Vertical Spillovers in Global Value Chains

By Swapnika Rachapalli *

Participation in global value chains (GVCs) is an important driver of economic growth and prosperity, especially for developing economies. The fragmentation of production processes has enabled firms, and thereby countries, to specialize in small parts of the value chain and improve efficiency (World Bank, 2019). It is however important that countries not become trapped in the production of specialized inputs, but to expand their production capabilities so as to capture more value in the global production process. In this paper, I ask whether GVC participation of countries in certain products enable them to improve their capabilities in other vertically related products in the corresponding value chain.

Using country-level trade data, I find that countries' expand production to a product in response to export shocks to other products upstream and downstream in the value chain. This suggests that getting integrated in GVCs by specializing in certain stages of production initially can facilitate expansion into more stages, and thereby enable countries to add more value, over time. Let us take the example of the following value chain: Cotton Yarn → Cotton Fabric → Cotton Shirts; Cotton yarn is used to make cotton fabric which is in turn used to make cotton shirts.[1] The results in this paper suggest that a country becomes better in supplying cotton fabric (stage two) to the world if it were to experience a demand shock to either its upstream products, i.e. cotton yarn (stage one), or its downstream products, i.e. cotton shirt (stage three).

What could be driving such expansion? While the exercises presented in this paper establish the above empirical regularity in the trade data, more systematic investigation is required to establish mechanisms driving the results. It is likely that export market access for an input like cotton yarn can help firms learn about different aspects of cotton fabric- like new demand for cotton fabric from other countries, or details of cotton fabric production technology/know-how from buyers of cotton yarn in the foreign markets (see Rachapalli (2021) for example). Improved export market access for an output like cotton shirt can induce domestic demand for cotton fabric production, thereby increasing incentives for firms in the country to invest in input production. These potential vertical spillovers from export market access contribute to the well established trade and firm productivity/innovation literature by highlighting new mechanisms through which export market access for a product can improve a country's comparative advantage in other products in the value chain.[2]

I. Data

There are two primary data sources: one for constructing input-output (I-O) linkages between products, and the second for trade data that forms the basis of the analysis. I describe them briefly below. See Appendix for more details.

I-O Linkages: For the purpose of defining vertical relationships between two products, I make use of the I-O table constructed in Rachapalli (2021) by aggregating firm-level data on outputs produced and inputs used to produce them from the Indian manufacturing survey for 2003-2009. Products in the Indian data are classified according to the Annual Survey of Industries Commodity Classification (AS-

* Rachapalli: University of British Columbia Sauder School of Business (email: s.rachapalli@sauder.ubc.ca).

[1] This example is directly taken from the input-output table constructed in Rachapalli (2021).

[2] See Shu and Steinwender (2019) for a review on the trade and firm productivity and innovation literature.

ICC) which contains ∼6,000 product codes. Of these, 3,971 products are used as inputs and 4,433 products are produced as outputs by Indian manufacturing firms. The I-O table provides the value of input flows from one product to another for every product pair. For each product p, I then obtain the set of products that are immediately upstream, $U(p)$, and the set of products that are immediately downstream, $D(p)$. Suppose the the flow of materials from product p to p' is given by $M_{pp'}$, then,

$$U(p) \equiv \{p' : M_{p'p} > 0\}, \tag{1}$$

$$D(p) \equiv \{p' : M_{pp'} > 0\}. \tag{2}$$

An advantage of using the Indian data to construct I-O linkages is the disaggregated level of product detail that allows one to classify a given product as either an input or as an output to another product cleanly (instead of classifying it as both an input and an output with respect to another product). In most publicly available national I-O tables that represent input flows between aggregated industries a large share of industry pairs have materials flowing in both directions.[3]

Trade Data: Primary data for this paper is taken from the CEPII BACI trade database which provides bilateral trade flows at the Harmonized System (HS) 6-digit level for 200 countries (Gaulier and Zignago, 2010). I employ a series of sample selection criterion which results in a final sample of 70 countries. The analysis is carried out for the time period 1996-2018. I construct a crosswalk from the 1992 HS classification that the trade data is reported at to ASICC, and bring all trade data to ASICC detail.

II. Revealed Comparative Advantage

The paper has two sets of empirical results. First, I show that countries are likely to have revealed comparative advantage (RCA) in a product if they also have RCA in products that are upstream (inputs) or downstream (outputs) to that product. Second, I find that the RCA of a product can improve over time if the country experiences exogenous demand shocks to its inputs or outputs.

Following Hidalgo et al. (2007), the measure of country i's RCA in product p in year t is constructed as

$$\mathrm{RCA}_{ipt} = \frac{X_{ipt}}{\sum_p X_{ipt}} \Bigg/ \frac{\sum_i X_{ipt}}{\sum_i \sum_p X_{ipt}}, \tag{3}$$

where X_{ipt} is the value of total exports of product p by country i in year t. This measure captures whether a country exports more of product p relative to the world's export of the product compared to all other products, thereby giving a proxy for its comparative advantage in the product (RCA>1). The RCA of upstream and downstream products of p are further constructed as the weighted average of the RCA of each product in the corresponding set with input shares and output shares as weights respectively. Formally, they are defined as follows:

$$\mathrm{RCA}_{iU(p)t} = \sum_{p' \in U(p)} s^I_{p'p} \mathrm{RCA}_{ip't}, \tag{4}$$

$$\mathrm{RCA}_{iD(p)t} = \sum_{p' \in D(p)} s^O_{pp'} \mathrm{RCA}_{ip't}, \tag{5}$$

$$s^I_{p'p} = \frac{M_{p'p}}{\sum\limits_{p' \in U(p)} M_{p'p}}, s^O_{pp'} = \frac{M_{pp'}}{\sum\limits_{p' \in D(p)} M_{pp'}}.$$

Figure 1 plots the average probability that a country has comparative advantage in product p conditional on the country having comparative advantage in some other products, denoted by $S(p)$. The conditional probability is defined as

$$\phi_{p|S(p)} = \frac{\sum_i \mathbb{I}(\mathrm{RCA}_{ipt}, \mathrm{RCA}_{iS(p)t} > 1)}{\sum_i \mathbb{I}(\mathrm{RCA}_{iS(p)t} > 1)}, \tag{6}$$

where the function $\mathbb{I}()$ takes value 1 if the condition inside the parenthesis is true. The figure plots the conditional probability

[3]For example, in the 2007 US I-O table 20% of all product pairs linked with input flows have flows in both directions. In the above constructed Indian I-O table this number is only 1%. I drop product pairs that have material flows in both directions from the analysis.

for three different sets of $S(p)$ - Upstream products $U(p)$, Downstream products $D(p)$, and 100 iterations of a randomly matched product.[4] The figure shows that on average, countries that are good at producing either upstream inputs (like yarn) or downstream outputs (like shirts) also have a comparative advantage in producing the focal product (like fabric). In other words, countries are more likely to co-produce inputs and outputs compared to two randomly chosen products.

III. Testing for Vertical Spillovers

In the rest of the paper, I explore if countries' comparative advantage in products improves in response to increased exports of vertically related products to the rest of the world. I estimate the following regression specification to explore this relationship.

$$\ln(\text{RCA}_{ipt}) = \alpha + \alpha^U \ln(X_{iU(p)(t-s)}) + \alpha^D \ln(X_{iD(p)(t-s)}) + \mathbf{Z}_{ipt}\delta + \epsilon_{ipt}, \tag{7}$$

where $X_{iU(p)(t-s)}$ and $X_{iD(p)(t-s)}$ are s-period lagged values of weighted averages of upstream and downstream exports.[5] $\mathbf{Z}_{ipt}$ are other controls including fixed effects.

Export performance of a country across products in different stages of the value chain are potentially endogenous resulting from common supply/technology shocks to the value chain. In order to establish causality I instrument upstream and downstream exports using plausibly exogenous shocks to foreign demand to these products. Following the instrument for exports constructed in Chor, Manova and Yu (2021), exports X_{ipt} is instrumented by a projected growth rate in foreign demand for that country's product p between $t-1$ to t. Specifically, I use a weighted average of the year-on-year growth rate in the foreign country j's import demand for product p from the rest of the world (excluding the focal country), M^{-i}_{jpt}. The formula used is

$$X^{IV}_{ipt} = X_{ip(t-1)} \left(1 + \sum_j s^x_{ijpt_0}\, g^{m_{-i}}_{jpt}\right), \tag{8}$$

$$s^x_{ijpt_0} = \frac{X_{ijpt_0}}{X_{ipt_0}}, \quad g^{m_{-i}}_{jpt} = \frac{M^{-i}_{jpt} - M^{-i}_{jp(t-1)}}{M^{-i}_{jp(t-1)}},$$

where $s^x_{ijpt_0}$ is the share of exports from i to j in the first period that country i exports product p in the sample, and $g^{m_{-i}}_{jpt}$ is the growth rate in foreign country j's demand for product p from the rest of the world. Using the above described export instrument, I construct instruments for upstream and downstream exports as follows:

$$X^{IV}_{iU(p)t} = \sum_{p' \in U(p)} s^I_{p'p} X^{IV}_{ip't}, \tag{9}$$

$$X^{IV}_{iD(p)t} = \sum_{p' \in D(p)} s^O_{pp'} X^{IV}_{ip't}. \tag{10}$$

A. Baseline Results

Table 1 reports the IV results for 3-period lagged explanatory variables with different sets of fixed effects. Column 1 includes product-year and country-year fixed effects, which controls for any trends within products across countries, and within countries across products. Column 2 includes country-product and product-year fixed effects. Country-product fixed effects controls for potential persistence of attributes of a specific product in a specific country over time. Finally, in column 3, my preferred specification, I control for country-year and country-product fixed effects which results in the most conservative of the three estimates. All three columns report positive and significant estimates on both upstream and downstream exports, showing that a country's comparative advantage in a product improves in response to exogenous shocks to exports market access in vertically related products.

A potential concern in the above exercises is that different products in the same value chain can experience country-specific cor-

[4] In each iteration k, for every country and year a focal product is randomly matched with another product p', after which the the conditional probability $\phi^{(k)}_{p|p'}$ is calculated. The figure plots the average of this value over 100 iterations.

[5] See equations 4-5 for the weights used to aggregate upstream and downstream variables.

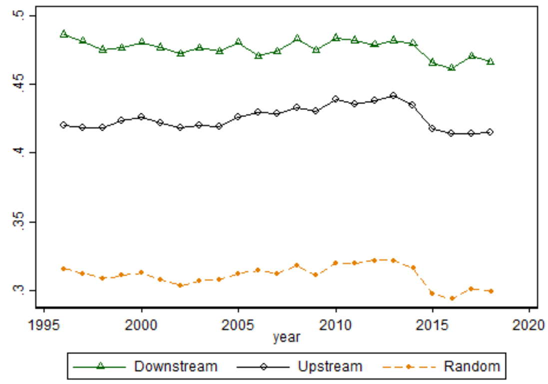

FIGURE 1. CONDITIONAL PROBABILITIES OF CO-PRODUCTION

Note: Figure plots the probability of a country having comparative advantage in a product conditional on the country having comparative advantage in that product's upstream product set, downstream product set, or a randomly matched product as defined in equation 6.

TABLE 1—BASELINE RESULTS - IV ESTIMATES

	Dependent Variable: $\ln(\text{RCA}_{ipt})$			
	(1)	(2)	(3)	(4)
$\ln(X_{iU(p)(t-3)})$	0.313^{a}	0.119^{a}	0.082^{a}	0.036^{a}
	(0.002)	(0.002)	(0.002)	(0.002)
$\ln(X_{iD(p)(t-3)})$	0.309^{a}	0.111^{a}	0.084^{a}	0.032^{a}
	(0.002)	(0.002)	(0.002)	(0.002)
$\ln(X^{IV}_{ip(t-3)})$				0.122^{a}
				(0.001)
Observations	3,452,034	3,450,370	3,450,370	3,347,237
F-Stat $\ln(X_{iU(p)(t-3)})$	306375.037	39171.743	36130.068	32491.573
F-Stat $\ln(X_{iD(p)(t-3)})$	313006.839	49677.839	42691.682	39302.183
Product-Year FE	Y	Y	-	-
Country-Year FE	Y	-	Y	Y
Country-Product FE	-	Y	Y	Y

Note: Each column reports IV estimates of the regression specification in equation 7 where instruments are defined in equations 9-10. All explanatory variables are 3-period lagged values. Standard errors reported in parenthesis are clustered at the product-year level. [a] Significance at 1%, [b] Significance at 5%, [c] Significance at 10%.

related foreign demand shocks, which can result in positive coefficients. In the cotton value chain example with cotton fabric (stage 2) as the focal product, increased foreign demand for fabrics can result in increased demand for the input to produce fabric, namely cotton yarn. Then, the RCA of cotton fabric improves due to cotton fabric experiencing a demand shock, and may not be a result of the demand shock experienced by cotton yarn. To address this issue, column 4 controls directly for lagged export shocks experienced by the focal product using the instrument for exports defined in equation 8. As expected, the estimates on both upstream and downstream exports are smaller, but are still positive and significant.

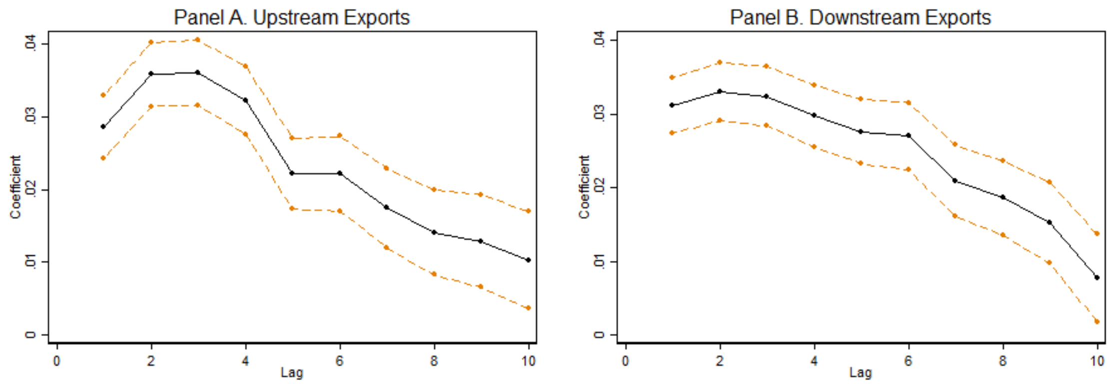

FIGURE 2. ESTIMATES FOR DIFFERENT LAGS

Note: Figure plots the IV estimates (solid lines), and the corresponding 95% confident intervals (dashed lines), of the regression specification in equation 7 for different lags s of the explanatory variables. Instruments are defined in equations 9-10. Regressions include country-product and country-year fixed effects, as well as lagged export IV for the focal product (specification used in column 4 of table 1). Standard errors are clustered at the product-year level.

Figure 2 plots the IV estimates for different lags of the explanatory variables. The causal effect of export shocks to vertically related products on the RCA of a product declines over time, with a peak around 3 years.

B. *Placebo Test*

In order to allay any other concerns regarding the IV estimates picking up spurious correlation, I conduct the following placebo test. For each product p, I randomly match a product p' from the set of all product in the sample. I proceed to then incorrectly use the upstream and downstream exports of product p' (and their corresponding export instruments) in place of product p's upstream and downstream exports respectively.[6] The idea behind the randomization exercise is to check whether a country's RCA in a particular product improves in response to randomly chose upstream and/or downstream products.

I repeat this randomization exercise 100 times, and obtain the IV estimates from the baseline specification using 3-period lagged explanatory variables. Figure 3 plots the histogram of the estimates obtained from the 100 iteration of the placebo exercise, as well as the estimate from column 4 in Table 1 for reference. The placebo estimates for both upstream and downstream exports are centered around zero. This shows that a country's comparative advantage in a product does not respond to export shocks in any random product, but specifically to other vertically related products within the value chain.

C. *Industry Heterogeneity*

Figure 4 plots the baseline IV estimates for different industries separately. The results show that vertical spillovers in a value chain are not similar across all industries. Products in the food and beverage manufacturing experience the largest spillover effects, while products in the mining, chemical, and transportation equipment industries have no significant relationship with their upstream and downstream exports.

IV. Concluding Remarks

The exercises presented in the paper suggest that countries can benefit from participating in GVCs through positive spillovers to different stages within the value chain over time. Do these spillovers occur within firms directly linked to the

[6]The product randomization is kept consistent within every country-year pair, i.e. for a given focal product, the same random product gets matched for every country and year.

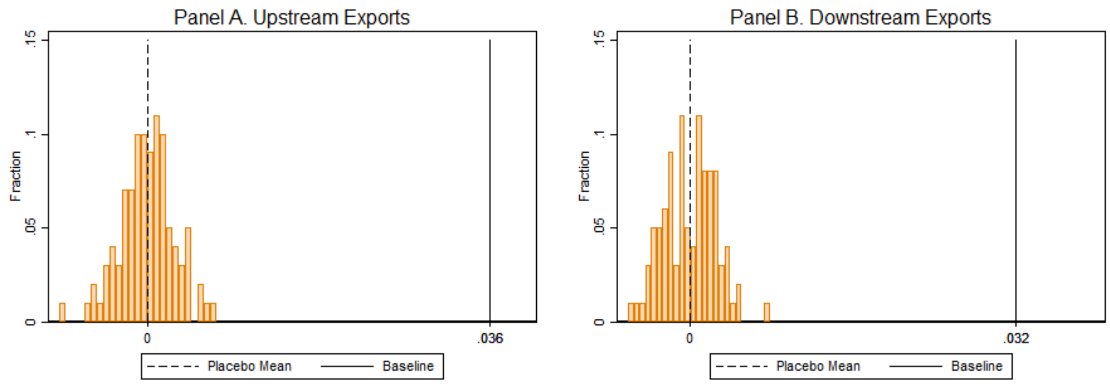

FIGURE 3. PLACEBO TEST

Note: Figure plots the histograms of the IV estimates from the the placebo exercise described in the text. Each estimate is obtained by randomizing the set of upstream and downstream products that a product is linked to, and running the regression specification in equation 7. Regressions include country-product and country-year fixed effects, as well as lagged export IV for the focal product (specification used in column 4 of table 1).

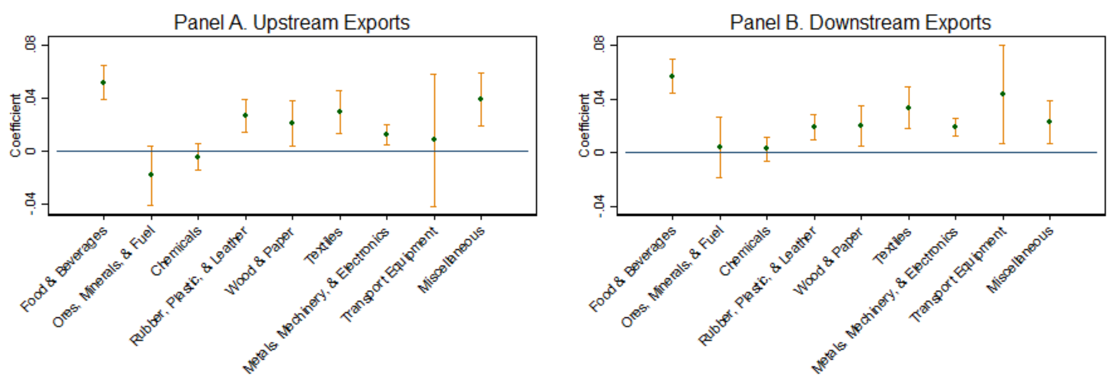

FIGURE 4. INDUSTRY HETEROGENEITY

Note: Figure reports IV estimates and corresponding 95% confidence intervals for different industries using the regression specification in equation 7. Regressions include country-product and country-year fixed effects, as well as lagged export IV for the focal product (specification used in column 4 of table 1). 1. Standard errors are clustered at the product-year level.

global trade network, potentially arising from learning from exporting? Or, are they across firm spillovers, for example, resulting from knowledge diffusion through domestic buyer-seller interactions. These are potential avenues for future research.

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