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Measuring trade in value added: How valid is the
proportionality assumption?

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ABSTRACT

The validity of the ‘proportionality assumption’ made in estimating value added in exports using aggregate input-output tables is tested using separately compiled domestic- and imported-input matrices for Indonesia, Thailand, Malaysia, Taiwan, and Australia. The results show that the use of the proportionality assumption results in overestimation of value-added exports, and that the magnitude of the bias becomes amplified when the export composition of a country shifts from primary products to manufactured goods through integration into global production networks.

JEL Classification Codes: F13, F14, O19, O24

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1. Introduction

It is now widely accepted that measurement based on trade data from Customs records (gross trade data) leads to overestimation of value added of exports, because ever-increasing share of global manufacturing production and trade takes place within global production networks (GPNs) (Lamy 2013). Within GPNs, value addition occurs at every stage of the value chain at each geographical location, with intermediate inputs crossing national borders many times in the process of making a final good. In response, several initiatives have been taken to measure ‘value-added’ in exports using the input-output tables (Brumm et al. 2009; Trimmer et al. 2014; Johnson 2014, Johnson and Noguera 2012 and 2017). The World Trade Organisation has joined hand with the Organisation of Economic Cooperation Development (OECD) to develop the Trade in Value Added (TiVA) database¹, which is now widely used in analysing trade interdependence among countries.

Input-output tables fall under two categories: ‘non-competitive type’ that presents domestic and import transactions in two separate inter-industry matrices, and ‘competitive type’ that lumps together the two types of inputs a single inter-industry table (Miller and Blair 2009). Input-output tables available for most countries (including major trading nations such as the USA, China and India) belong to the latter category. Value added exports for these countries are estimated by creating a ‘proxy’ imported-input matrix based on the ‘proportionally assumption’, that is the proportion of import content in the production of exports in each industry is identical with the average import content proportion in the production for the domestic market. However, even when industries are finely classified, in reality import content of an industry’s production for export tends to be higher than that in its production for home market because of the requirement to meet quality and other standards set by the foreign buyers (Michaely 1984; Koopman, Wang, and Wei 2014; Kee and Tang 2016). The validity of the proportionality assumption is

¹Available at <http://www.oecd.org/sti/ind/measuring-trade-in-value-added.htm>

even more questionable at the level of commodity disaggregation (mostly the 3-digit level of the International Standard Industry Classification) common to input-output tables.

In this paper, we test the validity of proportionality assumption using input-output tables of Indonesia, Thailand, Malaysia, Taiwan and Australia for which non-competitive type I-O tables are available. These countries represent different stages of export commodity diversification and engagement in global production sharing that add to the richness of our analysis.

2. Methodology

We begin with an input-output framework of the non-competitive import type. Let $\mathbf{X}$ be an $n \times 1$ vector of gross output and $\mathbf{M}$ be an $n \times 1$ vector of imports, and $\mathbf{Y}^D$ is an $n \times 1$ vector of final demands (consumption, investment, and exports) and $\mathbf{Y}^M$ is an $n \times 1$ vector of final demands for imports. Then we have:

$$\mathbf{A}^D \mathbf{X} + \mathbf{Y}^D = \mathbf{X} \quad (1)$$

$$\mathbf{A}^M \mathbf{X} + \mathbf{Y}^M = \mathbf{M} \quad (2)$$

where, $\mathbf{A}^D = [a_{ij}^D]$ is an $n \times n$ matrix of direct input coefficients for domestic products and $\mathbf{A}^M = [a_{ij}^M]$ is an $n \times n$ matrix of direct input coefficients for imported goods. That is,

$$a_{ij}^D = z_{ij}^D / X_j \quad (3)$$

$$a_{ij}^M = z_{ij}^M / X_j \quad (4)$$

where z_{ij}^D and z_{ij}^M are elements of $n \times n$ matrices $\mathbf{Z}^D$ and $\mathbf{Z}^M$ - the domestic and imported intermediate inputs transaction tables, respectively. We solve (1) for $\mathbf{X}$,

$$\mathbf{X} = (\mathbf{I} - \mathbf{A}^D)^{-1} \mathbf{Y}^D \quad (5)$$

where the first term in the right-hand side is the Leontief domestic inverse matrix with $\mathbf{I}$ being an identity matrix. The element of this matrix, $\tilde{a}_{ij}^D$, is the input required in the i th sector to sustain one unit of the output of j th sector.

The foreign content of domestic production (VS) is given by,

$$VS = \mathbf{u}\mathbf{A}^M(\mathbf{I} - \mathbf{A}^D)^{-1} \quad (6)$$

where $\mathbf{u}$ denotes an $1 \times n$ unity vector and $\mathbf{I}$ is the $n \times n$ identity matrix. Therefore, the domestic value added (DV) in exports is

$$DV = 1 - \frac{\sum_i (VS \times E)_i}{\sum_i E_i} \quad (7)$$

where $\mathbf{E}$ is gross exports.

Let us assume that the given country has only a competitive type I-O table. To estimate value added export we need to create a ‘proxy’ imported input transaction matrix.

Following the procedure laid out in NRC (2006), we allocate the total imports across sectors in the *same* proportion as total input use:

$$\mathbf{Z}^{MP} = [z_{ij}^{MP}], \quad z_{ij}^{MP} = (z_{ij}/S_j)M_j \quad (8)$$

where z_{ij} is the i,j -th element of total transaction matrix $\mathbf{Z}$ (from sector i to sector j), S_j is sector j ’s total use and M_j is its total import. The proxy, $n \times n$ import input-output coefficient matrix is therefore $\mathbf{A}^{MP} = [a_{ij}^{MP}]$, where

$$a_{ij}^{MP} = z_{ij}^{MP}/X_j \quad (9)$$

The ‘proxy’ foreign content of domestically produced output is:

$$VS^P = \mathbf{u}\mathbf{A}^{MP}(\mathbf{I} - \mathbf{A}^D)^{-1} \quad (10)$$

where A^{MP} has replaced A^M in equation (2). The proxy domestic value added in exports is

$$DV^P = 1 - \frac{\sum_i (VS^P \times E)_i}{\sum_i E_i} \quad (11)$$

3. Data

We estimate valued added in exports using equation (7) and (11) for Indonesia, Thailand, Malaysia, Taiwan, and Australia. In order to capture changes in export composition for each country we use I-O tables for intermittent years depending on data availability over two decades. The countries are chosen mainly because of the availability of non-competitive type IO tables directly constructed by the national statistical authorities, but these countries do exhibit considerable variability relating to the share of manufactured goods in export composition and the degree of engagement in GPNs (Table 2).

Table 1. Summary data on export structure

		Share of manufacturing in total merchandise exports	Share of exports within GPNs ¹ share in manufacturing exports
Indonesia	2000	66.8	30.8
	2010	54.9	31.6
Malaysia	2000	80.7	79.2
	2010	74.0	72.1
Thailand	2000	79.4	59.8
	2010	78.8	65.7
Taiwan	2001	79.2	72.6
	2011	83.3	76.5
Australia	2007	39.3	48.6
	2012	28.3	45.7

Note: 1. Parts and components exported within global production networks.

Source: Column a: calculated from input-output tables. Column b: computed using the commodity classification system and the data described in Athukorala (2014).

4. Results

Per unit value added of exports estimated directly from separate domestic- and imported input matrices ('direct' estimates) and those estimated under the proportionality assumption ('proxy' estimates) are reported separately for total exports and manufacturing exports in Table 2. The estimates, taken together with the export-structure data in Table 1, yield three important inferences.

Table 2. Domestic value added in exports: direct and proxy estimates (%)

		Direct value added		Proxy value added		Bias= [(proxy – direct)/direct]*100	
		All sectors	Manufacturing	All sectors	Manufacturing	All sectors	Manufacturing
Indonesia	1995	87.1	81.9	87.8	83	0.8	1.3
	2000	80.6	76.4	84.3	81.2	4.6	6.3
	2005	83.2	79	85.8	82.4	3.1	4.3
	2010	85.2	80.2	87.4	83.2	2.6	3.7
Malaysia	1991	62.5	53.2	68.8	61.2	10.1	15.0
	2000	47.7	40.7	59.2	53.3	24.1	31.0
	2010	59.6	51.8	67.6	61.3	13.4	18.3
Thailand	1995	66.6	60.6	70.9	66.2	6.5	9.2
	2000	59.1	52.7	65.4	60.8	10.7	15.4
	2005	55.6	48.7	61.2	56.2	10.1	15.4
	2010	59.4	53.1	64.4	59.4	8.4	11.9
Taiwan	1996	63.8	59.6	70.5	66.5	10.5	11.6
	2001	60.4	54.9	68.2	63.5	12.9	15.7
	2006	50.4	45.1	58.1	53.3	15.3	18.2
	2011	48	42.7	55.6	51	15.8	19.4
Australia	1998	84.8	77.1	87.2	81.9	2.8	6.2
	2005	85.6	78.8	87.5	82.2	2.2	4.3
	2007	84.7	77.3	87.1	81.6	2.8	5.6
	2012	84.7	73.7	86.9	78.4	2.6	6.4

Source: estimated from I-O tables using the methodology discussed in Section 2.

First, for all countries proportionality assumption consistently leads to an overstatement of domestic value added in exports for both total and manufactured exports. This comparison is consistent with the view that production for exports tends to be more import intensive compared to production for the domestic market. This finding is also consistent with that of Winkler and Milberg (2012) for German manufacturing.

Second, the discrepancy between direct estimates and proxy estimates is in general greater for manufacturing than for total production. Moreover, the discrepancy is much smaller for Indonesia and Australia. In these countries manufactured goods account for a smaller share of exports (Table 1) and most of these products are concentrated in resource

based industries (Sturgeon and Memedovic 2010), compared to the other three countries'. The upshot is that as an economy becomes more diversified into manufacturing from primary production, the validity of the proportionality assumption becomes increasingly unrealistic.

Third, the differences between direct and proxy estimates for manufactured goods are larger in Taiwan, Malaysia and Thailand, which are highly integrated into global production network (GPN) compared to Indonesia and Australia. Interestingly, discrepancy is much larger for Taiwan, which is at a more advanced stage in integration into GPN compared to Malaysia and Thailand. This comparison suggests that the validity of the proportionally assumption diminishes with the increase in exports taken place within GPNs. The data summarized in Table 3 for Taiwan, Malaysia and Thailand relating to selected I-O sectors that are heavily integrated within GPNs provides further support for this inference. Estimation biases for all these sectors are larger compared to those of total manufactured exports in these countries (between 2% to 8%, Table 2).

Table 3. Domestic Value added in exports of selected GPN products (%)

	Direct	Proxy	Bias
<i>Malaysia (2010)</i>			
Semi-conductor devices, tubes and circuit boards	36.1	49.2	13.1
TV, radio receivers & transmitters & assoc. goods	47.9	59.9	12.0
Office, accounting and computing machinery	35.9	51.1	15.2
<i>Thailand (2010)</i>			
Office and household machinery appliances	53.6	59.3	10.6
Motor vehicles	42.7	52.5	9.8
Radio, television and comm. equipment and apparatus	27.2	37.3	10.1
<i>Taiwan (2011)</i>			
Semi-conductors	48.3	61.5	13.2
Optoelectronic materials and components	43.0	56.1	13.0
Communication equipment	45.7	60.5	14.8

Source: Computed from input-output tables using the methodology discussed in Section 2.

5. Conclusion

Our analysis yields three inferences. First, the value added of exports is overstated when measured using aggregate (competitive-type) I-O tables based on the proportionality assumption. Secondly, the discrepancy is greater for manufacturing compared to total exports. Finally, countries' integration into global production networks tends to compound the discrepancy.

The obvious way to address the issue is of course to encourage countries to moving from 'competitive' to 'non-competitive' approach in compiling their I-O tables. Until this requirement is met, it is important to clearly spell out the limitations of the proportionality assumption in 'user-guides' to the existing databases, while clearly indicating the countries for which 'non-competitive' I-O tables are available, in order to help the users to qualify their inferences.

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