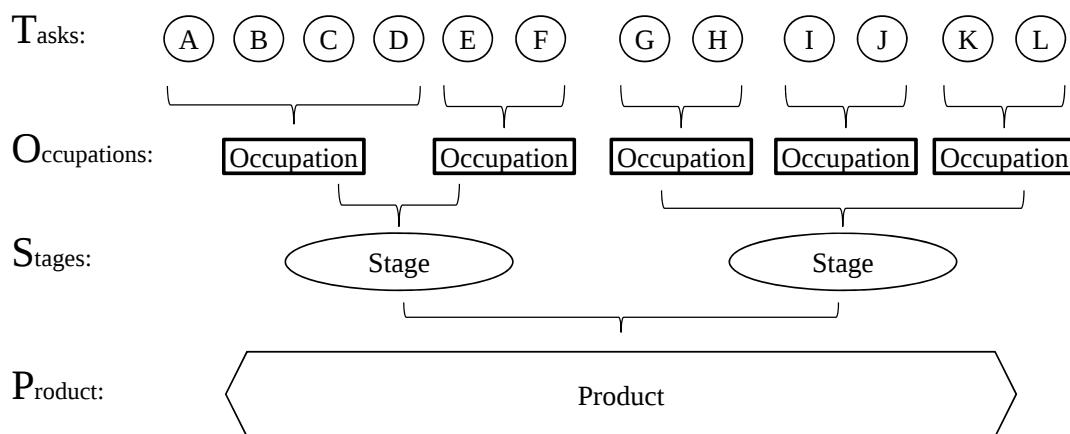


Figure 11: Tasks, occupations, stages and product – the TOSP framework

Source: Baldwin (2012a).

Notes: The circles represent individual tasks, the rectangles represent individual occupations and the ovals represent individual stages of production.

To this end, it is useful to view a firm's supply chain at four levels of aggregation (Figure 11):

- Tasks.

This is the list of everything that must get done to produce value for the corporation; the list includes all pre-fabrication and post-fabrication services.

- Occupations.

One natural intermediate aggregation of tasks is an 'occupation' – the group of tasks performed by an individual worker.

- Stages.

Stages are defined as a collection of occupations that are performed in close proximity due to the need for face-to-face interaction, fragility of the partially processed goods, etc. This is a

critical level of aggregation since supply chain internationalisation typically involves the offshoring of stages rather than individual occupations or individual tasks.

- Products.

The product is the supply chain's output broadly viewed.

3.1.1. Optimal task per occupation and occupations per stage

With this aggregation scheme in mind, consider the economics of the optimal:

1. Tasks per occupation; and
2. Occupations per stage.

Adam Smith illustrated the first issue an example – an 18th century pin factory where making a pin twelve distinct 'tasks', or what Smith called 'operations'. The full list of tasks/operations was: drawing out the wire, straightening the wire, cutting the wire, sharpening the pointy end, grinding the top end, making the pinhead (which itself involves three distinct tasks/operations), attaching the pinhead, whitening completed pin, and putting the pins in into the packaging.

Smith reported that pin factory managers had workers specialise in particular tasks. Workers did not make pins; they performed particular sets of tasks. This allowed each worker to get really good has his or her assigned task. The downside of splitting up tasks is the difficulty of coordinating the whole process. This is the fundamental trade-off we focus on – the benefit of specialisation versus the cost of coordination. Our key trade-off differs fundamentally from Costinot (2009) and Bloom et al (2009); see Box 1.

Fractionalisation and improved communication technology versus information technology

Since we are addressing the history and future Factory Asia, we focus on how ICT developments alter fractionalisation. Here the important point is that ICT affects the optimal division of labour via two channels, as Bloom et al (2009) have stressed.

- First, communication and organisational technologies – call them coordination technologies (CT) for short – lower the marginal cost of coordination.

Intuitively, better CT will make it easier to slice up production processes into more stages, and it will make it easier to disperse stages internationally. Thus CT will tend to foster the current trends in Asia towards more vertical specialisation, more offshoring, more FDI and more intra-industry trade.

- Second, information technology (IT) lowers the marginal benefit to specialisation; think of how robots make it easier for individual workers to master more tasks without loss of efficiency.

3D printing is the extreme where IT allows a single worker to perform all tasks simply by operating one machine. For example Japanese industry is a leading user of industrial robots. Without these machines, far more stages of production would have been offshored to low-skill abundant neighbours.

- Plainly, CT and IT cut in opposite directions. Better CT favours greater fractionalisation by making it cheaper; better IT discourages it by making it less necessary.²

To explain and explore these effects in greater detail and with greater precision of thought, we present a one-line sketch model of optimal fractionalisation.

Box 1: Related theoretical frameworks in the literature

The Costinot (2009) model looks at optimal ‘team size’ (akin to our stages) that turns on a very different trade-off, namely specialisation versus risk. Big teams allow workers to specialise in particular tasks and this lowers average time cost. Big teams, however, are assumed to be riskier.

Specifically, the model assumes an exogenous probability that each worker will fail to complete the assigned task. To avoid risk-pooling – which would obviate all the analysis and results – the paper adopts a series of strong assumptions. First no worker can help any other; a failure in any task is a failure in all tasks, so more workers mean more failure. Second, there can be no inventory that smooths-over task-level failures. Third, the firm cannot reduce the probability of failure with managers a la Garicano (2000).

While specialisation-versus-risk this is the fundamental trade-off in the model, the paper discusses it’s the key trade-off as if it were a specialisation-versus-transaction-costs trade-off.³ That is, the discussion simply asserts that the failure-risk is due to contracting problems, and then it simply asserts that contracting problems are transaction costs.

Bloom et al (2009) also model the team size choice based on a trade-off that is quite different to ours. Drawing on the seminal work by Garicano (2000), Bloom et al (2009) focus on firm hierarchy, where production requires problems to be solved and hierarchy is a way of economising on workers’ problem-solving-training. Their core trade-off is between spending more to train workers to solve problems by themselves, and spending more on managers who are not directly productive but who have the knowledge to solve all problems.

3.1.2. Functional unbundling: A basic model

To crystallise thinking about our specialisation-versus-coordination trade-off, this subsection provides a simple model of that allows us to be more precise about the basic trade-off between specialisation gains versus coordination costs as well as the very different effects that better CT and IT have on supply chain fractionalisation. We work in partial-equilibrium setting since when firms make these choices, they are likely to ignore the impact of their decisions on labour and product markets. Likewise, we initially work in a closed economy to

² This insight – which is due to Bloom et al (2009) – has recently received some empirical support from Lanz et al (2011). They find that offshoring of business services complements manufacturing activities, in the sense that increased import penetration in business services is associated with a shift in local task content from information and communication related tasks towards tasks related to handling machinery and equipment. Offshoring of other services complements local information-intensive tasks in that it shifts local task composition towards ICT-related tasks.

³ The iid nature of the risk is adopted for technical reasons, namely to convex-ify outcomes in a way that allows the authors to work in a general setting.

separate the organisation issues from the offshoring issues. Even though they are ultimately linked, intuition is severed by first dealing with them separately.

One factor, one-tier organisation

Consider a firm with a constant-returns-to-scale process whereby producing a good requires performance of a given list of tasks. To be concrete, view this as a continuum of tasks that we arbitrarily list them along the range zero to unity. The tasks are performed using homogenous labour and there is, in the simplest model, only one organisational choice – the number of occupations into which the tasks are organised. Stages are left out of the analysis for the time being.

The problem is to assign tasks to occupations optimally. In principle this assignment would involve a matching of task-types to worker-types. Even with homogenous workers the assignment problem could be complex if the degree of task-level efficiency depended upon the group of tasks assigned per worker. For example, it would be reasonable to assume that a worker would gain more efficiency by specialising in related tasks – say, painting tasks or welding tasks. In such a case, it would be natural to define the occupation by the nature of tasks assigned to it (e.g. painters, welders, etc.). While this degree of resolution is desirable, making progress would require seemingly arbitrary specificity concerning the efficiency effects of task specialisation.

To keep the analysis streamlined and transparent, we assume that the tasks as well as the workers are homogenous. With this simplification, all occupations are symmetric and the only choice is the range of tasks assigned to a typical worker. That is, each worker's 'occupation' is defined by his/her range of assigned tasks and all occupations will be identical.

The gains from specialisation are modelled as a link between the amount of labour per tasks and the range of task per occupation. Specifically, the labour input coefficient increase with the range tasks performed by a single worker. There are many ways of micro-founding such an outcome but to keep things focused on essentials we simple assume the hours per tasks rises with the range of tasks per worker. What we have in mind is some sort of learning curve.

From the production-cost perspective, the least efficient arrangement is to have each worker doing every task. The most efficient is to have each worker specialised in only one task. The least cost organisation with a given number of occupations will be to assign an equal range of task to each occupation; occupations are symmetric in equilibrium. Specifically, if there are n_o occupations, a range of $1/n_o$ task is assigned to each occupation.

Greater specialisation, however, engenders greater coordination costs among occupations. A worker specialising in a range of tasks that is one- n_o th of all tasks must coordinate with (n_o-1) other occupations. For simplicity, the between-occupation coordination costs are all identical and given by the parameter as χ_o (chi is a mnemonic for coordination). Ignoring within-occupation coordination, the number of coordination-pairs is $n_o(n_o-1)/2$.

More formally, the organisational cost-minimisation problem is:

$$\min_{\{n_o\}} w_l a[n_o; \alpha] + w_l \chi_o n_o \left(\frac{n_o - 1}{2} \right); \quad a'[\bullet] < 0 \quad (1)$$

Here w is the wage, the function $a[\cdot; \alpha]$ captures the efficiency-inducing effect of specialisation. That is, the per-task labour input coefficient 'a' falls as the number of occupations goes up (the range of task per work is $1/n_o$ with no symmetric occupations, so a higher n_o is associated with greater specialisation of workers). Here ' α ' – a mnemonic for

automation – parameterizes the impact of IT on the efficiency-specialisation effect; $a'[n_0; \alpha]$ indicates the first derivative with respect to n_0 as usual.

The first-order condition is:

$$0 = a'[n_0; \alpha]n_0 + \chi_0(n_0 - \frac{1}{2}) \quad (2)$$

The second order condition holds if $a'[\cdot; \alpha]$ is decreasing (i.e. the second derivative is positive) which is true if there are diminishing returns to specialisation – an assumption we maintain throughout.

The solution is illustrated in Figure 12. The marginal benefit of increased specialisation (i.e. more occupations) is shown $a'[n; \alpha]$ while the marginal coordination costs is rising with the number of occupations as shown. The optimal specialisation is n_1 as shown. This illustrates the specialisation-coordination trade-off that is central to our thinking on functional fragmentation.

With this framework, it is straightforward to illustrate the distinct impact of IT and CT. Improved IT makes it easier for one worker to master many tasks without loss of efficiency – this is why $a'[n; \alpha]$ is downward sloped. Improved IT, which is parameterised as a rise in α (automation) to α'' , shifts down the marginal benefit of specialisation. In other words, the marginal benefit of additional specialisation is lower, when α is higher. With the higher α'' , the optimal number of occupations is n_2 rather than n_1 .

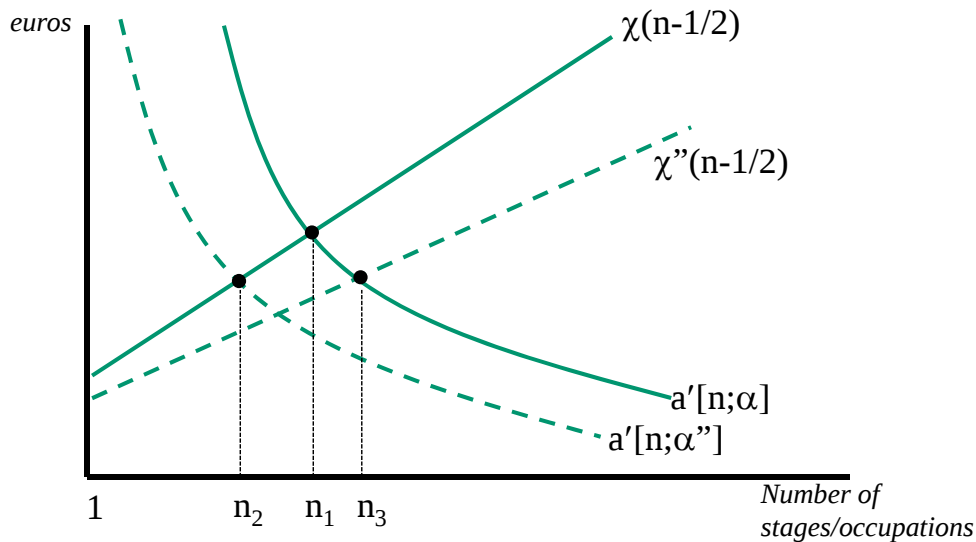


Figure 12: Functional unbundling: Stages and occupations in symmetric case.

Improved CT (communications), by contrast, makes it easier to coordinate occupations; this shows up as a reduction χ to χ'' . The result is a lower marginal cost of increasing the number of occupations; graphically this shows up as a shift down in $\chi(n-1/2)$. The resulting optimal number of occupations is therefore n_3 rather than n_1 .

One factor, two-tier organisation

It is straightforward to introduce additional levels of organisational hierarchy. We do this by assuming that occupations can be organised into ‘stages’ as a means of economising on coordination costs. The occupation-level coordination costs remain as before, but we assume that workers only face this for occupation inside their own stage. The new element is the cost of coordinating among stages. For simplicity, we assume that all stages are symmetric from

this perspective. Specifically, if all occupations are broken up into n_s stages, each stage will have to coordinate with $n_s(n_s-1)/2$ other stages.

The modified cost minimization problem then becomes:

$$\min_{\{n_o, n_s\}} w_l a[n_o n_s; \alpha] + w_l \left(\chi_o n_o \left(\frac{n_o - 1}{2} \right) + \chi_s n_s \frac{n_s - 1}{2} \right) \quad (3)$$

Note that the range of tasks per symmetric occupation is now $1/n_o n_s$, so the argument of $a[\cdot; \alpha]$ is $n_o n_s$, and the coordination cost parameter for stage-coordination is denoted as χ_s . The first-order conditions are:

$$0 = a'[n_o n_s; \alpha] n_s + \chi_o (n_o - 1/2), \quad 0 = a'[n_o n_s; \alpha] n_o + \chi_s (n_s - 1/2) \quad (4)$$

The simplest solution occurs when the χ 's are equal so the solution involves an equal number of stages and occupations. In this case, Figure 12 continues to characterise the basic trade-off between coordination and specialisation – as well as the role of CT and IT. More complex combinations of parameters would yield a different number of occupations and stages.

With a basic framework in place for the fractionalisation of production processes, we turn to the issue of spatial dispersion.

3.2. Geographical unbundling: Balancing dispersion & agglomeration forces

If it were not for offshoring, fractionalisation would be purely a matter of industrial organisation. To put in an international dimension we now turn to location decisions. The touchstone principle is that firms seek to put each stage in the lowest cost location.

In reality, places differ along many dimensions that matter for the location. The World Economic Forum's competitiveness index, for example, has 110 different measures. Our goal here, however, is to illustrate the first order trade-off that has influenced the development of Factory Asia. What we focus on is factor costs – for example, low versus high wage – as the gain from offshoring. The cost of offshoring is the downside.

The cost calculation involves a trade-off between direct factor costs and 'separation' costs.

- The direct costs include wages, capital costs and implicit or explicit subsidies.
- The separation costs should be broadly interpreted to include both transmission and transportation costs, increased risk and increased face-to-face managerial time.

The location decision may also be influenced by local spillovers of various types. In some sectors and stages, say fashion clothing, proximity between designers and consumers may be critical. In others, product development stages may be made cheaper, faster and more effective by co-location with certain fabrication stages. Yet other stages and sectors are marked by strong technological spillovers that make clustering of producers the natural outcome.

3.2.1. Production efficiency versus coordination costs

The first aspect of spatial unbundling turns on a trade-off that is closely aligned with the functional unbundling discussed above. Offshoring a particular stage can save on production costs but raise coordination costs.

To crystalize the fundamental economic logic, we adopt a simple setting with two nations – high-tech North and low-wage South – and stages that vary continuously in their technology intensity. We work with a 'spider-like' production process (Baldwin and Venables 2013) whereby the engineering of the production process implies no particular sequencing of stages.

Each stage produces a ‘part’ and the parts get assembled into the good in the final stage called ‘assembly’. This permits us to order the stages in analytically convenient ways.

Specifically, the stages – exogenously defined in this section – are arranged in order of increasing tech-intensity, i.e. in order of increasing North comparative advantage. This means that the high-tech North tends to have a comparative advantage in ‘high’ stages (those with an indices near unity) while low-wage South has a comparative advantage in ‘low’ stages.

More specifically, the per-stage production cost is $w_n a_{ni}$ in North and is $w_s a_{si}$ in South, where a_{ni} and a_{si} are the North and South unit labour input coefficient for stage i and the w ’s are the national wages. Since there are only two locations, relative cost is all that matters, so we normalise North’s $w_n a_{ni}$ to unity for all stages.⁴ Recalling that we have arranged stages such that North’s comparative advantage is greatest in stages with high indices, South cost per stage starts below North’s (i.e. below unity) and rises steadily to a number above unity.

A particularly simple case is illustrated in Figure 13 where $w_s a_{si}$ rises linearly with the sophistication of the stage; β is the slope of this relationship, i.e. $w_s a_{si} = \beta \cdot i$ where ‘ i ’ indexes the stages and i ranges from 0 to 1. Plainly South is the low cost producer in stages from 0 to $1/\beta$ and North is the low cost producer in the rest. It is convenient to think of β as the strength of North’s comparative advantage in stages since as β rises, more stages are most cheaply produced in the North.

To study the offshoring solution, the first anchor point is the cost minimising outcome when coordination costs are zero. As mentioned, the answer is that the lower tech stages are placed in South – namely, stages from 0 to $1/\beta$ -- with the rest in North. Separating stages, however, has implications for coordination costs. The nature of these costs matters greatly.

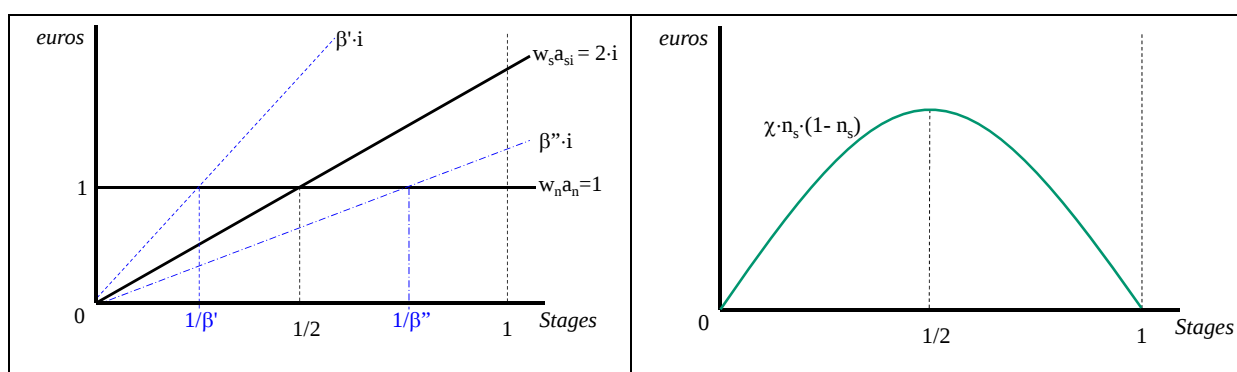


Figure 13: Comparative advantage, coordinate cost and optimal unbundling.

Note: Here North is offshoring stages to South.

Products with complex coordination demands

We begin with a case where coordination demands are complex, in the sense that every stage needs to coordinate with every other stage. An illustration of this is given in Table 2, which is drawn for the six stage case where stages 1 to 2 are undertaken in South and the rest in North. The table allows for different coordination costs for coordination of stages within North, χ_n , within South, χ_s , and ‘international’, χ_I .

Table 2: Coordination-cost matrix: Complex good case

⁴ As wages are exogenous here, we could do this by choosing North labour as numeraire and choosing units for all stages since that $a_{ni}=1$ for all i .

	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6
Stage 1	χ_s					
Stage 2	χ_s	χ_s				
Stage 3	χ_I	χ_I	χ_n			
Stage 4	χ_I	χ_I	χ_n	χ_n		
Stage 5	χ_I	χ_I	χ_n	χ_n	χ_n	
Stage 6	χ_I	χ_I	χ_n	χ_n	χ_n	χ_n

Note: This table discretises the continuum of parts for the sake of illustration.

To keep the expressions simple and to sharpen the intuition, we start with the simple example where within-nation coordination costs are zero, i.e. $\chi_n = \chi_s = 0$ but $\chi_I > 0$, so total coordination costs are:

$$w_n \chi_I n_s (1 - n_s)$$

where w_n , n_s , and n_n are the North wage and number of stages in South and North respectively. We assume that international coordination costs involve North labour, and have assumed that the mass of stages equals unity. Here coordination cost varies with the range of stages offshored to South according to a parabola.

It is important to note that this convexity means that coordination cost act as an agglomeration forces. That is to say, the coordinate-cost-minimising solution is to keep all stages bundled together. Coordination costs are maximised when stages are split evenly between North and South. Production cost considerations, by contrast, act as a dispersion force. The optimal unbundling and offshoring of stages from North to South involves the usual balancing of dispersion and agglomeration forces.

More formally, taking coordination and production costs together (assuming the linear example, i.e. $w_s a_{si} = \beta i$ where $0 < \beta < 1$), total costs as a function of the range of stages in South, $[0, n_s]$, are:

$$\left\{ \beta n_s^2 / 2 + 1 - n_s \right\} + \left\{ \chi_I n_s (1 - n_s) \right\}$$

This is a quadratic function whose second derivative is negative if and only if coordination costs are not too high relative to the strength of North's comparative advantage, specifically $\chi < \beta/2$. We assume this regularity condition so that the first order conditions indicate cost minimising rather than cost maximising solutions.

The first order condition with respect to the range of stages placed in South, n_s , is:

$$\left\{ \beta n_s - 1 \right\} + \left\{ \chi_I (1 - 2n_s) \right\} = 0$$

Solving the first order condition with respect to the range of stages placed in South, we have:

$$n_s = \frac{1 - \chi_I}{\beta - 2\chi_I}$$

This spatial unbundling setting presents some unusual features.

First, it is subject to threshold behaviour, with the threshold at $\chi_I > \beta/2$. The reason for this is simple. The solution is the cost-maximising solution for $\chi_I > \beta/2$ but the cost-minimizing solution for $\chi_I < \beta/2$. Thus:

If coordination costs are high relative to North's comparative advantage (as measured by β), then we have a corner solution, i.e. all stages are clustered in one nation.⁵

Which nation it is depends upon North's comparative advantage.⁶ Production is cheaper in the North if and only if $\beta > 2$; otherwise the cluster is in South.

For coordination costs lower than the clustering threshold (i.e. $\chi_I < \beta/2$), stages will be dispersed internationally according to 0.

Thus a continuous reduction in coordination costs starting from a very high level would have a discontinuous effect on offshoring at the threshold.

A second unusual feature is that cheaper coordination may lead to more or less production in South. The sign of the impact of χ_I on n_s depends switches at $\beta = 2$. If South has a strong comparative advantage – in the sense that more than half the stages would be produced there based solely on production cost considerations (e.g. $\beta > 2$) as in Figure 13), then considerations of communication costs will lead to 'too much' production in the South. The point is that even though Southern production costs are higher, the fact that more than half the stages are there already means that sending more stages lowers coordination costs. In this case, lower communication costs will lead to less offshoring to South. By contrast, if β is high, say β' in Figure 13, then lower χ_I will increase the offshoring to South.

One particularly intuitive case is when North has a strong comparative advantage in parts, e.g. $\beta' > 2$ in the diagram, so more than half the parts are produced in North. In this case, coordination cost considerations tend to reduce the amount of offshoring from the North to the South. As coordination costs fall, the range of stages placed in the South rises.

To summarise, even in the simplest framework that allows a trade-off between efficiency and coordination costs, the relationships between easier communication and offshoring is far from monotonic. The convex nature of coordination costs tends to create tipping points and comparative static results that can flip signs according to parameters that may be hard for the econometrician to observe.

⁵ β measures North's comparative advantage in the sense that the range of stages where North is the low cost producer ranges from $1/\beta$ to unity, so this expands as β rises.

⁶ Total cost with all stages in the South and North, respectively, will be $\beta/2$ and 1.

4. CONCLUDING REMARKS

This paper looks at the underlying interconnected processes that drove Factory Asia's development from the mid-1980s. We focused on two complementary trends: fractionalization of the manufacturing process into stages, and the dispersion of these stages around Asia. The paper organised the thinking by providing a formal model for the TOSP (tasks, occupations, stages, products) framework that was informally introduced in Baldwin (2012a). The TOSP framework views the production of goods as the performance of a range of tasks that are organised into occupations (collection of tasks) and stages (collections of occupations). Typically offshoring occurs at the level of stages rather than tasks or occupation.

4.1. Policy issues

While no formal evidence-based policy recommendations can be made based on our paper's contribution, a number of important themes emerge.

First, geography is an important determinant of the ease of participating in Factory Asia. Just as it is easier to set up a supply plant in or near an industrial district, joining Factory Asia is much easier for nations that are proximate to the headquarter economies in East Asia – Japan, Korea, Taipei, China, Singapore, and Hong Kong. As Factory Asia is not so developed, proximity to other factory economies is also important – especially proximity to China which is a massive and highly-competitive producer of industry inputs (parts and components).⁷ This is nothing more than an assertion that forward and backward linkages matter at the regional level as well as at the national or industrial district level.

The intuition is similarly straightforward. In the main production unbundling sectors – electrical and mechanical machinery – fractionalised production processes involve time-sensitive and shipping-cost sensitive elements. Being nearby other supply-chain traders – both headquarter and factory economies – makes it easier to join Factory Asia. Another way to put this is that 'regional comparative advantage' matters as well as 'national comparative advantage' when it comes to joining an international production network.

Second, size matters. Nations that have over a billion consumers (India and China) can pursue policies that smaller nations cannot. In essence the two giants can leverage their local market as a powerful attraction force for supply chain segments.

Third, providing assurances to tangible and intangible property rights is likely to be an important element in attracting supply chain production. As such production is necessarily networked; some firms or networks of firms must be coordinating the process. Such firms are naturally reluctant to expose their managerial, technical and marketing knowhow to tacit or explicit expropriation, which would facilitate the emergence of new competitors.

4.2. Future research

The charts in the paper suggest many correlations and relationships that can and should be tested more formally using the newly developed TiVa database. Such empirical work will be critical in developing evidence-based policy recommendations. How important are intellectual property rights protection versus quick port clearance? How damaging is distance to participation in international supply chains (controlling for other factors)? How important are formal free trade agreements overall, and particular provisions specifically (e.g. investment provisions, versus capital mobility provisions).

⁷ It is a quirk of language, but is remarkable that one can get from 'supply chain' to 'supply China' by moving just one letter!

A wide range of institutional measures exist in databases such as the World Bank's Doing Business, and the WEF's Global Competitiveness Report, and detailed work arise from the trade facilitations literature. These are essentially right-hand side variables that have been used to explain macro growth trends. It would be important to sort out how these various 'institutional or policy' measures interact with more fundamental determinants such as distance from headquarter economies, distance from final goods markets, wages, etc. The key contribution of the new value-added databases is that we now have left-hand side measures of supply-chain participation. Moreover, the network nature of the new data should allow us to go beyond simple nation-by-nation approaches where a nation's own right-hand side features are all that is allowed to affect outcomes. This would allow us to look at regional as well as national comparative advantage and perhaps better identify which sectors are more likely to be successful in which nations.

Factory Asia has been deepening and widening at a historically unprecedented rate since the 1980s. Despite the Global Crisis, the Great Trade Collapse and the rise of anti-globalisation elements in rich nations, Factory Asia does not seem to be levelling off. New nations like Vietnam seem to be joining with success. In short, the future of Factory Asia seems bright. The key question is: How can developing nations join, and how can they make sure that joining leads to an ever denser participation in value networks. Those are questions that economists would be well advised to tackle.

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