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Tesi di dottorato

THE VALUE-ADDED STRUCTURE OF TRADE FLOWS AND ITS IMPLICATIONS FOR TRADE POLICY ANALYSIS

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INTRODUCTION

International trade has never been unfettered and governments, with no exceptions, do intervene in trade across borders, globalization notwithstanding. Undoubtedly, after decades of efforts to render *trade flows smooth, free, fair and predictable*, through multilateral and bilateral negotiations, standard barriers have been overall strongly reduced and import tariffs are at historically lowest levels. However, at the sector level, sensitive sectors like labor-intensive manufactures (e.g. textiles and clothing) and agriculture result to be still differently protected on an effective base: they are subject to tariff peaks and tariff escalation. In the aftermath of the financial crisis, many analysis stressed the limited use of protectionist measures as countercyclical response to the severity of the post-2008 recession. Nevertheless, once the slowdown in global growth became apparent in 2012, the worldwide resort to protectionism had an acceleration.

Against the widespread perception in international trade research that the success of trade policy has rendered it less relevant, a recent strand of literature has emerged with the aim of investigating the conceptual and analytical consequences of the increased complexity of international trade patterns for trade policy analysis. The large diffusion of international networks and the increase in geographical fragmentation of productive processes in global value chains (GVCs) bring development in trade of intermediate goods at different stages of processing. Traded intermediates pass through GVCs and cross borders multiple times, directly implying that even small levels of tariffs, if cumulatively repeated, matter. In this context, nominal level of tariffs, which are applied on gross values, are a poor indicator of the protection granted to a national income. The development of new measures of value-added trade, brings back the effective protection rate in trade policy analysis. The theory of tariff structure accounts for the role of intermediate inputs and suggest to consider both tariffs on inputs and on outputs in the computation of the effective protection. Thanks to the diffusion of new data reporting inter-country, inter-sector transactions (e.g. WIOD, TiVA, GTAP), which allows to identify the origin of imported intermediate inputs, the measurement of the effective protection rate could be improved. From the point of view of market access, the effective protection rate is an indicator of the additional cost that importing firm pays for inputs, where the ability to source competitive imports is a crucial variable for firms in participating in GVCs. Also, when international competitiveness is concerned, it is a useful indicator of the overall impact of tariffs on intermediate inputs on the price of the output.

However, when one looks at the “true” structure of trade beyond gross statistics, the effective protection gives distorted and narrow lens through which a sector’s performance can be addressed. They are distorted because not only the effective protection rate as an index of value-added price changes has no definite relationship to general equilibrium output effects, but the effective schedule of price effects is finally unknown when several nodes of chains may develop completely outside the country before reaching the domestic sector. They are narrow since a further implication of the increase of vertical specialization is that indirect effects are in place, so that mercantilist-styled *beggar thy neighbour* strategies can turn out to be *beggar thyself’* miscalculations. If production processes are interconnected in international chains, a country’s incentive to impose import protection is altered, since restrictive measures impact domestic firms exporting intermediate inputs processed abroad and then imported back. Moreover, tariffs applied to the direct partner have indirect effects on third countries supplying inputs which are embodied in bilateral flows. With value chains that are global, new questions arise with respect to the effects of trade policy on value added: *what is the impact of the overall tariff system of a country on its value added which is activated by its trade*? Further: *what is its impact on the value added originated worldwide and embedded in a country bilateral flows*? This work conceptually and analytically extends the focus of the effective protection to account for the international fragmentation of productive processes, and gives a new “value added trade restrictiveness index” (VA-TRI) which is theoretically grounded, thus solving the main problem of aggregation in the measurement of protection. In a general equilibrium framework, the index which is proposed for the economic assessment of trade restriction in the contest of GVCs, synthesizes the upstream/downstream linkages and the protectionist measures on different sectors. The VA-TRI allows to assess the impact the bilateral protection has on different value added components distinguished by their origin. In order to measure the overall protectionist stance in terms of value added rather than with reference to the more traditional metrics, such as gross trade, we make use of the decomposition methods proposed in macro approaches by recent value-added trade literature.

The bulk of the analysis on the value-added trade is focused in giving a correct account of gross exports, with the exception of Foster-McGregor and Stehrer (2013). However, starting from the work of Koopman, Wang, and Wei (2014), the role of the double-counted components in gross trade statistics can be hardly ignored as the previous measure does. Thus, extending the prevalent focus on the export side, we give a variant for the decomposition of both final and intermediate trade with reference to the imports, at the bilateral and sector level. In the descriptive analysis presented in this work, we apply the decomposition of bilateral imports – which distinguishes imports by domestic usage, e.g., domestic consumption either direct or indirect or production for exports – and compare the results which are obtained through data from the two main databases used in GVCs analysis, that is GTAP database and WIOD. This development contributes to a better understand of the content of imports and to quantify the double-counting which is contained in gross statistics. Furthermore, the comparison between the two databases sheds light on the main differences and may give indications on which data are more suitable depending on the dimension under examination.

Finally, we empirically address the incidence of trade policies in a GVCs framework. In our comparative static analysis, we adapt and extend the code and data of a newly developed version of the GTAP model with sourcing of imports by agent, in order to implement the value-added decomposition of trade flows thus obtaining the reference criteria for the equivalent impact of trade policy. We bilaterally compute the VA-TRI for three of the major economies, European Union, United States and China.

1. The theory of tariff structure and the international fragmentation of production

Abstract

Following a critical review of the tariff structure theory, this work conceptually and analytically extends the focus of the effective protection in order to account for the relevance of global value chains (GVCs). We propose a new trade policy analysis instrument -à la Anderson and Neary- in a context of international fragmentation of productive processes. The "value added trade restrictiveness index" (VA-TRI) is theoretically grounded, thus solving the main problem of aggregation in the measurement of protection. In a general equilibrium framework, and using the decomposition methods proposed in macro approaches in the recent value added in trade literature, the index gives summary statistics for both the direct and indirect effects of protectionism.

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1.1 Introduction

International trade has never been unfettered and governments, with no exceptions, intervene in across border trade, globalization notwithstanding. Undoubtedly, following decades of efforts to render *trade flows smooth, free, fair and predictable*[1], through multilateral and bilateral negotiations, standard barriers have been reduced overall, and import tariffs are currently at historically low levels. Average applied rates in high income economies are in aggregate low (1.7% in 2012, down from 39.4% in 1996), and have been substantially reduced in middle- and low-income countries (respectively, from 13% to 4.9%, and from 35.6% to 9.6%, for the same reference years)[2]. At sector level, import tariffs on manufactured products in industrialized countries are at a very low level; however, sensitive sectors such as labor-intensive manufacturing (e.g. textiles and clothing) and agriculture are still significantly protected on a nominal base, and they are subject to tariff peaks and tariff escalation.

In the aftermath of the financial crisis, many analyses stressed the limited use of protectionist measures as a countercyclical response to the severity of the post-2008 recession (among others: Hoekman, 2012; Bown and Crowley, 2013; IMF, 2013). However, once the slowdown in global growth became apparent in 2012, the worldwide resort to protectionism accelerated. Among the discriminatory measures implemented since late 2008, traditional forms of protectionism continue to play an important role, still accounting for slightly less than 50 percent of total measures (Evenett, 2014:61; WTO 13th report on G-20 trade measures, 2015a). They are the most frequent form of protectionist measures affecting vulnerable poor countries, with an incidence more than twice that for non-tariff measures (Evenett and Fritz, 2015).

Against the widespread perception in international trade research that the success of trade policy renders it less relevant, a recent strand of literature has emerged aimed at investigating the conceptual and analytical consequences of the increased complexity of international trade patterns for trade policy analysis. The wide diffusion of international networks, and the increased geographical fragmentation of productive processes in global value chains (GVCs) imply that intermediate goods cross borders several times. These developments in the international division of labor - emerging from what Baldwin (2006) calls globalization 2nd

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[1] https://www.wto.org/english/thewto_e/whatis_e/inbrief_e/inbr02_e.htm

[2] Tariff rate, applied, weighted mean, all products (%). World Bank staff estimates using the World Integrated Trade Solution system, based on data from United Nations Conference on Trade and Development's (UNCTAD) Trade Analysis and Information System (TRAINS) database and the World Trade Organization's (WTO) Integrated Data Base (IDB) and Consolidated Tariff Schedules (CTS) database.

unbundling - have led countries to countries' increasing involvement in task trade (Grossman and Rossi-Hansberg, 2008) where value is added at various steps performed in different locations. Traded intermediates pass through GVCs and cross borders multiple times with the direct consequence that even small levels of tariffs when cumulated matter. As noted first by Yi (2003), the cost of vertical trade is more sensitive to tariff duties compared to traditional trade (in final goods) due to tariff amplification in GVCs. It is not only traded intermediates inputs that incur tariffs with each shipment to another country for further processing, tariffs also are amplified by being applied to the import value which can be less than the value which effectively is added in the final country in the productive process.

In this context, nominal level of tariffs is a poor indicator of the protection granted to a national economy. Tariff structure theory accounts for the role of intermediate inputs and suggests consideration of the tariffs on both inputs and outputs in the computation of the *effective* protection. Thus, the effective level of protection granted to a sector is related to its value added, and is measured as the increase in value added per unit of output in an economic activity which is made possible by the tariff structure *ceteris paribus* relative to the hypothetical free-trade situation. The development of value-added trade measures, reinserts the effective protection rate into trade policy analysis. The diffusion of new data reporting on inter-country, inter-sector transactions (e.g. WIOD, TiVA, GTAP), allows us to identify the origin of imported intermediate inputs, and the measurement of the effective protection rate is improved, i.e. by adjusting most favored nation MFN tariffs for preferential treatments, where relevant, and incorporating the indirect consumption of inputs in the original definition of effective protection (Diakantoni and Escaith, 2012; Rouzet and Miroudot, 2013). From the point of view of market access, the effective protection rate is an indicator of the additional cost that the importing firm pays for inputs, where the ability to source competitive imports is a crucial variable for firms participating in GVCs. Also, in the context of international competitiveness, it is a useful indicator of the overall impact of tariffs on intermediate inputs on the price of the output (WTO, UNCTAD, and ITC, 2015).

However, if the "true" structure of trade beyond gross statistics is considered, new interesting questions arise with respect to the effects of trade policy. In particular, another implication of the increase of vertical specialization is that *indirect* effects occur, so that mercantilist-styled beggar thy neighbour strategies can turn out to be beggar thyself' miscalculations (IMF, 2013; Miroudot and Yamano, 2013). If production processes are interconnected in chains involving many countries, a country's incentive to impose import protection is altered (Blanchard et al., 2016), since restrictive measures impact on domestic firms exporting intermediate inputs processed abroad and then re-imported. Moreover, tariffs applied to the direct partner have indirect effects on third countries supplying inputs which are embodied in bilateral flows. Thus, in evaluating the overall repercussions of trade policies a framework which conceptually and analytically extends the focus of the effective protection could be useful.

This chapter is organized as follows. Section 2 deals with the tariff structure theory, and introduces the concept and definition of the effective protection. Through the lens of its underlying assumptions, the theoretical evolution of effective protection is described (section 3), and developments in its application are analyzed (section 4). In section 5 we deal with the role of protection with international fragmentation of production. After describing the theoretically-based method for trade policy assessment (section 6), we propose an index of trade protection in value added (section 7). This extends the set of 'trade restrictiveness indexes' introduced by Anderson and Neary (1996; 2005) and accounts for the international fragmentation of production in GVCs. Using the decomposition methods proposed in the macro approaches in the recent value added in trade literature, the index is constructed so as to distinguish at the bilateral level, the domestic and foreign (bilateral or indirect) value-added content of imports. The main contribution is to develop a new instrument for trade policy analysis able to replace gross metrics with a value-added framework, and provide summary statistics for both the direct and indirect effects of protectionism.

1.2 Traditional tariff structure theory: concept and definitions

The *theory of tariff structure* was developed in the 1960s and systematically articulated (Johnson, 1965, 1969; Balassa, 1965; Corden, 1966, 1969). It originated from "the recognition that an industrial society is a complex of economic activities or processes each of which uses as inputs the products of other processes and produces outputs that in part serve as inputs into other processes" (Johnson, 1969:120). Thus, the idea of *effective protective rate* with respect to trade policies is concerned with "the effect of tariffs in a system with many traded goods", allowing "for the vertical relationship between tariff rates derived from the input-output relationship between products" (Corden, 1966:221). When the presence of intermediate inputs is acknowledged, the effective level of protection granted to a sector must be related to its value added, which is the remuneration for the productive factors used by that sector. Specifically, it is measured as the increase in value added per unit of output in an economic activity which is enabled by the tariff structure *ceteris paribus* relative to the hypothetical free-trade situation.

Let j and $i = 1, \ldots, n$ index sectors; define v_j as the value added per unit of good produced in sector j under free trade, and $v_j^{'}$ as the value added per unit of good j in the tariff-distorted situation; then, the effective protection rate (e_j) is:

$$(1) \qquad e_j = \frac{v_j^{'} - v_j}{v_j} \quad .$$

In the framework of an input-output system, v_j is computed as a residual after subtracting the unitary cost of all intermediate inputs from the unitary price of j. It can be defined as:

$$(2) \qquad v_j = p_j - \sum_i p_i z_{ij} \quad ,$$

where p_j and p_i are the prices of j and i respectively; z_{ij} is the physical input i per unit of output j. Since $z_{ij} = \frac{p_j}{p_i} a_{ij}$, where a_{ij} is an element of the structural (or technical input-output) value coefficients matrix A, giving the value of i per unit of output in j (at free trade prices), we get:

$$(3) \qquad v_j = p_j \left(1 - \sum_i a_{ij} \right) .$$

Let t_j and t_i be the nominal tariff rates on j and i; the tariff-distorted value added is:

$$(4) \qquad v_j^{'} = (1 + t_j) - (1 + t_i) \sum_i a_{ij} .$$

By substitution, equation (1) can be expressed as:

$$(5) \qquad e_j = \frac{t_j - (\sum_i t_i \, a_{ij})}{1 - \sum_i a_{ij}} ,$$

where $\sum_i t_i \, a_{ij}$ is the weighted average of input tariffs.

It is straightward to verify that the effective rate of protection (e_j) reduces to the nominal rate when there are no intermediates, that is for $a_{ij} = 0, \forall \, i = 1, .., n$; with intermediate inputs, the *effective* protection may depart widely from the nominal protection enjoyed by the final output sector. In particular, for the same value added per unit under free trade, e_j is greater than, equal to, or smaller than the nominal tariff rate on the final good according since the latter rate is greater than, equal to, or smaller than the nominal tariff rate on the intermediate inputs[3].

For example, assume a two-step productive process in which the final good is worth 1.000,00. The value of intermediate inputs used to produce the final good is 600,00; thus the value added under free trade is 400,00. A tariff of 20% is imposed on final production implying an increase in the price of output which is now sold to consumers at 1.200,00. If the nominal rates on inputs are zero, then the final step in production is *effectively* receiving a protection of 50% (the value added for output is now 600,00, hence 200,00/400,00*100=50%). If inputs are protected at the same level of 20%, the effective and the nominal protection will coincide. Finally, if tariffs on inputs are, say, 40%, then the cost of inputs is 840,00 and the effective protection on final output would be negative (-10%). The numerical example is reported in figure 1.1.

Figure 1.1 *Nominal tariffs and effective protection rates.*

Tariff on output	*Price of output*	*Tariff on input*	*Price of intput*	*Value added*	*Effective protection rate*
0%	1.000,00	0%	600,00	400,00	0%
20%	1.200,00	0%	600,00	600,00	50% [(600,00-400,00)/400,00*100]
20%	1.200,00	20%	720,00	480,00	20% [(480,00-400,00)/400,00*100]
20%	1.200,00	40%	840,00	360,00	-10% [360,00-400,00)/400,00*100]

Consider now an alternative form of (1) and (4):

$$(6) \qquad e_j = \frac{t_j}{v_j} - \frac{\sum_i t_i \, a_{ij}}{v_j},$$

then, the *dual subsidy-tax influence of the tariff structure* on the activity of sector j can be captured if the first term in (5) is interpreted as the gross subsidization rate (increment) per unit of value added in j due to t_j, and the second as the implicit tax rate (reduction) per unit of

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[3] For simplicity, consider the simple case of a unique input. It is possible to construct a mathematical equivalent by adding and subtracting the same quantity $t_j a_{ij}$ in the numerator of e_j:

$$e_j = \frac{t_j - t_j a_{ij} + t_j a_{ij} - t_i a_{ij}}{1 - a_{ij}} = \frac{t_j(1 - a_{ij}) + (t_j - t_i) a_{ij}}{1 - a_{ij}} = t_j + (t_j - t_i)\frac{a_{ij}}{1 - a_{ij}}$$

in order immediately to obtain the following when assuming the general case $a_{ij} < 1$:
if $t_j = t_i$, then $e_j = t_j = t_i$;
if $t_j > t_i$, then $e_j > t_j > t_i$;
if $t_j < t_i$, then $e_j < t_j < t_i$.

value added in j resulting from the tariffs on intermediate inputs used in sector j (Johnson, 1969). If the latter is of sufficiently high level which exceeds the level of protection at the final good stage, sector j receives negative effective protection ($e_j < 0$) even if the nominal rate on its output is strictly positive. This reflects a tariff structure which is negatively affecting the value added in j. e_j can be negative even for a *negative value added* under free trade (at world prices), which signals a production that could not exist without tariff protection[4].

Setting aside the negative value added case, the effective protection rate will be higher the higher is the difference in the value added per unit computed under protected trade or under free trade. Moreover, for the same distance between the two measures of value added per unit, the effective protection will be higher the lower is the free trade value added per unit. This can be seen through the sign of the derivatives of (4) with respect to each variable:

$$\begin{aligned} &\frac{\partial e_j}{\partial t_j} = \frac{1}{1-\sum_i a_{ij}} > 0\,; \quad \frac{\partial e_j}{\partial t_i} = \frac{-\sum_i a_{ij}}{1-\sum_i a_{ij}} < 0\ ; \\ &\text{and} \quad \frac{\partial e_j}{\partial a_{ij}} = \frac{t_j - t_i}{\left(1-\sum_i a_{ij}\right)^{2}} > 0\ \left(\text{for } t_j > t_i\right)\ . \end{aligned} \tag{7}$$

The framework given by the effective protection allows systematic consideration of the overall tariff structure, shedding light on the direction of its resource-allocation effects. As shown by Corden, resources will be drawn from the tradable industry with a lower effective protection on the tradable industry with the higher rate, and from both for tradable industries which are not protected (Corden, 1966), since the sector with the relatively high effective protection will increase remuneration of the productive factors compared to a situation of no trade distortions. In the next section, we specify the effective protection in partial equilibrium in order to address it explicitly as an indicator of resource allocation.

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[4] Refer, e.g., to Guisinger (1969) for a formal treatment of the implications of a *negative value added* at world prices for the theory of effective protection.

1.3 On the validity of the effective protection rate

Grubel and Johnson (1967) predicted that the effective protection rates would receive at least as much attention as nominal rates in international tariff negotiations (Grubel and Johnson, 1967:761). It is probable that the main strength of the effective protection rate is to provide policy analysts with an instrument to address the impact of commercial policy on world trade and specialization patterns which is tractable and requires relatively parsimonious data.

There are two alternative empirical approaches to implement the effective protection definition. A "detail[ed] study of the influence of the tariff structure on a particular narrowly-defined industry or output process" can be performed, or a more aggregated level can be accepted and the input-output tables used as a source of information (Johnson, 1969:121). The first micro-approach allows for a high degree of disaggregation but entails a serious problem related to aggregating the results into general conclusions about the effects of tariff structures. The latter approach is based on partial equilibria which are presumed to give general predictions. It is clear that this comes at the cost of imposing several restrictive assumptions in order to implement the index.

The economy described through the effective protection lens is characterized by the following assumptions:

(a) the tariff rate represents the rate of divergence between the free trade and protected prices in a tradable (small country);

(b) constant coefficient (e.g. Leontief) technology and/or separability between primary inputs and intermediate inputs;

(c) infinite foreign elasticities of demand (for all exports) and supply (of all imports);

(d) production and trade in tradable goods remain after protection;

(e) a two-step production process;

(f) the elasticity of supply of domestic factor inputs is less than infinite;

(g) perfect competition;

(h) production function with constant returns to scale;

(i) no joint-production.

If all the above are assumed, then the price system can be defined in a pure production context, and the sectoral value added becomes a function of the vector of prices disregarding adjustments in consumers' consumption. This *price* result "can be used as an index to rank different activities such that, in exact analogy with the nominal tariff theory, the change in the *quantity* of value added can be correctly predicted" (Bhagwati and Srinivasan, 1973a:262). This allows general indications from the *relative* effective protection rates obtained when partial equilibrium analyses in all sectors are performed, and the *ordering* scale of effective protection rates "summarizes the total protective-rate structure" (Corden, 1966:224) predicting changes in the sectoral outputs induced by the tariff structure.

In analytical terms, the partial equilibrium of an economy for the sector $j$is characterizedby the unit cost function. The separability assumption between commodities and factors imposes a real value added function and a price of value added function, and an economy with intermediates is formally equivalent to a final good economy (Woodland, 1977:518). Let $k = 1, \dots, f$ be the bundle of primary factors entering in value added and express the free-trade equilibrium (minimized) unit cost function in sector j as[5]:

$$C_j = \sum_k \omega_k f_{kj} + \sum_k z_{ij} p_i = p_j \,, \tag{8}$$

where, ω_k is the payment for factor k, and f_{kj} is its amount required to produce a unit of good in j. As before, z_{ij} is the coefficient of physical input giving the amount of i required per unit of j, p_i the price of input i, and p_j the price of output.

The total remuneration of primary factors, by definition, is the value added:

$$v_j = \sum_k \omega_k f_{kj} = p_j - \sum_k z_{ij} p_i \,. \tag{9}$$

When a set of non-prohibitive nominal tariff, t_j, are imposed, under the small country assumption, a complete tariff pass-through is given and protected prices equal (1+t_j) times the free-trade prices. Then, the unit cost function becomes:

$$C_j^{'} = \sum_k \omega_k f_{kj} + \sum_k z_{ij} p_i (1 + t_i) \gtreqless p_j \big(1 + t_j\big). \tag{10}$$

Under assumption (c) intermediate inputs are supplied at a constant cost (setting aside the tariff), while assumption (f) allows tariff distortions to alter the remuneration of primary factors, via changes in the unit cost function. If the increment in the price of final output produced in j exceeds the rise in the cost of inputs i as a consequence of the nominal tariffs on j and i (that is, $p_j t_j > \sum_k z_{ij} p_i \, t_i$), the value added in the downstream sector j increases with respect to its free trade level, and *vice versa*. This is illustrated in figure 1.2.

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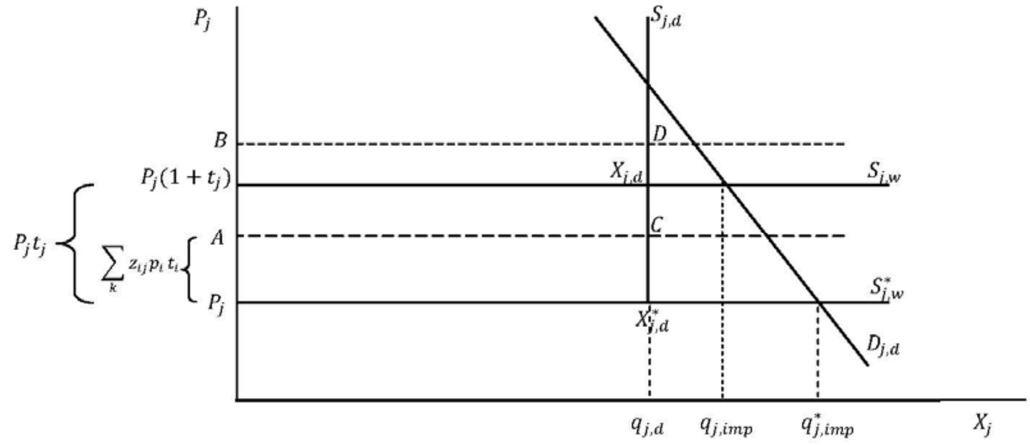
[5] This exposition of the effective protection rate in partial equilibrium follows Anderson (1970).

Figure 1.2. *The effective protection rate in short-run partial equilibrium.*



As in the simple case of a single good subjected to an import tariff, assuming homogenous products so that foreign produced j is a perfect substitute for the domestically produced j, tariff on j contracts imports from $q_{j,d}\ q^*_{j,imp}$ to $q_{j,d}\ q_{j,imp}$. The Harberger triangle, the area under the (compensated) Hicksian demand curve $D_{j,d}$, represents the relative welfare cost. The quantity domestically produced q^d_j is fixed under the assumption of Leontief production functions, since the output can be expanded only if all factors were available at the required proportion (L-shaped isoquant curves) which is fixed by the current technology. Then, given the (Viner) short-run constraint on capital, the domestic supply line is horizontal up to the free-trade output point and then vertical. It follows that the imposition of the nominal tariff on output will increase its price but not the quantity delivered to the economy, so that the free-trade output point X^*_d shifts up to X_d. $p_j(1+t_j)$ is the distorted level of prices for j. Now consider a tariff applied on inputs. It will raise the unit cost of producing, and under perfect competition this will translate in an increase of unit prices. The point A represents the case of $\sum_k z_{ij} p_i\, t_i < p_j t_j$, and area $ACX^{d'} p_j(1+t_j)$ is the increase in the remuneration of the composite primary factor. Conversely, in the point B is true $\sum_k z_{ij} p_i\, t_i < p_j t_j$, so that area $p_j(1+t_j)X^{d'}DB$ represents the negative rent for sector j caused by the structure of tariffs. In the first scenario, the positive increase in value added in sector j indicates the existence of profitable rents in that production, and will induce other firms to enter.

Consider now the long run partial equilibrium. Equation (10) can be expressed as:

$$C_j^{'} = \sum_k \omega_k f_{kj}(1+h_{kj}) + \sum_k z_{ij} p_i (1+t_i) = p_j\big(1+t_j\big)\,, \tag{11}$$

where h_{kj} captures the percentage change in factor k (used in j)'s remuneration caused by tariff-distortions.

From equation (11), the distorted value added is:

$$v_j^{'} = \sum_k \omega_k f_{kj}(1 + h_{kj}) = p_j(1 + t_j) - \sum_k z_{ij} p_i(1 + t_i)\,. \tag{12}$$

The effective protection rate formula in equation (1), can be rewritten combining equation (9) and equation (12) as:

$$e_j = \frac{\sum_k \omega_k f_{kj} h_{kj}}{\sum_k \omega_k f_{kj}}\,, \tag{13}$$

which expresses e_j as a weighted average of percentage changes in remuneration of factors in sector j, where the weights are proportions of free trade value added (Anderson, 1970:720).

In order to represent the production effect of the tariff structure using the effective protection rate, the elasticity of supply of the primary factors is introduced (see also Leith, 1971). The change in the amount of factor k used in sector j (F_{kj}) is a function of changes in the remuneration of all factors. The arc elasticity ($\propto_{kj}$) of supply of factor k to sector j can be expressed as:

$$\propto_{kj} = \frac{\frac{\Delta F_{kj}}{F_{kj}}}{h_{kj}} \;\rightarrow\; h_{kj} = \frac{1}{\propto_{kj}} \frac{\Delta F_{kj}}{F_{kj}}\,. \tag{14}$$

The Leontief production function implies that the proportional change in use of any input is equal to the proportional change in the sectoral output; thus, defining X_j as the output of j, we have: $\frac{\Delta X_j}{X_j} = \frac{\Delta F_{kj}}{F_{kj}}$. Hence:

$$h_{kj} = \frac{1}{\propto_{kj}} \frac{\Delta X_j}{X_j}\,. \tag{15}$$

Substituting (15) into (13) and solving for $\frac{\Delta X_j}{X_j}$:

$$\frac{\Delta X_j}{X_j} = e_j \left[\frac{\sum_k \frac{1}{\propto_{kj}} \omega_k f_{kj}}{\sum_k \omega_k f_{kj}}\right]^{-1}\,. \tag{16}$$

Assumptions (b) and (h), fixed coefficients and constant returns to scale, assure that the elasticity $\propto_{kj}$ is the same for every k and j. Under these conditions, the ranking of output changes can be inferred from the ranking of effective protection rates. In other words, assuming that the productive structures of sectors are the same for the two points under consideration (pre and post the tariff introduction), variations in the remuneration of productive factors caused by the trade policy are reflected in variations in the output levels.

It is worth noting that as long as substitution between inputs is admitted, the resource flow prediction of effective rates of protection calculated in a partial equilibrium framework is invalidated. With input substitution the effective protection analysis is susceptible to paradoxical results, where the direction of change in gross outputs does not necessarily correspond to the direction of change in value-added products as induced by a scale of the effective protection rate (Davis, 1998).

The more fundamental critique applied to the effective protection concept regards concern over drawing general equilibrium inferences from a partial equilibrium measure (Anderson, 1970; Ethier, 1971; 1977; Bhagwati and Srinivasan, 1973b; Greenway and Milner, 2003). The effective protection has a partial equilibrium nature. Nonetheless, the purpose of its measurement is to infer general equilibrium implications in terms of changes in outputs. The attempt to define a price system as a pure production concept, making "enough assumptions so that demand may be ignored" (Anderson, 1970:722) is fallacious when considering that a non-prohibitive import tariff in partial equilibrium might become prohibitive in a general equilibrium.

The effective protection rate considers the cross effect between sectors deriving from the intermediate stages of production; that is, tariffs on sector i's inputs harm sectoral incomes while sector i's own output tariff helps sectoral incomes. However, in general equilibrium, sector i's specific income may be harmed by the flight of mobile factors of production to sector j induced by j's tariff even if i does not require the products of j for inputs (Anderson, 2011). It follows that general equilibrium feedback to the distortion of value added may well overturn the inferences of partial equilibrium.

1.4 Applicative issues with the effective protection rates

The general equilibrium criticism seems to render vacuous the predictive content of effective protection rates in partial equilibrium. This notwithstanding, it has been, and is, applied extensively by academics and used in the policy arena. Thus, it is worth discussing the computational shortcomings of the effective protection rates, in order to present the main devices proposed to enhance its empirical utility.

1.4.1 Non-traded intermediate inputs

A problematic aspect in the theory of effective protection is the proper treatment of non-traded intermediate inputs. Recall assumptions (c) and (d): tradable intermediate inputs are assumed to be in infinite supply to a sector at a constant cost. Given (b), inputs are combined with value-added additional quantities of which can be obtained only at a higher cost. Non-traded inputs can be treated as i) tradable inputs, thus in infinite supply; or ii) they can be assimilated to the primary factor of production, thus assumed as indirect value added. These alternatives are referred to as the *Balassa method* and the *Corden method*, respectively.

i) Under the first hypothesis, effective protection can be interpreted as an indicator of the additional value added generated *directly* by the sector under examination, and attributable to tariff-structure induced distortions. The interest is in the incentive that the protective structure provides to the protected sector, thus that part of the total incentive which is passed through backward linkages to producers of non-tradable inputs used in that sector, is excluded. However, in the Balassa method, changes in the prices of non-tradable inputs are allowed by changes in prices of non-produced inputs (value added), given that the latter have supply functions which normally are upward sloped.

ii) The second hypothesis assimilates the cost of non-traded inputs in the direct cost of processing, allowing estimation of the total cost of protection (Balassa and Schydlowsky, 1974). It is acknowledged that "protection for an activity producing a trade product represents not only protection for those primary factors intensive in that activity but also protection for those industries producing non-traded inputs in which that activity is intensive and thus, indirectly, protection for the primary factors intensive in these non-traded input industries" (Corden, 1966:227). The Corden method puts the interest on the incentive a protective structure provides to the economy to reallocate resources towards a particular (domestic) input-output chain (Londero, 2001).

In empirical terms, the construction of the technical input-output coefficients matrix, A, will include (in the Balassa method) or exclude (in the Corden method) non-traded intermediates. It is apparent that cumulated value-added elements (i.e., the value added per unit originating in the rest of the economy producing non-tradable inputs) enter the denominator of the effective protection formula under the Corden method. Whenever non-traded inputs exist within a productive national system, this term is positive, implying that a positive (negative) effective protection rate will be smaller (larger) when using the Corden method.

1.4.2 The substitution problem

Substitutionability between primary factors and intermediate inputs

A key assumption in the effective protection rate is fixed technical coefficients which rules out the possibility for one input to be substituted for another if there is a change in their relative prices. This means that the same technical coefficients can be applied to the protection and free trade situations. If the possibility of substitution is allowed, the tariff structure induces changes to the input coefficients due to its effects on relative prices. This implies that the percentage increase in value added per unit due to the tariff structure is no longer equivalent to the effective protection, since that increase will depend partly on the substitution effects that have occurred (Corden, 1966; Leith, 1968). The Corden-Leith definition restates the effective protection rate as the proportional change due to the tariff structure in the "price" of the value-added[6]. That price can be meaningfully defined only if the existence of a separable production function is admitted. Assume a production function relating output Q to k primary factors (F) and m intermediates (Z); then the separability condition requires the gross output to be written as $\mathrm{Q} = \mathrm{G}(\phi(\mathrm{F}), \mathrm{Z})$, where G is concave and homogeneous by 1 degree in ϕ and Z, and ϕ is concave and homogeneous by 1 degree in F (Bhagwati and Srinivasan, 1998:241). Accordingly, the contribution made by the factors of production to gross output is considered separately from the contribution made by the material inputs (Sims, 1969), and where the production process first combines the primary factors independent of the prices of intermediate inputs, and then combines this “quantity” of value added, $\phi(\mathrm{F})$, with the intermediates Z to produce gross output Q. Under the assumption of separability which is equivalent to the existence of a real value added function and a price

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[6] Bruno (1973) and Woodland (1982) provide microeconomic foundations for Corden-Leith's approach.

of value added function or index, then formally, an economy with intermediate inputs is equivalent to a final good economy (Woodland, 1977). This approach allows the substitutability among primary inputs to be retained while maintaining the assumption of no-substitution between value added and intermediate inputs.

If this last assumption is dropped, and it is recognized that changes in the relative prices of primary and material inputs due to the tariffs imply a difference choice between the physical quantities of the two inputs (where the low priced input is preferred to the high price input),the physical input-output coefficients of the free-trade and the protected situations will be different. This implies that under protection the free-trade technical coefficients to be used in the formula for the effective protection rate in (5) are unknown, so that the appropriate measure is unclear (Ethier, 1972). Since the effective rate is supposed to show the direction of the resource movements induced it should not incorporate the effects of those resource shifts (Corden, 1966). Thus, the ideal calculation should show the changes in the return to primary inputs which would result if no substitution between primary and other inputs took place, and if the input coefficients did not change. Finger (1969) proves that assuming away input substitutability will cause the effective rate to be understated when free-trade data are used, and to be overstated when post-tariff data are used. The substitution theorem replaces the assumption of fixed physical input-output coefficients with the more general assumption of constant returns to scale production functions, which does not exclude substitution among inputs but still allows analysis of unit costs and unit isoquants. In equilibrium, the domestic prices of final goods must be equal to the unit costs, hence, in a free-trade situation and in a distorted situation we have:

(17) $$\mathrm{v_j} + \sum_{\mathrm{i}} \mathrm{a_{ij}} = 1 \ , \qquad \text{and}$$

(18) $$(1 + \mathrm{e_j})\mathrm{v_j'} + \textstyle\sum_{\mathrm{i}}(1 + \mathrm{t_i})\mathrm{a_{ij}'} = 1 + \mathrm{t_j} \ ,$$

where $\mathrm{v_j}$, $\mathrm{a_{ij}}$ are the shares of the primary inputs (value added) and the intermediate input i, respectively, in the cost of the final good j. As before, $\mathrm{t_j}$ and $\mathrm{t_i}$ are nominal tariffs on the final good and intermediate inputs. The prime denotes the post-tariff structural relationships. The cost minimization problem gives:

(19) $$\mathrm{v_j'} + \textstyle\sum_{\mathrm{i}} \mathrm{a_{ij}'} \geq 1 \ , \text{and}$$

(20) $(1+e_j)v_j + \sum_i (1+t_i)a_{ij} \ge 1 + t_j$.

Subtracting the distorted value added in (17) from (20) for the free-trade values, and in (19) from (18) for the post-tariff structural relationships, we obtain:

(21) $e_j v_j + \sum_i t_i a_{ij} \ge t_j$, and

(22) $e_j v_j' + \sum_i t_i a_{ij}' \le t_j$.

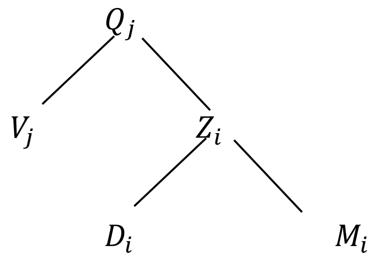
From (21) and (22) it follows that:

(23) $\frac{t_j - \sum_i a_{ij}'}{v_j'} \ge e_j \ge \frac{t_j - \sum_i a_{ij}}{v_j}$.

Thus, the effective rate is overstated when post-tariff coefficients are considered, and understated when free-trade coefficients are used.

Substitutionability between domestic and imported intermediate inputs

A necessary assumption to achieve equality between the domestic and world prices of traded goods is perfect substitutability between imported and domestic goods. If the country is a small one, the domestic price system is determined entirely by trade policy. De Melo and Robinson (1981) introduce product differentiation in a partial equilibrium model, and Devarajan and Sussangkarn (1992) use a general equilibrium framework. The main equations in these two works are similar. The product differentiation is obtained following Armington (1969) based on their origin; then, for each commodity a composite commodity is defined which is a constant elasticity of substitution (CES) function of the imported (M_i) and domestically produced (D_i) goods. The inverted tree representing the production function assumes the following shape:



The Leontief technology still characterizes the first level, at which value added (V_j) and intermediate inputs (Z_{ij}) are used in fixed proportions. At the second level, CES is assumed. For the composite commodity we have: $Q_i = [\delta_i M_i^{-\rho_i} + (1 + \delta_i) D_i^{-\rho_i}]^{-1/\rho_i}$, where δ_i and ρ_i are parameters, and $\sigma_i = (1 + \rho_i)^{-1}$ is the trade substitution elasticity (see eq. (4) in De Melo and Robinson, 1981). Assuming also that the import-competing good, D_i, is produced by value added alone, the value added in each sector will depend on the relative prices of the domestic intermediate and the value added. The cost minimization derived from the marginal productivity factor pricing (CES), implies that the optimum shares of imported and domestic intermediates will depend on the relative prices as well as on the substitution elasticity: $D_i/M_i = [p_{i,m}(1 + t)/p]^{\sigma_i}$. Finally, the price of the composite good Z_i is a CES combination which depends on the share of imports in total supply. As Devarajan and Sussangkarn (1992) find for Thailand, the structure of effective protection is amplified as the substitution elasticity increases, and the increased divergence results in a different ranking, and in some cases, in the opposite sign with respect to the traditional effective protection measures.

1.4.3 The complete-use coefficients

In dealing with input-output coefficients, a different problem arises in the computation of the effective protection which is that it considers the input-output structure of a vertical two-stage production structure. Under assumption (e), in the at an upstream stage primary factors produce pure intermediate products, which are combined with further primary factors in the at a downstream stage to produce final products (Dixit and Grossman, 1982). This is paramount to assuming that effective protection "is not influenced by tariffs on inputs into its inputs"; thus, with tradability of both final and intermediate products, the effect of a tariff structure on resource allocation can be assessed going "only one step downward in the input-output structure" (Corden, 1966:223). The links in the production chain related to producing the intermediate input used directly by the sector producing final output, are excluded in the traditional definition of effective protection. In Corden's (1966:223) example: "a tariff on raw cotton, while it reduces effective protection for spinning, has no effect on the effective rate for weaving. To the weavers only the cost of yarn matters, and that is determined by the given world yarn price plus tariff". However, when repeated use of traded intermediate inputs in the global input-output chain is considered, multiple stages enter the analysis. In a vertical structure with more than two stages spanning different countries, portions of cumulative value are added at each productive step, and intermediates in different processing stages are traded more than once before the final output is produced.

As before, j and $i = 1, \dots, N$ index sectors; introduce the country dimension, and countries are indexed ass, r, w and $t = 1, \dots, C$. Now the structural matrix A is derived from an *inter-country* input-output table and has the dimensionsNCxNC, so that the element a_{ij}^{sr} gives the share of i produced in s in the output of good j in country r[7]. This allows us to account for different technologies among countries.

For each national economy, define a vector of final demand y_j^s with dimension NCx 1. Assume a Leontief (1966) input-output system, then total output is used as intermediate or final consumption either at home or abroad. The balance condition between the total output ($\mathrm{x_j^r}$) and the combined inputs to the product from sector j can be expressed as follows:

$$x_j^r = \sum_{s=1}^{c} y_j^{rs} + \sum_{i=1}^{n}\sum_{s=1}^{c} Z_{ji}^{rs} = \sum_{s=1}^{c} y_j^{rs} + \sum_{i=1}^{n}\sum_{s=1}^{c} a_{ji}^{rs} x_i^s \quad , \tag{24}$$

where Z_{ji}^{rs} is the total value of intermediates j originating in country r which are used by sector i in country s. Expressed as a share of i's output, gives: $\frac{Z_{ji}^{rs}}{x_i^s} = a_{ji}^{rs}$.

Stacking equation (24) for all sectors, N general equilibrium relationships are traced for each country:

$$\begin{array}{ccccccccccccc}
\sum_{s=1}^{c} a_{11}^{rs} x_1^s & + & \sum_{s=1}^{c} a_{12}^{rs} x_2^s & + & \dots & + & \sum_{s=1}^{c} a_{1n}^{rs} x_n^s & + & \sum_{s=1}^{c} y_1^{rs} & = & x_1^r \\
\sum_{s=1}^{c} a_{21}^{rs} x_1^s & + & \sum_{s=1}^{c} a_{22}^{rs} x_2^s & + & \cdots & + & \sum_{s=1}^{c} a_{2n}^{rs} x_n^s & + & \sum_{s=1}^{c} y_2^{rs} & = & x_2^r \\
\dots & & \dots & & \dots & & \dots & & \dots & & \\
\sum_{s=1}^{c} a_{n1}^{rs} x_1^s & + & \sum_{s=1}^{c} a_{n2}^{rs} x_2^s & + & \cdots & + & \sum_{s=1}^{c} a_{nn}^{rs} x_n^s & + & \sum_{s=1}^{c} y_n^{rs} & = & x_n^r
\end{array} \tag{25}$$

Solving for y_j^{rs}:

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[7] Unless otherwise specified, superscripts denote countries and subscripts denote sectors.

$$\begin{array}{lllllllll} \sum_{s=1}^{c}(1-a_{11}^{rs})x_1^s & + & \sum_{s=1}^{c}(-a_{12}^{rs})x_2^s & - & \cdots & + & \sum_{s=1}^{c}(-a_{1n}^{rs})x_n^s & = & \sum_{s=1}^{c} y_1^{rs} \\ \sum_{s=1}^{c}(-a_{21}^{rs})x_1^s & + & \sum_{s=1}^{c}(1-a_{22}^{rs})x_2^s & - & \cdots & + & \sum_{s=1}^{c}(-a_{2n}^{rs})x_n^s & = & \sum_{s=1}^{c} y_2^{rs} \\ \ldots & & \ldots & & \ldots & & \ldots & & \ldots \\ \sum_{s=1}^{c}(-a_{n1}^{rs})x_1^s & + & \sum_{s=1}^{c}(-a_{n2}^{rs})x_2^s & - & \cdots & + & \sum_{s=1}^{c}(1-a_{nn}^{rs})x_n^s & = & \sum_{s=1}^{c} y_n^{rs} \end{array} \tag{26}$$

Given exogenous levels of final demand, the general solution to the system of equations expressed in (26) can be obtained for the endogenous variables x_j^s. Thus, consumption per unit can be linked to the total direct or indirect intermediate requirements. To put it more concretely, suppose an increase in consumers' demand for cars; this would imply increased demand for steel whose production requires iron, and so on. Mathematically, this can be obtained through inversion of the matrix resulting from subtracting the identity matrix I (with unitary elements in the diagonal and zero otherwise) from the technical coefficients matrix A. The Leontief inverse can be expressed as a converging geometric series where A is the common ratio: $(I-A)^{-1} = (I + A + A^2 + A^3 + \ \ldots)$, summing all rounds of intermediates required for a unitary increase in the output starting from the direct effect (I) and successively $(A^2, A^3 \ldots)$[8]. Define $L = (I-A)^{-1}$ as the global Leontief inverse matrix:

$$\begin{bmatrix} l_{11}^{11} & l_{12}^{11} & \cdots & \cdots & l_{1n}^{1c} \\ l_{21}^{11} & \ddots & \cdots & \cdots & l_{2n}^{1c} \\ \vdots & \cdots & \ddots & \cdots & \vdots \\ \vdots & \cdots & \cdots & \ddots & \vdots \\ l_{n1}^{c1} & l_{n2}^{c1} & \cdots & \cdots & l_{nn}^{cc} \end{bmatrix} = \begin{bmatrix} (1-a_{11}^{11}) & -a_{12}^{11} & \cdots & \cdots & -a_{1n}^{1c} \\ -a_{21}^{11} & \ddots & \cdots & \cdots & -a_{2n}^{1c} \\ \vdots & \cdots & \ddots & \cdots & \vdots \\ \vdots & \cdots & \cdots & \ddots & \vdots \\ -a_{n1}^{c1} & -a_{n2}^{c1} & \cdots & \cdots & (1-a_{nn}^{cc}) \end{bmatrix}^{-1} \tag{27}$$

In matrix notations, with known levels of final demand, the system of equations in (26) can be written as:

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[8] For a mathematical treatment of the approximation of $(I-A)^{-1}$ with a geometric series, see e.g., Tuchinsky (1983).

(28)
$$\begin{bmatrix} x_{11}^{11} & x_{12}^{11} & \cdots & \cdots & x_{1n}^{1c} \\ x_{21}^{11} & \ddots & \cdots & \cdots & x_{2n}^{1c} \\ \vdots & \cdots & \ddots & \cdots & \vdots \\ \vdots & \cdots & \cdots & \ddots & \vdots \\ x_{n1}^{c1} & x_{n2}^{c1} & \cdots & \cdots & x_{nn}^{cc} \end{bmatrix}$$
$$= \begin{bmatrix} l_{11}^{11} & l_{12}^{11} & \cdots & \cdots & l_{1n}^{1c} \\ l_{21}^{11} & \ddots & \cdots & \cdots & l_{2n}^{1c} \\ \vdots & \cdots & \ddots & \cdots & \vdots \\ \vdots & \cdots & \cdots & \ddots & \vdots \\ l_{n1}^{c1} & l_{n2}^{c1} & \cdots & \cdots & l_{nn}^{cc} \end{bmatrix} \begin{bmatrix} y_{11}^{11} & y_{12}^{11} & \cdots & \cdots & y_{1n}^{1c} \\ y_{21}^{11} & \ddots & \cdots & \cdots & y_{2n}^{1c} \\ \vdots & \cdots & \ddots & \cdots & \vdots \\ \vdots & \cdots & \cdots & \ddots & \vdots \\ y_{n1}^{c1} & y_{n2}^{c1} & \cdots & \cdots & y_{nn}^{cc} \end{bmatrix}$$

When all elements l_{ij}^{sr} are non-negative, for any given (positive) level of final demand there will exist a combination of positive total outputs which satisfies its production. This is assured if the Hawkins-Simons condition is satisfied, that is, if all successive principal minors of $(I - A)^{-1}$ are positive. The economic interpretation is that the economic system, to achieve sustainability, must be composed of smaller productive sub-systems each requiring less input from the economic system than it produces in outputs. If this holds, each sector that absorbs output from other sectors directly or indirectly will be able to sustain itself and to make a positive contribution to final demand.

The elements of the inverse Leontief matrix give a measure of the cumulative input intensity, and are used to capture the indirect absorption of intermediate inputs. This can be included in the original definition of effective protection by replacing the elements of the structural matrix with the corresponding elements of the Leontief inverse matrix. Following Diakantoni and Escaith (2012), a matrixL' can be defined as the matrix that has the same elements as the Leontief inverse for all $i \neq j$, and the Leontief coefficients minus 1 if $i = j$:

(29)
$$L^{'} = L - I$$

Then, the formulation for the effective protection rate in (4) can be rewritten as:

(30)
$$e_j^{'} = \frac{t_j - (\sum_i t_i \, l_{ij}^{'})}{1 - \sum_i l_{ij}^{'}},$$

to account for the iterated use of intermediate inputs.

However, since the operational definition of value added used by the effective protection formula is 1 minus the technical input-output coefficients (recall equation (2)), the substitution of L for the$A$will require some preliminary manipulations on the L matrix.

Specifically, the L matrix needs to be normalized so that each column includes the final (both direct and indirect) input share in the corresponding sector. Chen, Ma, and Jacks (2016) compute the normalized L as:

(31) $$L'' = LN \ ,$$

where N is a column vector with each element equal to the inverse of the sum of the corresponding column of L times the corresponding share of the intermediate inputs given in the A matrix.

Under the conventional hypothesis that nominal protection raises the prices of both domestic and imported goods by the value of the tariff, the origins of the intermediate input are irrelevant. However, Rouzet and Miroudot (2013) point out that if intermediate trade becomes a prominent feature of world trade, those inputs eventually cross the borders several times incurring different tariff rates. In those circumstances, the formula in (22) with either L' or L'' leads to a bias in the estimates since it assumes that the same tariff rates are applied to indirect trade flows. This implies, i.e., that preferential treatments are not considered in the computation of the effective protection.

Incorporating the indirect consumption of inputs decreases the free-trade value added (as long as $l_{ij} > a_{ij}$), and, as a consequence, increases, *ceteris paribus*, the effective protection rate (refer to section 1.2 for the inverse relationship between the effective protection and the free-trade value added) compared to conventional measures. More importantly, the conceptual incorporation of multiple stages of production in the tariff structure theory, leads to reconsideration of the interpretation of the effective protection rate.

1.5 International fragmentation of production and the role of protection

In the 1960s and 1970s, an *escalated* tariff structure – that is, nominal rates that increased with the degree of processing – maintained artificially high factorial returns from downstream activities, thus protecting and nourishing infant industries. This tariff structure was an industry policy instrument and part of an import substitution strategy. To varying degrees, tariff escalation continues to characterizes the trade regimes of many countries at different levels of income and industrial development. It is more pervasive in manufacturing than in agriculture, and at a less aggregate level, it is prevalent in most sectors including those important to developing countries such as apparel, animal products, tanning, and many light manufacturing sectors (UNCTAD, 2015). Thus, it continues to be much discussed as an obstacle faced by countries pursuing economic development.

In recent years, increased attention has been paid to the opportunities and challenges created by the wide diffusion of international vertical fragmentation of the productive processes. Barriers at the border are clearly a crucial variable for firms participating in GVCs, and national competitiveness depends on both efficient access to imported inputs, and the capacity to export processed or final goods (Taglioni and Winkler, 2014, 2016). With the shift in emphasis on export competitiveness two dominant arguments emerge. On the one side, protection of intermediate inputs penalized downstream sectors using these inputs. This is reflected by the effective protection rate (in both the traditional version and with the assumption of product differentiation): tariffs on tradable intermediate inputs lower the effective protection accorded to a sector (De Melo and Robinson, 1981). This effect is amplified if multiple stages are considered, coherent with the results obtained from equation (23). On the other side, high effective protection reveals an anti-export bias in trade policy given that the disproportionately high value added will make production for the domestic market more profitable. Recall the numerical example given in section 1.2. A final good is worth 1,000,00, and the free-trade value added is 400,00. The average nominal tariff on inputs (which now are interpreted better as *cumulated* intermediates) is 15%, and the final output enjoys a domestic nominal tariff of 30%, so that the effective protection for selling in the domestic market is 52.5%. When the output is exported to a preferential market, the effective protection depends on the import tariff rate applied by the destination country[9]. In our

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[9] Rouzet and Miroudot (2013) propose an effective rate for exporters. Prices in the sectors producing exports will depend on the nominal protection of output enjoyed by local producers in the destination market, which can be interpreted as an implicit tax on exports to that market. Hence, the effective protection afforded by an exporting

example, a preferential margin of 7% corresponds to a negative effective rate of -5%. Thus, a high effective rate does not work in the direction of sustaining a particular domestic sector, and protecting it from foreign competitors when opportunities are opened via insertion in global chains of production. Rather, the escalated structure of tariffs (some would say, trade policy *tout court*) is harmful to the downstream sector.

It is not just a matter of *interpretation* of the numbers related to the effective protection rate. Production processes show increasing interconnectedness in the vertical trading chains spanning multiple countries (Hummels et al., 2001). These developments in world trade, characterized by a notable increase in intermediate trade, are challenging the empirical validity and conceptual utility of the effective protection rate as a synthetic indicator when intermediate inputs are allowed.

Consider an intermediate good produced by an economy s. It is exported for intermediate use in a partner country, and after a certain number of productive steps (which can happen in one or more third countries) is imported back by the country of its origin through country s's (final or intermediate) imports from sector j of country r. The prediction of effective protection theory would be that a nominal tariff on the goods produced by sector $j$will would absorb domestic resources in the input-output chain involved in that production. The back and forth movements across borders of intermediate inputs questions this beneficial effect as long as substitution of imports would imply losses of off-shored manufacturing jobs and investment.

When strata of value are added in different countries, the *effective* technology becomes a combination of domestic and foreign technology. The international (as opposed to domestic) fragmentation of the production process allows production of a single value-added good to draw on different factor markets with differing factor prices. Thus, cost-savings are achieved through a suitable match between the production characteristics of individual fragments of value-added, and the pattern of factor prices prevailing in foreign countries. If the cost of procuring a value-added-fragment from foreign factor markets is lower than what would be obtained using domestic factors this disturbs the equilibrium condition of zero profits (Kohler,

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sector j of country s can be expressed by substituting the nominal tariff rate on output in the export market ($t_j^{s,foreign}$) for the domestic rate in the equation (4):

$$e_j^{s,ex} = \frac{-t_j^{s,foreign} - \sum_i \sum_r t_i^{rs} a_{ij}^{rs}}{1 - \sum_i \sum_r a_{ij}^{rs}} \quad ,$$

where t_i^{rs} is the nominal tariff rate applied by country s to imports from sector i of country r.

2003). This kind of incentive to outsource certain parts of the production process make the consequences of effective protection more ambiguous for domestic resource allocation.

A connected but different aspect is related to the system of prices underlying the effective protection rate breaks, since several links in the relevant chains may be outside the country and the domestic sector (or may be between the partner country and a third country, or among third countries). In those cases, domestic trade policy on intermediate inputs combines with foreign trade policy in determining price effects on those goods. Thus, it is not only the effective protection rate as an index of the price effects (specifically, value-added price changes) that has no definite relationship to the general equilibrium output effects, since “explicitly connecting a schedule of price effects to the magnitudes of resource flows and output changes in a multicommodity environment requires knowledge of production structures and factor shares” (Davis, 1998). However, that effective *schedule of price effects* finally is unknown under the usual definition of the effective protection rate.

When the international fragmentation of the production process is admitted as a large scale and world-wide phenomenon that is reorganizing the productive structure, the effective protection provides a quite narrowly focused lens through which to view sector performance. A broad mix of *indirect* effects should be included in the analysis which requires a multi-region, multi-sector general equilibrium framework of thinking.

All in all, there is a widespread view that the nature of international trade has changed; the *new paradigm* in international production and trade (Grossman and Rossi-Hansberg, 2008) – centered on trade in specific tasks and assessing how value added is created and traded among countries- alters the role of protectionist policies, and pushes for a different way of conceptualizing trade, and hence, reasoning about trade protection. The original definition of the notion of effective protection responds to a counterfactual question such as: *what would be the sectoral distribution of value added in the absence of the current tariff structure*? In a context of GVC, new questions arise with respect to the effects of trade policy on value added such as: *what is the impact of the overall tariff system of a country on the value added that is activated by its trade*? And: *what is its impact on the value added worldwide which is embedded in national bilateral flows*? The answers to these questions could provide interesting insights for trade negotiators.

To address these questions, we conduct an analysis grounded in the key theoretical contribution of Anderson and Neary (1996, 2005), and a behavioral model of tariff aggregation which is applied in a “value-added trade” framework that allows identification of the origin of all primary factor inputs contained in imports.

In what follows, we discuss the rationale for the aggregation method, and then present the model for the value-added analysis.

1.6 The theoretically-based method for trade policy assessment

Any effort to develop summary statistics of trade protection encounters the difficult of defining a proper procedure to aggregate more than a thousand protectionist barriers. The ideal aggregator would preserve the relationship between the object of interest, and the tariff vector being aggregated. First, we would ask: *aggregation for what purpose*? (Anderson, 2011). Consider tariff structure theory. The traditional effective protection concept measures (at best) no more than the level of protection provided to the sector. In general equilibrium, as already seen, “it predicts neither changes in output nor any other economically interesting variable” (Anderson, 1998:22). The rate at which the level of protection is translated into sector-specific factor income is a distinct, and more interesting issue for political economists. Anderson (1998) redefines the concept as the uniform tariff on inputs and outputs which yields the same sector specific factor income as the actual tariff structure. Starting from a standard neoclassical model, with competitive production and cost minimizing behavior, it is possible to specify a restricted profit function, $\rho_j(p,\omega)$, where ρ_j is defined as the earnings from the sector-specific factor used in j. Its properties can be used to derive an “exact” effective protection rate. In partial equilibrium, the price vector for primary inputs, ω, is invariant to the change in p, thus, for a given p, the effective rate of protection is defined implicitly as: $\rho_j\left[p^*\left(1+e_j\right),\omega^0\right] = \rho_j(p^0,\omega^0)$. p^* is the free trade price vector, and $p^0$is the initial price vector for distorted goods. This formulation allows us to obtain a uniform tariff on distorted goods which has the same effect on earnings as the sector-specific factor used in j as the initial tariff vector (Anderson, 1998; 2011). The *distributional* effective protection rate has the simple form given in Corden (1966) but in the special case of partial equilibrium with fixed input coefficients and fixed output coefficients.

In a general equilibrium framework, factor prices, ω, are not held constant but are endogenous. The cost-minimizing property of the restricted profit function gives the vector of demand for inter-sectoral mobile factors by derivation: $\partial\rho_j/\partial\omega$. The sum of all the factors equals the vector $f$of factor endowments: $\sum_j \frac{\partial\rho_j}{\partial\omega} = f$. In the short-run, the supply of the primary factor is fixed, and factor prices are given by market clearance conditions as a function of prices and factor endowments, $g(p, f)$. In a general equilibrium, the restricted profit function can be rewritten as: $R_j\ (p, f)\ \equiv \rho_j\ [p, g(p, f)]$. Thus, in a general equilibrium, effective protection can be reformulated as the solution to: $\rho_j\left[p^*\left(1 + e_j\right), g(p^*\left(1 + e_j\right), f^0\right] = \rho_j[p^0, g(p^0, f^0)]$.

In *distributional* effective protection, the precise focus is on *the effect on rents to residual claimants in sector* j, and shows that rents are kept constant to obtain the equivalence. Clearly, other possible ideal aggregators could be defined (e.g. level of utility, volume of imports, level of output,…). To sum up, the main idea is to apply the index number and duality theory. A behavioral model of tariff aggregation is usedto define the weights *representing the effects of the tariffs according to a fundamental economic structure* (Cipollina and Salvatici, 2008). The theoretical anchorage allows resolution of the endogeneity between the tariff levels and the input intensity, or imports in general which is particularly pronounced for high elasticity of demand (Anderson and Neary, 2003). More importantly, these kind of tariff index numbers have the valuable property of unambiguous interpretation since they are constructed precisely and according to a formerly defined economic question. Having a specific variable as a *true* benchmark against which to measure trade policies, they give a uniform tariff equivalent of a non-uniform tariff structure yielding the same value in relation to that specific variable (Anderson and Neary, 1992; 2005). It is the theory which dictates the construction of the specific trade restrictiveness index[10].

The next section deals with the theoretical developments we made to define a *true* benchmark to be used in the context of value-added analysis.

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[10] This theoretical approach was proposed first to compute the *uniform price deflator which, when applied to the new levels of distorted prices, yields the old level of utility of the representative agent* (Anderson and Neary, 1996). Based on the intuition related to the trade restrictiveness index several alternative emerged: the *distributional* effective protection (Anderson, 1998), mentioned in the main text; the mercantilist trade restrictiveness index developed by Anderson and Neary (2003) takes trade volume as the reference point. Antimiani (2004) computes the distortionary effects of protection on the level of output.

1.7 Assessing trade policy with global production: the value-added trade restrictiveness index

1.7.1 *Model setup*

The economy is assumed to be in competitive equilibrium with no distortions other than tariffs[11]. The environment is standard as for the consumption side. The representative consumer maximizes its utility, $U(y)$, subject to the budget constraint, $py \leq E$, where E represents income and p are prices. Standard proprieties apply.

First, we characterize the behavioral model to be used in the analysis, summarizing all consumption and production decisions within the economy within an indirect trade utility function (Woodland, 1980):

$$H(p,b,f) \equiv U[p,g(p,f)+b]\,, \tag{32}$$

which expresses the maximum level of utility that a trading economy can obtain when the restricted profit functions, $g(p,f)$, plus the lump-sum income from abroad (b) are substitutes for the disposable income in the indirect utility function, U. As before, f are factor endowments. The indirect trade utility function is quasi-convex in p, weakly increasing in b, non-decreasing and quasi-concave in *f,* and homogeneous by degree zero in (*p,b*). It has the useful property that the net import demand functions are obtained directly through differentiation, that is, it exhibits a generalization of Roy's identity.

Trade in goods can be considered indirectly as trade in factors. Following Neary and Schweinberger's (1986), embodied factor trade could substitute for the commodity trade by allowing the same level of utility, given that factors affect utility through the income they generate. Under the assumption of constant returns to scale, and in absence of joint production, the representative firm's technology can be expressed by a unit cost function, $c(\omega)$, which is non-decreasing, concave, twice differentiable, and homogenous by degree 1 with respect to factor prices, ω. The unit cost function depends also on the prices of the intermediate inputs; however, since these prices are kept constant throughout they are not included as arguments. The condition that allows this treatment is the assumption of separability which implies that the conditional demand for primary inputs is independent of the prices of the intermediate inputs[12].

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[11] Theoretically, all forms of trade distortions can be accounted for; the choice to focus only on tariffs was dictated by data constraints.

[12] The separability in the production function was introduced in section 1.4.2.

In a competitive equilibrium, unit costs equal prices[13]; then the *indirect factor trade utility function*, W, can be defined by substituting $c(\omega)$ for p in the indirect trade utility function. Hence:

(33) $$W(\omega, b, f) \equiv H[c(\omega), b, f] .$$

Differentiating with respect to ω:

(34) $$W_\omega(\omega, b, f) = c_\omega(\omega)\, H_\omega[c(\omega), b, f] .$$

By Shephard's Lemma, the derivative of the cost function with respect to the factor prices gives the conditional demand for input. Generalization of Roy's identity states that *the derivatives of the indirect factor trade utility function with respect to factor prices are proportional to the factor content of net imports, the constant of proportionality being the marginal utility of income* (Neary and Schweinberger, 1986:424). Then, the last term in (34) can be expressed as:

(35) $$H_\omega[c(\omega), b, f] = -H_b[c(\omega), b, f]m[c(\omega), b, f] \ ,$$

where the scalar $-H_b$ is the marginal utility of income, and m represents net imports.
By substitution,

(36) $$W_\omega(\omega, b, f) = -H_b[c(\omega), b, f]D(\omega)m[c(\omega), b, f] \ ,$$

where D is the matrix of the direct factor requirement coefficients[14]. Setting aside the scalar $-H_b$,on the right-hand-side of (36), we obtain the Marshallian import demand *factor content* function. More specifically, the k-th element of the Marshallian import demand *factor content* function can be expressed as:

(37) $$M_k(\omega, b, f) = \sum_j d_{kj}(\omega_k)\, m_j[c(\omega_k), b, f] \ ,$$

where d_{kj} is an element of the matrix D, giving the cost-minimizing factor k per unit of output in sector j; and m_j are net imports from sector j.

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[13] The representative firm, in the absence of any market power, prices at marginal cost. Under the assumption of constant returns to scale, the marginal cost equals the unit cost since the total cost function is homogeneous by degree 1 with respect to the production level, and both the marginal and unit costs are invariant to the level of output.

[14] Formal proof of the generalization of Roy's identity to the factor content functions is given by Neary and Schweinberger (1986).

In what follows, intermediate trade is introduced in the model; then we decompose the import side of the net trade reallocating the value added contained therein according to its geographical origin.

1.7.2 *The extension to intermediate trade*

In order to accommodate production processes that are globally fragmented, the *effective* techniques of production are considered to be a combination of domestic and foreign technologies. That is, whenever techniques of production differ among countries Deardorff's (1982) definition of *actual* factor content, imputing *to traded goods those factors actually used in their production wherever that took place*, is preferred to factor content based on domestic coefficients. When techniques of production are allowed to differ internationally, cost minimizing derives from the marginal productivity factor pricing. This is tantamount to holding the technology constant under factor mobility, to describe the cost functions of all goods in all countries. Thus, intermediate trade is accounted for by applying the algorithm in Trefler and Zhu (2010) which is based on the theoretical developments introduced in section 1.4.4. Specifically, as in the previous sections, let j and $i = 1, \dots, N$ index sectors; $s, r$and $t = 1, \dots, C$ index countries; and $k = 1, \dots, F$ primary factors. The inverse Leontief matrix, L, gives a measure of cumulative input intensity which captures the indirect absorption of intermediate inputs. We assume that the Hawkins-Simons condition is satisfied, and that the Leontief coefficients are parameters.

In this context, the factor content of net trade in (37) can be expressed in terms of *total* factor requirements, including both direct and indirect usage for all stages of processing implied by the production of final trade. Both exports and imports are expressed explicitly, and the bilateral dimension is introduced for subsequent usage:

$$\begin{aligned} M^{s}_{k\_tot}(\omega, b, f) \\ &= \sum_{r} \sum_{i,j} d^{r}_{ki}(\omega^{r}_{k})\, \bar{l}^{rs}_{ij}\, m^{s*}_{j}[c(\omega^{r}_{k}), b, f] \\ &- \sum_{r} \sum_{t \neq s} \sum_{i,j} d^{r}_{ki}(\omega^{r}_{k})\, \bar{l}^{rt}_{ij}\, m^{ts}_{j}[c(\omega^{r}_{k}), b, f] \ . \end{aligned} \tag{38}$$

The first term in equation (38) represents the amount of factor k directly or indirectly employed worldwide to produce sector j country s's exports to the world (m_j^{s*}), and the second term is the factor k content of s's imports from all other countries ($\sum_{t\neq s} m_j^{ts}$).

1.7.3 *The value-added trade restrictiveness indexes*

In order to operationalize the model, physical factor requirement coefficients are multiplied by factor prices and summed over all factors, thus using value added shares instead of the physical input coefficients in (38) (Johnson and Noguera, 2012; Foster-McGregor and Stehrer, 2013)[15]. Define V as the diagonal matrix with diagonal elements equal to the share of direct domestic value added in total output in each sector of each country. As for the total factor content, the total value added content of trade flows can be computed using the total value added multiplier, VL, in which the typical element $v_i^s l_{ij}^{sr}$ gives the share of country s' value added originated in sector i of goods produced by country r and sector j. It provides a breakdown of the flows of value added across country/sector of production; diagonal (off-diagonal) sub-blocks represent domestic (foreign) value added in domestic production. In what follows, the analysis is restricted to the import side of equation (38). Then, the trade vector can be specified as a diagonal matrix with positive entries for imports and zero otherwise. With all the information on the partition of value added by sources in the production process, and exploiting the property that the sum along each column of $the\ VL$ matrix is unity, since all value added must be domestic or foreign, country s's imports can be decomposed in terms of value added according to where they originate[16]. For sector j:

$$M_j^{*s} = \sum_r \sum_i v_i^r\, \bar{l}_{ij}^{r*}\, m_j^{*s} = \sum_{r\neq s} \sum_i v_i^r\, \bar{l}_{ij}^{r*}\, m_j^{*s} + \sum_i v_i^s\, \bar{l}_{ij}^{s*}\, m_j^{*s}\,. \tag{39}$$

Equation (39) splits country s's imports in sector j from the rest of the world into a portion containing *foreign value added* (first term) and a portion embedding *domestic value added* which is first exported and successively imported back after processing abroad (second term).

Applying this decomposition at the bilateral level, we can define three main components of bilateral imports. Namely, from the point of view of country $s$importing from r: i) the direct

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[15] The statistical inter-country input-output (ICIO) tables are the principal source of information on the input requirements used in applied analysis; they contain intermediates transactionswithin and between countries at sector level, direct value added, and gross output at country/sector level. All data are available only in value to achieve homogeneity per columns and per rows.

[16] The method used to split bilateral imports into different value-added components is treated exhaustively in ch. 2.

foreign value added originated in all sectors of the exporting country r embodied in its exports of sector j to s ($fvab\_imp$), ii) the domestic value added originated in all sectors of s which is imported back from the sector j of country$r$ (dva_imp)[17], and iii) the indirect foreign value added of third countries which is indirectly imported by s from sector j of r ($fvai\_imp$). Formally:

$$M_j^{rs} = \underbrace{\textstyle\sum_i v_i^r\, \bar{l}_{ij}^{rr}\, m_j^{rs}}_{fvab\_imp} + \underbrace{\textstyle\sum_i v_i^s\, \bar{l}_{ij}^{sr}\, m_j^{rs}}_{dva\_imp} + \underbrace{\textstyle\sum_{t\neq r,s} \sum_i v_i^t\, \bar{l}_{ij}^{tr}\, m_j^{rs}}_{fvai\_imp}. \tag{40}$$

The three components in (40) are used as the benchmark against which to measure trade policies, defining the uniform tariff equivalents yielding the same value for each component of the bilateral imports. Thus, the uniform tariff that, if imposed on imports instead of the existing structure of protection, would leave the value added of the direct exporter at its current level, is given by:

$$\begin{aligned} \check{\mathrm{T}}_{FVAB,j}^{rs}\colon \sum_i v_i^r\, \bar{l}_{ij}^{rr} m_j^{rs} \left[\left(1 + \mathrm{T}_j^{(\mu)rs}\right) p^*(T), b^0, \omega\right] \\ = \sum_i v_i^r\, \bar{l}_{ij}^{rr} m_j^{rs} [p^0, p^*(T), b^0, \omega]\,. \end{aligned} \tag{41}$$

The same applies for the other two components of bilateral imports:

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[17] Hummels et al.'s (2001) assumption that all imported intermediate inputs include only foreign value-added was first relaxed by Daudin et al. (2011) who introduced the concept of "reflected exports" (VS1*), measuring the exports that further down the production chain, are embedded in re-imported [final] goods. Foster-McGregor and Stehrer (2013) give a measure of the domestic value added that which is re-imported as final and intermediate imports. Amador and Stehrer (2014) label the same measure "DVAiM" and give an application for Portuguese trade in the period 1995-2011. Johnson and Noguera (2012) propose an approximation of the amount of exports embedded as intermediates in goods that are reimported back to the source country, considering only first round effects of the Leontief inverse, [I + A], i.e., the direct effect on output linked to an increase in final demand, and the effect on intermediate inputs directly needed to produce that output. Koopman et al. (2014) give a decomposition of intermediate flows according to the country of final absorption. This allowsthem to differentiate all portions of value which are double-counted in gross trade statistics due to intermediate inputs computed repeatedlywhen they cross borders multiple times. Their VS1* measure captures the reflected trade embodied in final imports and the portion of value added which is re-imported for domestic processing and consumption. Wang et al. (2013) extend Koopman et al.'s (2014) framework to the bilateral/sector level, and take account of the reflected value added which is imported back via a third country. We follow the method proposed by Foster-McGregorand Stehrer (2013) using a trade vector which includes both final and intermediate imports, since our interest here is in the value added content of imports and not final consumption, anddoes not justify the computational difficulties implied by decomposition of intermediate flows. However, it should be noted that the portion of re-imported intermediates which is used for producing final exports is over-counted since it is already included in the product of VL and final trade. This can lead to overestimation of our measure. However, in ch. 2 we give a measure of the bias and the two measures are compared. We find that the difference is negligible.

$$\begin{aligned} \check{\text{Ʈ}}^{rs}_{DVA,j}\colon & \sum_i v_i^s\, \bar{l}_{ij}^{sr} m_j^{rs} \left[\left(1 + \text{Ʈ}_j^{(\mu)rs}\right) p^*(T), b^0, \omega\right] \\ & = \sum_i v_i^s\, \bar{l}_{ij}^{sr} m_j^{rs} [p^0, p^*(T), b^0, \omega]\ ; \end{aligned} \tag{42}$$

and:

$$\begin{aligned} \check{\text{Ʈ}}^{rs}_{FVAI,j}\colon & \sum_{t \neq r,s} \sum_i v_i^t\, \bar{l}_{ij}^{tr}\, m_j^{rs} \left[\left(1 + \text{Ʈ}_j^{(\mu)rs}\right) p^*(T), b^0, \omega\right] \\ & = \sum_{t \neq r,s} \sum_i v_i^t\, \bar{l}_{ij}^{tr}\, m_j^{rs}\, [p^0, p^*(T), b^0, \omega]. \end{aligned} \tag{43}$$

In equations (41)-(43), superscript ^{0} refers to the reference period, so that b^0 expresses the equilibrium at the point of reference which must be maintained once the uniform tariff is replaced by the distorted tariff structure, and p^0 are the initially distorted prices. International prices (p^*) are expressed as a function of the tariff vector (T) in order to allow for endogenous world prices, and thus dropping the small country assumption (Salvatici, 2001; Antimiani and Salvatici, 2005).

2. A picture of the content and usage of imports. Comparing GTAP-MRIO Database and WIOD

Abstract

After reviewing the main indicators used to assess the international vertical fragmentation of productive processes, this work uses Wang's method to treat flow of intermediate products and gives a variant for the decomposition of intermediates with reference to the import side, extending the prevalent focus on exports. It applies this decomposition to bilateral flows for three of the major economies, European Union, United States and China, for six selected sectors, namely, primary, food, textiles, manufacturing, motor vehicles and services. Finally, it compares the results which are obtained through data from the two main databases used in GVCs analysis, that is GTAP database and WIOD.

JEL Codes: E16, F14

Keywords: Value-added trade, Double-counting, GTAP-MRIO Database, WIOD.

> *"Studying commodity chains is for the political economist something like ... looking through the Hubble telescope for the cosmologist. We are measuring indirectly and imperfectly a total phenomenon that we cannot see directly no matter what we do… It requires imagination and audacity along with patience. The only thing we have to fear is looking too narrowly."*
>
> *Immanuel Wallerstein, 2009*

2.1 Introduction

The global value chains (GVCs) metaphor evokes the interconnectedness that increasingly characterizes global economy and is an appealing concept in international economics. Almost half of world trade in goods and services takes place within GVCs (WTO, 2015:18) where geographically dispersed activities which generate value for each of the economies involved are linked through a single industry. The concept of GVCs suggests that it is firms not nations that are involved in "inter-national" trade, and that competition is related more to the "tasks" that are performed (Grossman and Rossi-Hansberg, 2008) than to the product space. The increased complexity and the speed of expansion of global interactions, driven by technological progress and trade policy reforms, along with the evidence revealed by the 2008 global financial crisis about the coordination of trade patterns (Keane, 2014), have led to renewed interest in GVCs from academic disciplines and the international policy community. GVCs have become "more mainstream in policy thinking" and a growing literature is trying to deconstruct the productive processes spanning multiple agents and geographic spaces, and track the *loci* of the sources of value along the supply chain, from the sector/country of origin to the country of absorption.

With the rise of international transactions in intermediate goods, standard trade statistics - recorded on a gross basis- include double counting and do not provide a true picture of trade relations. The UN Broad Economic Categories (BEC) classification scheme reclassifies merchandise imports categorized using the standard international trade classification (SITC), into end-use product categories, and is used to breakdown trade statistics according to goods classes (e.g., intermediate, capital or consumption goods). The WITS GVC module uses an advanced version of this methodology (Sturgeon and Memedovic, 2010) to give trade indicators related to a country's participation in manufactured intermediate trade, and to analyze GVC-related performance at the country/regional/inter-regional and product (electronics, automobiles and motorcycles, and apparel and footwear) level. While trade statistics allow estimation of the shares of parts and components in gross trade, on their own they do not enable direct measurement of imported goods on a value-added basis, or enable measurement of the domestic or indirect content of imports (IMF, 2013). For example, the assumption that imported intermediates contain 100% foreign value added is violated if upstream sectors in the importing country have provided intermediate inputs which are imported back further down the production process. In this case, imports contain re-imported domestic value added, and its quantification at the sector and bilateral levels can provide interesting insights for policy makers planning trade policy. Also of interest is the domestic content of exports (i.e., the accumulation of the value added incorporated by each of the various domestic sectors within the supply chain) or how an importing country uses imported intermediates from different partner countries (i.e., for domestic consumption or as inputs in producing for exports). Inter-country input-output (ICIO) tables which gather national accounts and bilateral trade data on goods and services into a consistent statistical framework, trace transactions in final and intermediate goods both within and between countries, and allow (indirectly) trade to be measured on a value-added basis. They take account of all backward linkages between countries and sectors, and capture the value of the imported inputs used directly and indirectly (at all stages of a country's production) in the manufacture of exported goods, while also tracing the domestic content of imports (IDE-JETRO/WTO, 2011).

The improvement to value-added trade data supplied by a number of international organizations and research entities, is encouraging more work to estimate the structure of the value added underlying gross trade (among others: Johnson and Noguera, 2012; Foster-McGregor and Stehrer, 2013; Wang et al., 2013; Koopman et al. 2014; Borin and Mancini, 2015). With the exception of Foster-McGregor and Stehrer (2013), most analyses of trade value-added focuses on gross exports. However, since Koopman, Wang, and Wei's (2014) study, the double-counting of the components of gross trade cannot be ignored. The present study is motivated by the contribution of Wang and coauthors (Koopman, Wang and Wei, 2014; Wang, Wei, and Zhu, 2013; Wang and Wei, 2016) which advances the decomposition of intermediate flows. Itextends the prevailing focus on the export side, and proposes a method to decompose both final and intermediate trade on the import side at the bilateral and sector levels. In the descriptive analysis presented in this work, we apply the decomposition of bilateral imports – which distinguishes imports by domestic usage, e.g., domestic consumption either direct or indirect or production for exports – and compare the results obtained with GTAP - Global Trade Analysis Project and WIOD -World Input-Output Database data. These are the main databases used for GVC analysis. This development contributes to a better understanding of the content of imports, and quantifies the double-counting in gross statistics. Comparison with GTAP and WIOD reveals the main differences, and suggests which data are more suitable depending on the dimension being investigated.

As already noted, trade is not directly observable on a value-added basis, and the estimates deriving from the use of ICIO tables depend on the decisions made in the construction methodologies adopted. National input-output tables vary widely in their level of detail and scope, and therefore, are not consistent (IMF, 2013). Moreover, in reconciling input-output (or supply-use) data and trade flows, harmonization procedures vary; for example, GTAP is benchmarked mainly against trade statistics, while WIOD prioritizes supply-use data. Finally, discrepancies in the estimates based on different databases emerge from the different sectoral classifications used in the databases, i.e., GTAP database provides very detailed agricultural and food sectors data but mostly aggregates manufacturing and service sectors (Andrew 2013; Wang et al., 2014).

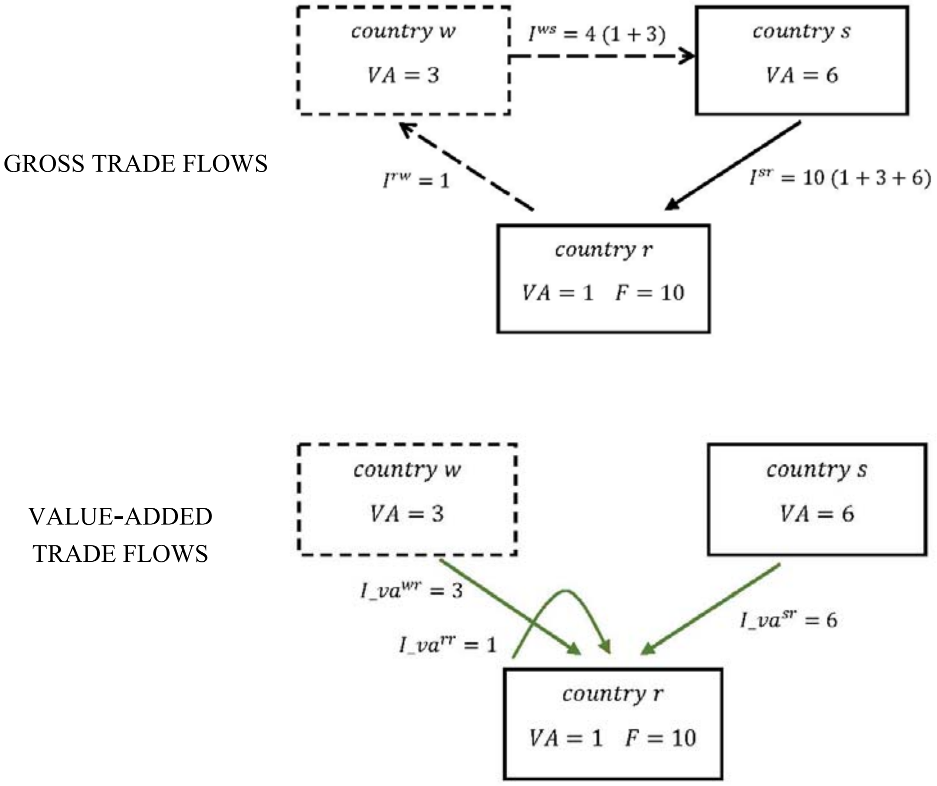
The following section presents the main indicators used to assess the international (vertical) fragmentation of productive processes. This introduces the decomposition method proposed to treat the flow of intermediate products. Based on this, section 3 proposes a method to decompose intermediates in imports and extends the focus on exports in particular by measuring vertical specialization in international trade (import content of exports). Section 4 provides an application of the proposed decomposition of bilateral flows at sector level, and compares the results with GTAP and WIOD data. Section 5 concludes.

2.2 Some preliminary insights and definitions

GVCs are defined as inter-country, inter-sector systems of value-added sources and destinations (Koopman et al., 2014). Value is added at each successive stage in the productive process, this value added equaling the value of the cost of the primary factors of production in the country-sector which hosts the particular stage of production. "Value-added thinking" in international trade has resulted in a break with traditional trade statistics which report gross flows that include both final and intermediate exchanges. If intermediate trade is recognized as a significant feature of world trade (Baldwin and Lopez-Gonzalez, 2015), a double counting problem emerges if gross values rather than net value added between border crossing are recorded. This compounds the linked phenomenon of indirect trade which is indirect trade between two countries via a third country, and implies a hidden trade in value added underlying gross trade flows (Johnson and Noguera, 2012).

In figure 2.1, the bilateral flow from country s to country r is depicted. Country r is the final market for the good worth 10 \$ (F = 10). A basic GVC is described: country r produces 1\$ of intermediate inputs using only its primary factors, which are exported to country w. In turn, country w adds to 1\$ of imported inputs, 3\$ of domestic value added. The 4\$ of intermediate inputs are sent to country s which performs the last stage of production adding 6\$ of value to satisfy the final demand in country r. In gross trade statistics (upper panel of figure 2.1), it would appears 10\$ exchanges from country s to r, 4\$ from w to s, and 1\$ from r to w. Thus, the first 1\$ originating in r is counted three times, and the 3\$ originating fromw is counted twice. Total accounting is clearly over-counted due to these pure double- counted terms which cannot be traced back to the individual country's GDP (Koopman et al., 2014). From a value-added trade perspective (lower panel of figure 2.1), country r is satisfying its 10\$ final consumption by importing 6\$ from s, 3\$ indirectly from w, and 1\$ from r itself (reflected value added). From the exporter's point of view, country s's value-added exports to country r amount to 6\$, while its gross exports are 10\$, so that foreign content of its bilateral exports amounts to 4\$.

Figure 2.1. *Gross and value-added trade flows*.



A first definition of vertical specialization can be formulated as: i) two or more sequential stages performed to produce a final product; ii) two or more countries provide value added to that production; iii) at least one country uses imported inputs in its stage of the production process, and some of the resulting output is exported (Hummels et al., 2001). It is clear that whenever vertical specialization occurs, traditional trade measures and value-added trade measures will not coincide.

A growing body of research focuses on the correct measurement of the structure of value added underlying gross trade. Complementary and alternative concepts related to value-added trade have been proposed; the main measures are summarized in table 2.1. The key idea in the value-added conceptualization of trade is that gross flows contain domestic as well as foreign value-added, and this is true for both exports and imports (Johnson, 2014).

Table 2.1. *Main measures of value-added trade.*

VS (vertical specialization)	Share of directly and indirectly imported input content in exports	Hummels, D., Ishii, J., and Yi, K.M. (2001)
VS1	Intermediate exports sent indirectly through third country to final destination	Hummels, D., Ishii, J., and Yi, K.M. (2001)
VS1*	Portion of VS1 that comes back to the country of origin of intermediate exports	Daudin, G., Rifllart, C., and Schweisguth, D. (2011)
Value-added exports (VAX ratio)	Domestic content of exports absorbed abroad (to gross exports)	Johnson, R.C., and Noguera, G. (2012)
Pure double-counted terms	Double-counted value added originated in the home country or in foreign countries.	Koopman, R., Wang, Z., Wei, S.J. (2014)

Hummels, Ishii, and Yi (2001) provided the first metric of vertical trade related to the use of the foreign inputs embedded in a country's exports. The imported content in exports includes both their direct and indirect contribution, and can be defined as:

$$(1)\quad VS^{s} = A^{*s}(I - A^{ss})^{-1}e^{s*} \quad ,$$

where A^{*S} represents the matrix of technical coefficients, giving the intermediate usage by country s of products originated in all countries other than s; A^{ss} is the domestic structural matrix, and e^{s*} is the vector of country s's total exports to the world. The assumption that foreign inputs are completely foreign sourced is in place.

A second channel through which a country can participate in vertical trade is by producing intermediate exports which are used by the receiving country to produce its exports. In the literature, it is labeled $VS1$, and a first approximation gives:

$$(2)\quad VS1^{s} = \sum_{r \neq s} A^{sr}(I - A^{rr})^{-1}\, e^{r*}.$$

As can be seen from the superscript of the A matrix, the computation of the $VS1$ measure requires the existence of a *global* input-output matrix, since inter-country movements of intermediate inputs need to be tracked. Specifically, input-output tables for individual countries are combined with trade flows at sectoral level in order to give four dimensional information on the country/sector pairs of inputs identified from the country/sector outputs. With these data (see section 4.1 for their development), it is possible to drop the assumption that all imported intermediate inputs are 100% foreign value-added. The concept of *reflected* trade is introduced, accounting for a subset of the VS1 which is re-imported back to the country of origin and originated in the first exported intermediate inputs. Daudin, Rifflart, and Schweisguth (2011) introduced this measure, and define the $VS1^*$ as "the exports that further down the production chain, are embedded in re-imported goods that are either consumed, invested or used as inputs for domestic final use" (Daudin et al., 2011:1408). Analytically, it is done by:

$$(3) \quad VS1^{*s} = \textstyle\sum_{r \neq s} A^{sr}(I - A^{rr})^{-1} e^{rs} \ .$$

The trade vector e^{rs} includes only the final trade that returns home. This method causes an under-estimation of the actual vertical specialization, since it excludes the part of domestic value-added that is re-imported via intermediate trade (Koopman et al., 2014).

Johnson and Noguera (2012) suggest looking at the country of absorption[18]. They give a measure of inter-country production sharing, the VAX ratio, as the ratio of value-added to gross exports where value-added exports are defined as the value added produced in one country but absorbed by another. The VAX ratio is an interesting measure of the importance of vertical specialization at the country aggregate level but performs less well at the sector, bilateral, and bilateral sector levels. Note that that an equal VAX ratio between two countries may correspond to different positions along the GVC. Suppose that a country used 50% foreign intermediate inputs to produce exports which are absorbed abroad then the VAX ratio is 50%. The other country sources all the input for its exports domestically, but re-imports 50% of its exports. Then, the VAX ratio is 50% but the position in the GVC clearly differs between the two countries (Wang et al. 2013).

According to the criterion of country of absorption, bilateral exports can be split into the three components of absorption, reflection, and redirection, based on where they are finally consumed. Johnson and Noguera (2012)'s decomposition:

$$(4) \quad e^{sr} = (f^{sr} + A^{sr}y^{rr}) + A^{sr}y^{rs} + \textstyle\sum_{t \neq r,s} A^{sr}y^{rt},$$

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[18] This approach reflects the concept of "trade in value added" (TiVA) which focuses on computing the origin country's value-added induced by a destination country's consumption (Johnson and Noguera, 2012; Los et al., 2013, 2015; Koopman et al., 2014; Wang et al., 2014; Lejour et al., 2014; Cappariello and Felettigh, 2015). A slightly different concept is "value added in trade" which decomposes value-added by source in a country's trade flows (Daudin et al., 2011; Stehrer et al., 2012; Foster-McGregor and Stehrer, 2013; Amador and Stehrer, 2014). This is consistent with the factor content literature starting from Reimer (2006; 2011) and Trefler and Zhu (2010), built on the seminal contribution of Vanek (1968). For a comparison of the two value added flowmeasures, see Stehrer (2012).

distinguishes between final and intermediate goods in bilateral exports, decomposing the output of the foreign destination. That is, gross bilateral exportse^{sr}, are used for final consumption in rf^{sr}, or as intermediate inputsA^{sr}, for r's production ending in r itself, y^{rs} (absorption), or in all other destinationsy^{rt} (redirection). The second term gives an approximation of the amount of exports "embedded as intermediates in goods that are reflected back to the source country" (reflection). In Johnson and Noguera's analysis, only first round effects are considered, $[I + A]$, that is, the direct effect on output linked to an increase in final demand, and the effect on direct intermediate inputs needed to produce that output.

Foster-McGregor and Stehrer (2013) in line with the factor content literature -starting from Reimer (2006; 2011) and Trefler and Zhu (2010), and built on the seminal contribution of Vanek (1968)- and following Trefler and Zhu's (2010) analytical framework[19], provide a decomposition of net trade flows looking at both exports and imports of the value-added content of trade simultaneously. In a three country world, for country s this is given by:

$$(5)\quad t_v^s = v^s l^{ss} e^{s*} + \textstyle\sum_{r\neq s} v^r l^{rs} e^{s*} - \left(\sum_{r\neq s} v^s l^{sr} m^{rs} + \sum_{r\neq s} v^r l^{rr} m^{rs} + \sum_{t\neq r\neq s} v^t l^{tr} m^{rs}\right)\ ,$$

where v^s is an element of the V matrix giving the value-added share of country s's total output; $l^{sr}$is an element of the global Leontief inverse (or multiplier) matrix, L, giving the amount of total output directly or indirectly required to produce one unit of consumption. The trade vector is defined as $t^s = e^s - m^s$, with e^{s*} denoting total exports of country s to the world, and the negative entries m^{rs} denoting country s's bilateral imports from country r. The sum of the first two terms gives the value-added content of exports split between domestic ($v^s l^{ss} e^{s*}$) and foreign ($\sum_{r\neq s} v^r l^{rs} e^{s*}$). The third to the fifth terms give the value added content of imported goods which are distinguished in the reflected component ($\sum_{r\neq s} v^s l^{sr} m^{rs}$), the value added of the direct bilateral partner ($\sum_{r\neq s} v^r l^{rr} m^{rs}$), and the value added of third countries embedded in the bilateral imports ($\sum_{t\neq r\neq s} v^t l^{tr} m^{rs}$).

Foster-McGregor and Stehrer (2013) construct a trade vector composed of both intermediate and final flows. This implies that their method, unlike that proposed in Daudin et al. (2011), leads to over-estimation of the computed value-added content of trade flows. When the value-added coefficients are multiplied by the global Leontief inverse and the trade vector, which includes both intermediate and final goods, some portion of the intermediate inputs is

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[19] The factor content literature is treated in section 1.7.2.

computed repeatedly when they cross borders multiple times (Koopman et al., 2014). Suppose a final export from s to r which requires intermediate inputs imported from r. If these intermediate inputs are in turn, produced using intermediate inputs imported from s, then this last portion is counted twice, since the global Leontief inverse contains the direct and all rounds of indirect output caused by the final demand. Amador and Stehrer (2014) justify the double-counting caused by adding intermediate to final goods in the trade vector by taking a national accounting perspective in which both types of flows have to be considered as a source of value-added. While this is true, this method implies a more fundamental problem: it is based conceptually on the assumption of full exogeneity of exports (e.g. exports are supposed not to induce other exports). It is a good approximation for the period when intermediate flows were relatively negligible (Wang et al., 2013) but is violated if the extent of intermediate exchange implies a situation where final exports are produced using other exports (from an upstream link in the chain) which are embedded in the intermediate inputs imported from the partner country to produce final exports.

When a global input-output model is used to identify the foreign/domestic value added components in the presence of internationally fragmented production processes, the original Leontief insights have to be extended in order to properly manage the endogeneity that operates through intermediate input channels (Wang et al., 2013; Zhang, 2015).

In what follows, we present the input-output model on which analyses of value-added trade are based. Then, Wang's decomposition of intermediate flows method is discussed. Finally, we apply that method to give a value-added decomposition of bilateral imports split by importer's use.

2.3 Leontief's insights and beyond: the decomposition of intermediate flows

All the previous measures of value-added content of trade are rooted in the input-output economics developed by Leontief (1936). The economy is described in terms of inter-industry (or inter-sector) relationships, exhibiting the relational character of the production, as a way to bring together micro- and macro-economics. The network of inter-activity flows is represented through an input-output table which is structured as a matrix that lists economic sectors, in the same sequence in both the columns and the rows. The rows give the delivery of output among sectors while the columns report the cost structure of production. From the numbers that emerge from these flows, the technical coefficients are calculated as a share of total sectoral output kept fixed by technology which is tantamount to presuming a developmental division of labor process. When several national input-output tables are harmonized with bilateral trade flows, and assuming an endogenous estimate aggregated for the “rest of the world”, some aspects of the whole world economy can be analyzed through an ICIO table. Figure 2.2 represents the structure of the ICIO table for the generic c countries and n sectors case.

Figure 2.2. *Inter-country, input-output table (c countries and n sectors).*

		Intermediate flows								*Final demand*			*Output*
Country		1			⋯	⋯	c			1	⋯	c	
	Sector	1	⋯	n	⋯	⋯	1	⋯	n				
1	1	z_{11}^{11}	⋯	z_{1n}^{11}	⋯	⋯	z_{11}^{1c}	⋯	z_{1n}^{1c}	f_1^{11}	⋯	f_1^{1c}	x_1^1
	2	z_{21}^{11}	⋯	z_{2n}^{11}	⋯	⋯	z_{21}^{1c}	⋯	z_{2n}^{1c}	f_2^{11}	⋯	f_2^{1c}	x_2^1
	⋮	⋮	⋯	⋮	⋯	⋯	⋮	⋯	⋮	⋮	⋯	⋮	⋮
	n	z_{n1}^{11}	⋯	z_{nn}^{11}	⋯	⋯	z_{n1}^{1c}	⋯	z_{nn}^{1c}	f_n^{11}	⋯	f_n^{1c}	x_n^1
2	1	z_{11}^{21}	⋯	z_{1n}^{21}	⋯	⋯	z_{11}^{2c}	⋯	z_{1n}^{2c}	f_1^{21}	⋯	f_1^{2c}	x_1^2
	⋮	⋮	⋯	⋮	⋯	⋯	⋮	⋯	⋮	⋮	⋯	⋮	⋮
	n	z_{n1}^{21}	⋯	z_{nn}^{21}	⋯	⋯	z_{n1}^{2c}	⋯	z_{nn}^{2c}	f_n^{21}	⋯	f_n^{2c}	x_n^2
⋮	⋮	⋮	⋯	⋮	⋯	⋯	⋮	⋯	⋮	⋮	⋯	⋮	⋮
⋮	⋮	⋮	⋯	⋮	⋯	⋯	⋮	⋯	⋮	⋮	⋯	⋮	⋮
⋮	⋮	⋮	⋯	⋮	⋯	⋯	⋮	⋯	⋮	⋮	⋯	⋮	⋮
c	1	z_{11}^{c1}	⋯	z_{1n}^{c1}	⋯	⋯	z_{11}^{cc}	⋯	z_{1n}^{cc}	f_1^{c1}	⋯	f_1^{cc}	x_1^c
	⋮	⋮	⋯	⋮	⋯	⋯	⋮	⋯	⋮		⋯		⋮
	n	z_{n1}^{c1}	⋯	z_{nn}^{c1}	⋯	⋯	z_{n1}^{cc}	⋯	z_{nn}^{cc}	f_n^{c1}	⋯	f_n^{cc}	x_n^c
Value added		va_1^1	⋯	va_n^1	⋯	⋯	va_1^c		va_n^c				
Total input		x_1^1	⋯	x_n^1	⋯	⋯	x_1^c	⋯	x_n^c				

Let the superscripts denote countries and subscripts the sectors, specifically, put $c = 1, \dots, C$ denoting countries, and $n = 1, \dots, N$ sectors. The element z_{21}^{1c}gives the intermediate production of sector 2 in country 1 used for the production of the sector 1 in country c; f_2^{1c} is the final demand in c for goods produced by sector 2in country 1(i.e., exports of sector 2 in country 1to $c$for government and private consumption in c); $va_1^c$is the value added created in $c$for the production of x_1^c, the total output of the first sector in country c. The value added is a residual obtained by subtracting all intermediate inputs from the total output: $va_1^c = x_1^c - [z_{11}^{1c} + z_{21}^{1c} + \dots + z_{n1}^{cc}]$. The corresponding value added per unit of output is then given by: $v_1^c = va_1^c / x_1^c$. The technical input-output coefficient matrix, A, is obtained directly from the intermediate flows in the ICIO table, with the a_{21}^{1c} element given by z_{21}^{1c}/x_1^c, which describes the usage of the intermediate goods produced in the origin sector 2 in country 1 by sector 1 in country c as a share of total output of c's first sector. The construction of the A matrix differentiates goods across countries for the techniques used for its production (Reimer, 2011). The sub-matrices on the diagonal in the A matrix are the domestic input-output coefficients matrices, while the off-diagonal blocks track the requirement for foreign intermediates.

The basic output identity can be expressed in block matrix notation as[20]:

$$\begin{bmatrix} X^1 \\ X^2 \\ \vdots \\ X^c \end{bmatrix} = \begin{bmatrix} A^{11} & A^{12} & \cdots & A^{1c} \\ A^{21} & A^{22} & \cdots & A^{2c} \\ \vdots & \vdots & \ddots & \vdots \\ A^{c1} & A^{c2} & \cdots & A^{cc} \end{bmatrix} \begin{bmatrix} X^1 \\ X^2 \\ \vdots \\ X^c \end{bmatrix} + \begin{bmatrix} F^{11} & F^{12} & \cdots & F^{1c} \\ F^{21} & F^{22} & \cdots & F^{2c} \\ \vdots & \vdots & \ddots & \vdots \\ F^{c1} & F^{c2} & \cdots & F^{cc} \end{bmatrix}, \tag{6}$$

which expresses the row balance condition derived from the ICIO table in figure 2.2. For the $c - th$ row, it states that the production of country c's gross output is used totally as intermediate or final consumption either at home (respectively, $A^{cc}X^c$and F^{cc}) or abroad ($\sum_{s=1}^{c} A^{cs}X^s$ and $\sum_{s=1}^{c} F^{cs}$).

For exogenous levels of F, the system in (6) can be solved for X, which gives:

$$\begin{bmatrix} X^{11} & X^{12} & \cdots & X^{1c} \\ X^{21} & X^{22} & \cdots & X^{2c} \\ \vdots & \vdots & \ddots & \vdots \\ X^{c1} & X^{c2} & \cdots & X^{cc} \end{bmatrix} = \tag{7}$$

$$\begin{bmatrix} I - A^{11} & -A^{12} & \cdots & -A^{1c} \\ -A^{21} & I - A^{22} & \cdots & -A^{2c} \\ \vdots & \vdots & \ddots & \vdots \\ -A^{c1} & -A^{c2} & \cdots & I - A^{cc} \end{bmatrix}^{-1} \begin{bmatrix} F^{11} & F^{12} & \cdots & F^{1c} \\ F^{21} & F^{22} & \cdots & F^{2c} \\ \vdots & \vdots & \ddots & \vdots \\ F^{c1} & F^{c2} & \cdots & F^{cc} \end{bmatrix} =$$

$$\begin{bmatrix} L^{11} & L^{12} & \cdots & L^{1c} \\ L^{21} & L^{22} & \cdots & L^{2c} \\ \vdots & \vdots & \ddots & \vdots \\ L^{c1} & L^{c2} & \cdots & L^{cc} \end{bmatrix} \begin{bmatrix} F^{11} & F^{12} & \cdots & F^{1c} \\ F^{21} & F^{22} & \cdots & F^{2c} \\ \vdots & \vdots & \ddots & \vdots \\ F^{c1} & F^{c2} & \cdots & F^{cc} \end{bmatrix},$$

where $L = (I - A)^{-1}$ is the Leontief inverse (or multiplier) matrix giving the total requirement of output directly *and* indirectly required to produce one unit of consumption. It exists as long as the economic system is composed of all smaller productive sub-systems which make a positive delivery to final demand (Hawkins-Simons condition).

Suppose a unitary increase in the demand for a final good; this would imply an increase in the demand for the input required directly for its production. In turn, the increase in the output of the direct input will correspond to an increased demand for the inputs needed to produce the direct input, and so on for all successive rounds of production. At each step a stratum of value

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[20] For the input-output model, refer also to section 1.4.3.

is added. Thus, the value-added multiplier which reflects the production structure contained in the ICIO table, can be expressed as a geometric series: $V + VA + VAA + \cdots = V(I - A)^{-1} = VL$.

Expressing the diagonal matrix corresponding to the vector of value-added shares we obtain:

$$(8) \quad \hat{V}L = \begin{bmatrix} V^1L^{11} & V^1L^{12} & \cdots & V^1L^{1c} \\ V^2L^{21} & V^2L^{22} & \cdots & V^2L^{2c} \\ \vdots & \vdots & \ddots & \vdots \\ V^cL^{c1} & V^cL^{c2} & \cdots & V^cL^{cc} \end{bmatrix}$$

The VL is the key matrix in the value-added trade literature (alternatively referred to as VB or VAS matrix). It contains all the information about the partition of value added by country/sector sources in the production process. Specifically, a typical sub-matrix in the main diagonal represents the domestic value-added share in domestic production per sector. For country c it is given by:

$$(9)\ \text{a)} \quad \hat{V}^cL^{cc} = \begin{bmatrix} v_1^c l_{11}^{cc} & v_1^c l_{12}^{cc} & \cdots & v_1^c l_{1n}^{cc} \\ v_2^c l_{21}^{cc} & v_2^c l_{22}^{cc} & \cdots & v_2^c l_{2n}^{cc} \\ \vdots & \vdots & \ddots & \vdots \\ v_n^c l_{n1}^{cc} & v_n^c l_{n2}^{cc} & \cdots & v_n^c l_{nn}^{cc} \end{bmatrix}$$

The off-diagonal sub-matrices denote foreign value-added shares in the same production, disentangled along country-sector. The value added of country 1 embedded in country c's domestic production is represented by:

$$(9)\ \text{b)} \quad \hat{V}^1L^{1c} = \begin{bmatrix} v_1^1 l_{11}^{1c} & v_1^1 l_{12}^{1c} & \cdots & v_1^1 l_{1n}^{1c} \\ v_2^1 l_{21}^{1c} & v_2^1 l_{22}^{1c} & \cdots & v_2^1 l_{2n}^{1c} \\ \vdots & \vdots & \ddots & \vdots \\ v_n^1 l_{n1}^{1c} & v_n^1 l_{n2}^{1c} & \cdots & v_n^1 l_{nn}^{1c} \end{bmatrix}$$

Since all value embedded in the production of an output must be either domestic or foreign, the sum along each column of the VL matrix is unity. For the generic column referring to the production of j in country r the following is true:

$$(10) \quad \sum_{s=1}^{c} \sum_{i=1}^{n} v_i^s l_{ij}^{sr} = 1$$

This property allows the value-added production and trade to be derived by pre-multiplying these flows by VL matrix. Applying the VL to the diagonal matrix of final production, F, we obtain the NC x NC matrix:

$$(11)\quad \hat{V}L\hat{F} =$$

$$\begin{bmatrix} v_1^1 l_{11}^{11} f_1^1 & \dots & v_1^1 l_{1n}^{11} f_n^1 & v_1^1 l_{11}^{12} f_1^2 & \dots & v_1^1 l_{1n}^{12} f_n^2 & \dots & v_1^1 l_{11}^{1c} f_1^c & \cdots & v_1^1 l_{1n}^{1c} f_n^c \\ v_2^1 l_{21}^{11} f_1^1 & \dots & v_2^1 l_{2n}^{11} f_n^1 & v_2^1 l_{21}^{12} f_1^2 & \dots & v_2^1 l_{2n}^{12} f_n^2 & \dots & v_2^1 l_{21}^{1c} f_1^c & \cdots & v_2^1 l_{2n}^{1c} f_n^c \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots & \ddots & \vdots & \vdots & \vdots \\ \vdots & \dots & \vdots & \vdots & \dots & \vdots & \dots & \vdots & \ddots & \vdots \\ v_n^c l_{n1}^{c1} f_1^1 & \dots & v_n^c l_{nn}^{c1} f_n^1 & v_n^c l_{n1}^{c2} f_1^2 & \dots & v_n^c l_{nn}^{c2} f_n^2 & \dots & v_n^c l_{n1}^{cc} f_1^c & \cdots & v_n^c l_{nn}^{cc} f_n^c \end{bmatrix}$$

A row of the $\hat{V}L\hat{F}$ gives the usage of a specific sector/country value added by the sector itself and by all its downstream sectors and countries. For example, the sum of the first row gives the contribution of the value added originating from the first sector of country 1 (v_1^1) to the world production of final goods which is equal to sector 1 in country 1's GDP. That is:

$$(12)\quad GDP_1^1 = v_1^1 x_1^1 = v_1^1 (l_{11}^{11} f_1^1 + \dots + v_1^1 l_{1n}^{1c} f_n^c) = v_1^1 l_{11}^{11} f_1^1 + v_1^1 l_{12}^{11} f_2^1 + \dots + v_1^1 l_{1n}^{1c} f_n^c$$

The sums of each column give the contribution of all sectors/countries of origin to the production of a given sector/country. That is, the final production of the $n - th$ sector in country c (f_n^c) can be decomposed according to the sector/country from which value added originated as:

$$(13)\quad f_n^c = (\textstyle\sum_{s=1}^{c} \sum_{i=1}^{n} v_i^s l_{in}^{sc}) f_n^c = v_1^1 l_{1n}^{1c} f_n^c + v_2^1 l_{2n}^{1c} f_n^c + \cdots + v_n^c l_{nn}^{cc} f_n^c =$$
$$(\textstyle\sum_i v_i^c l_{in}^{cc}) f_n^c + (\sum_{s \neq c} \sum_i v_i^s l_{in}^{sc}) f_n^c \ ,$$

where i= $1, \dots, N$ is a generic sector, and $s = 1, .., C$ denotes a generic country. The first term in (13) is the total domestic value added embedded in country c's final production of sector n. The second term is the foreign value added (originating in all the $n - 1$ countries other than c) in the same production.

These are the main intuitions and analytical instruments used in the aforementioned metrics of value-added trade. In order to account for the double-counting that results from the back and forth of intermediate goods, the intermediate part of the trade flows also has to be decomposed. However, as noted by Wang (2013), the decomposition of intermediate goods trade flows cannot be achieved simply by applying Leontief's insight because of the endogeneity of gross intermediate trade flows which is solved within the model for exogenous levels of final demand. Koopman, Wang, and Wei (2014) seminal contribution decomposes intermediate trade, linking the literature on vertical specialization and the literature on trade in value added. Their accounting identity provides a decomposition of gross outputs in terms of final demand according to where it is absorbed, tracking the value-added linkages between origin and final destination. This allows us to express a country's gross exports in terms of nine components which conceptually can be traced back to three main categories. These are the generalized measures of the measures proposed in the vertical specialization and value added in trade literature: exports of value added (domestic value added absorbed abroad), domestic value added that returns home, and foreign value added. A fourth component of "pure double-counted items" is added to the accounting formula including the terms which are not part of countries' GDP, and which arise from two way intermediate trade. Quantification of the different double-counted terms provides information on the country's position within the GVC. When considering two countries with similar amounts of value-added exports, the relevance of the double-counting caused by using foreign intermediate inputs, and the double-counting caused by that part of the domestic value-added that is re-imported after being exported, can give an intuition about the country's upstreamness or downstreamness in the global production process. In Koopman, Wang, and Wei's example, countries performing upstream stages such as product conception, tend to show a large value for the re-imported domestic value-added, whereas stages such as assembly of final products are associated with a large use of foreign value-added (Koopman et al., 2014:466).

Wang, Wei, and Zhu (2013) extended Koopman et al.'s (2014) framework to provide a breakdown of bilateral exports at sector level. The aggregate level in Koopman et al. (2014) cannot be immediately disaggregated to the bilateral/sector level by applying their methodology to bilateral or sector level data, since it does not capture the backward or forward linkages among the different sectors implied in the trade, and also does not provide information on the structure of a given bilateral relation (Wang et al., 2013; Borin and Mancini, 2015). For example, if the aim is to compute the domestic value-added "reflected" by the direct trade partner, since the interest is in the bilateral protection in that specific trade link, it is necessary to distinguish this from the case where it is first exported to the bilateral partner and then re-imported from a third country, or where it is re-imported from the bilateral partner after further processing in a third country. In what follows we implement Wang's method to decompose intermediate flows at the sector/bilateral level, and provide an application using imports instead of exports. The aim is to express the value added by origin embedded in imports which are distinguished by domestic usage (e.g., domestic consumption either direct or indirect, or production for exports). In doing so, we adopt a source-based approach taking the perspective of the country where the value added originated.

Let $r, s, t, w = 1, \dots, C$ denoting countries. Consider the bilateral flow from country r to country s, and define I^{rs} as the N x 1 vector of country s' gross imports from country r. Bilateral gross imports can be expressed as the sum of final imports and imports of intermediate inputs:

$$(14) \qquad I^{rs} = F^{rs} + A^{rs}X^{s} \quad .$$

In order to resolve the endogeneity issue arising in the input-output model for intermediate flows, all bilateral intermediate trade flows are categorized into major final demand groups according to their final destination of absorption. This is the key technical step given by Wang to convert gross output and gross trade to exogenous variables in the trade accounting framework.

From the expression in (7), gross output can be decomposed according to where it is finally consumed. Then, for country s we obtain:

$$(15) \quad X^{s} = X^{ss} + \sum_{t \neq s}^{c} X^{st} = \sum_{t=1}^{c} \sum_{w=1}^{c} L^{st} F^{tw} = L^{ss}F^{ss} + L^{ss} \sum_{t \neq s}^{c} F^{st} + \sum_{t \neq s}^{c} \sum_{w=1}^{c} L^{st} F^{tw} \quad .$$

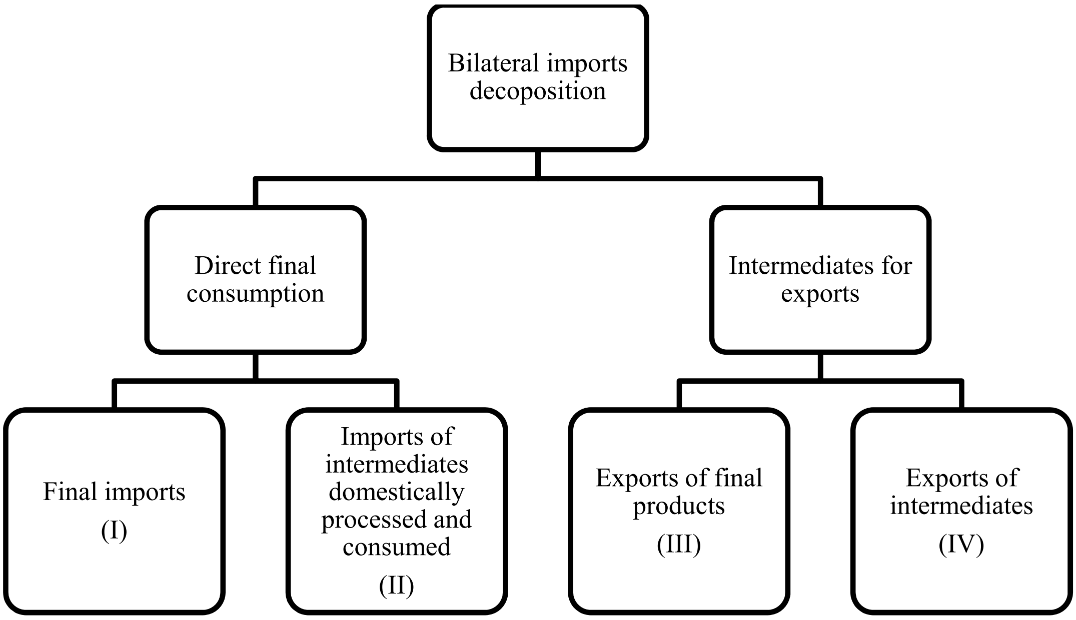
The first term in (15) represents the domestic production for final goods directly consumed domestically; the second term is domestic production for final goods which are exported to all countries other than s; finally, the third term is production in s to produce intermediate goods which are exported and consumed all over the world (including country s as an indirect final market).

Substituting equation (15) into (14), we obtain the decomposition of gross bilateral imports:

$$(16) \quad I^{rs} = F^{rs} + A^{rs}(L^{ss}F^{ss} + L^{ss} \sum_{t \neq s}^{c} F^{st} + \sum_{t \neq s}^{c} \sum_{w=1}^{c} L^{st}F^{tw}) = \quad F^{rs} + A^{rs}L^{ss}F^{ss} + A^{rs}L^{ss} \sum_{t \neq s}^{c} F^{st} + A^{rs} \sum_{t \neq s}^{c} \sum_{w=1}^{c} L^{st}F^{tw} \, .$$

From (16) bilateral imports are split into four main blocks. The first term represents s's final imports from country r which are directly consumed in s. The second to fourth terms are country s's imports of intermediate goods which are processed domestically in order to directly satisfy domestic final demand (second term) or to produce exports of final goods (third term) or of intermediate goods (fourth term). The last term includes a portion of intermediate exports from country s which are finally consumed in country s (for $w = s$). According to Wang and Wei (2016), the third and the fourth terms can be defined as the GVC segment which implies that it crosses borders at least twice, thus reflecting a deeper cross country production sharing. Figure 2.3 represents the major categories of gross bilateral imports given by equation (16).

Figure 2.3. *Decomposition of gross bilateral imports. Main categories.*



Each of the components in equation (16) combines portions of value added from all sectors and countries. To reallocate the value added by country of origin, we use the total value added multiplier expressed in equation (13). It can be applied directly to the component of final exports, exploiting the property in (10), as follows:

$$F^{rs} = V^r L^{rr} F^{rs} + V^s L^{sr} F^{rs} + \sum_{t\neq r,s}^{c} V^t L^{tr} F^{rs} \quad , \tag{17}$$

where the first term is the exporter's value added in its final exports to s, the second term is the importer's value added which is re-imported through imports from r, and the last term is the value added originating from a third country which is embedded in bilateral final flows from r to s.

However, the intermediate part of bilateral imports needs further decomposition in order to take account of the double counting.

From the row balance condition of (6) we know that the gross output of country s is used as final consumption either at home or abroad, and as intermediate inputs for domestic production or for foreign production. Mathematically:

$$X^s = F^{ss} + F^{s*} + A^{ss} X^s + A^{s*} X^* \quad , \tag{18}$$

where $F^{s*} = \sum_{t \neq s}^{c} F^{st}$, that is the total s' exports of final goods, and $A^{s*}X^{*} = \sum_{t \neq s}^{c} A^{st}X^{t}$, total s' exports of intermediate goods which are used in the production of each of the receiving country. Solving for X^swe get:

$$X^s = (I - A^{ss})^{-1}F^{ss} + (I - A^{ss})^{-1}(F^{s*} + A^{s*}X^{*}) \ , \tag{19}$$

where $\widetilde{L^{ss}} = (I - A^{ss})^{-1}$ is the domestic value added multiplier, that is, the Leontief inverse matrix calculated on the domestic input-output table of country s.

Explicitly considering inter-sectoral linkages within each block matrix, we define:

$$X^s = \begin{bmatrix} x_1^s \\ x_2^s \\ \vdots \\ x_n^s \end{bmatrix}, \quad F^{ss} = \begin{bmatrix} f_1^{ss} \\ f_2^{ss} \\ \vdots \\ f_n^{ss} \end{bmatrix}, \quad F^{s*} = \begin{bmatrix} \sum\limits_{t \neq s}^{c} f_1^{st} \\ \sum\limits_{t \neq s}^{c} f_2^{st} \\ \vdots \\ \sum\limits_{t \neq s}^{c} fy_n^{st} \end{bmatrix},$$

$$A^{s*}X^{*} = \begin{bmatrix} \sum_{t \neq s}^{c} a_{11}^{st}\, x_1^t & \sum_{t \neq s}^{c} a_{12}^{st}\, x_2^t & \dots & \sum_{t \neq s}^{c} a_{1n}^{st} x_n^t \\ \sum_{t \neq s}^{c} a_{21}^{st} x_1^t & \sum_{t \neq s}^{c} a_{22}^{st}\, x_2^t & \dots & \sum_{t \neq s}^{c} a_{2n}^{st} x_n^t \\ \vdots & \vdots & \ddots & \vdots \\ \sum_{t \neq s}^{c} a_{n1}^{st} x_1^t & \sum_{t \neq s}^{c} a_{n2}^{st}\, x_2^t & \dots & \sum_{t \neq s}^{c} a_{nn}^{st} x_n^t \end{bmatrix}, \qquad \widetilde{L^{ss}} =$$

$$\begin{bmatrix} 1 - a_{11}^{ss} & -a_{12}^{ss} & \dots & -a_{1n}^{ss} \\ -a_{21}^{ss} & 1 - a_{22}^{ss} & \dots & -a_{2n}^{ss} \\ \vdots & \vdots & \ddots & \vdots \\ -a_{n1}^{ss} & -a_{n2}^{ss} & \dots & 1 - a_{nn}^{ss} \end{bmatrix}^{-1} = \begin{bmatrix} \widetilde{l^{ss}_{11}} & \widetilde{l^{ss}_{12}} & \dots & \widetilde{l^{ss}_{1n}} \\ \widetilde{l^{ss}_{21}} & \widetilde{l^{ss}_{22}} & \dots & \widetilde{l^{ss}_{2n}} \\ \vdots & \vdots & \ddots & \vdots \\ \widetilde{l^{ss}_{n1}} & \widetilde{l^{ss}_{n2}} & \dots & \widetilde{l^{ss}_{nn}} \end{bmatrix} .$$

Then, equation (19) can be written as:

$$\begin{bmatrix} x_1^s \\ x_2^s \\ \vdots \\ x_n^s \end{bmatrix} = \begin{bmatrix} \widetilde{l^{ss}_{11}} & \widetilde{l^{ss}_{12}} & \dots & \widetilde{l^{ss}_{1n}} \\ \widetilde{l^{ss}_{21}} & \widetilde{l^{ss}_{22}} & \dots & \widetilde{l^{ss}_{2n}} \\ \vdots & \vdots & \ddots & \vdots \\ \widetilde{l^{ss}_{n1}} & \widetilde{l^{ss}_{n2}} & \dots & \widetilde{l^{ss}_{nn}} \end{bmatrix} \begin{bmatrix} f_1^{ss} \\ f_2^{ss} \\ \vdots \\ f_n^{ss} \end{bmatrix} + \begin{bmatrix} \widetilde{l^{ss}_{11}} & \widetilde{l^{ss}_{12}} & \dots & \widetilde{l^{ss}_{1n}} \\ \widetilde{l^{ss}_{21}} & \widetilde{l^{ss}_{22}} & \dots & \widetilde{l^{ss}_{2n}} \\ \vdots & \vdots & \ddots & \vdots \\ \widetilde{l^{ss}_{n1}} & \widetilde{l^{ss}_{n2}} & \dots & \widetilde{l^{ss}_{nn}} \end{bmatrix} \begin{bmatrix} \sum_{t \neq s}^{c} f_1^{st} \\ \sum_{t \neq s}^{c} f_2^{st} \\ \vdots \\ \sum_{t \neq s}^{c} fy_n^{st} \end{bmatrix} + \tag{20}$$

$$\begin{bmatrix} \widetilde{l^{ss}_{11}} & \widetilde{l^{ss}_{12}} & \dots & \widetilde{l^{ss}_{1n}} \\ \widetilde{l^{ss}_{21}} & \widetilde{l^{ss}_{22}} & \dots & \widetilde{l^{ss}_{2n}} \\ \vdots & \vdots & \ddots & \vdots \\ \widetilde{l^{ss}_{n1}} & \widetilde{l^{ss}_{n2}} & \dots & \widetilde{l^{ss}_{nn}} \end{bmatrix} \begin{bmatrix} \sum_{t \neq s}^{c} a_{11}^{st}\, x_1^t & \sum_{t \neq s}^{c} a_{12}^{st}\, x_2^t & \dots & \sum_{t \neq s}^{c} a_{1n}^{st} x_n^t \\ \sum_{t \neq s}^{c} a_{21}^{st} x_1^t & \sum_{t \neq s}^{c} a_{22}^{st}\, x_2^t & \dots & \sum_{t \neq s}^{c} a_{2n}^{st} x_n^t \\ \vdots & \vdots & \ddots & \vdots \\ \sum_{t \neq s}^{c} a_{n1}^{st} x_1^t & \sum_{t \neq s}^{c} a_{n2}^{st}\, x_2^t & \dots & \sum_{t \neq s}^{c} a_{nn}^{st} x_n^t \end{bmatrix} .$$

Let i and $j = 1, \dots, n$ be generic sectors. By construction, $a_{ij}^{st} x_j^t = z_{ij}^{st}$; for ease of exposition, we sum all the receiving sectors, and define the total intermediate usage by country t of intermediate input from sector i originating in country s as: $z_{i*}^{st} = \sum_{j=1}^{n} z_{ij}^{st}$. The sectoral outputs in country s are decomposed by equation (20) through forward inter-sector linkages:

$$x_1^s = \sum_{j=1}^{n} \tilde{l}_{1j}^{ss} f_j^{ss} + \sum_{j=1}^{n} \tilde{l}_{1j}^{ss} \sum_{t \neq s}^{c} f_j^{st} + \sum_{j=1}^{n} \tilde{l}_{1j}^{ss} \sum_{t \neq s}^{c} z_{j*}^{st}$$

(21) $$x_2^s = \textstyle\sum_{j=1}^{n} \tilde{l}_2^{ss} f_j^{ss} + \sum_{j=1}^{n} \tilde{l}_{2j}^{ss} \sum_{t \neq s}^{c} f_j^{st} + \sum_{j=1}^{n} \tilde{l}_{2j}^{ss} \sum_{t \neq s}^{c} z_{j*}^{st}$$

...

$$x_n^s = \sum_{j=1}^{n} \tilde{l}_{nj}^{ss} f_j^{ss} + \sum_{j=1}^{n} \tilde{l}_{nj}^{ss} \sum_{t \neq s}^{c} f_j^{st} + \sum_{j=1}^{n} \tilde{l}_{nj}^{ss} \sum_{t \neq s}^{c} z_{j*}^{st}$$

By substitution, the last term of equation (14) can be rewritten as:

(22) $$A^{rs} X^s = A^{rs} \widetilde{L^{ss}} F^{ss} + A^{rs} \widetilde{L^{ss}} F^{s*} + A^{rs} \widetilde{L^{ss}} Z^{s*}.$$

Hence, in detailed matrix notation:

(23) $$\begin{bmatrix} a_{11}^{rs} & a_{12}^{rs} & \cdots & a_{1n}^{rs} \\ a_{21}^{rs} & a_{22}^{rs} & \cdots & a_{2n}^{rs} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1}^{rs} & a_{n2}^{rs} & \cdots & a_{nn}^{rs} \end{bmatrix} \begin{bmatrix} x_1^s \\ x_2^s \\ \vdots \\ x_n^s \end{bmatrix} =$$

$$\begin{bmatrix} a_{11}^{rs} & a_{12}^{rs} & \cdots & a_{1n}^{rs} \\ a_{21}^{rs} & a_{22}^{rs} & \cdots & a_{2n}^{rs} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1}^{rs} & a_{n2}^{rs} & \cdots & a_{nn}^{rs} \end{bmatrix} \begin{bmatrix} \widetilde{\tilde{l}_{11}^{ss}} & \widetilde{l_{12}^{ss}} & \dots & \widetilde{l_{1n}^{ss}} \\ \widetilde{l_{21}^{ss}} & \widetilde{l_{22}^{ss}} & \dots & \widetilde{l_{2n}^{ss}} \\ \vdots & \vdots & \ddots & \vdots \\ \widetilde{l_{n1}^{ss}} & \widetilde{l_{n2}^{ss}} & \dots & \widetilde{l_{nn}^{ss}} \end{bmatrix} \begin{bmatrix} f_1^{ss} \\ f_2^{ss} \\ \vdots \\ f_n^{ss} \end{bmatrix} +$$

$$\begin{bmatrix} a_{11}^{rs} & a_{12}^{rs} & \cdots & a_{1n}^{rs} \\ a_{21}^{rs} & a_{22}^{rs} & \cdots & a_{2n}^{rs} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1}^{rs} & a_{n2}^{rs} & \cdots & a_{nn}^{rs} \end{bmatrix} \begin{bmatrix} \widetilde{\tilde{l}_{11}^{ss}} & \widetilde{l_{12}^{ss}} & \dots & \widetilde{l_{1n}^{ss}} \\ \widetilde{l_{21}^{ss}} & \widetilde{l_{22}^{ss}} & \dots & \widetilde{l_{2n}^{ss}} \\ \vdots & \vdots & \ddots & \vdots \\ \widetilde{l_{n1}^{ss}} & \widetilde{l_{n2}^{ss}} & \dots & \widetilde{l_{nn}^{ss}} \end{bmatrix} \begin{bmatrix} \sum_{t \neq s}^{c} f_1^{st} \\ \sum_{t \neq s}^{c} f_2^{st} \\ \vdots \\ \sum_{t \neq s}^{c} f y_n^{st} \end{bmatrix} +$$

$$\begin{bmatrix} a_{11}^{rs} & a_{12}^{rs} & \cdots & a_{1n}^{rs} \\ a_{21}^{rs} & a_{22}^{rs} & \cdots & a_{2n}^{rs} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1}^{rs} & a_{n2}^{rs} & \cdots & a_{nn}^{rs} \end{bmatrix} \begin{bmatrix} \widetilde{\tilde{l}_{11}^{ss}} & \widetilde{l_{12}^{ss}} & \dots & \widetilde{l_{1n}^{ss}} \\ \widetilde{l_{21}^{ss}} & \widetilde{l_{22}^{ss}} & \dots & \widetilde{l_{2n}^{ss}} \\ \vdots & \vdots & \ddots & \vdots \\ \widetilde{l_{n1}^{ss}} & \widetilde{l_{n2}^{ss}} & \dots & \widetilde{l_{nn}^{ss}} \end{bmatrix} \begin{bmatrix} \sum_{t \neq s}^{c} a_{11}^{st} x_1^t & \sum_{t \neq s}^{c} a_{12}^{st} x_2^t & \dots & \sum_{t \neq s}^{c} a_{1n}^{st} x_n^t \\ \sum_{t \neq s}^{c} a_{21}^{st} x_1^t & \sum_{t \neq s}^{c} a_{22}^{st} x_2^t & \dots & \sum_{t \neq s}^{c} a_{2n}^{st} x_n^t \\ \vdots & \vdots & \ddots & \vdots \\ \sum_{t \neq s}^{c} a_{n1}^{st} x_1^t & \sum_{t \neq s}^{c} a_{n2}^{st} x_2^t & \dots & \sum_{t \neq s}^{c} a_{nn}^{st} x_n^t \end{bmatrix}$$

The last step is to attribute to country/sector of origin the value added embedded in country s' imports of intermediate goods from sector i of country r.The value added originated by all sectors in the importing country, s, which is re-imported through its imports from sector i of country r, as well as the value added of all other third countries indirectly imported by country s through the same imports from r, are calculated applying the subcomponents of the global Leontief matrix in (8) to equation (19). Differently, we use the local Leontief applied to (16) to account for the value added of the direct exporter country r, in order to exclude all its backward linkages within the international production networks in the intermediate flows under examination (Borin and Mancini, 2015). The corresponding value-added multipliers are:

$$\text{(24)} \quad \hat{V}^s L^{sr} = \begin{bmatrix} v_1^s l_{11}^{sr} & v_1^s l_{12}^{sr} & \cdots & v_1^s l_{1n}^{sr} \\ v_2^s l_{21}^{sr} & v_2^s l_{22}^{sr} & \cdots & v_2^s l_{2n}^{sr} \\ \vdots & \vdots & \ddots & \vdots \\ v_n^s l_{n1}^{sr} & v_n^s l_{n2}^{sr} & \cdots & v_n^s l_{nn}^{sr} \end{bmatrix},$$

$$\hat{V}^t L^{sr} = \begin{bmatrix} \sum_{t\neq s,r}^c v_1^t\, l_{11}^{tr} & \sum_{t\neq s,r}^c v_1^t\, l_{12}^{tr} & \cdots & \sum_{t\neq s,r}^c v_1^t\, l_{1n}^{tr} \\ \sum_{t\neq s,r}^c v_2^t\, l_{21}^{tr} & \sum_{t\neq s,r}^c v_2^t\, l_{22}^{tr} & \cdots & \sum_{t\neq s,r}^c v_2^t\, l_{2n}^{tr} \\ \vdots & \vdots & \ddots & \vdots \\ \sum_{t\neq s,r}^c v_n^t\, l_{n1}^{tr} & \sum_{t\neq s,r}^c v_n^t\, l_{n2}^{tr} & \cdots & \sum_{t\neq s,r}^c v_n^t\, l_{nn}^{tr} \end{bmatrix},$$

$$\hat{V}^r L^{rr} = \begin{bmatrix} v_1^r l_{11}^{rr} & v_1^r l_{12}^{rr} & \cdots & v_1^r l_{1n}^{rr} \\ v_2^r l_{21}^{rr} & v_2^r l_{22}^{rr} & \cdots & v_2^r l_{2n}^{rr} \\ \vdots & \vdots & \ddots & \vdots \\ v_n^r l_{n1}^{rr} & v_n^r l_{n2}^{rr} & \cdots & v_n^r l_{nn}^{rr} \end{bmatrix}, \text{ and}$$

$$\hat{V}^r \widetilde{L^{rr}} = \begin{bmatrix} v_1^r \widetilde{l_{11}^{rr}} & v_1^r \widetilde{l_{12}^{rr}} & \cdots & v_1^r \widetilde{l_{1n}^{rr}} \\ v_2^r \widetilde{l_{21}^{rr}} & v_2^r \widetilde{l_{22}^{rr}} & \cdots & v_2^r \widetilde{l_{2n}^{rr}} \\ \vdots & \vdots & \ddots & \vdots \\ v_n^r \widetilde{l_{n1}^{rr}} & v_n^r \widetilde{l_{n2}^{rr}} & \cdots & v_n^r \widetilde{l_{nn}^{rr}} \end{bmatrix}$$

Using (17) and (24), and substituting (15) and (19) into equation (14), the gross imports of country s from country r can be decomposed in the following value-added components:

$$\text{(25)} \quad I^{rs} = F^{rs} + A^{rs}X^s = F^{rs} + A^{rs}\left(L^{ss}F^{ss} + L^{ss}\sum_{t\neq s}^c F^{st} + \sum_{t\neq s}^c \sum_{w=1}^c L^{st}F^{tw}\right) = F^{rs} +$$

$$A^{rs}\left(\widetilde{L^{ss}}F^{ss} + \widetilde{L^{ss}}\sum_{t\neq s}^c F^{st} + \sum_{t\neq s}^c \sum_{w=1}^c \widetilde{L^{ss}}A^{st}X^{tw}\right) = \overbrace{(V^r L^{rr})^T F^{rs}}^{I} +$$

$$\overbrace{\left(V^r \widetilde{L^{rr}}\right)^T A^{rs} L^{ss} F^{ss}}^{II} + \overbrace{\left(V^r \widetilde{L^{rr}}\right)^T A^{rs} L^{ss} \sum_{t\neq s}^c F^{st}}^{III} + \overbrace{\left(V^r \widetilde{L^{rr}}\right)^T A^{rs} \sum_{t\neq s}^c \sum_{w=1}^c L^{st} F^{tw}}^{IV} +$$

$$\overbrace{\left(V^r L^{rr} - V^r \widetilde{L^{rr}}\right)^T A^{rs} X^s}^{V} + \overbrace{(V^s L^{sr})^T F^{rs}}^{VI} + \overbrace{(V^s L^{sr})^T A^{rs} \widetilde{L^{ss}} F^{ss}}^{VII} +$$

$$\overbrace{(V^s L^{sr})^T A^{rs} \widetilde{L^{ss}} \sum_{t\neq s}^c F^{st}}^{VIII} + \overbrace{(V^s L^{sr})^T A^{rs} \widetilde{L^{ss}} \sum_{t\neq s}^c Z^{st}}^{IX} + \overbrace{\left(\sum_{t\neq r,s}^c V^t L^{tr}\right)^T F^{rs}}^{X} +$$

$$\overbrace{\left(\sum_{t\neq r,s}^{c} V^{t}L^{tr}\right)^{T} A^{rs}\widetilde{L^{ss}}F^{ss}}^{XI} + \overbrace{\left(\sum_{t\neq r,s}^{c} V^{t}L^{tr}\right)^{T} A^{rs}\widetilde{L^{ss}}\sum_{t\neq s}^{c} F^{st}}^{XII} +$$

$$\overbrace{\left(\sum_{t\neq r,s}^{c} V^{t}L^{tr}\right)^{T} A^{rs}\widetilde{L^{ss}}\sum_{t\neq s}^{c} Z^{st}}^{XIII}\ .$$[21]

The components I to V are related to the imported value added originating in the exporting country r; components VI to IXrefer to the importing country s's value added which is re-imported through country r; components X to $XIII$ refer to third countries' value added indirectly imported by country s through its imports from r. In aggregate, third countries can be thought of as the "rest of the world"; however, this decomposition allows computation of the value added of each specific third country within the ICIO table. Specifically, interpretation of the 13 components in the decomposition of bilateral imports from country r to country s in equation (25) is as follows:

(I). Direct exporter's value added which is imported in s through final goods, and originates in the sector which is exporting and in all its backward-linked sectors.

(II). Direct exporter's total value added embedded in country s' intermediate imports which are processed by downstream sectors in country s for its domestic final consumption.

(III). Direct exporter's total value added embedded in country s' intermediate imports which are processed by downstream sectors in country s to produce final exports.

(IV). Direct exporter's total value added embedded in country s' intermediate imports which are processed by downstream sectors in country s to produce intermediate

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[21] It is useful to relate the components in (25) to the Wang et al.'s (2013) components reported in table J1:

Terms in equation (25):	Terms in Table J1 of Wang et al. (2013)'s paper:
(I)	T1
(II)	T2
(III)	T4+T6
(IV)	T3+T5+T7+T8+T9
(V)	T10
(VI)	T11
(VII)	T12
(VIII)	T13
(IX)	
(X)	T14
(XI)	T15
(XII)	T16
(XIII)	

exports to all other countries other than s, that finally are consumed by all countries (including s and r).

(V). Double-counted term related to the exporting country, which gives the total output requirement by its production of intermediate goods via its intermediate goods trade.

(VI). Importer's value added which is re-imported as embedded in the exporting sector of final goods in country r.

(VII). Importer's value added which is re-imported and processed again in country s to produce final goods consumed domestically.

(VIII). Importer's value added which is re-imported from country r and processed again in country s to produce final exports.

(IX). Importer's value added which is re-imported from country r, is processed domestically and re-exported as intermediate goods which are consumed by all countries (including r and s).

(X). Third country (indirect) value added embedded in final bilateral imports.

(XI). Third country value added embedded in intermediate bilateral imports which are consumed in the importing country.

(XII). Third country value added embedded in intermediate bilateral imports which are re-exported by the importing country as final exports.

(XIII). Third country value added embedded in intermediate bilateral imports which are re-exported by the importing country s as intermediate exports.

To disentangle the origin of the value added in bilateral imports based on their use by the importing country is informative for policy makers in the context of both bilateral and multilateral trade negotiations. For example, in relation to the reasoning behind discretionary tariffs on imports, the extended framework proposed in this paper allows to the impact of protection to be detached from the direct exporter production of value added and the domestic production which is implied by bilateral imports (both upstream and, indirectly, downstream), and third countries' value added.

2.4 Decomposition of bilateral imports: An application using the GTAP-MRIO database and WIOD

2.4.1 Data issues

The Implementing the above decomposition requires information on cross-border input-output relationships. In particular, to construct the ICIO table (such as that represented in figure 2.2), requires data on transactions of intermediate and final goods both within and between each country at sector level, direct value added in the production of every sector in all countries, and the gross output of every sector in all countries (Koopman et al., 2010). Existing international trade statistics provide data for the value of traded goods and services, however, bilateral trade flows at the industry level are not collected systematically[22], and work on value-added trade relies on datasets constructed outside of the official statistical systems. The existing global datasets involve choices about how to distinguish sectoral level bilateral trade flows into different uses (essentially, intermediate use or final consumption), and within intermediate flows, how to allocate them from a certain source country to individual purchasing sectors in all destination countries (Koopman et al., 2014). The "proportionality method" (used in the EXIOBASE database, and the first GTAP-based MRIO developed by Trefler and Zhu, 2010; Daudin et al., 2011; Johnson and Noguera, 2012) is an approximation built on the twofold assumption that within each sector the overall break down of imports by use (final or intermediate) in the destination country is applied proportionally to the split by use of imports from each source country, and that the destination sectors of intermediate imports are derived as a proportion of the total imported intermediate use in those destinations. Another approach relies on the use of end use categories to distinguish imports. The BEC concordance method provides an improved split by source, and is used in TiVA, WIOD, EORA, and the GTAP-ICIO developed by Koopman et al. (2010), and the recently constructed GTAP-MRIO. Table 2.2 reports the various alternative datasets used to conduct value-added trade analysis. As is the case in many other fields, there is no “right” database, the rightness depends on the purpose of the analysis. In what follows we focus on the two best known and most widely used databases, WIOD and GTAP, both of which are exploited to compute our decomposition of trade flows.

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[22] A partial exception is the IDE-JETRO database which uses data from industry surveys in the Asia-Pacific countries. However, this is a regional rather than a global database. The CompNet Database is also regional: it extends the WIOD database and aggregates information from industry statistics provided by Eurostat or EU KLEMS, for 58 sectors in 11 European countries during the period 1995-2011.

Table 2.2. *Main global Input-Output databases for GVCs analysis.*

	Geographical coverage	Sector breakdown	Time span	Methodological reference
GTAP-MRIO Database	140 regions	57 sectors	2004, 2007, 2011	Narayanan et al., 2012; Koopman et al, 2014; Wamsley et al., 2014
World Input-Output Database (WIOD)	40 countries	35 sectors	1995 to 2011	Dietzenbacher et al., 2013; Timmer et al., 2015

Other databases for GVCs analysis

OECD Input-Output Tables and OECD/WTO TiVA Database	62 countries	34 sectors	1995, 2000, 2005 and 2008 to 2011	Yamano and Ahmad, 2006; OECD-WTO concept note, 2012
IDE-Jetro, Asian International Input-Output Tables (AIIOTs)	10 countries	76 sectors	1975, 1980, 1985, 1990, 1995, 2000, 2005	Meng et al., 2013
EXIOBASE Database	43 countries, 5 RoW regions	163 industries	2007	Tukker et al., 2009
Eora MRIO Database	187 countries	between 25 and 500 sectors (depending on the data from original source)	1990-2011	Lenzen et al., 2012; 2013

The GTAP database was developed by the Center of Global Trade Analysis at Purdue University. The database version 9 has broad country and sector coverage; it covers 57 sectors in 140 countries/regions. It provides a consistent representation of the world economy in the year base (the current release includes 2004, 2007 and 2011 reference years), giving a consistent cross-section data on consumption, production, and trade. It combines detailed bilateral trade, transport, and protection data characterizing the economic linkages among regions, with ICIO data which account for inter-sectoral linkages within regions (Aguiar et al., 2016). As already mentioned, a key aspect related to the construction of a full MRIO table is that import sources can be attributed to intermediate and final demand and to individual source countries and sectors. The standard GTAP database aggregates these flows at border level (Narayanan et al., 2012). Sourcing information from disaggregated trade data obtained from the UN COMTRADE database at the six digit HS (Harmonized System) level (obtained for 2011 from the TASTE for GTAP 9) are mapped from the six digit 5052 HS codes to 19 BEC end-use categories. Then a BEC-SNA concordance is used to map the 19 BEC categories to explicit SNA end use classes (intermediate use, final consumption, and capital goods). A final HS-GTAP concordance is applied to map each HS line to a GTAP commodity. This procedure produces values for intermediate and final demand denoted by source which should be consistent with the rest of the GTAP data, that is, they should sum to the total imports by source for each commodity for each use. The rebalancing procedure follows the spirit of the GTAP data by focusing mainly on trade policy analysis, giving priority to trade data which are kept intact to allow a split between domestic and imported goods contained in the input-output tables adjusted to reflect information from the BEC shares[23].

The WIOD project started in 2009 and has been developed by a consortium of 11 European research institutions, and funded by the European Commission. It provides annual time-series of world input-output tables, covering the period 1995 to 2011 for 27 EU countries and 13 other major world countries (Timmer et al., 2014). The national supply and use tables (SUTs) are the building blocks of the database - supply tables provide information on goods produced by each domestic industry, and use tables indicate the use of each product by an industry or final user- which are used to construct the symmetric world input-output table. Three types of data are used in the process: national accounts statistics (NAS), SUTs, and international trade statistics (ITS). The procedure used to breakdown imports of a product according to their use category by country and sector of origin, is similar to that used in the GTAP-MRIO. The UN COMTRADE database gives bilateral import flows for all the countries in the WIOD from all world partners at the 6-digit product level of the HS. The BEC concordance is used to allocate imported goods to intermediate use, final consumption use, or investment use. Within each

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[23] The GTAP-MRIO database used in our application has been developed under the Public Procurement Project contracted by the Centre for Global Trade Analysis and the European Commission. It is extensively explained in chapter III, section 4 in this thesis.

end-use category, the allocation is based on the assumption of proportionality[24]. Contrary to the GTAP database, in WIOD the supply-use data are prioritized (Walmsley et al., 2014). The WIOD data used in our application rely on the November 2013 release.

2.4.2 Application and results

We consider bilateral flows in both directions for three major economies, the European Union, the United States, and China, and for six sectors, primary, food, textiles, manufacturing, motor vehicles, and services. Table 2.3 provides a mapping of the sectors used for the application[25]. Table 2.4 presents the decomposition of bilateral imports according to importers' use, as a percentage of gross imports. The left panel shows the results using GTAP-MRIO data; the right panel gives the shares derived from WIOD data. The first column in both panels gives bilateral imports in final goods, and the second column presents the bilateral imports which are processed domestically to satisfy domestic demand. The third column gives the total share of imports ending in the importing country's domestic market. The fourth and fifth columns present intermediate imports used to produce final exports, and intermediate exports respectively. The sixth columns in each panel refer to the total share of imports used by an importer to produce its exports.

In the bilateral flows under examination, the European Union and the United States mostly use imports for domestic consumption (between 88.3% and 91.8%). In both regions, at the aggregate level, the highest shares in imports from China are recorded as final goods used directly in the domestic markets (50.6% for the European Union and 57.1% for the United States). At sector level, these shares are particularly high for textiles (80.3% and 79% respectively). Overall, the European Union and the United States show a similar structure of imports. China's imports from both the European Union and the United States are used mainly for domestic processing to produce domestic final consumption (48.1% and 55.4%), and a relatively high percentage of imports is used to produce both final and intermediate exports (19.4% and 23.3%). This is consistent with the results in Stehrer (2013). At sector

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[24] E.g., for intermediate use by sector, we apply the ratio of imported use to total use that is equal across industries but differs from the corresponding ratio in the context of consumption. See Timmer et al. (2014) for further details.

[25] The concordance between GTAP and WIOD, linked to ISIC rev.3.1 codes, is in line with Lin and Wang (2014).

level, we find that half of Chinese imports in textiles from the United States are used as intermediate inputs to produce exports.

The difference between the shares obtained from the two databases is low at the aggregate bilateral level, negligible for China's imports and for United States imports from the European Union (between 0% and 2$). However, we observe significant differences at sector level. Among sectors, food is the most sensitive: GTAP data gives percentages that are consistently lower for final imports directly consumed compared to WIOD (the variation ranges from -17% to -42%), however, in the case of services WIOD data generally provide lower percentages. Manufacturing is the most similar (between 0% and 9%) for the use made by the importer of bilateral imports.

Next, we consider the value-added content of each of the previous components of bilateral imports. Table 2.5 presents the results in absolute values (upper panel) and as a percentage of total gross imports (lower panel), obtained from the GTAP data (upper half of each panel) and WIOD data (lower half of each panel). Column I presents the exporter's direct value added absorbed as final consumption in the importing country; it corresponds to term I in equation (25). Column II gives the importer's value added which is reflected in its final goods imports from the bilateral partner; it is given by the VI term in equation (25). Column (III) reports the value added originating in a third country which is imported indirectly; it corresponds to term X in equation (25). Columns IV to VI present the same components of the value added (direct, reflected, and indirect) for the portion of bilateral imports which are processed for final domestic consumption goods. They correspond respectively to terms II, VII, and XI in equation (25). Columns VII to IX present the same components for the proportion of bilateral imports used by the importing country to produce both final and intermediate exports. Specifically, column VII presents the sum of terms III and IV in equation (25); column VIII is the sum of terms VIII and IX; and, column IX is the sum of terms XII and XIII. Column X is the double counting related to the first exporter (V term in equation (25)). Finally, column XI in the upper panel (US $, mio) reports bilateral imports in gross terms while columns XI, XII, and XIII in the lower panel (percentages of gross imports) sum the same component of value added over all uses. They correspond, respectively, to the sum of columns I, IV, and VII (total direct exporter's value added); the sum of columns II, V, VIII (total reflected value added); and the sum of columns III, VI, and IX (total indirect value added).

First, we find that the double counting component is negligible at the aggregate level for all bilateral flows examined (between 0.2% and 0.4%). At sector level, the corresponding shares are slightly higher (up to 0.7%) for manufacturing and motor vehicles (sectors showing a higher level of participation in GVCs), and for textiles in China’s imports from the United States. The results for this component are equivalent between the two databases.

Second, the shares related to the importer’s domestic value added which is reflected in bilateral imports, in aggregate is quite low; it is slightly higher for European Union imports from China (2.6% with GTAP, and 3.2% with WIOD). At sector level, China’s textile exports from the European Union and the United States have a higher share of total reflected value added (respectively between 2.6% and 4%, and between 4% and 4.2%). However, if we consider only imports of final goods, motor vehicles is the sector which reflects comparatively more value added from both bilateral relationships (column II). European Union imports both from the United States and China mostly reflect domestic value added in motor vehicles (between 4.5% and 5.4%, and between 4.6% and 4.8% respectively). This applies also to United States imports from the European Union (between 2.8% and 3.3%). United States imports from China have a more homogeneous division among sectors of reflected value added based on GTAP data although slightly higher for food (2.2%), mainly for direct final consumption. The WIOD data show a comparatively higher weight of manufacturing in domestic value added (2.6%). It should be noted that in the case of all other bilateral relationships, the ranking among sectors for the reflected component of value added derived from GTAP and WIOD data is the same.

Third, the value added of third countries which is traded through bilateral flows, ranges between 10.2 percent and 20.5 percent, at the aggregate level. China diverts a higher share of indirect value added in its exports to both the European Union and the United States (around 18% and 20% respectively), mainly in manufacturing.

The results for the aggregated components in the last three columns show little difference. However, GTAP data gives lightly higher percentage values for the indirect value added component, and slightly lower shares for the value added of direct exporters compared to WIOD data. Finally, we find that the ranking among sectors for each component of value added is mostly the same except for the reflected value added of United States imports from China, and for the indirect value added in European Union imports from the United States. The former has been mentioned already; with regard to the latter, GTAP data give a higher weight to manufacturing while WIOD data give a higher value for motor vehicles.

2.5 Concluding remarks

In This paper proposed a decomposition of bilateral imports at sector level. The increased interconnectedness among economies has intensified the back and forth of intermediate goods, and is introducing difficulties related to the measurement of trade. In order to reflect the underlying structure of the value addition related to trade flows, we used the ICIO model. However, when the origin of value added is traced for intermediate flows this introduces an endogeneity issue. The technical step introduced by Wang can be applied: it categorizes bilateral intermediate trade flows into major final demand groups according to where they are absorbed as final consumption. The decomposition proposed here gives involves 13 components of value added in gross bilateral imports. Conceptually, they can be grouped into four main blocks according to the use the importer makes of its bilateral imports: a) imports can satisfy domestic demand for consumption directly, or b) they can be consumed domestically after a further processing stage; alternatively, c) they can be used in domestic productive processes to produce final exports, or d) to produce intermediate exports. Within each of the four blocks, the value added is reallocated accordingly to its origin; that is, the portion of value added which originates in the direct exporting country, in the importing country in a previous processing stage, and in a third country traded indirectly through bilateral flows. A further pure double-counted component is calculated.

The empirical results presented reflect the focus on comparing the findings obtained using the two main databases for GVC analyses.

The main problem related to developing this work is the difficulty of going beyond the two steps involved in the decomposition of intermediate flows. For instance, it would be interesting to further decompose the part of bilateral imports which is used for the production of intermediate exports, according to the final absorption destination. However, this involves computational difficulties; for each term we can have only one local multiplier $(\tilde{L})$ and one global multiplier L, while further decomposition would imply the need for at least two local multipliers. This would be useful to precisely compute the double counting components related to the importer value added and the indirect value added. However, the proposed framework is a good approximation of the *hidden structure* of trade in value added underlying gross imports.

Table 2.3. *Concordance between GTAP and WIOD sectors.*

Harmonized sector	*GTAP sector**	*WIOD sector***	*ISIC Rev.3.1 Division*
Primary	pdr, wht, gro, v_f, osd, c_b, pfb, ocr, ctl, oap, rmk, wol, frs	c1	01-05
Food	omn, cmt, omt, vol, mil, pcr, sgr, ofd	c3	15-15
Textiles	b_t, tex, wap	c4, c5	17-19
Manufacture	fsh, coa, oil, gas, lea, lum, ppp, p_c, crp, nmm, i_s, nfm, otn, ele, ome	c2, c6-c12, c14, c16	10-14, 20-28, 30-33, 36-37
Motor vehicles	fmp, mvh	c13, c15	29, 34-35
Services	omf, ely, gdt, wtr, cns, trd, otp, wtp, atp, cmn, ofi, isr, obs, ros, osg, dwe***	c17-c35	40-95

* Primary: paddy rice; wheat, cereal grains nec; vegetables, fruit, nuts; oil seeds; sugar cane, sugar beet; plant-based fibers; crops nec; bovine cattle, sheep and goats, horses; animal products nec; raw milk; wool, silk-worm cocoons; forestry; fishing. Food: bovine cattle, sheep and goat meat products; meat products; vegetable oils and fats; dairy products; processed rice; sugar; food products nec; beverages and tobacco products. Textiles: textiles; wearing apparel; leather products. Manufacture: coal; oil; gas; minerals nec; wood products; paper products, publishing; petroleum, coal products; chemical, rubber, plastic products; mineral products nec; ferrous metals; metals nec; metal products; electronic equipment; machinery and equipment nec; manufactures nec. Motor vehicles: motor vehicles and parts; transport equipment nec. Services: electricity; gas manufacture, distribution; water; construction; trade; transport nec; water transport; air transport; communication; financial services nec; insurance; business services nec; recreational and other services; Public Administration and defense, education, health; ownership of dwellings)

** Primary: Agriculture, Hunting, Forestry and Fishing. Food: Food, Beverages and Tobacco. Textiles: Textiles and Textile Products; Leather, Leather and Footwear. Manufacture: Mining and Quarrying; Wood and Products of Wood and Cork; Pulp, Paper, Paper, Printing and Publishing; Coke, Refined Petroleum and Nuclear Fuel; Chemicals and Chemical Products; Rubber and Plastics; Other Non-Metallic Mineral; Basic Metals and Fabricated Metal; Electrical and Optical Equipment; Manufacturing, Nec; Recycling. Motor vehicles: Machinery, Nec; Transport Equipment. Services: Electricity, Gas and Water Supply; Construction; Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel; Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles; Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods; Hotels and Restaurants; Inland Transport; Water Transport; Air Transport; Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies; Post and Telecommunications; Financial Intermediation; Real Estate Activities; Renting of M&Eq and Other Business Activities; Public Admin and Defence; Compulsory Social Security; Education; Health and Social Work; Other Community, Social and Personal Services; Private Households with Employed Persons.

*** dwe is not part of the ISIC classification. We include it for completeness, but its value for bilateral imports is always zero, it follows that our estimates are not biased.

Table 2.4. *Decomposition of bilateral imports by use. A comparison between GTAP and WIOD data.*

European Union imports from China

		Bilateral imports for domestic market (%)			Bilateral imports used to produce exports (%)		
		final imports	intermediate imports	total	final exports	intermediate exports	total
	sector	(I)	(II)	(III)	(IV)	(V)	(VI)
GTAP data	primary	26,7%	64,8%	91,5%	4,4%	4,1%	8,5%
	food	73,8%	23,4%	97,2%	1,4%	1,5%	2,8%
	textiles	80,3%	16,5%	96,7%	1,6%	1,7%	3,3%
	manufacture	41,7%	45,9%	87,6%	5,1%	7,3%	12,4%
	motor vehi	48,7%	40,5%	89,2%	6,0%	4,7%	10,8%
	services	53,5%	40,1%	93,6%	2,6%	3,8%	6,4%
	total	50,6%	39,4%	90,0%	4,2%	5,8%	10,0%

		Bilateral imports for domestic market (%)			Bilateral imports used to produce exports (%)		
		final imports	intermediate imports	total	final exports	intermediate exports	total
	sector	(I)	(II)	(III)	(IV)	(V)	(VI)
WIOD data	primary	43,2%	47,9%	91,1%	5,8%	3,1%	8,9%
	food	91,1%	7,3%	98,5%	0,8%	0,8%	1,5%
	textiles	74,8%	17,7%	92,5%	4,6%	2,9%	7,5%
	manufacture	39,3%	44,0%	83,4%	6,6%	10,0%	16,6%
	motor vehi	59,8%	28,4%	88,2%	5,7%	6,1%	11,8%
	services	21,6%	63,8%	85,4%	5,6%	9,0%	14,6%
	total	44,2%	41,7%	85,9%	5,9%	8,2%	14,1%

European Union imports from United States

		Bilateral imports for domestic market (%)			Bilateral imports used to produce exports (%)		
		final imports	intermediate imports	total	final exports	intermediate exports	total
	sector	(I)	(II)	(III)	(IV)	(V)	(VI)
GTAP data	primary	40,8%	52,3%	93,2%	3,4%	3,4%	6,8%
	food	52,5%	42,5%	95,0%	2,4%	2,6%	5,0%
	textiles	32,5%	56,1%	88,6%	5,5%	5,9%	11,4%
	manufacture	28,6%	56,6%	85,1%	6,1%	8,7%	14,9%
	motor vehi	36,1%	51,3%	87,4%	7,1%	5,6%	12,6%
	services	38,5%	53,7%	92,1%	3,2%	4,6%	7,9%
	total	33,6%	54,7%	88,3%	5,0%	6,7%	11,7%

		Bilateral imports for domestic market (%)			Bilateral imports used to produce exports (%)		
		final imports	intermediate imports	total	final exports	intermediate exports	total
	sector	(I)	(II)	(III)	(IV)	(V)	(VI)
WIOD data	primary	54,3%	38,1%	92,4%	4,6%	3,0%	7,6%
	food	77,8%	17,7%	95,5%	2,0%	2,5%	4,5%
	textiles	59,9%	28,5%	88,4%	6,7%	4,9%	11,6%
	manufacture	35,9%	47,4%	83,2%	6,4%	10,3%	16,8%
	motor vehi	52,2%	33,8%	86,0%	6,9%	7,1%	14,0%
	services	14,9%	71,1%	86,1%	5,1%	8,9%	13,9%
	total	27,2%	58,2%	85,4%	5,7%	8,9%	14,6%

(*Continued*)

(*Continued*)

United States imports from China

GTAP data

	Bilateral imports for domestic market (%)			Bilateral imports used to produce exports (%)		
	final imports	intermediate imports	total	final exports	intermediate exports	total
sector	(I)	(II)	(III)	(IV)	(V)	(VI)
primary	43,3%	48,4%	91,7%	3,1%	5,1%	8,3%
food	75,5%	22,0%	97,4%	1,0%	1,5%	2,6%
textiles	79,0%	17,4%	96,4%	1,3%	2,3%	3,6%
manufacture	54,7%	36,1%	90,8%	3,0%	6,2%	9,2%
motor vehi	27,0%	57,5%	84,5%	7,8%	7,7%	15,5%
services	21,5%	72,2%	93,6%	2,3%	4,1%	6,4%
total	57,1%	34,6%	91,8%	2,8%	5,4%	8,2%

WIOD data

	Bilateral imports for domestic market (%)			Bilateral imports used to produce exports (%)		
	final imports	intermediate imports	total	final exports	intermediate exports	total
sector	(I)	(II)	(III)	(IV)	(V)	(VI)
primary	27,6%	63,2%	90,8%	4,8%	4,5%	9,2%
food	93,2%	5,9%	99,1%	0,4%	0,5%	0,9%
textiles	78,6%	17,4%	96,0%	1,6%	2,4%	4,0%
manufacture	53,8%	36,9%	90,7%	3,5%	5,8%	9,3%
motor vehi	57,0%	31,9%	88,9%	5,3%	5,8%	11,1%
services	13,2%	77,1%	90,3%	3,1%	6,6%	9,7%
total	52,7%	38,6%	91,3%	3,3%	5,4%	8,7%

United States imports from European Union

GTAP data

	Bilateral imports for domestic market (%)			Bilateral imports used to produce exports (%)		
	final imports	intermediate imports	total	final exports	intermediate exports	total
sector	(I)	(II)	(III)	(IV)	(V)	(VI)
primary	24,9%	65,0%	90,0%	4,0%	6,1%	10,0%
food	55,6%	40,0%	95,5%	1,9%	2,5%	4,5%
textiles	48,1%	43,9%	92,0%	2,8%	5,2%	8,0%
manufacture	41,2%	46,6%	87,7%	4,0%	8,3%	12,3%
motor vehi	66,0%	26,7%	92,7%	3,7%	3,7%	7,3%
services	24,4%	69,4%	93,8%	2,2%	4,0%	6,2%
total	39,9%	50,6%	90,6%	3,3%	6,1%	9,4%

WIOD data

	Bilateral imports for domestic market (%)			Bilateral imports used to produce exports (%)		
	final imports	intermediate imports	total	final exports	intermediate exports	total
sector	(I)	(II)	(III)	(IV)	(V)	(VI)
primary	31,9%	58,1%	90,0%	4,5%	5,5%	10,0%
food	88,5%	10,0%	98,5%	0,6%	0,9%	1,5%
textiles	69,6%	24,7%	94,3%	2,3%	3,4%	5,7%
manufacture	43,1%	44,9%	88,1%	4,2%	7,7%	11,9%
motor vehi	61,3%	29,1%	90,4%	4,6%	5,0%	9,6%
services	14,3%	76,7%	90,9%	2,8%	6,2%	9,1%
total	39,6%	50,3%	89,9%	3,7%	6,4%	10,1%

(*Continued*)

(*Continued*)

China imports from United States

		Bilateral imports for domestic market (%)			Bilateral imports used to produce exports (%)		
		final imports	intermediate imports	total	final exports	intermediate exports	total
	sector	(I)	(II)	(III)	(IV)	(V)	(VI)
GTAP data	primary	4,7%	70,3%	74,9%	15,0%	10,1%	25,1%
	food	27,1%	55,6%	82,7%	10,4%	6,9%	17,3%
	textiles	8,1%	42,1%	50,1%	33,4%	16,5%	49,9%
	manufacture	15,7%	57,3%	73,0%	12,6%	14,4%	27,0%
	motor vehi	64,7%	29,1%	93,8%	3,0%	3,2%	6,2%
	services	40,0%	47,2%	87,2%	6,2%	6,5%	12,8%
	total	21,3%	55,4%	76,7%	11,7%	11,6%	23,3%

		Bilateral imports for domestic market (%)			Bilateral imports used to produce exports (%)		
		final imports	intermediate imports	total	final exports	intermediate exports	total
	sector	(I)	(II)	(III)	(IV)	(V)	(VI)
WIOD data	primary	10,9%	68,6%	79,5%	11,9%	8,6%	20,5%
	food	68,7%	25,0%	93,7%	3,3%	3,0%	6,3%
	textiles	29,4%	37,9%	67,3%	20,6%	12,1%	32,7%
	manufacture	18,6%	54,9%	73,4%	11,7%	14,9%	26,6%
	motor vehi	48,7%	36,0%	84,7%	7,0%	8,3%	15,3%
	services	7,4%	67,3%	74,7%	11,1%	14,1%	25,3%
	total	21,3%	55,4%	76,7%	10,6%	12,7%	23,3%

China imports from European Union

		Bilateral imports for domestic market (%)			Bilateral imports used to produce exports (%)		
		final imports	intermediate imports	total	final exports	intermediate exports	total
	sector	(I)	(II)	(III)	(IV)	(V)	(VI)
GTAP data	primary	31,7%	48,3%	80,0%	11,1%	8,9%	20,0%
	food	46,6%	41,8%	88,3%	6,8%	4,9%	11,7%
	textiles	36,0%	30,0%	66,0%	22,7%	11,3%	34,0%
	manufacture	24,3%	51,8%	76,1%	11,1%	12,8%	23,9%
	motor vehi	52,5%	38,7%	91,2%	4,2%	4,6%	8,8%
	services	35,3%	49,9%	85,2%	7,3%	7,5%	14,8%
	total	32,5%	48,1%	80,6%	9,3%	10,1%	19,4%

		Bilateral imports for domestic market (%)			Bilateral imports used to produce exports (%)		
		final imports	intermediate imports	total	final exports	intermediate exports	total
	sector	(I)	(II)	(III)	(IV)	(V)	(VI)
WIOD data	primary	11,1%	68,4%	79,4%	11,8%	8,8%	20,6%
	food	82,8%	13,8%	96,6%	1,8%	1,7%	3,4%
	textiles	60,4%	20,8%	81,2%	12,1%	6,6%	18,8%
	manufacture	26,5%	51,9%	78,4%	9,6%	12,0%	21,6%
	motor vehi	49,6%	36,8%	86,4%	6,4%	7,2%	13,6%
	services	17,0%	65,3%	82,3%	7,8%	9,8%	17,7%
	total	34,2%	48,4%	82,6%	8,0%	9,4%	17,4%

Table 2.5. *Decomposition of bilateral imports by origin of value added. GTAP and WIOD data.*

European Union imports from China

	Final imports			Intermediate imports for domestic consumption			Intermediate imports used to produce exports (final+intermediate)				
	(US $, mio)										
sector	direct exporter's value added	importer's value added (reflected)	third countries value added (indirect)	direct exporter's value added	importer's value added (reflected)	third countries value added (indirect)	direct exporter's value added	importer's value added (reflected)	third countries value added (indirect)	double-counted (direct exporter)	gross bilateral imports
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
primary	764,48	6,64	48,44	1.849,79	16,08	117,37	243,66	2,12	15,46	3,07	3.067,11
food	3.861,88	56,92	502,92	1.220,70	18,04	159,37	147,66	2,18	19,28	3,42	5.992,35
textiles	55.079,79	1.317,05	9.284,26	11.236,00	270,29	1.905,34	2.227,96	53,59	377,80	81,02	81.833,10
manufacture	91.125,09	3.463,35	26.170,56	99.510,99	3.811,74	28.803,18	26.986,65	1.033,72	7.811,21	992,51	289.709,00
motor vehi	5.609,79	333,16	1.314,75	4.627,31	276,80	1.092,36	1.234,06	73,82	291,32	42,52	14.895,90
services	16.162,60	278,71	1.732,69	12.056,33	208,50	1.296,20	1.923,67	33,27	206,82	40,22	33.939,00
total	172.603,62	5.455,82	39.053,62	130.501,13	4.601,45	33.373,82	32.763,65	1.198,70	8.721,89	1.162,76	429.436,46

GTAP data

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
primary	1.278,24	16,80	90,23	1.414,68	18,63	100,05	263,67	3,47	18,65	3,08	3.207,50
food	6.173,85	123,49	708,17	495,01	9,93	56,93	104,35	2,09	12,00	1,60	7.687,43
textiles	39.999,25	1.221,50	5.954,23	9.412,73	288,94	1.408,44	3.988,38	122,43	596,79	69,56	63.062,25
manufacture	68.235,54	3.122,73	20.593,70	75.657,54	3.494,17	23.043,30	28.608,17	1.321,24	8.713,30	957,15	233.746,83
motor vehi	23.958,59	1.480,22	5.597,43	11.312,07	704,63	2.664,54	4.690,22	292,15	1.104,78	131,47	51.936,10
services	16.182,06	452,77	2.021,19	47.574,35	1.336,23	5.964,94	10.928,23	306,94	1.370,20	224,08	86.361,00
total	155.827,53	6.417,51	34.964,96	145.866,38	5.852,52	33.238,20	48.583,02	2.048,33	11.815,71	1.386,94	446.001,11

WIOD data

European Union imports from China

	Final imports			Intermediate imports for domestic consumption			Intermediate imports used to produce exports (final+intermediate)						
	(% of gross imports)												
sector	direct exporter's value added	importer's value added (reflected)	third countries value added (indirect)	direct exporter's value added	importer's value added (reflected)	third countries value added (indirect)	direct exporter's value added	importer's value added (reflected)	third countries value added (indirect)	double-counted (direct exporter)	total direct exporter's value added	total importer's value added (reflected)	total indirect value added
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII
primary	24,9%	0,2%	1,6%	60,3%	0,5%	3,8%	7,9%	0,1%	0,5%	0,1%	93,2%	0,8%	5,9%
food	64,4%	0,9%	8,4%	20,4%	0,3%	2,7%	2,5%	0,0%	0,3%	0,1%	87,3%	1,3%	11,4%
textiles	67,3%	1,6%	11,3%	13,7%	0,3%	2,3%	2,7%	0,1%	0,5%	0,1%	83,8%	2,0%	14,1%
manufacture	31,5%	1,2%	9,0%	34,3%	1,3%	9,9%	9,3%	0,4%	2,7%	0,3%	75,1%	2,9%	21,7%
motor vehi	37,7%	2,2%	8,8%	31,1%	1,9%	7,3%	8,3%	0,5%	2,0%	0,3%	77,0%	4,6%	18,1%
services	47,6%	0,8%	5,1%	35,5%	0,6%	3,8%	5,7%	0,1%	0,6%	0,1%	88,8%	1,5%	9,5%
total	40,2%	1,3%	9,1%	30,4%	1,1%	7,8%	7,6%	0,3%	2,0%	0,3%	78,2%	2,6%	18,9%

GTAP data

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII
primary	39,9%	0,5%	2,8%	44,1%	0,6%	3,1%	8,2%	0,1%	0,6%	0,1%	92,2%	1,2%	6,5%
food	80,3%	1,6%	9,2%	6,4%	0,1%	0,7%	1,4%	0,0%	0,2%	0,0%	88,1%	1,8%	10,1%
textiles	63,4%	1,9%	9,4%	14,9%	0,5%	2,2%	6,3%	0,2%	0,9%	0,1%	84,7%	2,6%	12,6%
manufacture	29,2%	1,3%	8,8%	32,4%	1,5%	9,9%	12,2%	0,6%	3,7%	0,4%	73,8%	3,4%	22,4%
motor vehi	46,1%	2,9%	10,8%	21,8%	1,4%	5,1%	9,0%	0,6%	2,1%	0,3%	76,9%	4,8%	18,0%
services	18,7%	0,5%	2,3%	55,1%	1,5%	6,9%	12,7%	0,4%	1,6%	0,3%	86,5%	2,4%	10,8%
total	34,9%	1,4%	7,8%	32,7%	1,3%	7,5%	10,9%	0,5%	2,6%	0,3%	78,5%	3,2%	17,9%

WIOD data

(*Continued*)

(*Continued*)

United States imports from China

	Final imports			Intermediate imports for domestic consumption			Intermediate imports used to produce exports (final+intermediate)				
						(US $, mio)					
sector	direct exporter's value added	importer's value added (reflected)	third countries value added (indirect)	direct exporter's value added	importer's value added (reflected)	third countries value added (indirect)	direct exporter's value added	importer's value added (reflected)	third countries value added (indirect)	double-counted (direct exporter)	gross bilateral imports
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
primary	586,87	5,62	36,66	655,00	6,28	40,97	112,11	1,08	7,01	1,13	1.452,72
food	4.170,40	104,25	500,31	1.211,54	30,36	145,71	141,64	3,55	17,03	3,38	6.328,17
textiles	49.251,02	1.214,45	8.264,98	10.804,22	268,02	1.824,00	2.207,02	54,75	372,60	78,29	74.339,35
manufacture	140.348,59	3.692,86	41.948,55	91.964,38	2.438,76	27.702,74	23.357,75	619,41	7.036,13	904,83	340.014,00
motor vehi	2.537,87	69,91	675,61	5.360,82	148,74	1.437,46	1.446,81	40,14	387,95	49,39	12.154,69
services	2.794,26	32,52	315,22	9.371,55	109,39	1.060,23	826,62	9,65	93,52	29,34	14.642,30
total	199.689,01	5.119,61	51.741,32	119.367,51	3.001,56	32.211,12	28.091,93	728,58	7.914,24	1.066,35	448.931,23

GTAP data

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
primary	463,19	4,72	34,06	1.057,52	10,80	77,92	154,58	1,58	11,39	2,22	1.817,97
food	5.798,87	106,87	674,28	364,64	6,74	42,51	56,36	1,04	6,57	1,12	7.059,00
textiles	34.652,70	696,58	5.520,00	7.644,64	154,47	1.224,07	1.762,78	35,62	282,26	48,83	52.021,95
manufacture	102.361,13	3.551,44	32.025,92	69.594,86	2.436,77	21.974,16	17.434,37	610,44	5.504,80	798,92	256.292,83
motor vehi	19.066,89	607,78	5.024,80	10.571,96	339,76	2.808,98	3.685,80	118,45	979,32	117,14	43.320,88
services	6.010,96	100,60	818,37	34.861,47	585,69	4.764,45	4.368,52	73,39	597,04	150,26	52.330,76
total	168.353,73	5.067,99	44.097,44	124.095,09	3.534,23	30.892,10	27.462,41	840,53	7.381,38	1.118,50	412.843,39

WIOD data

United States imports from China

	Final imports			Intermediate imports for domestic consumption			Intermediate imports used to produce exports (final+intermediate)						
							(% of gross imports)						
sector	direct exporter's value added	importer's value added (reflected)	third countries value added (indirect)	direct exporter's value added	importer's value added (reflected)	third countries value added (indirect)	direct exporter's value added	importer's value added (reflected)	third countries value added (indirect)	double-counted (direct exporter)	total direct exporter's value added	total importer's value added (reflected)	total indirect value added
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII
primary	40,4%	0,4%	2,5%	45,1%	0,4%	2,8%	7,7%	0,1%	0,5%	0,1%	93,2%	0,9%	5,8%
food	65,9%	1,6%	7,9%	19,1%	0,5%	2,3%	2,2%	0,1%	0,3%	0,1%	87,3%	2,2%	10,5%
textiles	66,3%	1,6%	11,1%	14,5%	0,4%	2,5%	3,0%	0,1%	0,5%	0,1%	83,8%	2,1%	14,1%
manufacture	41,3%	1,1%	12,3%	27,0%	0,7%	8,1%	6,9%	0,2%	2,1%	0,3%	75,2%	2,0%	22,6%
motor vehi	20,9%	0,6%	5,6%	44,1%	1,2%	11,8%	11,9%	0,3%	3,2%	0,4%	76,9%	2,1%	20,6%
services	19,1%	0,2%	2,2%	64,0%	0,7%	7,2%	5,6%	0,1%	0,6%	0,2%	88,7%	1,0%	10,0%
total	44,5%	1,1%	11,5%	26,6%	0,7%	7,2%	6,3%	0,2%	1,8%	0,2%	77,3%	2,0%	20,5%

GTAP data

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII
primary	25,5%	0,3%	1,9%	58,2%	0,6%	4,3%	8,5%	0,1%	0,6%	0,1%	92,2%	0,9%	6,8%
food	82,1%	1,5%	9,6%	5,2%	0,1%	0,6%	0,8%	0,0%	0,1%	0,0%	88,1%	1,6%	10,2%
textiles	66,6%	1,3%	10,6%	14,7%	0,3%	2,4%	3,4%	0,1%	0,5%	0,1%	84,7%	1,7%	13,5%
manufacture	39,9%	1,4%	12,5%	27,2%	1,0%	8,6%	6,8%	0,2%	2,1%	0,3%	73,9%	2,6%	23,2%
motor vehi	44,0%	1,4%	11,6%	24,4%	0,8%	6,5%	8,5%	0,3%	2,3%	0,3%	76,9%	2,5%	20,3%
services	11,5%	0,2%	1,6%	66,6%	1,1%	9,1%	8,3%	0,1%	1,1%	0,3%	86,5%	1,5%	11,8%
total	40,8%	1,2%	10,7%	30,1%	0,9%	7,5%	6,7%	0,2%	1,8%	0,3%	77,5%	2,3%	20,0%

WIOD data

(*Continued*)

(*Continued*)

European Union imports from United States

sector	Final imports			Intermediate imports for domestic consumption			Intermediate imports used to produce exports (final+intermediate)				
	(US $, mio)										
	direct exporter's value added	importer's value added (reflected)	third countries value added (indirect)	direct exporter's value added	importer's value added (reflected)	third countries value added (indirect)	direct exporter's value added	importer's value added (reflected)	third countries value added (indirect)	double-counted (direct exporter)	gross bilateral imports
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
primary	2.548,26	54,23	202,61	3.254,90	69,45	259,49	425,27	9,07	33,90	9,89	6.867,08
food	3.237,37	81,63	355,41	2.612,65	66,10	287,80	307,74	7,79	33,90	9,95	7.000,34
textiles	843,74	32,85	154,53	1.447,41	56,70	266,73	293,18	11,49	54,03	10,77	3.171,41
manufacture	54.416,37	2.067,13	12.406,51	107.001,91	4.095,74	24.581,84	28.086,72	1.075,08	6.452,44	1.031,28	241.215,00
motor vehi	13.043,92	746,94	2.902,48	18.371,90	1.062,17	4.127,41	4.525,42	261,64	1.016,68	220,49	46.279,04
services	66.858,28	1.064,41	3.557,31	93.093,49	1.484,68	4.961,87	13.648,04	217,66	727,44	186,81	185.800,00
total	140.947,93	4.047,18	19.578,85	225.782,27	6.834,84	34.485,14	47.286,37	1.582,73	8.318,38	1.469,18	490.332,87

GTAP data

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
primary	2.608,18	69,99	265,42	1.821,68	49,05	186,03	362,50	9,76	37,02	7,55	5.417,19
food	3.308,89	96,59	427,68	751,75	22,03	97,55	189,29	5,55	24,56	3,74	4.927,63
textiles	1.153,21	54,70	217,35	544,14	25,97	103,20	221,69	10,58	42,04	4,83	2.377,72
manufacture	39.862,99	1.664,30	8.797,76	52.248,89	2.198,11	11.619,55	18.500,47	778,31	4.114,29	541,29	140.325,96
motor vehi	24.113,78	1.735,97	6.138,49	15.451,20	1.124,68	3.976,94	6.393,41	465,37	1.645,58	242,30	61.287,73
services	37.086,05	595,56	1.672,95	176.572,85	2.840,18	7.978,19	34.607,44	556,66	1.563,69	344,80	263.818,37
total	108.133,10	4.217,11	17.519,65	247.390,51	6.260,03	23.961,46	60.274,79	1.826,24	7.427,19	1.144,52	478.154,59

WIOD data

European Union imports from United States

sector	Final imports			Intermediate imports for domestic consumption			Intermediate imports used to produce exports (final+intermediate)						
	(% of gross imports)												
	direct exporter's value added	importer's value added (reflected)	third countries value added (indirect)	direct exporter's value added	importer's value added (reflected)	third countries value added (indirect)	direct exporter's value added	importer's value added (reflected)	third countries value added (indirect)	double-counted (direct exporter)	total direct exporter's value added	total importer's value added (reflected)	total indirect value added
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII
primary	37,1%	0,8%	3,0%	47,4%	1,0%	3,8%	6,2%	0,1%	0,5%	0,1%	90,7%	1,9%	7,2%
food	46,2%	1,2%	5,1%	37,3%	0,9%	4,1%	4,4%	0,1%	0,5%	0,1%	88,0%	2,2%	9,7%
textiles	26,6%	1,0%	4,9%	45,6%	1,8%	8,4%	9,2%	0,4%	1,7%	0,3%	81,5%	3,2%	15,0%
manufacture	22,6%	0,9%	5,1%	44,4%	1,7%	10,2%	11,6%	0,4%	2,7%	0,4%	78,6%	3,0%	18,0%
motor vehi	28,2%	1,6%	6,3%	39,7%	2,3%	8,9%	9,8%	0,6%	2,2%	0,5%	77,7%	4,5%	17,4%
services	36,0%	0,6%	1,9%	50,1%	0,8%	2,7%	7,3%	0,1%	0,4%	0,1%	93,4%	1,5%	5,0%
total	28,7%	0,8%	4,0%	46,0%	1,4%	7,0%	9,6%	0,3%	1,7%	0,3%	84,4%	2,5%	12,7%

GTAP data

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII
primary	48,1%	1,3%	4,9%	33,6%	0,9%	3,4%	6,7%	0,2%	0,7%	0,1%	88,5%	2,4%	9,0%
food	67,1%	2,0%	8,7%	15,3%	0,4%	2,0%	3,8%	0,1%	0,5%	0,1%	86,2%	2,5%	11,2%
textiles	48,5%	2,3%	9,1%	22,9%	1,1%	4,3%	9,3%	0,4%	1,8%	0,2%	80,7%	3,8%	15,2%
manufacture	28,4%	1,2%	6,3%	37,2%	1,6%	8,3%	13,2%	0,6%	2,9%	0,4%	78,8%	3,3%	17,5%
motor vehi	39,3%	2,8%	10,0%	25,2%	1,8%	6,5%	10,4%	0,8%	2,7%	0,4%	75,0%	5,4%	19,2%
services	14,1%	0,2%	0,6%	66,9%	1,1%	3,0%	13,1%	0,2%	0,6%	0,1%	94,1%	1,5%	4,3%
total	22,6%	0,9%	3,7%	51,7%	1,3%	5,0%	12,6%	0,4%	1,6%	0,2%	87,0%	2,6%	10,2%

WIOD data

(*Continued*)

(*Continued*)

United States imports from European Union

	Final imports			Intermediate imports for domestic consumption			Intermediate imports used to produce exports (final+intermediate)				
	(US $, mio)										
sector	direct exporter's value added	importer's value added (reflected)	third countries value added (indirect)	direct exporter's value added	importer's value added (reflected)	third countries value added (indirect)	direct exporter's value added	importer's value added (reflected)	third countries value added (indirect)	double-counted (direct exporter)	gross bilateral imports
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
primary	446,82	6,42	35,94	1.161,08	16,74	93,67	179,39	2,59	14,47	4,21	1.961,33
food	10.381,04	166,13	998,97	7.436,52	119,42	718,08	828,82	13,31	80,03	28,50	20.770,84
textiles	4.079,91	74,35	554,91	3.709,84	67,98	507,42	675,72	12,38	92,42	24,74	9.799,67
manufacture	89.561,80	2.543,96	17.932,25	100.412,34	2.877,25	20.281,63	26.505,16	759,49	5.353,60	1.116,52	267.344,00
motor vehi	36.087,49	1.427,04	6.146,83	14.470,26	577,14	2.485,99	3.961,67	158,01	680,61	158,93	66.153,96
services	35.217,75	538,58	2.456,67	99.696,37	1.529,13	6.974,95	8.944,70	137,19	625,79	319,88	156.441,00
total	175.774,81	4.756,47	28.125,56	226.886,41	5.187,67	31.061,75	41.095,45	1.082,97	6.846,93	1.652,78	522.470,80

GTAP data

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
primary	904,40	15,81	77,80	1.640,19	28,79	141,69	282,26	4,95	24,38	8,09	3.128,36
food	12.027,49	288,21	1.423,25	1.345,12	32,40	160,00	207,94	5,01	24,73	8,04	15.522,18
textiles	5.086,68	109,80	717,58	1.794,64	39,00	254,88	417,00	9,06	59,22	14,97	8.502,85
manufacture	75.838,27	2.603,51	16.305,36	78.123,10	2.712,12	16.985,60	20.697,95	718,55	4.500,17	1.111,99	219.596,62
motor vehi	52.031,60	1.703,85	8.201,98	24.505,88	810,26	3.900,44	8.042,30	265,91	1.280,04	315,65	101.057,91
services	20.848,24	355,84	1.207,49	111.521,21	1.909,01	6.477,94	13.177,91	225,58	765,47	364,04	156.852,73
total	166.736,67	5.077,02	27.933,45	218.930,15	5.531,59	27.920,56	42.825,34	1.229,06	6.654,01	1.822,78	504.660,64

WIOD data

United States imports from European Union

	Final imports			Intermediate imports for domestic consumption			Intermediate imports used to produce exports (final+intermediate)						
	(% of gross imports)												
sector	direct exporter's value added	importer's value added (reflected)	third countries value added (indirect)	direct exporter's value added	importer's value added (reflected)	third countries value added (indirect)	direct exporter's value added	importer's value added (reflected)	third countries value added (indirect)	double-counted (direct exporter)	total direct exporter's value added	total importer's value added (reflected)	total indirect value added
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII
primary	22,8%	0,3%	1,8%	59,2%	0,9%	4,8%	9,1%	0,1%	0,7%	0,2%	91,1%	1,3%	7,3%
food	50,0%	0,8%	4,8%	35,8%	0,6%	3,5%	4,0%	0,1%	0,4%	0,1%	89,8%	1,4%	8,7%
textiles	41,6%	0,8%	5,7%	37,9%	0,7%	5,2%	6,9%	0,1%	0,9%	0,3%	86,4%	1,6%	11,8%
manufacture	33,5%	1,0%	6,7%	37,6%	1,1%	7,6%	9,9%	0,3%	2,0%	0,4%	81,0%	2,3%	16,3%
motor vehi	54,6%	2,2%	9,3%	21,9%	0,9%	3,8%	6,0%	0,2%	1,0%	0,2%	82,4%	3,3%	14,1%
services	22,5%	0,3%	1,6%	63,7%	1,0%	4,5%	5,7%	0,1%	0,4%	0,2%	92,0%	1,4%	6,4%
total	33,6%	0,9%	5,4%	43,4%	1,0%	5,9%	7,9%	0,2%	1,3%	0,3%	84,9%	2,1%	12,6%

GTAP data

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII
primary	28,9%	0,5%	2,5%	52,4%	0,9%	4,5%	9,0%	0,2%	0,8%	0,3%	90,4%	1,6%	7,8%
food	77,5%	1,9%	9,2%	8,7%	0,2%	1,0%	1,3%	0,0%	0,2%	0,1%	87,5%	2,1%	10,4%
textiles	59,8%	1,3%	8,4%	21,1%	0,5%	3,0%	4,9%	0,1%	0,7%	0,2%	85,8%	1,9%	12,1%
manufacture	34,5%	1,2%	7,4%	35,6%	1,2%	7,7%	9,4%	0,3%	2,0%	0,5%	79,5%	2,7%	17,2%
motor vehi	51,5%	1,7%	8,1%	24,2%	0,8%	3,9%	8,0%	0,3%	1,3%	0,3%	83,7%	2,8%	13,2%
services	13,3%	0,2%	0,8%	71,1%	1,2%	4,1%	8,4%	0,1%	0,5%	0,2%	92,8%	1,6%	5,4%
total	33,0%	1,0%	5,5%	43,4%	1,1%	5,5%	8,5%	0,2%	1,3%	0,4%	84,9%	2,3%	12,4%

WIOD data

(*Continued*)

(*Continued*)

China imports from European Union

	Final imports			Intermediate imports for domestic consumption			Intermediate imports used to produce exports (final+intermediate)				
	(US $, mio)										
sector	direct exporter's value added	importer's value added (reflected)	third countries value added (indirect)	direct exporter's value added	importer's value added (reflected)	third countries value added (indirect)	direct exporter's value added	importer's value added (reflected)	third countries value added (indirect)	double-counted (direct exporter)	gross bilateral imports
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
primary	633,11	5,23	54,79	960,56	7,95	83,39	398,31	3,30	34,58	4,27	2.185,49
food	2.054,90	19,19	211,44	1.838,28	17,22	189,80	513,10	4,81	52,98	8,11	4.909,83
textiles	1.495,25	44,99	185,62	1.236,78	37,43	154,40	1.403,30	42,46	175,19	14,89	4.790,33
manufacture	27.465,63	603,98	5.675,39	58.081,17	1.288,47	12.107,24	26.793,79	594,39	5.585,27	746,66	138.942,00
motor vehi	20.941,16	528,49	3.866,54	15.294,69	389,32	2.848,33	3.470,34	88,34	646,28	161,80	48.235,29
services	10.849,28	89,86	832,86	15.261,03	126,77	1.174,99	4.525,89	37,60	348,46	58,26	33.305,00
total	63.439,33	1.291,74	10.826,65	92.672,51	1.867,17	16.558,16	37.104,73	770,89	6.842,76	993,99	232.367,93

GTAP data

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
primary	309,42	3,40	28,63	1.902,86	21,00	176,78	572,11	6,31	53,15	10,41	3.084,07
food	5.884,34	84,54	752,77	977,45	14,12	125,69	242,58	3,50	31,19	6,31	8.122,49
textiles	4.385,58	203,33	510,02	1.503,77	70,19	176,06	1.353,46	63,17	158,47	19,35	8.443,40
manufacture	24.311,59	715,60	5.346,04	47.182,17	1.404,42	10.491,96	19.659,48	585,18	4.371,70	752,14	114.820,29
motor vehi	46.135,25	1.423,50	7.359,77	33.944,45	1.057,51	5.467,54	12.561,71	391,35	2.023,35	451,02	110.815,45
services	12.590,59	112,97	831,15	48.236,77	434,05	3.193,59	13.048,97	117,42	863,93	178,91	79.608,36
total	93.616,77	2.543,34	14.828,39	133.747,46	3.001,29	19.631,62	47.438,30	1.166,94	7.501,79	1.418,14	324.894,05

WIOD data

China imports from European Union

	Final imports			Intermediate imports for domestic consumption			Intermediate imports used to produce exports (final+intermediate)						
	(% of gross imports)												
sector	direct exporter's value added	importer's value added (reflected)	third countries value added (indirect)	direct exporter's value added	importer's value added (reflected)	third countries value added (indirect)	direct exporter's value added	importer's value added (reflected)	third countries value added (indirect)	double-counted (direct exporter)	total direct exporter's value added	total importer's value added (reflected)	total indirect value added
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII
primary	29,0%	0,2%	2,5%	44,0%	0,4%	3,8%	18,2%	0,2%	1,6%	0,2%	91,1%	0,8%	7,9%
food	41,9%	0,4%	4,3%	37,4%	0,4%	3,9%	10,5%	0,1%	1,1%	0,2%	89,7%	0,8%	9,3%
textiles	31,2%	0,9%	3,9%	25,8%	0,8%	3,2%	29,3%	0,9%	3,7%	0,3%	86,3%	2,6%	10,8%
manufacture	19,8%	0,4%	4,1%	41,8%	0,9%	8,7%	19,3%	0,4%	4,0%	0,5%	80,9%	1,8%	16,8%
motor vehi	43,4%	1,1%	8,0%	31,7%	0,8%	5,9%	7,2%	0,2%	1,3%	0,3%	82,3%	2,1%	15,3%
services	32,6%	0,3%	2,5%	45,8%	0,4%	3,5%	13,6%	0,1%	1,0%	0,2%	92,0%	0,8%	7,1%
total	27,3%	0,6%	4,7%	39,9%	0,8%	7,1%	16,0%	0,3%	2,9%	0,4%	83,2%	1,7%	14,7%

GTAP data

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII
primary	10,0%	0,1%	0,9%	61,7%	0,7%	5,7%	18,6%	0,2%	1,7%	0,3%	90,3%	1,0%	8,4%
food	72,4%	1,0%	9,3%	12,0%	0,2%	1,5%	3,0%	0,0%	0,4%	0,1%	87,5%	1,3%	11,2%
textiles	51,9%	2,4%	6,0%	17,8%	0,8%	2,1%	16,0%	0,7%	1,9%	0,2%	85,8%	4,0%	10,0%
manufacture	21,2%	0,6%	4,7%	41,1%	1,2%	9,1%	17,1%	0,5%	3,8%	0,7%	79,4%	2,4%	17,6%
motor vehi	41,6%	1,3%	6,6%	30,6%	1,0%	4,9%	11,3%	0,4%	1,8%	0,4%	83,6%	2,6%	13,4%
services	15,8%	0,1%	1,0%	60,6%	0,5%	4,0%	16,4%	0,1%	1,1%	0,2%	92,8%	0,8%	6,1%
total	28,8%	0,8%	4,6%	41,2%	0,9%	6,0%	14,6%	0,4%	2,3%	0,4%	84,6%	2,1%	12,9%

WIOD data

(*Continued*)

(*Continued*)

China imports from United States

	Final imports			Intermediate imports for domestic consumption			Intermediate imports used to produce exports (final+intermediate)				
	(US $, mio)										
sector	direct exporter's value added	importer's value added (reflected)	third countries value added (indirect)	direct exporter's value added	importer's value added (reflected)	third countries value added (indirect)	direct exporter's value added	importer's value added (reflected)	third countries value added (indirect)	double-counted (direct exporter)	gross bilateral imports
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
primary	970,91	10,65	87,21	14.575,35	160,28	1.312,71	5.198,15	57,16	468,17	53,15	22.893,75
food	1.205,74	12,85	149,93	2.465,44	26,36	307,60	767,34	8,20	95,74	11,01	5.050,21
textiles	113,52	5,61	19,60	589,84	29,35	102,45	698,68	34,77	121,36	7,97	1.723,15
manufacture	10.521,66	285,89	2.512,65	38.149,91	1.044,51	9.180,05	17.938,62	491,14	4.316,59	428,18	84.869,20
motor vehi	7.466,98	282,39	1.806,71	3.321,27	126,82	811,35	711,11	27,15	173,72	38,83	14.766,33
services	4.081,83	30,94	251,22	4.814,85	36,57	296,85	1.302,81	9,89	80,32	10,71	10.916,00
total	24.360,64	628,34	4.827,32	63.916,66	1.423,88	12.011,02	26.616,72	628,32	5.255,89	549,85	140.218,64

GTAP data

sector	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
primary	1.238,18	14,73	144,50	7.778,65	92,87	910,92	2.326,62	27,78	272,46	34,93	12.841,65
food	2.634,92	42,65	374,83	954,99	15,52	136,39	240,58	3,91	34,36	4,76	4.442,91
textiles	281,46	14,48	51,91	360,86	18,69	66,98	311,02	16,10	57,73	4,24	1.183,47
manufacture	11.146,42	279,90	2.645,48	32.712,55	827,74	7.823,37	15.834,29	400,66	3.786,85	371,43	75.828,69
motor vehi	11.026,82	548,48	3.052,38	8.072,80	406,00	2.259,45	3.427,81	172,39	959,39	127,57	30.053,09
services	3.554,70	31,13	186,30	32.306,42	283,42	1.695,95	12.117,74	106,31	636,13	72,53	50.990,62
total	29.882,50	931,38	6.455,40	82.186,26	1.644,24	12.893,06	34.258,06	727,16	5.746,92	615,45	175.340,43

WIOD data

China imports from United States

	Final imports			Intermediate imports for domestic consumption			Intermediate imports used to produce exports (final+intermediate)						
	(% of gross imports)												
sector	direct exporter's value added	importer's value added (reflected)	third countries value added (indirect)	direct exporter's value added	importer's value added (reflected)	third countries value added (indirect)	direct exporter's value added	importer's value added (reflected)	third countries value added (indirect)	double-counted (direct exporter)	total direct exporter's value added	total importer's value added (reflected)	total indirect value added
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII
primary	4,2%	0,0%	0,4%	63,7%	0,7%	5,7%	22,7%	0,2%	2,0%	0,2%	90,6%	1,0%	8,2%
food	23,9%	0,3%	3,0%	48,8%	0,5%	6,1%	15,2%	0,2%	1,9%	0,2%	87,9%	0,9%	11,0%
textiles	6,6%	0,3%	1,1%	34,2%	1,7%	5,9%	40,5%	2,0%	7,0%	0,5%	81,4%	4,0%	14,1%
manufacture	12,4%	0,3%	3,0%	45,0%	1,2%	10,8%	21,1%	0,6%	5,1%	0,5%	78,5%	2,1%	18,9%
motor vehi	50,6%	1,9%	12,2%	22,5%	0,9%	5,5%	4,8%	0,2%	1,2%	0,3%	77,9%	3,0%	18,9%
services	37,4%	0,3%	2,3%	44,1%	0,3%	2,7%	11,9%	0,1%	0,7%	0,1%	93,4%	0,7%	5,8%
total	17,4%	0,4%	3,4%	45,6%	1,0%	8,6%	19,0%	0,4%	3,7%	0,4%	81,9%	1,9%	15,8%

GTAP data

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII
primary	9,6%	0,1%	1,1%	60,6%	0,7%	7,1%	18,1%	0,2%	2,1%	0,3%	88,3%	1,1%	10,3%
food	59,3%	1,0%	8,4%	21,5%	0,3%	3,1%	5,4%	0,1%	0,8%	0,1%	86,2%	1,4%	12,3%
textiles	23,8%	1,2%	4,4%	30,5%	1,6%	5,7%	26,3%	1,4%	4,9%	0,4%	80,6%	4,2%	14,9%
manufacture	14,7%	0,4%	3,5%	43,1%	1,1%	10,3%	20,9%	0,5%	5,0%	0,5%	78,7%	2,0%	18,8%
motor vehi	36,7%	1,8%	10,2%	26,9%	1,4%	7,5%	11,4%	0,6%	3,2%	0,4%	75,0%	3,7%	20,9%
services	7,0%	0,1%	0,4%	63,4%	0,6%	3,3%	23,8%	0,2%	1,2%	0,1%	94,1%	0,8%	4,9%
total	17,0%	0,5%	3,7%	46,9%	0,9%	7,4%	19,5%	0,4%	3,3%	0,4%	83,5%	1,9%	14,3%

WIOD data

3. Value added protection: a comparison between selected economies

Abstract

In this work the incidence of trade policies in a GVCs framework is empirically addressed. The value-added trade restrictiveness indexes (VA-TRIs) are used in setting the reference criteria for the equivalent impact of trade policies, allowing to measure the overall protectionist stance in terms of value added, rather than with reference to the more traditional metrics, such as gross trade. The index is constructed in such a way as to distinguish, at the bilateral level, the domestic and the foreign (bilateral or indirect) value added content of imports. In the comparative static analysis, we adapt and extend the code and data of a newly developed version of the GTAP model with sourcing of imports by agent, and with the decomposition of trade flows in value-added components. We bilaterally compute the VA-TRI for three of the major economies, European Union, United States and China.

JEL Codes: C68, F13, F17

Keywords: Trade Protection, Global Trade Analysis Project (GTAP), Global Value Chains (GVCs), Trade Restrictiveness Indexes (TRI), Value added trade.

"In a regime of Free Trade and free economic intercourse it would be of little consequence that iron lay on one side of a political frontier, and labor, coal, and blast furnaces on the other. But as it is, men have devised ways to impoverish themselves and one another; and prefer collective animosities to individual happiness.

John Maynard Keynes, 1920

"Since ultimately the case for free trade is a scientific hypothesis, theoretically sound but potentially false, some measure of trade restrictiveness is necessary if satisfactory tests of the impact of trade on growth and economic performance are to be possible"

Anderson, J.E., and Neary, J.P. 2005

3.1. Introduction

International economists have long been concerned with empirical assessment of trade policy restrictiveness. The topic is still relevant after more than half a century of efforts to multilaterally or regionally liberalize trade (Goldberg and Pavcnik, 2016). Recent developments in the international division of labor (Daudin et al., 2011) - emerged from what Baldwin (2006) labels globalization 2nd unbundling - have lead countries to be increasingly involved in *task trade* (Grossman and Rossi-Hansberg, 2008) in which value is added at various steps performed in different locations. Traded intermediates pass through global value chains (GVCs) and cross borders multiple times, directly implying that even small levels of tariffs, if cumulatively repeated, matter (Yi, 2003 and 2010; Koopman et al., 2010; Rouzet and Miroudot, 2013).

To develop summary statistics of trade protection, the first challenge is to define a proper method of aggregating across different policy instruments over thousands of commodities. While the issue of *how trade restrictiveness should be measured* is still a controversial one

(Krishna, 2009) - as the existence of a variety of indexes of protection witnesses[26] - a theoretical foundation has been given trough the work of Anderson and Neary (1996; 2005), which lays the intellectual foundations for the development of index numbers for policy variables that maintain the link between the aggregated information and the economic variable of interest.

Building on this insight, we set a new framework for trade restrictiveness indexes in order to account for the rising of the international fragmentation of production in GVCs. This allows to reckon with the symbiotic relation emerged between exports and imports, which implies that mercantilist-styled *beggar thy neighbour* strategies can turn out to be *beggar thyself* miscalculations (IMF, 2013; Miroudot and Yamano, 2013). If production processes are interconnected in chains involving many countries, a country's incentive to impose import protection is altered (Blanchard et al., 2016), since restrictive measures impact domestic firms exporting intermediate inputs processed abroad and then imported back[27]. Moreover, tariffs applied to the direct partner have indirect effects on third countries supplying inputs which are embodied in bilateral flows. Evaluating the repercussions of trade policies requires a departure from the gross measurement of trade, and identification of the origin of value added - or equivalently of primary factor inputs - in trade flows. This work is an attempt to include both the direct and indirect consequences of the international fragmentation of the productive process in empirical analysis of trade policy.

Several methods have been proposed for the decomposition of gross trade in terms of value added starting with the pioneering work of Hummels, Ishii, and Yi (2001), and extended by a large number of more recent contributions (Daudin et al., 2011; Johnson and Noguera, 2012; Foster-McGregor, and Stehrer (2013); Los et al., 2013, 2015; Wang et al., 2013; Koopman et al. 2014; Cappariello and Felettigh, 2015; Borin and Mancini, 2015)[28]. Rooted in Leontief (1936), these efforts – with different degrees of sophistication –propose "new trade numbers" (Baldwin and Robert-Nicoud, 2014) replacing gross statistics, allowing more accurate analysis of trade, and revealing the hidden structure of trade in value added underlying gross

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[26] For a discussion of tariff aggregation methods proposed in the literature, see Cipollina and Salvatici (2008). Within the aggregation methods, the effective protection rates have been the argument of the first chapter of this thesis.

[27] This effect adds to the direct impact that an increase in import costs has on domestic firms processing imported inputs for exports, whose competitiveness crucially depends on their ability to source inputs cheaply (OECD 2013).

[28] The second chapter of this thesis proposes a method to decompose bilateral imports which, in the spirit of Wang et al. (2013), Koopman et al. (2014), and Borin and Mancini (2015), keeps track of the double-counting emerging from the back and forth passage of intermediate goods.

trade flows. We make use of these instruments and decompose trade flows into their value-added content by source, giving a measure of the value added embodied in imports according to the country of origin (Foster-McGregor and Stehrer, 2013; Amador and Stehrer, 2014). This decomposition is applied at the bilateral level, redefining the reference criterion for the equivalent impact of trade policies. This is done by incorporating the factor content approach in Neary and Schweinberger (1986) into a behavioral model of tariff aggregation, and extending it to a value-added framework. The extended model is used to define three different benchmarks against which to measure restrictiveness, according to where the value added originates. The resulting indexes are equivalent to the actual trade policies in terms of the impact, i.e. on domestic or foreign (direct or indirect) value added.

In the next section, we briefly present the setup of the model underlying the definition of the indexes of trade restrictiveness in value-added terms. In section 3, the computable general equilibrium (CGE) model used in the empirical application, the GTAP (Global Trade Analysis Project) model, is introduced, and is extended in order to implement the value-added decomposition of trade flows. Section 4 discusses data issues and introduces a newly developed GTAP-MRIO database, build on the GTAP Data Base version 9, with sourcing information by agent. In section 5 we present the simulations and discuss the results. Section 6 concludes the chapter.

3.2. Theoretical set up

The model is described in two stages. First, an abstract general equilibrium model is used to derive the value-added indexes of trade restrictiveness. Second, the abstract model is operationalized through the GTAP model.

The theoretical anchor of the index for trade policy allows assessment of the distorting effects on the macroeconomics variables of interest due to protectionism (Anderson, 2003; Cipollina and Salvatici, 2008; Anderson et al., 2013). It also allows cross-country comparison among different trade policies. A seminal contribution to the theoretical analysis and empirical measurement of the restrictiveness of trade policy was proposed by Anderson and Neary (2005)[29] who developed a solution to the aggregation or index number problem of

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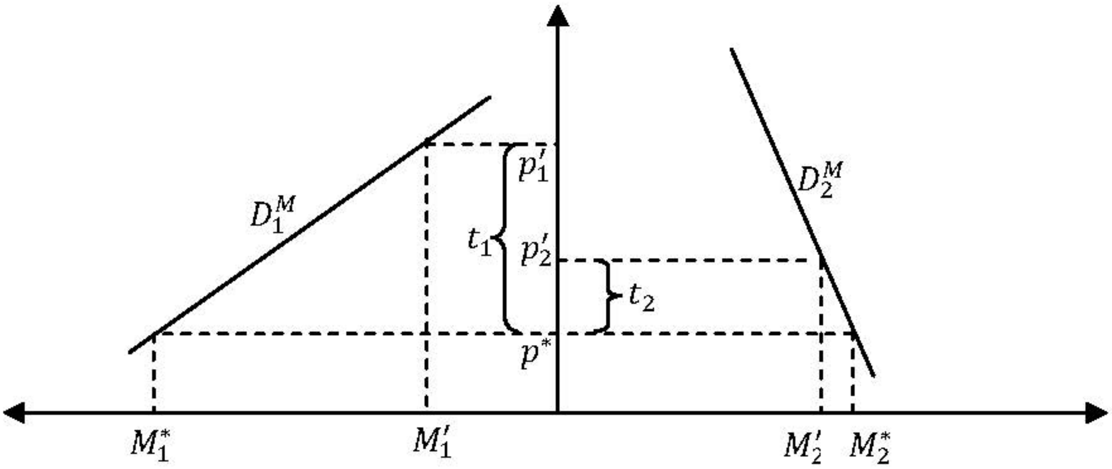
[29] Their book, *Measuring the restrictiveness of international trade policy*, presents in a coherent framework their research agenda since the 1990s. To assess the effect of the structure of trade policy on national welfare, they propose the trade restrictiveness index (TRI) defined as the *uniform price deflator which, applied to the new levels of distorted prices, yields the old level of utility of the representative agent*. They also assume an iso-

measuring trade restrictiveness in the presence of differentiated tariff structures. While for a single tariff its height is an unambiguous measure of the restrictiveness of policy, ambiguity emerges when thousands of different tariff lines are synthesized in a single number. The choice of a proper aggregation procedure is not straightforward. Simple averages of tariff rates have the obvious drawback that they ignore any economic differences among traded goods; in addition, they are sensitive to changes in the classification of commodities in the tariff code (Anderson and Neary, 2005). It follows that tariffs should be weighted by their relative importance in some sense. Different weighting schemes have been proposed such as actual trade volumes, consumption or production shares, GDP, and world exports; however, the resulting outcome measures[30] of tariffs present the worrisome problem of statistical endogeneity. For example, consider a tariff level sufficiently high to block trade; then the trade-weighted average tariff will assign a lower weight to that tariff. This is true especially if the high tariff is applied to imports in relatively elastic demand, that is where the tariff has major effects on trade volumes (Anderson and Neary, 2003; 2005). Figure 3.1 illustrates this point.

Figure 3.1. *Tariff rates and import demand elasticities. The case of positive correlation.*



The lift side of figure 3.1 depicts the domestic market for good 1, and the right side depicts the same market for good 2. For ease of exposition, both goods have the same world price level (p^*). The two curves, D_1^M and D_2^M are the demand for imports of goods1 and 2,

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volume perspective and define the mercantilist trade restrictiveness index (MTRI) as the uniform tariff equivalent that maintains the aggregate import volume of a country at its current level with heterogeneous tariffs.

[30] For a precise categorization of the measures of protection in incidence, outcome and equivalence, see Cipollina and Salvatici (2008).

respectively. At p^*, the quantity of imports for good 1 is given by M_1^*, and for good 2 by M_2^*. Assume that tariffs t_1 and t_2 are imposed on goods1 and 2, respectively, then, their prices rise to p_1' and p_2' so that the quantities of imports decrease to M_1' and M_2'. In this example, the correlation between demand elasticities and tariff level is positive, that is the higher tariff is applied to the good which shows higher price elasticity of import demand ($t_1 > t_2$). In such circumstances, the impact of t_1 on imported quantities of good 1 is strong but in the calculation of the trade-weighted average tariff rate the weight it receives is lower than the weight of t_2 ($M_2' > M_1'$). The serious drawback is that the index may be decreasing in the tariff rate. The same endogeneity bias emerges if the input intensity is used as a weight since for a prohibitive tariff, inputs are not imported and they do not enter the computation of effective protection.

Thus, purely statistical measures are poor indicators of the tariff's height, and lack any economic interpretation: an average tariff of 50 percent may or may not restrict trade more than an average tariff of 25 percent (Irwin, 2010). As a mental experiment, in the example given in figure 3.1, set the tariff rate at the level of t_1 on the less elastic good 2, and the tariff rate at the level of t_2 on good 1. The higher tariff will have comparatively less impact on imports so that the trade-weighted average tariff rate will now be lower than the previous case. It follows that the index is flawed and unreliable. Overall, what we can obtain from such indexes are "answers without questions". Against this backdrop, the use of a behavioral model of tariff aggregation allows definition of the weights *representing the effects of the tariffs according to a fundamental economic structure* (Cipollina and Salvatici, 2008). The index is constructed depending on the specific dimension under examination, such that an unambiguous answer to a formerly defined economic question can be provided. Starting from a formal criterion against which restrictiveness is measured, a uniform tariff equivalent of a non-uniform tariff structure yielding the same value in terms of a specific variable, is calculated (Anderson et al., 2013).

With developments in the nature of international trade due to the rise of international fragmentation of production, a gap between countries' national income and the value of final production has emerged, since imports contain domestic value added, and exports are produced importing foreign value added. Consequently, the link between macroeconomic models, reasoning in terms of value added, and trade statistics, recorded in gross values, seems to be dissolving. This introduces new questions. As previously mentioned, the protection imposed on imports limits imports from the rest of the world, and at the same time, potentially impacts on domestic production. Moreover, when bilateral flows are being considered, an analytical framework that allows us to distinguish that part of intermediate production embodied in bilateral imports which takes place in a third country, could be useful. We define the index of trade restrictiveness in such a way as to distinguish among these different effects. To do so, we express the value-added content of bilateral flows, introducing a decomposition of bilateral imports according to the country in which the different strata of value are added. Using this criterion, we obtain three different benchmarks against which to measure restrictiveness, according to where the value added originates. The resulting indexes are equivalent to the actual trade policies in terms of the chosen impact, namely on domestic or foreign (direct or indirect) value added.

The step by step derivation of the model is described in chapter I of this thesis; in what follows, the main equation for the value-added content of bilateral imports is introduced to obtain the benchmarks for the value-added trade restrictiveness indexes (VA-TRI) used in the empirical application. Let $r, s, t = 1, .., C$ represent countries $i$and$j = 1, \dots, N$ sectors, and $k = 1, \dots, F$ primary factors of production. Also, let m_j^{rs} denote imports of sector j from country r to country s valued at world prices. Assume a tariff-distorted trading economy in competitive equilibrium. Trade flows can be thought of in terms of factor content. Then, exploiting duality, and the factor content functions developed by Neary and Schweinberger (1986), m_j^{rs} is defined in terms of its content of factor k as $M_k^{rs} = \sum_t \sum_{r \neq s} \sum_i d_{ki}^t \bar{l}_{ij}^{tr} m_j^{rs}$, where d_{ki}^t is the cost-minimizing factor k per unit of output in sector i of country t, and $\bar{l}_{ij}^{tr}$ is the global multiplier that gives the indirect consumption of intermediate inputs i originated in country t by sector $j$in country r. Multiplyingphysical factor requirement coefficients by factor prices (ω_k) and summing over all factors, and defining the value added as the total remuneration of primary factors ($v_i = \sum_k \omega_k d_{ki}$), we obtain sectoral bilateral imports expressed as value-added content by country of origin:

1. $$M_j^{rs} = \sum_t \sum_{r \neq s} \sum_i v_i^t \; \bar{l}_{ij}^{tr} \; m_j^{rs} = \underbrace{\sum_i v_i^r \; \bar{l}_{ij}^{rr} \; m_j^{rs}}_{fvab\_imp} + \underbrace{\sum_i v_i^s \; \bar{l}_{ij}^{sr} \; m_j^{rs}}_{dva\_imp} + \underbrace{\sum_{t \neq r,s} \sum_i v_i^t \; \bar{l}_{ij}^{tr} \; m_j^{rs}}_{fvai\_imp}$$

Equation (1) defines the three main components of bilateral imports. Namely, from the point of view of country s importing from r: i) the direct foreign value added originated in all sectors of the exporting country r embodied in its exports of sector j to s ($fvab\_imp$), ii) the domestic value added originated in all sectors of s which is imported back from the sector j of country r (dva_imp), and iii) the indirect foreign value added of third countries which is indirectly imported by s from sector j of r ($fvai\_imp$).

The value added equivalent uniform tariffs yielding the same value of each component of the bilateral imports can be expressed for each of the component in (1) as follows:

(a) $$\tau^{(\mu)rs}_{fvab\_imp} : \sum_j \sum_i v_i^r \, \bar{l}_{ij}^{rr} m_j^{rs} \left[\left(1+\tau_j^{(\mu)rs}\right) p^*(T), b^0, \omega\right] = \sum_j \sum_i v_i^r \, \bar{l}_{ij}^{rr} m_j^{rs} \, (p^0, b^0, \omega);$$

(b) $$\tau^{(\mu)rs}_{dva\_imp} : \sum_j \sum_i v_i^s \, \bar{l}_{ij}^{sr} m_j^{rs} \left[\left(1+\tau_j^{(\mu)rs}\right) p^*(T), b^0, \omega\right] = \sum_j \sum_i v_i^s \, \bar{l}_{ij}^{sr} m_j^{rs} \, (p^0, b^0, \omega);$$

and

(c) $$\tau^{(\mu)rs}_{fvai_{imp}} : \sum_{t \neq r,s} \sum_j \sum_i v_i^t \, \bar{l}_{ij}^{tr} \, m_j^{rs} \left[\left(1+\tau_j^{(\mu)rs}\right) p^*(T), b^0, \omega\right] =$$

$$\sum_{t \neq r,s} \sum_j \sum_i v_i^t \, \bar{l}_{ij}^{tr} \, m_j^{rs} \, (p^0, b^0, \omega),$$

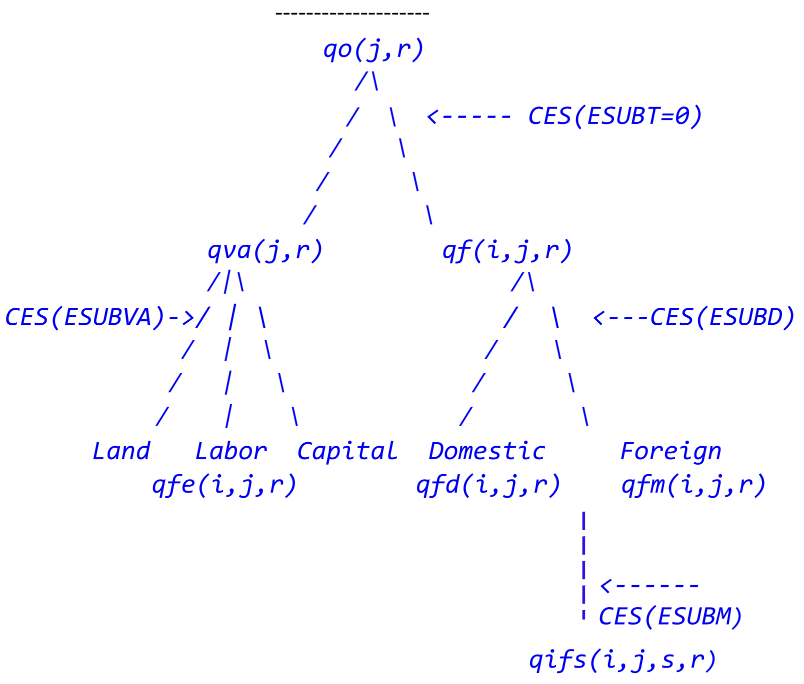
where b^0 is the level of the balance of trade function in the reference period giving the equilibrium for the economy subjected to tariffs. p^0 denotes the initially distorted prices vector and p^* is the world prices vector. International prices (p^*) are expressed as a function of the tariff vector (T) in order to allow for endogenous world prices (Salvatici, 2001; Antimiani and Salvatici, 2005). The right-hand side in each equation is the total value originated (a) in the exporting country, (b) in the importing country, and (c) in third countries, which is embedded in bilateral imports at the initial non-uniform tariffs. The left-hand side maintains the same values applying a uniform (product-generic) tariff.

Next, we turn to the GTAP model which is used for the general equilibrium application. After a description of the main features of the standard GTAP model, we discuss extensions to the model introduced in order to apply the value-added decomposition of bilateral trade.

3.3. The extended GTAP model for value-added analysis

The economic assessment of trade restriction is performed through a modified version of the standard GTAP model, which is a multi-region, multi-sector global CGE model, with perfect competition and constant returns to scale technology, designed to assess the inter-regional, economy-wide incidence of economic policies. It is built on a complete set of economic accounting and detailed inter-sector linkages for each of the economies represented. Across regions, symmetric treatment of production and utility functions is given, so that the only differences in regional behavior in the model are those arising from differences in the relative importance of economic flows, and differences in the model parameters related to consumer demand (Hertel, 2013). Expenditures by regional household, which receives the factor rewards, are governed by a utility function which aggregates private consumption, government spending and savings. The utility function is nested as in the standard GTAP model, with a first aggregation made over distinct goods or sectors, and between the latter a choice is made over domestic or imported quantities[31]. The import demand is modeled following the Armington aggregation structure, with an exogenously differentiation scheme given by the geographical origin of homogeneous products. In the standard GTAP model the sourcing of imports occurs at the border; we need to modify household behavior to accommodate the addition of sourcing information. In doing so, we follow Aguiar et al. (2015) in reallocating imports for government and private households according to the origin of these imports. Firm behavior is depicted in figure 3.2.

Figure 3.2. *Production structure in the GTAP model (Version 6.2-SC, which introduces sourcing of imports by agent).*



Source: Based on figure 2.2 in Walmsley et al. (2014).

In the production tree assumed by the model, composite value-added (qva) and intermediates (qf) enter in fixed proportions (Leontief technology) in the production of output (qo), and intermediates are broken down into domestic and imported components. To incorporate the

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[31] Non-homotheticity (i.e., dependence of consumer demand on income levels) is assumed for private household demands whose preferences are modeled by a constant difference of elasticities (CDE) functional form (Hanoch, 1975).

sourcing of imports in the production structure, the aggregate level for the sourcing decisions for imports has to be split at the agent level. This maintains the Armington assumption, which now is applied to demand for imports from the specific agent (government, private households, and firms) and not to total demand for imports. For firms, this is done by adding a new nest level linking the imported intermediates (qfm) and the imports indexed by the country of origin (qifs).

Building on this structure, we introduce the decomposition of gross bilateral flows into the three components previously introduced. Namely, the original variable for bilateral flows (qxs) is split into three sub-components (figure 3.3): the total reflected domestic value added (dva_imp), the foreign value added of direct exporter (fvab_imp), and the redirected foreign value added (fvai_imp).

Figure 3.3. *Bilateral imports decomposition.*

```
               ------------

                   qxs
                 (i,r,s)
                   /|\
                  / | \
                 /  |  \
                /   |   \
               /    |    \
         dva_imp  fvab_imp  fvai_imp
         (i,r,s)  (i,r,s)   (i,r,s)
```

The value-added multipliers[32], which combines the sectoral value-added shares in each country with the direct and indirect intermediate usage in the productive process, are used to obtain the decomposition in figure 3.3.

Finally, in order to compute the uniform tariff, we follow Salvatici (2001), and Antimiani and Salvatici (2005) and define a new variable, tr(r, s), as the *product-generic tariff levied on imports from region r into region s*.

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[32] For details on the value-added multipliers, refer to ch. 2, section 3.2 in this thesis.

3.4. The GTAP-MRIO Database with a value-added decomposition of bilateral flows

In order to implement the VA-TRI, a four-dimensional information level on source and destination country-sector is required. For the purpose of our simulations, we use a newly developed GTAP-MRIO database, derived from the reconciliation of trade data with the input-output structure available for each region, build on the GTAP database version 9 (Aguiar et al., 2016)[33]. The key aspect in the construction of a full MRIO table is that import sources are to be attributed for intermediate and final demand to individual source countries and sectors[34]. The standard GTAP database traces imports to specific agents (i.e., private households, government, and firms) in the domestic economy, however, it aggregates these flows at the border (Narayanan et al., 2012), while bilateral trade data are not distinguished by end use. In order to obtain sourcing information, the standard GTAP database is supplemented with bilateral trade data from the tariff analytical and simulation tool for economists (TASTE), which consists of UN COMTRADE data at the six-digit level of the harmonized system (HS). A two-step processing procedure is followed. First, three concordances are applied in order to assimilate the cost structure of each country-agent pair in the GTAP database with the agent specific import demands of the bilateral trade data from TASTE, namely, the HS-BEC (Broad Economic Categories) concordance, the BEC-USE concordance, and the HS-GTAP concordance. Figure 3.4 reports this process.

Figure 3.4. *Application of the HS-BEC, BEC-SNA, and HS-GTAP concordances to the UN COMTRADE data*.

Source: Based on Figure 2 in Aguiar et al., 2016a

Starting from the left, the first arrow represents the UN COMTRADE import data from the TASTE database. On these data, which are indexed on HS line h, source country s, and importing country r, we apply the first concordance between HS and BEC revision 4. This concordance maps from 5052 HS codes at the six-digit level to 19 BEC categories,

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[33] The database was developed under the Public Procurement Project contracted by the Centre for Global Trade Analysis and the European Commission.

[34] The GTAP database for value-added analysis was introduced in ch. 2 of this thesis, with the aim of comparing the value-added decomposition results calculated on GTAP data and on WIOD. Here, more details on the construction of GTAP-MRIO are provided.

introducing the index b which represents BEC codes (second arrow). Subsequently, the end use categories of the System of National Accounts (SNA) are used to mapthe 19 BEC categories to the three SNA end use classes (i.e., intermediate use, final consumption, and capital goods). The index u is added for end use categories (third arrow). Finally, the HS-GTAP concordance is applied to map each HS line to a GTAP commodity which gives the index for the GTAP commodity, i.

The second step is to reformat the trade data to be compatible with the GTAP database, to obtain import values by agent and source for each GTAP commodity. The data must be consistent with the other GTAP data, that is, they must add up to the total imports by source for each commodity in each use. The original bilateral trade data in the standard database are prioritized in the rebalancing procedure in which the constrained optimization problem allows the value of imports by producers and in final consumption to be adjusted to satisfy the constraints imposed by the original bilateral trade data[35].

Then, the data from the GTAP-MRIO database are used to split bilateral flows at sector level according to where the value-added embedded in the bilateral flows originates. Specifically, they are used to obtain the Leontief inverse coefficients, indexes for source sector i, receiving sector j, source country s, and importing country r. Using country and sector specific value-added shares, we obtain the coefficient of the value-added multipliers for each source of production which allows computation of the value added originating in all sectors of the domestic economy, the exporter country, and in third countries which is embodied in total bilateral trade in each commodity. Since by construction, the sum of all sector/country sources gives unity, we maintain consistency with the GTAP database by ensuring that the sum of the three coefficients gives the bilateral flows as in the standard GTAP database.

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[35] In GTAP notational conventions: purchases of imports i for use by j in region r, VIFMS(i,j,r,s), government demand for imports of i from s in region r, VIGMS(i,r,s), and private consumption expenditure on imported i from s in r, VIPMS(i,r,s), must add to the total value of imports of i from s to r, VIMS (i,r,s). Moreover, adding for all importing sources in each end use, we have: $\sum_r VIFMS(i,j,r,s) = VIFM(i,j,s)$, $\sum_r VIGMS(i,r,s) = VIGM(i,s)$, and $\sum_r VIPMS(i,r,s) = VIPM(i,s)$.

3.5. Simulations and results

3.5.1. The value-added content of gross imports

Table 3.1 reports the value-added shares in gross sectoral bilateral imports for each of the three components of equation (1) for three major economies, namely the European Union, the United States, and China. The bilateral foreign value added exported directly by the exporting country has the highest shares among the three components of the value added in all the cases analyzed. Its shares are lower for Chinese exports, around 78% (the first and the second panels on the right side in table 3.1), while in both the European Union and the United Statesaround 85% of the value of their exports originate in the exporting country.

The sector level provides a more interesting picture. The extractive industries (e.g. coke, petroleum products, processing of nuclear fuel) account for the highest share of foreign value added originating in a 'third' country (between 53% in United States imports from China, to 51% in European Union imports from the United States), reflecting that they supply key inputs to various sectors involved in GVC trade. The electronic equipment sector also shows a high degree of international fragmentation; when considering both indirect foreign value added and the reflected domestic value added, between 22% (in European Union exports to both China and the United States) and 29% (in Chinese exports to both the United States and the European Union) of value added is traded indirectly.

The 'reflected' component is around 2% at the aggregate level; however, differences arise at the sectoral level for the various importing countries. As percentages, European Union imports from its main trading partners reflect value added originating in the European Union mostly in motor vehicles (around 5%). It follows chemicals and electronics sectors in its imports from United States (4%), and electronics and machinery in its imports from China (around 3.5%). About 6% of the value that is imported by China from both the European Union and the United States in electronic equipment originates in China; the textiles sector also has a relatively high share of reflected value added, particularly in Chinese imports from the United States (almost 5%). Finally, the United States share of value added re-imported back after further processing abroad is more similar among sectors although slightly higher for motor vehicles and electronics imported from the European Union.

Table 3.1. *Value-added composition of sectoral bilateral trade, by country of origin. Selected bilateral partners and sectors.*

European Union's imports (market prices)

Exporter: United States

Sector	Gross imports (US $, mio)	Domestic value added (%)	Foreign value added	
			bilateral (%)	indirect (%)
Agriculture	6.547	2,00%	90,19%	7,79%
Extraction	8.266	1,52%	93,56%	4,91%
Food	7.914	2,32%	88,06%	9,62%
Textiles	3.385	3,63%	80,65%	15,75%
Wood	7.317	2,15%	88,88%	8,98%
Petroleum	36.016	2,21%	46,93%	50,87%
Chemicals	76.247	4,18%	81,05%	14,77%
Metals	27.074	2,77%	84,75%	12,48%
MotorVehi	47.607	4,55%	79,54%	15,90%
ElecEquip	18.434	4,01%	72,26%	23,73%
Machinery	63.664	2,71%	86,59%	10,70%
Manufacture	8.477	3,16%	83,64%	13,20%
Services	185.799	1,46%	93,45%	5,09%
Total	496.746	2,63%	84,25%	13,12%

Exporter: China

Sector	Gross imports (US $, mio)	Domestic value added (%)	Foreign value added	
			bilateral (%)	indirect (%)
Agriculture	3.054	0,85%	92,60%	6,55%
Extraction	1.284	1,71%	86,92%	11,45%
Food	6.668	1,45%	85,66%	12,88%
Textiles	90.380	2,04%	84,11%	13,84%
Wood	18.099	2,76%	80,77%	16,47%
Petroleum	3.260	2,21%	45,74%	52,06%
Chemicals	31.695	2,92%	75,93%	21,15%
Metals	35.466	2,50%	75,94%	21,56%
MotorVehi	15.303	5,19%	75,78%	19,04%
ElecEquip	96.269	3,34%	70,96%	25,70%
Machinery	80.110	3,61%	76,53%	19,86%
Manufacture	29.424	1,99%	85,69%	12,32%
Services	33.937	1,60%	87,93%	10,47%
Total	444.950	2,79%	78,45%	18,76%

(*Continued*)

(*Continued*)

United States' imports (market prices)

Exporter: European Union

Sector	Gross imports (US $, mio)	Domestic value added (%)	Foreign value added bilateral (%)	Foreign value added indirect (%)
Agriculture	1.680	1,25%	90,42%	8,27%
Extraction	1.715	1,22%	91,31%	7,52%
Food	21.282	1,57%	88,96%	9,47%
Textiles	10.551	1,72%	85,62%	12,64%
Wood	9.076	1,60%	90,25%	8,15%
Petroleum	16.374	1,25%	47,07%	51,69%
Chemicals	102.011	2,99%	82,62%	14,39%
Metals	27.478	2,14%	83,71%	14,15%
MotorVehi	66.665	3,44%	83,11%	13,45%
ElecEquip	10.069	3,33%	78,35%	18,33%
Machinery	90.293	2,65%	84,83%	12,52%
Manufacture	13.647	2,09%	86,34%	11,57%
Services	156.442	1,37%	91,41%	7,22%
Total	527.283	2,28%	85,14%	12,59%

Exporter: China

Sector	Gross imports (US $, mio)	Domestic value added (%)	Foreign value added bilateral (%)	Foreign value added indirect (%)
Agriculture	1.351	0,96%	92,60%	6,37%
Extraction	793	1,01%	86,89%	12,11%
Food	6.505	2,44%	85,67%	11,90%
Textiles	82.911	2,07%	84,12%	13,81%
Wood	27.152	2,41%	80,77%	16,82%
Petroleum	1.201	1,17%	45,71%	53,12%
Chemicals	33.060	2,32%	75,93%	21,74%
Metals	28.295	1,58%	75,94%	22,48%
MotorVehi	12.349	2,24%	75,78%	21,98%
ElecEquip	135.234	2,85%	70,96%	26,19%
Machinery	83.400	2,11%	76,53%	21,35%
Manufacture	34.873	1,50%	85,69%	12,82%
Services	14.643	1,05%	87,93%	11,02%
Total	461.768	2,24%	77,58%	20,18%

(*Continued*)

(*Continued*)

China's imports (market prices)

Exporter: European Union

Sector	Gross imports (US $, mio)	Domestic value added (%)	Foreign value added	
			bilateral (%)	indirect (%)
Agriculture	1.935	0,67%	90,44%	8,84%
Extraction	3.352	0,72%	91,29%	8,00%
Food	5.478	0,86%	88,96%	10,17%
Textiles	5.263	2,95%	85,64%	11,42%
Wood	6.494	1,19%	90,25%	8,56%
Petroleum	786	0,64%	47,07%	52,29%
Chemicals	29.089	1,42%	82,62%	15,96%
Metals	21.494	1,48%	83,72%	14,80%
MotorVehi	56.085	2,17%	83,11%	14,72%
ElecEquip	7.839	5,40%	78,34%	16,25%
Machinery	75.891	2,37%	84,83%	12,80%
Manufacture	1.804	2,05%	86,31%	11,64%
Services	33.304	0,74%	91,41%	7,86%
Total	248.814	1,92%	85,04%	13,05%

Exporter: United States

Sector	Gross imports (US $, mio)	Domestic value added (%)	Foreign value added	
			bilateral (%)	indirect (%)
Agriculture	22.318	0,93%	90,20%	8,88%
Extraction	4.695	0,83%	93,57%	5,60%
Food	5.551	0,90%	88,06%	11,04%
Textiles	1.848	4,60%	80,63%	14,77%
Wood	7.821	1,71%	88,88%	9,41%
Petroleum	2.199	0,82%	46,93%	52,25%
Chemicals	24.736	1,66%	81,05%	17,29%
Metals	11.644	1,46%	84,75%	13,78%
MotorVehi	16.576	3,00%	79,54%	17,45%
ElecEquip	10.362	6,88%	72,26%	20,86%
Machinery	27.161	2,15%	86,59%	11,26%
Manufacture	1.042	2,02%	83,69%	14,30%
Services	10.916	0,69%	93,45%	5,86%
Total	146.870	2,05%	84,47%	13,48%

3.5.2. The protection on value added

The comparative static analysis of trade restrictiveness is performed employing the previously introduced modified GTAP model with six regions - "European Union 28", "United States", “China”, “high income countries”, “middle income countries[36]”, and “low income countries”. Countries in the latter three groups are classified by their level of per capita gross national income (GNI) following the United Nations classification, and based on threshold levels of per capita GNI established by the World Bank. We give weights in the indexes for 12 selected sectors (excluding services). See table 3.2 for details of the aggregation procedure. The baseline refers to 2011.

The tariff data in the GTAP 9 database are from the third version of MAcMap-HS6, a database at the HS-6 level intended to provide a set of consistent and exhaustive *ad valorem* equivalents of applied border protection worldwide. The methodology relies on reference groups of countries, built using a clustering procedure based on GDP per capita and trade openness, and designed to represent large groups of countries with similar trade-relevant characteristics. Since protection patterns differ across the countries in each group, this method allows the direct influence of protection to be limited, thus reducing the endogeneity bias which arises when computing ad valorem equivalents of tariff protection, and when computing averages at aggregate levels[37].

To compute uniform tariffs, we ask the model to remove taxes on imports from region r into s, setting in the closure the value-added component of interest to be exogenous, instead of the previous exogenous product-generic tariff levied on imports from region r into s. This gives the uniform tariff which if imposed on imports instead of the existing structure of protection, would leave the specific value-added component of interest at its pre-shock level. We performed our simulations for the bilateral trade relationships between the three disaggregated regions, and for each bilateral link we calculated the VA-TRI for each of the value-added components.

Table 3.3 presents the results. Columns I to VI refer to the uniform tariff equivalents related to the value-added components embodied in bilateral trade following the decomposition introduced in equation (1). The indirect foreign value added is split among different countries/regions of origin (columns III-VI). Column VII refers to the uniform tariff which keeps constant the total foreign value added (bilateral plus indirect) embedded in

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[36] “Middle income countries” includes upper and lower middle income countries.

[37] For the documentation, see Guimbard et al. 2012.

Table 3.2. *GTAP database aggregation.*

Commodities and Activities*
Agriculture
Extraction
Food
Textiles
Wood
Petroleum
Chemicals
Metals
Motor vehicles
Electronic equipment
Machinery
Manufacturing
Services
Country/Region*
European Union 28
United States of America
China
High income countries
Middle income countries
Low income countries
Endowment commodities (mobile)
Labor
Capital***

* Agriculture: paddy rice; wheat, cereal grains nec; vegetables, fruit, nuts; oil seeds; sugar cane, sugar beet; plant-based fibers; crops nec; bovine cattle, sheep and goats, horses; animal products nec; raw milk; wool, silk-worm cocoons. Extraction: forestry; fishing; coal; oil; gas; minerals nec. Food: bovine cattle, sheep and goat meat products; meat products; vegetable oils and fats; dairy products; processed rice; sugar; food products nec; beverages and tobacco products. Textiles: textiles; wearing apparel; leather products. Wood: wood products; paper products, publishing. Petroleum: petroleum, coal products. Chemicals: chemical, rubber, plastic products. Metals: mineral products nec; ferrous metals; metals nec; metal products. MotorVehi: motor vehicles and parts; transport equipment nec. ElecEquip: electronic equipment. Machinery: machinery and equipment nec. Manufacturing: manufactures nec. Services: electricity; gas manufacture, distribution; water; construction; trade; transport nec; water transport; air transport; communication; financial services nec; insurance; business services nec; recreational and other services; Public Administration and defense, education, health; ownership of dwellings.

** European Union 28: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom. High income countries: Australia, Bahrain, Brunei Darussalam, Canada, Hong Kong, Israel, Japan, Korea Republic of, Kuwait, New Zealand, Norway, Oman, Puerto Rico, Qatar, Saudi Arabia, Singapore, Switzerland, Taiwan, Trinidad and Tobago, United Arab Emirates. Middle income countries: Albania, Argentina, Armenia, Azerbaijan, Belarus, Botswana, Brazil, Cameroon, Caribbean, Chile, Colombia, Costa Rica, Cote d'Ivoire Dominican Republic, Ecuador, Egypt, El Salvador, Georgia, Ghana, Guatemala, Honduras, India, Indonesia, Iran Islamic Republic of, Jamaica, Jordan, Kazakhstan, Lao People's Democratic Republic, Malaysia, Mauritius, Mexico, Mongolia, Morocco, Namibia, Nicaragua, Nigeria, Pakistan, Paraguay, Peru, Philippines, Rest of Central America, Rest of East Asia, Rest of Eastern Europe, Rest of Europe, Rest of Former Soviet Union, Rest of North Africa, Rest of North America ,Rest of South America, Rest of Southeast Asia, Rest of Western Asia, Russian Federation, Senegal, South Africa, Sri Lanka, Thailand, Tunisia, Turkey, Uruguay, Venezuela, Viet Nam, Zambia, Bolivia, Panama, Ukraine. Low income countries: Bangladesh, Benin, Burkina Faso, Cambodia, Central Africa, Ethiopia, Guinea, Kenya, Kyrgyzstan, Madagascar, Malawi, Mozambique, Nepal, Rest of Eastern Africa, Rest of Oceania, Rest of ROW, Rest of South African Customs Union, Rest of South Asia, Rest of the World, Rest of Western Africa, Rwanda, South Central Africa, Tanzania United Republic of, Togo, Uganda, Zimbabwe.

*** Capital: land, capital, natural resources.

Table 3.3. *Value added trade restrictiveness indexes.*

European Union 28 imports from United States

	Uniform tariff equivalents								valorem import	weighted average
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)	(IX)	(X)
	τ_fvab	τ_dva		τ_fvai			τ_fvatot	τ_gross		
Country/region, origin of VA	(usa)	(eu)	(chn)	(hics)	(mics)	(lics)				
Sector-generic	1,90	1,88	1,74	1,85	1,94	1,90	1,89	1,89		1,28
Agriculture	0,05	0,01	0,01	0,01	0,01	0,03	0,04	0,04	3	
Extraction	0	0	0	0	0	0	0	0	0	
Food	0,19	0,09	0,04	0,09	0,12	0,07	0,18	0,17	13	
Textiles	0,08	0,08	0,16	0,06	0,07	0,04	0,08	0,08	7	
Wood	0,01	0	0,01	0	0	0	0,01	0,01	0	
Petroleum	0,06	0,07	0,03	0,37	0,48	0,92	0,12	0,13	2	
Chemicals	0,49	0,57	0,33	0,47	0,44	0,42	0,48	0,48	2	
Metals	0,19	0,19	0,15	0,18	0,23	0,14	0,19	0,19	2	
MotorVehi	0,39	0,54	0,53	0,39	0,33	0,15	0,39	0,39	3	
ElecEquip	0,04	0,05	0,14	0,06	0,05	0,02	0,05	0,05	1	
Machinery	0,35	0,24	0,3	0,19	0,17	0,08	0,32	0,32	1	
Manufacture	0,03	0,02	0,02	0,02	0,02	0,01	0,03	0,03	1	

European Union 28 imports from China

	Uniform tariff equivalents								valorem import	weighted average
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)	(IX)	(X)
	τ_fvab	τ_dva		τ_fvai			τ_fvatot	τ_gross		
Country/region, origin of VA	(chn)	(eu)	(usa)	(hics)	(mics)	(lics)				
Sector-generic	3,46	2,88	3,28	2,61	2,95	2,76	3,32	3,49		3,44
Agriculture	0,01	0	0	0	0	0	0,01	0,01	4	
Extraction	0	0	0	0	0	0	0	0	0	
Food	0,11	0,02	0,08	0,01	0,07	0,04	0,1	0,09	11	
Textiles	1,74	1,12	1,66	0,98	1,12	0,93	1,61	1,79	10	
Wood	0,03	0,02	0,02	0,01	0,02	0,05	0,03	0,03	1	
Petroleum	0	0	0	0	0	0	0	0	0	
Chemicals	0,3	0,29	0,33	0,28	0,37	0,51	0,31	0,31	4	
Metals	0,26	0,22	0,17	0,22	0,36	0,34	0,25	0,26	3	
MotorVehi	0,11	0,18	0,12	0,1	0,09	0,09	0,11	0,11	3	
ElecEquip	0,26	0,32	0,35	0,45	0,29	0,18	0,28	0,27	1	
Machinery	0,49	0,64	0,47	0,51	0,55	0,52	0,5	0,49	2	
Manufacture	0,14	0,06	0,07	0,04	0,07	0,09	0,12	0,12	2	

(*Continued*)

(*Continued*)

United States imports from China

	Uniform tariff equivalents								valorem import	weighted average
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)	(IX)	(X)
	τ_fvab	τ_dva		τ_fvai			τ_fvatot	τ_gross		
Country/region, origin of VA	(chn)	(usa)	(eu)	(hics)	(mics)	(lics)				
Sector-generic	2,16	1,95	1,70	1,42	1,81	1,86	2,03	2,41		2,84
Agriculture	0	0	0	0	0	0	0	0	1	
Extraction	0	0	0	0	0	0	0	0	0	
Food	0,03	0,02	0,01	0	0,02	0,01	0,02	0,02	3	
Textiles	1,1	1,01	0,67	0,55	0,71	0,61	0,99	1,4	12	
Wood	0,03	0,02	0,02	0,01	0,02	0,05	0,03	0,03	1	
Petroleum	0	0	0	0	0	0,01	0	0	0	
Chemicals	0,22	0,22	0,2	0,18	0,26	0,37	0,22	0,22	3	
Metals	0,18	0,11	0,14	0,12	0,21	0,23	0,17	0,17	3	
MotorVehi	0,06	0,06	0,08	0,05	0,04	0,04	0,06	0,06	2	
ElecEquip	0,08	0,11	0,1	0,13	0,09	0,06	0,09	0,08	0	
Machinery	0,35	0,32	0,43	0,33	0,38	0,38	0,35	0,33	1	
Manufacture	0,12	0,06	0,06	0,04	0,07	0,09	0,1	0,1	2	

United States imports from European Union 28

	Uniform tariff equivalents								valorem import	weighted average
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)	(IX)	(X)
	τ_fvab	τ_dva		τ_fvai			τ_fvatot	τ_gross		
Country/region, origin of VA	(eu)	(usa)	(chn)	(hics)	(mics)	(lics)				
Sector-generic	1,26	1,11	1,21	1,21	1,38	1,42	1,27	1,27		0,90
Agriculture	0,01	0	0	0	0	0	0,01	0,01	2	
Extraction	0	0	0	0	0	0	0	0	0	
Food	0,08	0,03	0,02	0,03	0,07	0,07	0,08	0,08	2	
Textiles	0,24	0,15	0,35	0,15	0,2	0,21	0,24	0,24	8	
Wood	0	0	0	0	0	0	0	0	0	
Petroleum	0,01	0,03	0,02	0,15	0,28	0,3	0,05	0,05	2	
Chemicals	0,32	0,35	0,21	0,33	0,34	0,32	0,32	0,32	1	
Metals	0,12	0,11	0,1	0,13	0,16	0,19	0,13	0,13	2	
MotorVehi	0,13	0,14	0,13	0,13	0,11	0,1	0,13	0,12	1	
ElecEquip	0,01	0,02	0,04	0,02	0,01	0,01	0,01	0,01	0	
Machinery	0,27	0,24	0,29	0,22	0,17	0,16	0,25	0,25	1	
Manufacture	0,04	0,03	0,04	0,03	0,03	0,04	0,04	0,04	1	

(*Continued*)

(*Continued*)

China imports from European Union 28

	Uniform tariff equivalents								valorem import	weighted average
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)	(IX)	(X)
	τ_fvab	τ_dva		τ_fvai			τ_fvatot	τ_gross		
Country/region, origin of VA	(eu)	(chn)	(usa)	(hics)	(mics)	(lics)				
Sector-generic	6,52	6,20	6,20	6,30	6,22	5,87	6,47	6,46		7,04
Agriculture	0,07	0,02	0,02	0,05	0,08	0,04	0,06	0,06	13	
Extraction	0	0	0	0	0	0	0	0	1	
Food	0,16	0,05	0,05	0,08	0,14	0,18	0,16	0,16	12	
Textiles	0,24	0,31	0,31	0,16	0,24	0,25	0,24	0,25	10	
Wood	0,07	0,02	0,02	0,03	0,04	0,03	0,06	0,06	2	
Petroleum	0	0	0	0,04	0,08	0,08	0,01	0,01	5	
Chemicals	0,75	0,48	0,48	0,82	0,97	0,89	0,76	0,79	6	
Metals	0,39	0,25	0,25	0,35	0,47	0,5	0,38	0,38	4	
MotorVehi	2,18	2,17	2,17	2,35	2,13	1,91	2,19	2,17	16	
ElecEquip	0,1	0,27	0,27	0,16	0,09	0,08	0,11	0,11	2	
Machinery	2,43	2,49	2,49	2,17	1,88	1,77	2,37	2,35	6	
Manufacture	0,12	0,11	0,11	0,09	0,1	0,12	0,12	0,12	16	

China imports from United States

	Uniform tariff equivalents								valorem import	weighted average
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)	(IX)	(X)
	τ_fvab	τ_dva		τ_fvai			τ_fvatot	τ_gross		
Country/region, origin of VA	(usa)	(chn)	(eu)	(hics)	(mics)	(lics)				
Sector-generic	4,62	4,13	4,68	4,49	4,57	4,57	4,61	4,59		4,78
Agriculture	0,29	0,1	0,15	0,13	0,14	0,18	0,26	0,29	3	
Extraction	0	0	0	0	0	0,01	0	0	1	
Food	0,29	0,09	0,16	0,17	0,22	0,2	0,27	0,27	10	
Textiles	0,11	0,2	0,14	0,09	0,12	0,11	0,11	0,12	7	
Wood	0,06	0,03	0,03	0,03	0,02	0,02	0,04	0,05	1	
Petroleum	0,02	0,01	0,03	0,14	0,19	0,5	0,04	0,04	4	
Chemicals	1,02	0,7	1,26	1,18	1,19	1,56	1,05	1,06	6	
Metals	0,34	0,19	0,25	0,28	0,34	0,35	0,33	0,33	4	
MotorVehi	1,04	1,45	1,47	1,32	1,25	0,84	1,09	1,06	12	
ElecEquip	0,07	0,23	0,1	0,13	0,11	0,07	0,08	0,08	1	
Machinery	1,28	1,05	0,98	0,9	0,88	0,65	1,21	1,18	5	
Manufacture	0,11	0,09	0,09	0,1	0,1	0,08	0,11	0,1	14	

bilateral imports Column VIII expresses the uniform tariff required to maintain import volumes at their current levels measured in gross terms. The last two columns report the ad valorem import tariff rates by sector (IX) and the trade-weighted average tariff (X). Values in the rows, unless they refer to the ad valorem import tax, represent the contribution of each sector in the index.

Our results suggest that the weighted average scheme of aggregation is not reliable as an approximation of the protection on value added; in most cases, the weighted average tariff underestimates the protection, while for Chinese exports to the United States, and Chinese imports from both the United States and the European Union overestimates the level of protection. As expected, the distorting effects of the tariff structure on the import volumes in gross terms (column VIII) are similar to the impacts on the exporter value added (column I). However, the index for gross trade is higher than the index of bilateral foreign value added for Chinese exports where the indirect trade shares are comparatively high (see table 3.1). Domestic value added faces a significant level of protection (column II) relative to total foreign value added, direct and indirect (column VII), meaning that protection has a major impact on upstream domestic firms exporting intermediate inputs processed abroad and then re-imported.

The uniform tariffs required to maintain China's value added directly exported (3.46 to the European Union, and 2.16 to the United States) is higher than the value which maintains constant its indirectly exported value added (respectively, 1.74 and 1.21). This reflects the sectoral specialization involved in the different trade links. Textiles is a major direct exporting sector for China, and has high levels of nominal protection. The value added originating in China that is exported indirectly to the United States and the European Union is mainly embedded in the chemicals, motor vehicles, and machinery, sectors which are subject to lower tariff levels.

European Union exports to China face high levels of protection, both directly (6.52) and indirectly through the United States (4.68). As can be seen from the sectoral weights in the indexes, these results are driven mainly by motor vehicles, a strategic sector for European Union trade which faces high barriers to access in the Chinese market. Also, machinery (mainly in direct links) and chemicals (in indirect trade) are key sectors for explaining the overall level of trade restrictions faced by the European Union when trading with China. The pattern is similar for United States exports, both direct and indirect, to China.

The indexes obtained for the domestic value-added component in imports (6.20 and 4.13) indicates that the tariff structure in China have a heavy impact on domestic Chinese firms producing intermediate inputs for European Union and United States production, mainly in machinery and motor vehicles sectors exporting to China. The most affected European Union upstream domestic sectors providing inputs processed in China and then re-imported, are used in the production of textiles and machinery, while chemicals and motor vehicles have a higher weight on the overall protection towards United States on the domestic value-added components. Further, United States domestic inputs that enter Chinese production of textiles for re-export, are the most affected by United States trade policy. The chemicals sector has the highest weight for United States re-imports from the European Union.

Finally, we find that the value added originated in high-income countries which is indirectly embodied in bilateral flows faces generally a lower protection among the three broad groups of countries (high-middle-low income). One exception is found for China’s imports from European Union, where motor vehicles and machinery sectors have the highest weight. The backward participation of low income countries in GVCs results to be impacted negatively by the tariff structures under examination.

3.6. Policy implications and conclusions

Our analysis has some policy implications. First, a high value of the index for the domestic value-added (reflected) component relative to the foreign direct value added is indicative of advantages for the protecting economy in relation to liberalizing, mainly for its upstream production providing inputs to the exporting sectors of the partner country. For example, our results for the European Union suggest that a less restrictive policy towards China would be beneficial for the former’s domestic production, particularly textiles and chemicals which enter in Chinese textiles exports, and machinery and metals which provide inputs for China’s machinery sector. Also, further liberalization towards the Unites States would boost European Union chemicals and motor vehicles exports. This demonstrates the *beggar thyself* content of protectionism. Also, the results for indirect foreign value added imply that there are benefits to be gained from bilateral liberalization towards “third” countries, supporting the view of regionalism as a favorable or potentially “constructive force in the world trade system” (Baldwin and Freund, 2011).

To conclude, the indexes for the economic assessment of trade restriction in the context of the GVCs considered in this paper, synthesize the backward/forward linkages and the protectionist measures in different sectors. The input-output structure underlying the value-added trade restrictiveness indexes (VA-TRIs), provides insights into the impact that bilateral protection has on different segments of globally fragmented productive processes. The analytical framework of VA-TRIs could be applied to other indicators of GVC (e.g., vertical specialization, position and participation indexes, value-added exports to gross exports,…).

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