Special Feature C

Where are Countries Positioned along Global Production Lines?

by Davin Chor[1]

Introduction

The East Asian region, including Singapore, has been very much in the thick of the action as global production lines have expanded. Over the past three decades, production processes have become increasingly fragmented across country borders. Parts and components are now routinely sourced from multiple locations, while intermediate stages of assembly often take place in countries different from where final assembly occurs. The short label, "Made in China", on a finished item of clothing or an electronics product is without doubt an oversimplification, in light of the many countries involved at some stage in its production. These developments raise several questions of interest both to economists and policy-makers alike: Where are countries positioned along global production lines? Do a country's exports tend to be in relatively upstream stages near the start of production processes, or in downstream industries closer to the final consumer? What implications do these patterns of specialisation and trade have for value added per worker or welfare at the country level?

Towards a Measure of "Upstreamness"

To answer these questions, one first needs to have a measure on hand that summarises the production line position of each industry. A natural starting point is to draw on the rich information contained in a country's Input-Output Tables on the inter-linkages between industries, specifically how much an industry *j* purchases from each industry *i* as inputs. In my recent joint work in Antràs *et al*. (2012), we propose a novel measure of the "upstreamness" of an industry that is based on these input-output relationships.

Our measure of upstreamness has several useful and appealing properties. From a theoretical perspective, we show that the distinct approaches towards devising a measure of upstreamness put forward independently in Fally (2012) and Antràs and Chor (2013) actually yield an identical measure. That the two approaches lead to the same outcome lends credence to its use as a measure of an industry's production line position. From a practical perspective, the measure can be easily computed with a few simple matrix algebra manipulations. One can therefore readily calculate the upstreamness of each industry given any standard set of Input-Output Tables, and we provide an example using the 2002 benchmark tables from the United States. As an application, we show how our measure can shed light on the average upstreamness of a country's trade flows, in order to address the question of where a country is positioned in global production lines *vis-à-vis* its trade partners. In this Special Feature, we also present the average export and import upstreamness values for selected countries in ASEAN and the broader Asia Pacific region, to illustrate the potential uses of our measure.

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Conceptual Foundations

We first describe how we define our measure of upstreamness from input-output relationships. This will require the use of some concepts and notation from input-output accounting, but will nevertheless be helpful for fixing ideas on what our measure seeks to capture. We discuss this for the basic case of a closed economy where the linkages across industries are self-contained within country borders.

Consider an economy in which there are N industries. Our starting point is the following accounting identity that describes the various uses for the output of a particular industry i:

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

Here, Y_i denotes the total output of the industry, while F_i is the value of this output that goes to final uses (namely, final consumption or investment). Note that d_{ij} is the value of inputs from industry i that are required by industry j to produce \$1 of the latter's output, denoted Y_j; d_{ij} is referred to in input-output terminology as a direct requirements coefficient. The above identity thus states that the output of industry i is equal to the sum of: (i) the amount that goes to final uses, F_i; and (ii) the amount that is purchased by all other industries j as intermediate inputs, $d_{ij}Y_j$, where $j = 1,2,\ldots,N$. We next make use of this identity to substitute out repeatedly for the output terms that appear on the right-hand side. This yields:

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

The output of industry i is therefore equal to the sum of: (i) the amount that goes directly to final use, F_i; (ii) the amount that is sold as an input to all other industries one stage before final use, $\sum_{j=1}^{N} d_{ij} F_j$; (iii) the amount that is sold as an input to all other industries two stages before final use, $\sum_{j=1}^{N} \sum_{k=1}^{N} d_{ik} d_{kj} F_j$; and so on.

This motivates a measure of upstreamness, originally suggested in Antràs and Chor (2013), which we denote by U_i for industry i. Intuitively an industry whose output tends to be used mainly as an intermediate input for other industries (rather than for final use) should be considered as relatively upstream. Moreover, an industry's level of upstreamness should be higher if it tends to enter production processes at earlier stages before final use. We therefore weight each of the terms in the above output identity by an integer equal to the respective number of stages before final use plus one, and normalise the expression by the total output of industry i:

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

With this definition, an industry that has its entire output channelled to final uses, namely with $F_i = Y_i$, will have $U_i = 1$. This is in fact the smallest possible value that U_i can take, since such an industry would be the least upstream (most downstream) among all industries. Of note, one can interpret $U_i - 1$ as the weighted average number of stages prior to final use at which an industry tends to enter production processes.

In Antràs *et al*. (2012), we establish that U_i is in fact mathematically equivalent to a separate measure of upstreamness put forward by Fally (2012), which is based on an alternative recursive definition. In our paper, we also provide matrix algebra expressions for computing U_i explicitly. It is worth stressing that what is required for this calculation—specifically, information on Y_i, F_i and d_{ij}—is data that would be contained in any standard set of input-output tables. It is thus straightforward to compute this measure in practice. We also show how to adapt our measure of upstreamness in an open economy setting. This requires that we adjust each

direct requirements coefficient, d_{ij}, to correct for the inter-industry linkages that arise from the possible uses of a country's exports and imports. An analogous adjustment is also required to take into account the net flows of inventories of each industry.[2]

Computing Industry Upstreamness

How do different industries line up according to our upstreamness measure? We provide an example using the 2002 United States Input-Output Tables. A distinct advantage of the US Tables is that the data on input-output linkages is available at a very detailed level of industry disaggregation.[3] For the 2002 Tables, there are a total of 426 industries, with 279 of these in manufacturing. We computed U_i for each industry, applying the necessary open economy and net inventory corrections mentioned above. At one end of the spectrum, 19 industries have an upstreamness value of 1, these being industries whose entire output goes to final uses. On the other end, the most upstream sector is 'Petrochemical' with a value of 4.65. The mean value of upstreamness across all 426 industries is 2.09, meaning that the average industry enters production processes about one stage removed from final use. Table 1 reports the 10 least and most upstream industries among the 279 manufacturing industries. Not surprisingly, the most upstream industries tend to be related to the extraction and processing of raw minerals and resources. Among the most downstream industries are textiles, footwear, furniture and motor vehicles, these being industries that are very close to the end-user. Note that there is no obvious relationship between production line position and how capital-intensive an industry is, as there are capital-intensive industries that are very downstream (Automobile) as well as very upstream (Petrochemical).

[2] The Stata code for computing the upstreamness measure and for replicating our work is available at: http://www.aeaweb.org/aer/data/may2012/2012_1467_app.zip

[3] We have also computed upstreamness using the country input-output tables available in the OECD STAN database. These seek to present the tables for different countries using a standardised industry classification system, albeit a coarser one with just 41 sectors. We have nevertheless verified that there is a high level of agreement across countries in the upstreamness ranking of these sectors.

Table 1
The 10 Least and Most Upstream US Manufacturing Industries

Industry (IO2002 industry codes in parentheses)	Upstreamness
Automobile (336111)	1.0003
Light truck and utility vehicle (336112)	1.0005
Non-upholstered wood household furniture (337112)	1.0052
Upholstered household furniture (337121)	1.0072
Footwear (316200)	1.0073
Motor home (336213)	1.0123
Truck trailer (336212)	1.0165
Manufactured home (mobile home) (321991)	1.0194
Women's and girls' cut and sew apparel (315230)	1.0244
Mattress (337910)	1.0288
Plastics material and resin (325211)	3.5712
Copper rolling, drawing, extruding and alloying (331420)	3.6109
Alkalies and chlorine (325181)	3.6112
Carbon and graphite product (335991)	3.7484
Fertilizer (325310)	3.7617
Alumina refining and primary aluminium (33131A)	3.8144
Other basic organic chemical (325190)	3.8529
Secondary smelting and alloying of aluminium (331314)	4.0637
Primary smelting and refining of copper (331411)	4.3547
Petrochemical (325110)	4.6511

Computing Upstreamness for Country Trade Flows

We can now return to our initial motivating question, namely: Where are countries positioned in global production lines? To shed light on this, we computed the following weighted average measure of the upstreamness of each country *c*'s exports:

$$\sum_{i=1}^{N} \frac{X_{ci}}{X_c} U_i$$

Here, U_i is the upstreamness of industry *i* as calculated above from the 2002 US Input-Output Tables, with X_{ci} being the value of country *c*'s exports in industry *i*, and X_c being the total value of country *c*'s exports (summed over all industries). The above thus captures the average upstreamness of the country's export mix; an analogous calculation was used to obtain the upstreamness of the country's imports. Together, these are intended to reflect the average position of a country's trade flows within global production processes. We calculated these for a sample of 181 countries for the year 2002. The mean value of export upstreamness across these countries was 2.30, with a standard deviation of 0.58.

Table 2 reports the export and import upstreamness values for various countries in the broader Asia Pacific rim and ASEAN, to provide a sense of where the region is positioned. Of note, a number of these economies feature exports that are relatively downstream compared to their import mix. This includes Cambodia, China, Japan, South Korea, Taiwan, Thailand, and Vietnam, these being economies where the manufacturing sector has been a key source of export-led growth. Taking China as an example, the gap between the upstreamness of its exports and imports (1.82 versus 2.57) indicates that China is plugged into global production lines as an importer of upstream intermediate inputs that are subsequently processed and assembled; when these are exported, they are substantially closer

to being the finished products that end-users will purchase. Conversely, we also observe countries whose export profile is more upstream than its import profile, including Brunei, Myanmar, Australia and New Zealand, these being countries whose exports are concentrated in agriculture products and primary commodities. The United States also has a slightly more upstream export profile relative to its imports (2.15 versus 1.96), but this likely reflects its position as a large importer of finished consumer goods instead of being a reflection of the composition of its exports. As for Singapore, there is little difference between the production line position of her exports and imports. Interestingly, Singapore's export upstreamness comes close to the mean value observed across all countries.

Table 2
Export and Import Upstreamness for Selected Countries (2002)

	Export Upstreamness	Import Upstreamness
ASEAN		
Brunei	2.96	1.86
Cambodia	1.37	2.18
Indonesia	2.46	2.58
Laos	1.91	2.00
Malaysia	2.31	2.46
Myanmar	2.43	2.26
Philippines	2.29	2.50
Singapore	2.30	2.32
Thailand	2.07	2.51
Vietnam	1.93	2.34
Broader Asia Pacific		
Australia	2.67	1.94
China	1.82	2.57
Hong Kong	1.96	2.11
India	2.05	2.40
Japan	1.98	2.32
New Zealand	2.15	1.98
South Korea	2.07	2.59
Taiwan	2.27	2.64
USA	2.15	1.96

Conclusion

We have proposed in our work a theoretically-founded measure of industry upstreamness that is convenient to compute from Input-Output Tables. As we have demonstrated in this article, this measure is very amenable for applied empirical work, providing a useful descriptive tool for summarising where each industry and hence each country sits in global production processes.

There is clearly still a lot of scope to further exploit this measure in future research. I highlight two such open questions that should be of interest to policy-oriented economists. First, it would be useful to investigate how the upstreamness of country trade flows has evolved over time. Looking at the past 50 years for example, are there countries that have become discernibly more upstream or more downstream in their export composition? This could be informative for our understanding of how a country's global production line position changes as it moves from one stage of its economic development to the next. Second, what is the connection between production line position and such economic outcomes as value added per worker, total factor productivity, and ultimately country welfare? From a policy perspective, it would be useful to understand whether there is any benefit, if any, in governments trying to position the economy towards the downstream assembly of manufactured goods instead of more upstream stages of production.

References

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