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Does Vertical Specialization Increase Productivity?

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Abstract

This paper investigates the impact of global value chain participation on productivity, using data on trade in value added from the World Input-Output Database. The results based on a panel estimation covering 13 sectors in 40 countries over 15 years suggest that participation in global value chains is a significant driver of labor productivity. Backward participation in global value chains, that is, the use of imported inputs to produce for exports, emerges as particularly important. An increase by 10 percent in the level of global value chain participation increased average productivity by close to 1.7 percent.

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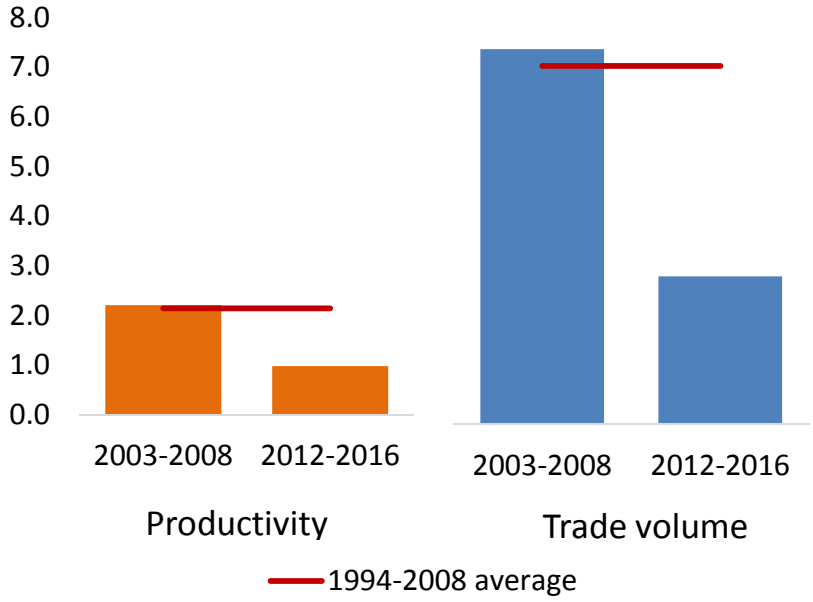
1. Introduction

We are witnessing a decline in the growth of trade and productivity. World trade grew at approximately 3 percent per year from 2012 to 2016, which is much lower than the pre-crisis average of 7 percent for 1994 to 2008. Productivity growth also has declined, to 1 percent per year after the crisis from an average of 2 percent from 1994 to 2008 (figure 1).

Figure 1. Growth in global labor productivity and trade volume, percent



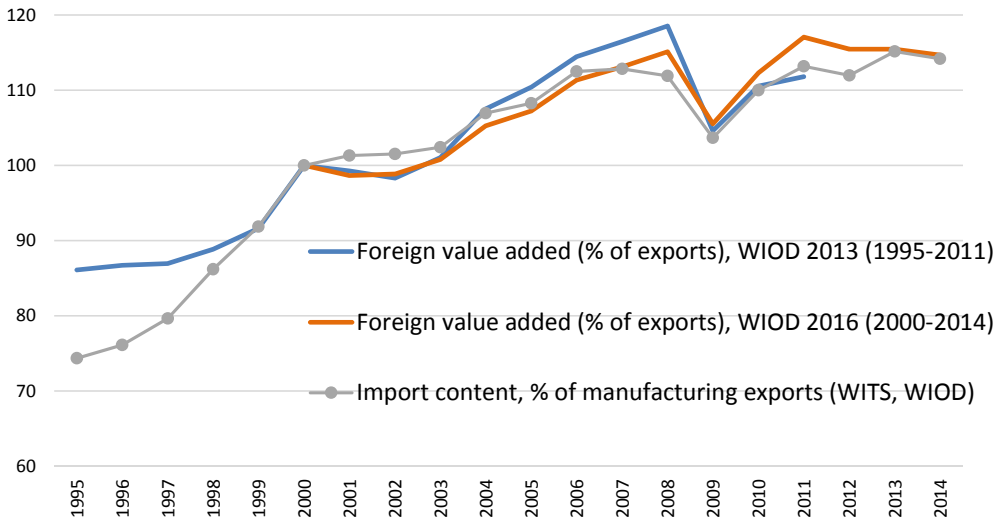
Source: The Total Economy Database (November 2016), International Monetary Fund World Economic Outlook, and authors' calculations.
Note: Trade refers to goods and services. Productivity is measured as gross domestic product in constant U.S. dollars per hour worked.

Consider now the development of global value chains (GVCs) over broadly the same period.[1] One measure of the importance of GVCs is the share of foreign value added embodied in gross exports. Data on this measure from the recent update of the World Input-Output Database (WIOD 2016) point to stalled or even negative growth in vertical specialization since 2011 (figure 2). World GVC participation had been increasing throughout the 2000s, but at a slower rate than in the 1990s. The share of foreign content in manufacturing exports, an alternative

[1] GVC-related data are only available from 1995 to 2014.

measure of vertical specialization, computed using a simplified methodology applied to trade data from UN Comtrade (via WITS) and sectoral output data from WIOD, suggests a similar dynamic.

Figure 2. Measures of world vertical specialization, 1995-2014



Source: The 2013 and 2016 releases of World Input-Output Database (WIOD 2013 and WIOD 2016) (Timmer et al. 2015), UN Comtrade (World Integrated Trade Solution (WITS)), and authors' calculations.
Notes: The measures of vertical specialization based on WIOD 2013 and 2016 data are shares of foreign value added in gross exports of goods and services. The third measure relies on manufacturing trade data from the UN Comtrade (obtained via WITS) and output data from WIOD.

Previous research has demonstrated that the slowing expansion in global value chains can partially explain the current trade slowdown (World Bank Group 2015; Constantinescu, Mattoo and Ruta 2015). Specifically, research has shown, first, that world trade is growing slowly not only because GDP growth is sluggish, but also because the long-run relationship between trade and GDP is changing. The elasticity of world trade to GDP was greater than 2 in the 1990s but closer to 1 and declining throughout the 2000s. Second, the varying pace of the expansion of GVCs is a key contributing factor of the changing long-run relationship between world trade and

GDP. Changes in GVC participation over the period 1990 to 2014 at the world level account for approximately half of the decline in trade elasticity to income. [2]

This note investigates whether changes in vertical specialization, as manifested in GVCs, can explain the current productivity slowdown. Trade in general can lead to productivity gains through multiple channels that are the object of a large body of research.[3] As far as participation in GVCs is concerned, recent theoretical models have shown that productivity gains associated with offshoring and GVCs may accrue from the finer international division of labor, which is isomorphic to factor-augmenting technical change (Grossman and Rossi-Hansberg 2007), as well as from increased competition, greater diversity in input varieties, learning externalities and technology spillovers (Li and Liu 2012; Baldwin and Robert-Nicoud 2014).

Empirical research in support of the theoretical predictions linking GVCs to productivity is limited. Contributions include older strands of work focusing on benefits to countries that initiate offshoring (Feenstra and Hanson 1996; Egger and Egger 2006; Amiti and Wei 2009; Winkler 2010), but also recent efforts that analyze the impact of vertical specialization on countries participating in GVCs (Formai and Vergara Caffarelli 2016, Kummritz 2016, Taglioni and Winkler 2016).

We empirically investigate the link between GVC participation and productivity. Results based on a panel estimation covering 13 sectors in 40 countries over 15 years suggest that participation in GVCs is a significant driver of labor productivity. In our preferred specification, an increase by 10 percent in the level of GVC participation increased average productivity by 1.7 percent. We also perform a number of robustness tests. Interestingly, while trade that is not-GVC related also has a positive impact on productivity, we find that this relationship is less robust.

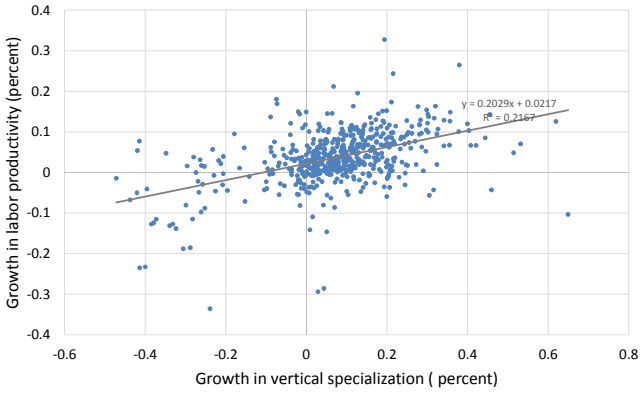
[2] Recent studies by Haugh et al. (2016), Al-Haschimi et al. (2016), and Timmer et al. (2016) confirm this earlier finding. IMF (2016) finds that structural factors account for a quarter of the current global trade slowdown.
[3] See IMF (2016), Chapter 2, for a brief survey.

The rest of the paper is organized as follows. Section 2 presents the data and our empirical strategy. Regression results and robustness tests are discussed in Section 3. Concluding remarks follow.

2. Data and empirical strategy

We begin by inspecting whether manufacturing data by country and year reveal a link between labor productivity and GVCs. Labor productivity is computed as real value added divided by number of persons employed. Vertical specialization in manufacturing is defined as the sum of the foreign value added embodied in exports (backward linkages) and the domestic value added in exports that the direct importer exports further or that returns home as imports (forward linkages). The data (figure 3), indicate a positive association between growth in real labor productivity per employee in manufacturing by country and year, and growth in vertical specialization.

Figure 3. Manufacturing industries: Vertical specialization and labor productivity, 1995-2009



Source: Constantinescu, Mattoo and Ruta (2017) based on data from the 2013 Release of the World Input-Output Database (WIOD 2013) (Timmer et al. 2015).
Notes: Each dot represents a country–year combination. Petrochemicals are excluded from the manufacturing aggregate. Labor productivity is computed as the real value added divided by the number of persons employed. Vertical specialization in manufacturing for each country and year includes the foreign value added embodied in exports (backward linkages) as well as the domestic value added embodied in exports that the direct importer exports further or that returns home as imports (forward linkages).

Although suggestive, the correlation in figure 3 does not demonstrate a causal relationship. Therefore, we provide a more formal econometric analysis of this relationship. The econometric estimation relies on a production function that expresses value added $VA_{c,s,t}$ of industry s in country c and year t as a function of capital, $K_{c,s,t,}$, labor, $L_{c,s,t}$, and a technology shifter $A_{c,s,t}$ (Eq. 1). The latter is driven in part by a range of trade-related determinants (θ_1, $\theta_{2,\ldots,}$ $\theta_{n),}$ that capture both traditional trade and trade occurring in a GVC context.

$$VA_{c,s,t} = A_{c,s,t}(\theta_1, \theta_2, \ldots, \theta_n) * F(K_{c,s,t}, L_{c,s,t}) \quad (1)$$

Dividing by $L_{c,s,t}$ taking logs, and adding fixed effects yields the following reduced form:

$$\ln(LP)_{c,s,t} = \alpha + \beta * \ln(K/L)_{c,s,t} + \sum_{i=1}^{n} \gamma_i * \ln(\theta_{i,c,s,t-1}) + FE_{c,s} + FE_{c,t} + FE_{s,t} + \varepsilon_{c,s,t} \quad (2)$$

Labor productivity - computed as real value added divided by employment - and the real capital stock per employee are denoted by *LP* and *K*, respectively. The effects of trade and participation in GVCs on labor productivity are unlikely to be instantaneous. We capture this idea by lagging the trade-related variables, an approach that may also help alleviate concerns of endogeneity due to reverse causality. A range of unobserved determinants, such as, for instance, labor market reforms, global technology shocks, and time-invariant technology differences across countries and industries, are captured by three types of fixed effects (*FE*): country-industry, country-year and industry-year.

The two main sources of the data are the World Input-Output Database (WIOD 2013) and WIOD Socio-Economic accounts (Timmer et al. 2015). WIOD covers 40 countries, 35 sectors (ISIC rev. 3) and 17 years (1995-2011). [4] Estimations are based on a subsample of 13 manufacturing industries, and span 1995 to 2009 because missing real capital stock caused 2010 and 2011 to be

[4] WIOD updates for the input-output table data have been posted online (as WIOD 2016). They cover three additional countries, period 2000-2014 and ISIC rev.4 industries. However, data on employment, capital stocks and price deflators by industry are not available. Employment and capital flow data from UNIDO extend up to 2013, but the coverage is uneven especially in the recent years.

dropped from the sample.[5] All trade related measures are deflated to eliminate price effects. We focused the analysis on the productivity of manufacturing industries, because these are more GVC intensive. The fact that the participation of services industries in GVCs is more difficult to quantify fully further motivated their exclusion.

To capture vertical specialization, we consider two conventionally used indicators, computed by applying the Leontief's approach to synthetically derived international input-output tables (Hummels, Ishi and Yi 2001; Koopman, Wang, and Wei 2014). The first indicator measures the extent of backward participation in GVCs and consists of the foreign value added embodied in gross exports. The second indicator measures the forward participation in GVCs, and includes the domestic value added embodied in gross exports that direct importers export further or that returns home as imports.

3. Results and robustness tests

Equation (2) is estimated sequentially, as we explore several measures of the trade-related determinants of the technology shifter $A_{c,s,t}$. We start from trade indicators of broad scope and work our way towards specifications that allow for greater focus on the GVC-related trade. While this approach provides an overall perspective of the trade-productivity nexus, it is ultimately intended to minimize the problem of omitted variables in the regressions. Results are provided in columns 1 through 3 of table 1.

As reported in column 1 of table 1, labor productivity is significantly associated with both imports and exports of goods and services. This result is consistent with the literature, which identifies multiple routes through which trade affects productivity: enhanced competition through imports at the same stage of production, greater access to better-quality or more-diverse imported inputs (eg. Amiti and Konings 2007; Goldberg et al. 2010), as well as through learning by exporting (De Loecker 2013).

[5] Data for the sector "Coke, refined petroleum and nuclear fuel" are excluded, to minimize distortions from specific dynamics of fuel and petrochemical exports.

Table 1. Effect of Vertical Specialization on Labor Productivity

	OLS (in levels) Dependent variable (dv): ln(LP)c,s,t			Robustness tests			
				IV (in levels) dv: ln(*LP*)c,s,t		OLS (in differences) dv: dln(LP)c,s,t	
						WIOD-based covariates	UN Comtrade-based covariates
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Real capital stock per employee: ln(K)	0.554***	0.558***	0.545***	0.551***	0.554***	0.620***	0.654***
	(0.0560)	(0.0548)	(0.0572)	(0.0532)	(0.0531)	(0.0748)	(0.0710)
Imports: ln(IMP)	0.122***						
	(0.0351)						
Exports: ln(EXP)	0.125***						
	(0.0234)						
Imports of final goods/services: ln*(FIN_IMP)*		-0.000956	0.00148	0.00875	-0.000563	-0.00186	
		(0.0203)	(0.0213)	(0.0218)	(0.0222)	(0.00883)	
Imports of intermediates: ln*(INT_IMP)*		0.199***					
		(0.0379)					
Exports of final goods/services: ln(*INT_EXP*)		0.0223*					
		(0.0134)					
Exports of intermediates: ln(*INT_EXP*)		0.0227					
		(0.0213)					
Imports of intermediates embodied in domestically-asorbed output: ln(*INT_IMP_noGVC*)			0.0866***	0.0828***	0.0749***	0.0121	0.00120
			(0.0169)	(0.0169)	(0.0155)	(0.00992)	(0.0107)
Foreign value added embodied in exports: ln(*INT_IMP_GVC*)			0.0885***	0.125**	0.168***	0.0447***	0.0338***
			(0.0211)	(0.0491)	(0.0418)	(0.0117)	(0.0130)
Kleibergen-Paap rk Wald F statistics:				49.23	90.74		
Cragg-Donald Wald F statistics:				706.7	747.6		
Country-Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-Year fixed effects	Yes	Yes	Yes	No	No	Yes	Yes
R-squared	0.988	0.989	0.989	0.987	0.987	0.533	0.521
Number of country-industry groups	519	515	519	519	519	518	483
Number of observations	6851	6811	6793	6789	6793	6249	5321

Source: WIOD, UN Comtrade (via WITS), CEPII and authors' calculations. Notes: Robust standard errors corrected for clustering at country-industry level are reported in parentheses. * p<0.10; ** p<0.05; p<0.01. The dependent variable is the real labor productivity (LP), by industry s, country c and year t, calculated as real value added per employee. K is the real capital stock per employee. All indicators are deflated. The instrument for INT_IMP_GVC is the average of the value added originating from Germany, Japan and the United States that is embodied in the exports of three neighboring countries to the country in question, either geographically (col. 4) or as concerns the per capita income level (col. 5). F-statistics exceed the Stock-Yogo (2005) critical values in all cases. In column (6), the allocation of imports to industries is based on WIOD-derived proportionality coefficients, averaged across 1995-2011.

Next, we split imports and exports by the type of goods and services. The results reported in column 2 of table 1 highlight the relative importance of the imported input channel. A 10 percent increase in the level of imports of intermediates increases labor productivity by 2 percent.[6] Coefficients of other types of trade are not significant or weakly significant.[7]

Finally, we dig deeper into the relationship between intermediate imports and labor productivity, by separating GVC-related imported inputs from non-GVC related imported inputs.[8] As discussed, the proxy for GVC-related imports of inputs is the foreign value added embodied in exports, the conventional measure of backward vertical specialization. For imports that are not related to GVCs, we use the foreign value added absorbed domestically. Results presented in column 3 of table 1 suggest that imported inputs matter for productivity whether or not they are related to GVCs, with the two coefficients comparable in magnitude. Specifically, a 10 percent increase in the level of GVC-related or non-GVC-related imports of intermediates increases labor productivity by 0.8 percent.

These findings suggest that GVCs in particular, and trade more broadly, play a role in boosting productivity. However, our efforts to control for omitted variables (through the inclusion of a battery of fixed effects and non-GVC related components of trade) and to deal with reverse causality (by using lagged independent variables) may be insufficient to eradicate all causes of bias in the coefficients of the vertical specialization measures. We attempt to address concerns relating to reverse causality, omitted variables and measurement errors in a series of robustness tests.

First, we use an instrumental variable technique to address the possibility that reverse causality is biasing the coefficient of backward vertical specialization. The approach is based on the work of Baldwin and Lopez-Gonzalez (2015) who argue that there is a technological asymmetry in the

[6] The magnitude of the effect is the result of averaging across countries and sectors that vary widely in their propensity to import intermediates. These compositional aspects may explain why country-specific and firm-level studies typically find larger effects (Amiti and Konings 2007; Blaum, Lelarge and Peters 2014).
[7] The lack of significance of final goods imports and exports of intermediates may result from multicollinearity- because imports of intermediates embodied in exports are included in the import and export covariates.
[8] Including export variables in this specification leads to instability in the backward vertical specialization indicator (INT_IMP_GVC) due to multicollinearity. The same problem affects the identification of the forward vertical specialization indicator, even in regressions that focus on exports components only.

international production networks between "headquarter" and "factory" economies. Headquarter economies (the United States, Germany and Japan) are the main providers of intermediates essential to exporting and arrange the production networks. Factory economies provide the labor. Specifically, Baldwin and Lopez-Gonzalez (2015) find that the headquarter-versus-factory-economy distinction emerges clearly when they analyze the data on backward specialization, which they refer to as "import to export" (or I2E).

Based on this finding, for each country c, industry s and year t, the instrument is computed as the average foreign value added from the United States, Japan and Germany embodied in exports of industry s of three countries in the sample that are closest geographically or in income to country c.[9] The underlying assumption is that technological developments in these three countries (i.e. the information and communication technology revolution) and declining trade costs globally were the main drivers of GVC expansion.[10] The instrument is positively and significantly correlated with the backward vertical specialization measure and standard tests rule out its weakness.[11]

The results in columns 4 and 5 point to a significant effect of the foreign value added embodied in exports on labor productivity.[12] Focusing on the specification reported in column (5), which may more effectively address any endogeneity problem than the one in column (4) (see footnote 11), a 10 percent increase in the level of GVC-related trade is associated with an increase in labor productivity of 1.7 percentage points. The impact of GVC-trade on labor productivity is somewhat larger than that of non-GVC trade.

[9] Distance data are from CEPII, and per capita PPP income from the International Monetary Fund World Economic Outlook.
[10] Our identification strategy is similar to the approach used in Autor, Dorn and Hanson. (2013) who instrument the import growth in the United States from China with the Chinese import growth in other high-income markets.
[11] There is a small risk that this instrument violates the exclusion restriction because the expansion of GVCs into neighboring countries might be at the expense of the participation of the country in question, or there may be spillovers from productivity benefits from expansion of GVCs into neighboring countries. The first effect would in fact work against finding a positive relationship, while the second could lead to a biased estimate. Even though we doubt the significance of the second channel, we attempted to address this concern by defining neighborhood not just in geographical terms, but also in income terms.
[12] Industry-year fixed effects tend to absorb the variation in our instrument in the second stage regressions, and are therefore excluded from the IV estimation.[13] Country imports are assigned to industries based on WIOD-based simplified coefficients of proportionality. Like the conventional indicator, the alternative one is deflated using WIOD price deflators.

Second, to deal with the problem of omitted variables, we run alternative regressions to those presented in column 3, using a differenced dependent variable as well as the standard covariates. This specification is more demanding than the one in levels because it deals with time-invariant country-industry heterogeneity in two ways. The first control is implicit and it is due to the fact that differencing itself wipes out the impact of potential country-industry omitted variables such as technology differences across countries, industries, or country-industry pairs. The second control is explicit, in the form of the country-industry fixed effects, and captures the fact that some country-industry pairs are more dynamic participants in GVCs or exhibit higher technical progress than others throughout the period of analysis (Amiti and Wei 2009). In the results presented in column 6, only imports associated with vertical specialization are significant. Specifically, an acceleration in the pace of the backward vertical specialization by 10 percentage points increases the average productivity growth by close to half a percentage point.

Finally, we try to address two sources of measurement error associated with the conventional vertical specialization measures: the application of Leontief's methodology to estimate value added in all production stages, and the extrapolation techniques used to obtain input-output tables in years with no data. Using real trade data from WITS and the formulation in Hummels, Ishii and Yi (2001, page 78), we construct an alternative measure of backward vertical specialization in manufacturing industries, that essentially captures - for industry s in country c - the foreign content of directly imported inputs embodied in exported output.[13] We use the alternative indicator in place of the conventional backward vertical specialization measure in the difference specification presented in column 6. The results reported in column 7 support the original conclusion that growth in GVC-related trade and growth in labor productivity are positively and significantly associated.

4. Conclusion

This note provides evidence that global value chains boost productivity. While there are many other factors that determine the rate of productivity growth, this evidence suggests that the

[13] Country imports are assigned to industries based on WIOD-based simplified coefficients of proportionality. Like the conventional indicator, the alternative one is deflated using WIOD price deflators.

slower pace of GVC expansion is also contributing to the slower growth of world productivity. Data constraints have limited the scope of this exercise, especially in terms of the countries covered. Improvements in data would help to determine the broader validity of these conclusions. Beyond establishing the relative importance of backward participation in GVCs – i.e., the reliance on imported inputs to produce for exports - the analysis has also not fully illuminated the channels through which GVCs contribute to enhanced productivity. Understanding these channels, as well as how policy can either inhibit or encourage them, is an important area for future research.

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