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Production fragmentation, Upstreamness, and Value-added: Evidence from Factory Asia 1990-2005

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August 2015

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Keywords: Factory Asia, supply chains, upstreamness
JEL classification: F13, F15

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PRODUCTION FRAGMENTATION, UPSTREAMNESS, AND VALUE ADDED

EVIDENCE FROM FACTORY ASIA 1990-2005

Tadashi Ito[1] *and Pierre-Louis Vézina*[2]

August 2015

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1. Introduction

"A Barbie doll costs $20, but China only gets about 35 cents of that."– New York Times 2006

Two questions may come to mind when reading the above quote. First, is Chinese production really only about adding cents of value to intermediate inputs? Second, is China adding so little value to Barbie dolls because its stage is at the downstream end of the production chain? The conventional wisdom among economists is that China is not using Chinese factors of production for most of Chinese exports (Baldwin 2011). Ma and Van Assche (2010) suggest that the Chinese content of its 'processing exports' is less than 20%, and processing exports accounted for more than 50% of the nation's boom in manufactured trade. A famous anecdote is that of the iPad, assembled in China by Foxconn, a Taiwanese company. According to a report by the Personal Computing Industry Centre, Chinese labour accounts for less than 3% of its value added. These numbers are often translated in the policy sphere as "China must solve the value added problem".

In this paper we use newly-released Input-Output data from the Institute of Developing Economies, part of the Japan External Trade Organization (IDE-JETRO), to dress a picture of value-added fragmentation in Factory Asia from 1990 to 2005 and in doing so shed new light on the two questions above. We establish three stylized facts. The first is that the share of foreign value added embedded in final production rose by about 7 percentage points between 1990 and 2005, from 9% to 16%. The second is that, contrary to popular belief, China's production of final goods embeds a smaller share of foreign value added than that of other Factory Asia countries. The anecdotal evidence on Barbie dolls and iPads as examples of low-value-added exports for China may not be a good indicator of China's overall production. The data suggests otherwise across all industries. Between 1985 and 2005 among factory Asia countries China grew most after Japan as a source of value added to other countries' production. Third, country-industries at the upstream and downstream extremities of the supply chain embed a smaller share of foreign value added than those with intermediate levels of upstreamness, a phenomenon known as the smile curve.

Our paper fits in the literature on production fragmentation pioneered by, among others, Jones and Kierzkowski (1990), Hummels, Ishii, and Yi (2001), and in the context of Asia, Ando and Kimura (2005). Our contribution is to focus on the geographic and sectoral distribution of the value-added embedded in the production of final goods, rather than on studying the trade flows of intermediate goods. Our paper is similar to Baldwin and Lopez-Gonzalez (2013). The latter presents a portrait of global supply-chain trade and its evolution since 1995 using the recent World Input-Output Database. While they introduce import-to-produce and import-to-export measures of supply-chains we trace the origin of value-added through Input-Output structures. The relevance of our approach is linked to the trade-and-growth debate, as highlighted by Baldwin and Lopez-Gonzalez (2013) who argue that value-added is directly related to national income, especially wages. What's more, Low (2014) writes that knowing where the value is created by trade is absolutely crucial when jobs are at stake.

In this way, our work is also related to Johnson and Noguera's (2011) who estimate the value-added of exports using the GTAP Input-Output matrices. Yet it differs in that we are interested in the foreign origin of the value added of a country's production of final goods, rather than trade in value added per se. In other words, we stop one step before the final destination of the goods. Our aim is to study where the value added of production originates rather than where the products end up, whether at home or abroad.

Finally, one unique contribution of our paper is to cover the period 1990-2005, hence starting earlier than previous studies and before the information and communication technology (ICT) revolution, which is considered to be the kick-starter of production fragmentation (Baldwin 2011).

The rest of our paper is structured as follows. In the next section we describe the data and our methodology to calculate value added. Section 3 presents descriptive statistics for production fragmentation patterns. Section 4 examines the relationship between upstreamness and value added. The last section concludes.

2. Data

The data come from the Asian International Input-Output Table compiled by IDE-JETRO. This international IO table has been constructed by IDE-JETRO every 5 years since 1985. The 2005 table covers nine Asian nations (Indonesia, Malaysia, Philippines, Singapore, Thailand, China, Taiwan, Korea, and Japan) plus the US and 76 sectors (the 1985 table covered 24 sectors). We focus on these 76 sectors to trace the evolution from 1990 to 2005. It includes the US since it is a major trade partner for almost all Asian countries. Other countries are aggregated as the Rest of the World (ROW). While other datasets are now available for many nations, e.g. the OECD – WTO Trade in Value-Added (TiVA) initiative and the World Input-Output Database (WIOD), they do not include information on the critical pre-1995 period, i.e., before the ICT revolution.

By recursive use of information in an international IO table, we can determine the source of value added in every dollar of production of final goods. The key is the simple accounting identity that states that the sale value of a product equals to the cost of intermediate inputs plus value added. Here value added refers to payments to factors of production, i.e. wages as well as profits. The same identity applies to the intermediate goods used as inputs, so a recursive application can generate a full map of where the value was added. For example, if labour were the only productive factor, we could identify where all the workers behind a given final product were employed (by sector and by nation).

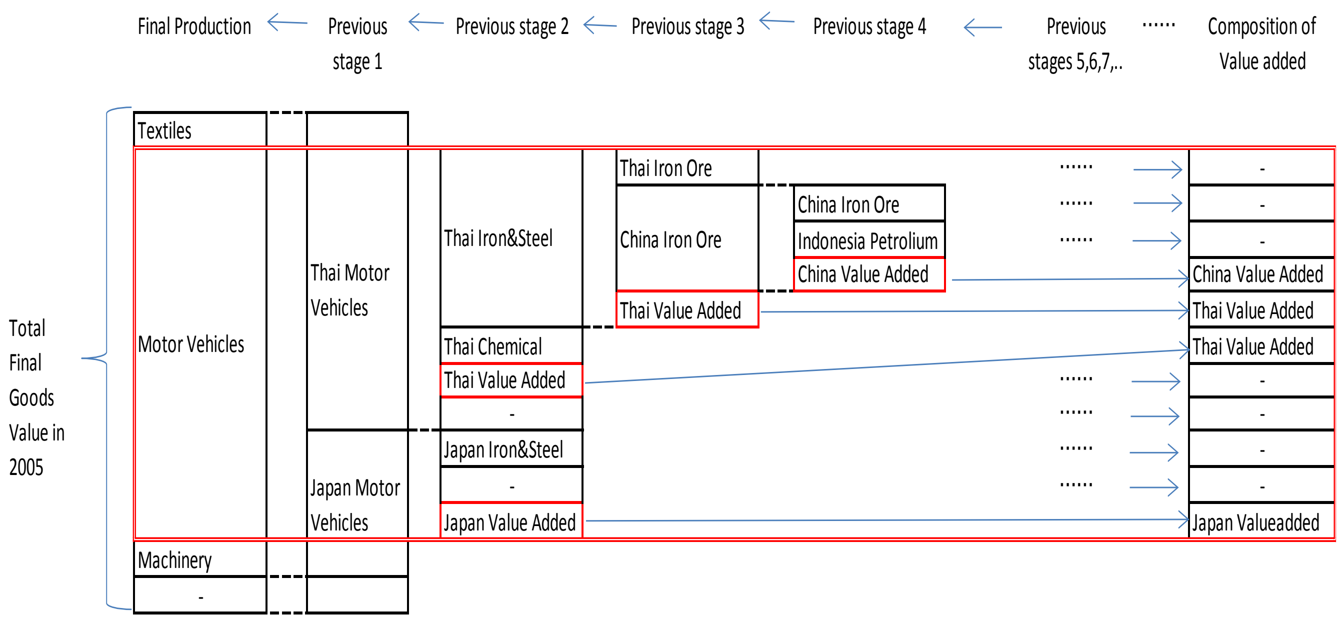
For example, the value added embedded in Thai auto production can be decomposed into countries involved in the international supply chain which sources motors from Japan and petrol from Indonesia, as well as other inputs from the chemical and metal industries, which themselves source their inputs from other industries in other countries. By tracking down the whole process until the output value equals the sum of value added, we can decompose the total value added by industry and country. Decomposing value-added across input-output structures is straightforward using matrix algebra (see Johnson and Noguera 2012):

$$VA = F[I - B]^{-1}X$$

where VA is value-added embodied in the final goods production of a given country (N countries and J sectors), F is a (NJ;NJ) diagonal matrix with the ratio of direct value-added to gross output for each country and sector on the diagonal, $(I\text{-}B)^{-1}$ is the (NJ;NJ) Leontief inverse - it estimates the amount of intermediates per US$ of final output after all rounds intermediate shipments across sectors and countries. X is the (NJ; 1) vector of final goods production.

To ease understanding of the calculation process, Figure 1 provides a sketch of the scheme of the computation.

Figure 1. Tracing the value added of production of final goods



3. A portrait of production fragmentation in Factory Asia

Our first step is to measure the share of the value of each country's final production added in foreign countries. The results are presented in Figure 2. In each of the nine countries we cover the share of foreign value added increased from 1990 to 2005, as would be predicted by the growth of production fragmentation. In 1990 China's production of final goods included only about 3% of foreign value added. In 2005 that number is closer to 6%. Yet, contrary to anecdotal evidence, China is surprisingly not number 1 in terms of foreign sourcing, quite to the contrary. The anecdotal evidence on the little value added in China on products like the iPad and the Barbie doll may not be representative of China's production. That honour belongs to Malaysia in both 1990 and 2005, with shares around 26%.

Figure 3 gives the same numbers but focusing on manufacturing in 1990 and 2005. China's final manufactured goods are the ones that embed the least foreign value added among the 9 countries we cover. This confirms that the idea that Chinese manufacturing is only good for assembly, with the lucrative parts of the process remaining in the US and Japan, is a persistent myth (The Economist 2015). The bottom panel gives the numbers by sector for the most fragmented sectors. In 2005, more than 20% of the value of electronics was embedded in imported inputs. In 1990 that number was below 10%.

Figure 2. Share of foreign value added: 1990-2005

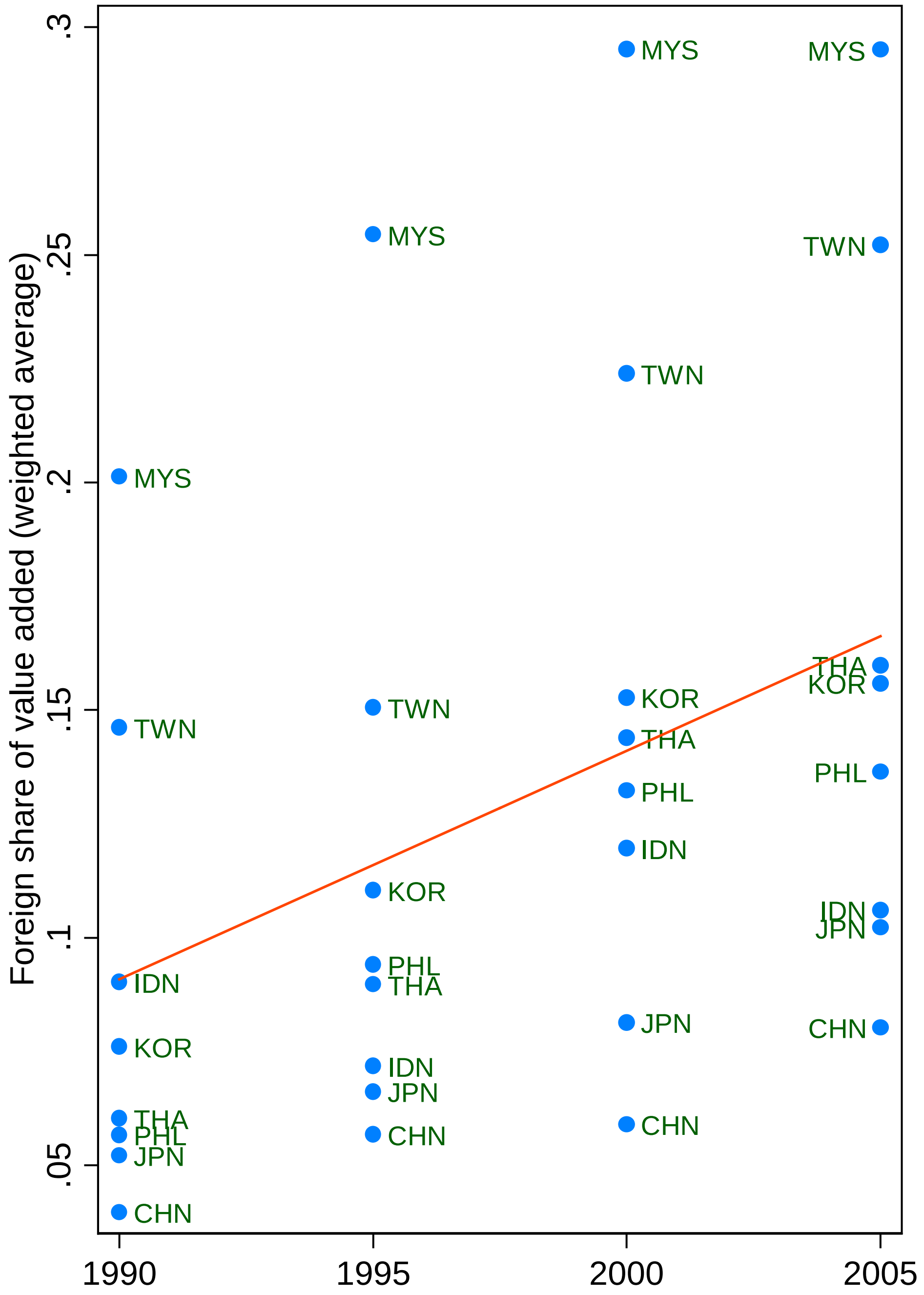
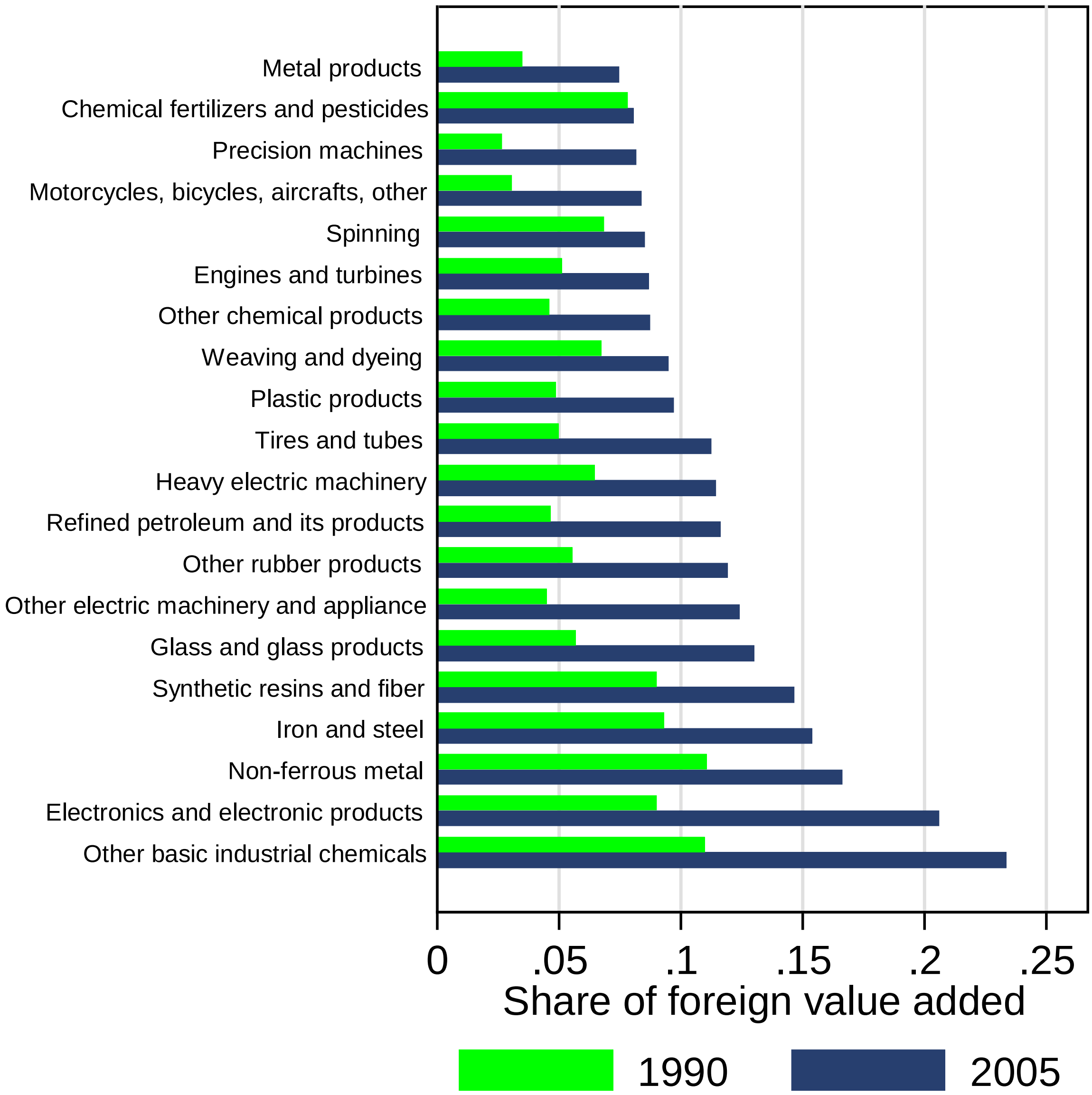


Figure 3. Share of foreign value added across sectors

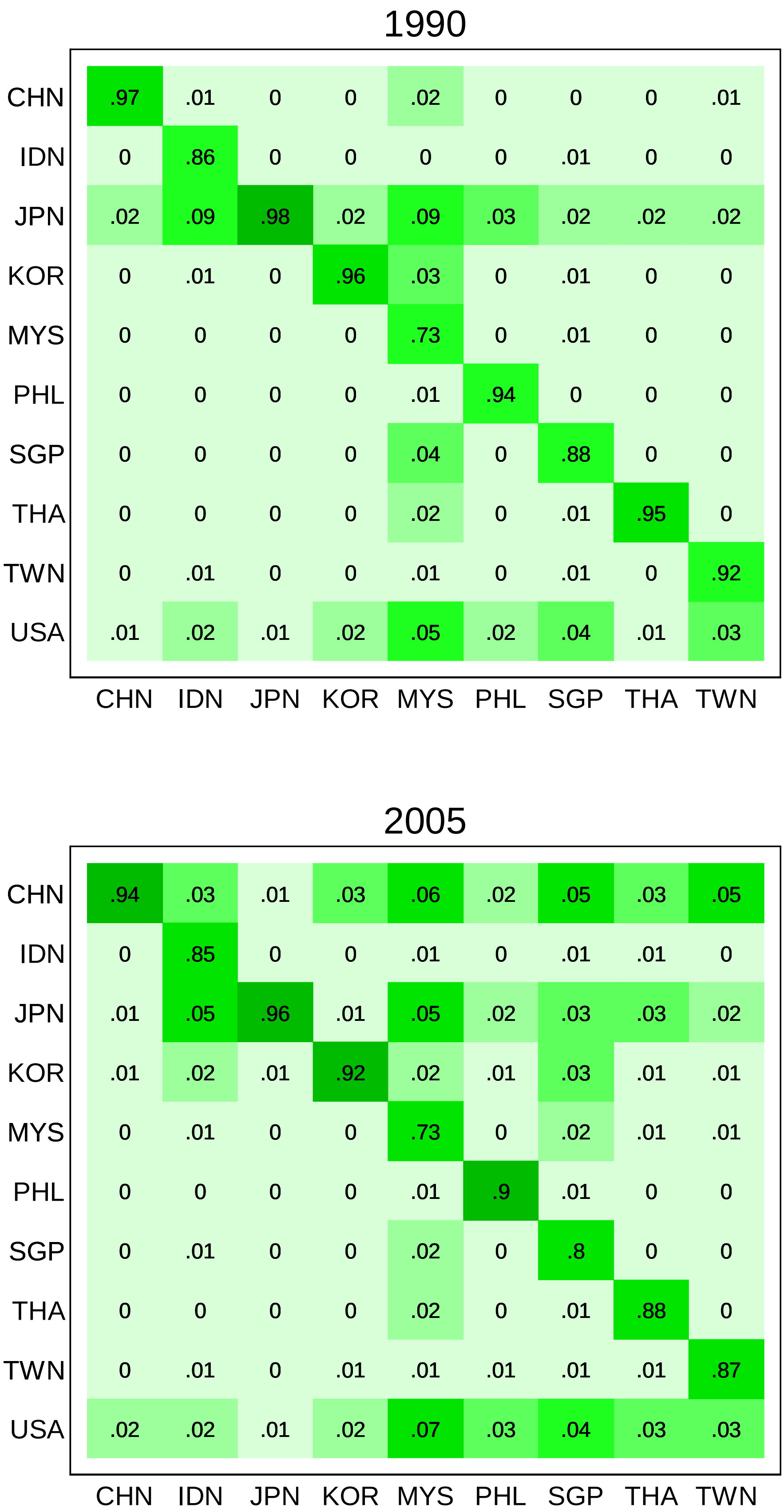


The IO matrix also allows us to break down this foreign value added by country, including the US as a source of value added. Figure 4 summarizes the results. It breaks down the value added of each country's by source country in 1990 and 2005. A column nation's production of final goods is composed of value added in row nations. For example, the first column gives the value-added shares of China's final demand. The extent of production fragmentation is first observed in the pseudo diagonal (without the USA row)[3], which represents value added at home. China's home-value-added share of exports fell from 97% in 1990 to 94% in 2005. The numbers below 0.01 (1%) are represented as zeros. The number of zeros in the matrix decreased from 49 to 29 (out of 90 possible spots), indicating the spread of global supply chains.

[3] The US does not appear as a column as the Asian IO Table does not provide the value-added origin of US production outside of Asia.

One of the most striking changes is the rise of China as a source of value added. In 1985 it accounted for a very small share of the value added embedded in other countries' production. In none of the countries' except Malaysia did it account for more than 1% of value. While the US and Japan were and still are important sources of value added in all of these countries' production, in 2005 China's value added accounted for around 6% of production in Malaysia, 3% in Korea and Thailand, and 5% of Taiwan. The other noticeable feature is the geographic fragmentation of value added embedded in Malaysia's production.

Figure 4. The geography of value added



4. Upstreamness and value added

While this portrait of production fragmentation in Factory Asia makes it clear that China's production is not only about adding cents to products embedding foreign value added, the second question of our introduction is still left unanswered. Does the position of the production stage along the value chain predict the share of value added to the final product?

To answer this questions we first compute a measure of upstreamness suggested by Antras et al. (2012) for each country-industry in all years (we treat Factory Asia as one economy). Their measure is simply the ratio of final use to input use of a country-industry's output. The intuition is straightforward. An industry whose output is used mostly as intermediate input for other industries should be relatively upstream. Consider a particular industry *i*. Its output can be divided into final uses, i.e. consumption, and intermediate uses, i.e. sales to other industries down the production stream. Let's denote the total output of the industry Y and the value of this output that goes to final uses F. We can express each industry's output as:

$$Y_i = F_i + \sum_{j=1}^{N} d_{ij} Y_j$$

where d_{ij} is the value of inputs from industry *i* that are required by industry *j* to produce $1 of output and *N* is the number of industries. If we replace repeatedly the output terms on the right-hand side we get:

$$Y_i = F_i + \sum_{j=1}^{N} d_{ij} F_j + \sum_{j=1}^{N} \sum_{k=1}^{N} d_{ik} d_{kj} F_j + \sum_{j=1}^{N} \sum_{k=1}^{N} \sum_{l=1}^{N} d_{il} d_{lk} d_{kj} F_j + \cdots$$

The output of an industry is thus equal to the sum of its final sales and sales of input to all other industries before final use. If we assume that the distance between each sector is 1, upstreamness can be expressed as

$$U_i = 1 \cdot \frac{F_i}{Y_i} + 2 \cdot \frac{\sum_{j=1}^{N} d_{ij} F_j}{Y_i} + 3 \cdot \frac{\sum_{j=1}^{N} \sum_{k=1}^{N} d_{ik} d_{kj} F_j}{Y_i} + 4 \cdot \frac{\sum_{j=1}^{N} \sum_{k=1}^{N} \sum_{l=1}^{N} d_{il} d_{lk} d_{kj} F_j}{Y_i} + \cdots$$

In other words, industry *i*'s upstreamness is akin to a weighted average of its sales along the production process, where the weights are the production distances to industry *i*. The intuition is that the more sales are used as inputs in faraway industries, the more upstream the industry. Upstreamness thus increases in the number of non-zero input-output coefficients.

Antras et al. (2012) show that, in matrix form:

$$U_i = [I - \Delta]^{-1} 1$$

where 1 is a column vector of ones and Δ is a matrix with $\frac{d_{ij}Y_j}{Y_i}$ in entry (*i,j*). Their measure is thus easily computable using the IO matrix.[4]

The 2005 upstreamness indices average by industries are shown in Table 2. Non-ferrous metal, spinning, iron and steel, other basic industrial chemicals appear among the most upstream industries, selling their output mostly as input to other industries. The most downstream industries are beverages, apparel and other manufacturing, which sell most of their output to final consumers.

Table 2. Upstreamness by industry, 2005

Industry	Upstreamness	Industry	Upstreamness
Non-ferrous metal	5.90	Other chemical products	1.74
Other electric machinery and appliance	3.59	Leather and leather products	1.71
Other basic industrial chemicals	3.30	Other wooden products	1.71
Spinning	3.29	Other machinery	1.63
Synthetic resins and fiber	3.26	**Motor vehicles**	1.57
Heavy electric machinery	3.07	Other non-metallic mineral products	1.56
Iron and steel	2.70	Oil and fats, Sugar, Other food products	1.41
Weaving and dyeing	2.47	Furniture	1.39
Pulp and paper	2.30	**Motorcycles, bicycles, aircrafts, etc…**	1.35
Plastic products	2.24	Printing and publishing	1.33
Other rubber products	2.21	Milled rice, Other milled grain and flour	1.33
Glass and glass products	2.17	Shipbuilding	1.29
Tires and tubes	2.12	Tobacco	1.29
Refined petroleum and its products	1.97	Cement and cement products	1.26
Electronics and electronic products	1.93	Slaughtering, meat and dairy products	1.24
Timber	1.87	Chemical fertilizers and pesticides	1.20
Metal products	1.82	Fish products	1.18
Knitting	1.81	Drugs and medicine	1.17
Precision machines	1.80	Beverage	1.15
Engines and turbines	1.77	Wearing apparel	1.14
Other made-up textile products	1.75	Other manufacturing products	0.87

We then plot upstreamness against the average of the country-industry's value added shares of final demand industries it contribues to in 2005 (Figure 5). The data reveals a u-shaped relationship where

[4] The Stata code for computing the upstreamness measure is available from the authors at http://www.aeaweb.org/aer/data/may2012/2012_1467_app.zip

country-industries in the middle of the supply chain add least value to final demand. A similar relationship has been documented with more aggregated data by Baldwin and Ito (2014) and labelled the smile curve.[5]

Figure 5. Upstreamness and value added share

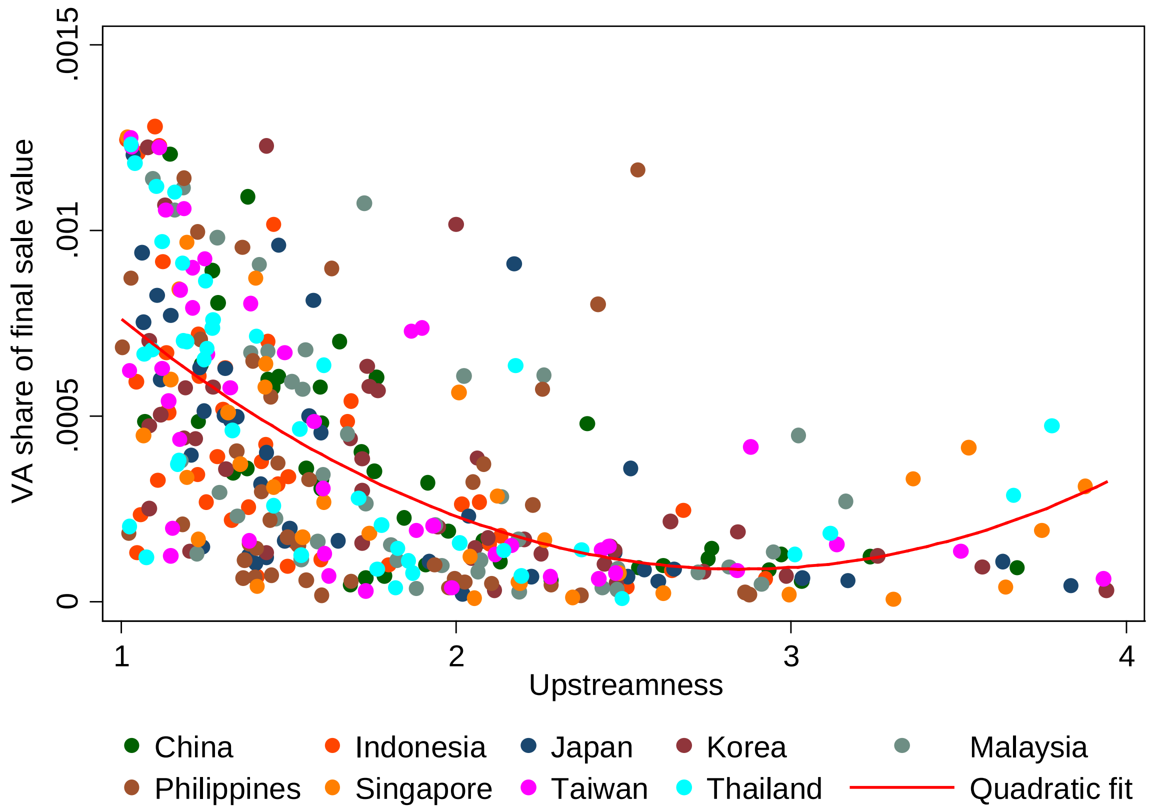


Figure 6 suggests that this pattern also holds across countries in electronics and motor vehicles, industries known for their global value chains. This suggests that countries at the upstream end of the supply chain in cars, i.e. Japan, add a larger share of value than countries at mid-stream such as China. In electronics, countries as the downstream end of the supply chain, e.g. Indonesia and China, add more value than Korea and Japan which are more upstream.

Figure 7 plots the smile curves by country for the 6 developing, or emerging, countries in our data. We observe a smile curve in all countries in 2005. Overall, the data suggests that the middle of the stream is where less value is added.

Figure 6. The smile curve across industries and across countries

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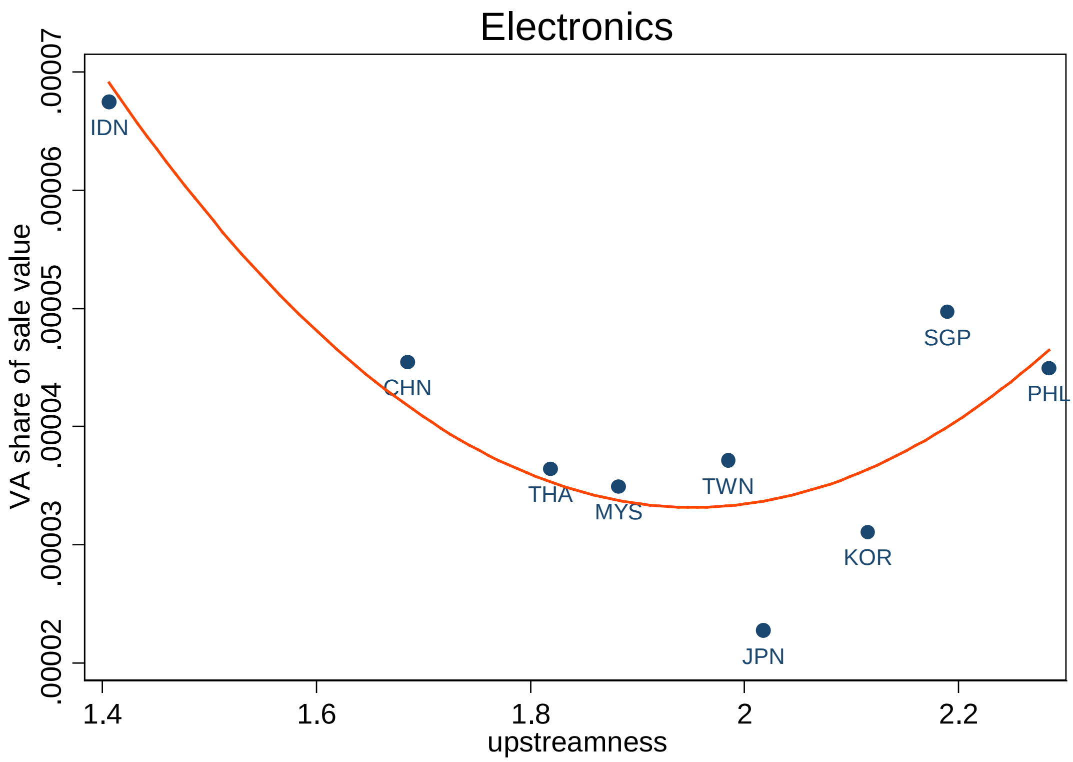
[5] Whereas Baldwin and Ito (2014) use the standard industry classification for the definition of production stages (the horizontal axis of the "smile curve") and focuses on the increasing presence of service industries as the source of value added, our study uses an upstreamness index to define production stages.


Electronics
VA share of sale value
.00002
.00003
.00004
.00005
.00006
.00007
1.4
1.6
1.8
2
2.2
upstreamness
IDN
CHN
THA
MYS
TWN
JPN
KOR
SGP
PHL

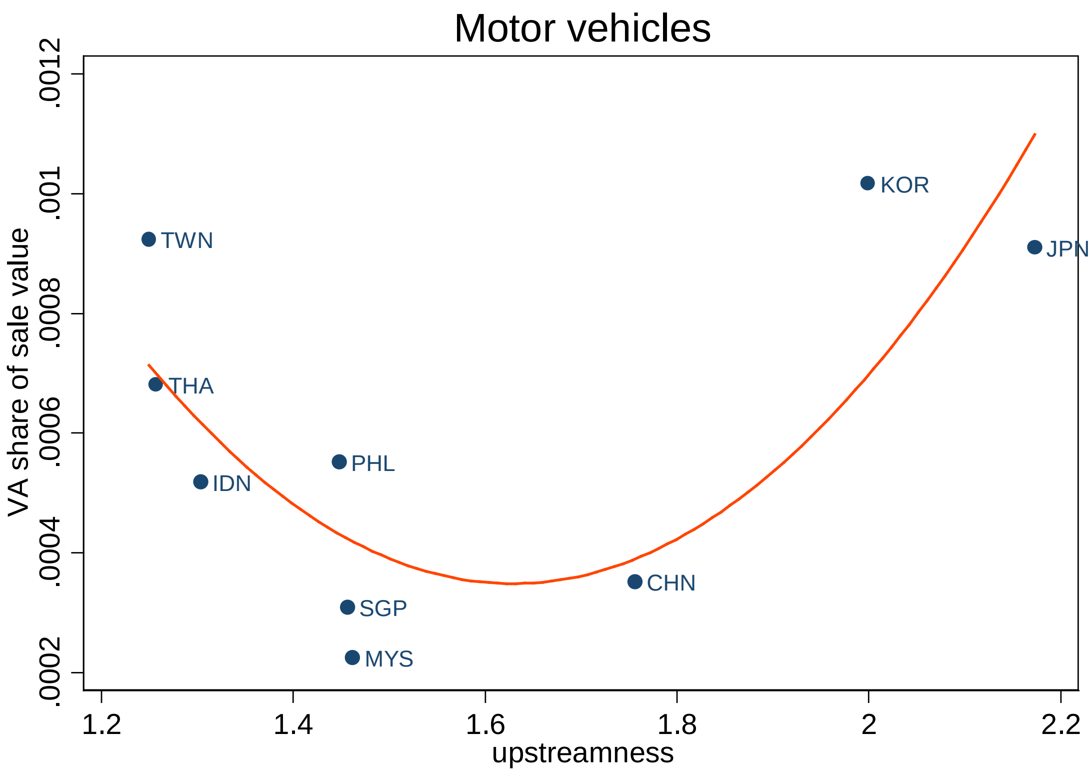
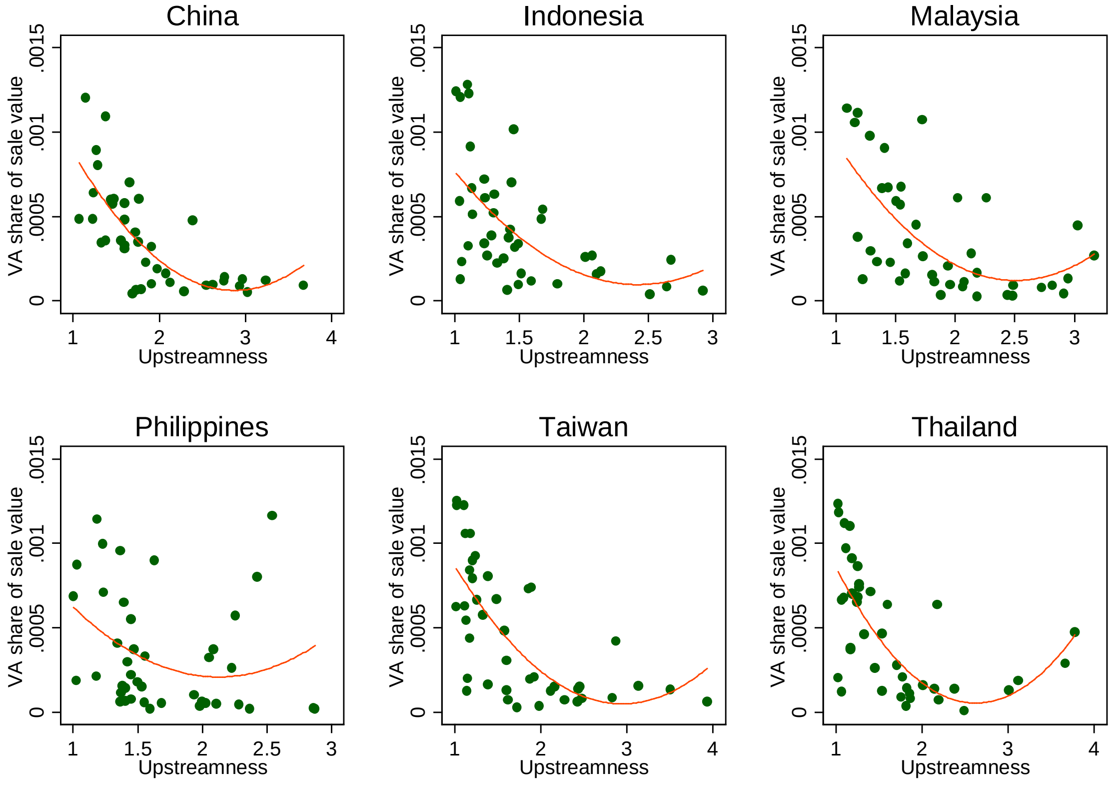

Motor vehicles
VA share of sale value
.0002
.0004
.0006
.0008
.001
.0012
1.2
1.4
1.6
1.8
2
2.2
upstreamness
TWN
THA
IDN
PHL
SGP
MYS
CHN
KOR
JPN

Figure 7. The smile curve across countries



We then test the smile curve significance with a quadratic term regression:

$$VA\ share_{ik} = \alpha_i + \delta_k + \beta_1 U_{ik} + \beta_2 U_{ik}^2 + \epsilon_{ik}$$

where $VA\ share_{ik}$ is country *k*'s sector *i* average share of value added embedded in the final goods industries it contributes to, α_i and δ_k are sector and country fixed effects, U_{ik} is the upstreamness of country *k*'s sector *i* and ϵ_{ik} is an error term. Results are in table 4. Across specifications we observe a u-shape pattern only in 2005, which indicates that the "smile curve" is a relatively recent phenomenon.

Table 4. Testing the smile curve

	(1) VA share	(2) VA share	(3) VA share	(4) VA share
upstreamness	-0.186***	-0.183***	-0.0568***	-0.0376**
	(0.0341)	(0.0353)	(0.0213)	(0.0183)
upstreamness^2	0.00640***	0.00634***	0.00239***	0.00193***
	(0.00114)	(0.00115)	(0.000708)	(0.000584)
Country FE		X		X
Industry FE			X	X
Observations	378	378	378	378
R-squared	0.185	0.199	0.673	0.699

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. (VA share is multiplied by 1000).

5. Conclusion

The second unbundling, or fragmentation of production across countries, is probably the most important aspect of contemporary globalization (Baldwin 2011). It implies, for example, that products "Made in China" may have little Chinese value added embedded in them. In this paper we dressed a portrait of the geographic fragmentation of the value added embedded in Factory Asia's output of final goods from 1990 to 2005. We showed that the share of foreign value added embedded in production rose significantly from 1990 to 2005 and that contrary to popular belief, China's final production embeds a smaller share of foreign value added than other Factory Asia countries. The anecdotal evidence on Barbie dolls and iPads as examples of low-value-added exports for China may not be good indicators of China's overall production. We also showed that country-industries at the upstream and downstream extremities of the supply chain account for a larger share of value added than those with intermediate levels of upstreamness, a phenomenon known as the smile curve. So, Is Chinese production really only about adding cents of value to intermediate inputs? No. Is China adding so little value to Barbie dolls because its stage is at the downstream end of the production chain? Probably not.

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