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Value Added Trade Restrictiveness Indexes.
Measuring Protection within Global Value Chains

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Abstract

Production and trade are increasingly organized within Global Value Chains (GVCs) and therefore assessing who effectively pays the cost of protection is not straightforward. Since exports rely on imported inputs, the evaluation of trade policies requires the use of new trade metrics on a value-added base in order to assess in which country the value embedded in trade has been actually produced. We define a new set of trade policy indexes in the spirit of the protection indexes introduced by Anderson and Neary, based on the value added in trade: the Value Added Trade Restrictiveness Indexes (VATRIs). VATRIs are theoretically sound protection measurements that make use of the trade flow decomposition proposed by the recent value added in trade literature. We compute the direct and indirect components of trade protection by computing the VATRIs using the Global Trade Analysis Project computable general equilibrium model.

JEL Codes: F130, C670

Keywords: Trade policies, Trade Restrictiveness Index (TRI), Value-added trade, Global Trade Analysis Project (GTAP), Global Value Chains (GVCs), Value added trade.

1. Introduction

After decades of efforts to render "trade flows smooth, free, fair and predictable"[1], through multilateral and bilateral negotiations, overall, tariff barriers have been strongly reduced and import tariffs are at historically low levels. Average applied rates in high income economies are low and they have been substantially reduced in middle- and low-income countries. At the sector level, import tariffs on manufactured products in industrialized country are at a very low level; however, sensitive sectors such as labor-intensive manufactures (e.g. textiles and clothing) and agriculture are still significantly protected and they are subject to tariff peaks and tariff escalation.

In the aftermath of the financial crisis, many analyses have 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). Nevertheless, once the slowdown in global growth became apparent in 2012, the worldwide resort to protectionism underwent an acceleration. Among the discriminatory measures implemented since late 2008, traditional forms of protectionism continue to play an important role, still accounting for little less than 50 percent of total measures (Evenett, 2014; WTO 13th report on G-20 trade measures, 2015), being also the most frequent form of protectionist measures affecting vulnerable poor countries, with an incidence that is double non-tariff measures (Evenett and Fritz, 2015).

Against the widespread perception in international trade research that the success of trade policy has made it less relevant, a recent strand of literature has emerged whose aim is to investigate 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 through Global Value Chains (GVCs) imply that intermediate goods cross borders several times. These developments in the international division of labor –

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

emerging from what Baldwin (2006) labels the globalization second unbundling - have led countries to be increasingly involved 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 and this implies that even small tariffs may have a significant cumulative impact. As first noted by Yi (2003), the cost of vertical trade is more sensitive to tariff duties than traditional trade in final goods due to tariff amplification effects: tariffs are incurred several times along the chain and are applied on the full value of exports, including tariffs paid previously. A deeper understanding of the interactions within GVCs shows that trade policies negatively affect domestic producers' competitiveness in international markets since they reduce access to the most efficient inputs (Cattaneo et al., 2013; Taglioni and Winkler, 2014). Such an understanding may reduce policy makers' incentives to impose import protection (Antràs and Staiger, 2012; Blanchard and Matschke, 2015; Gawande et al., 2015; Blanchard et al., 2016; Caliendo et al., 2016).

In a world where more than half of trade is represented by intermediate exchanges, the empirical assessment of trade policy must acknowledge which country is the source of the value that is embedded in trade. This information can be used to determine who is effectively paying the cost of protection. For instance, an economy that requires a large share of intermediate imports to produce its exports faces higher protection in terms of value added (Cusolito et al., 2016). Moreover, tariffs faced in the destination market have ripple effects on the production activities which are linked to the GVC, spanned across different countries (Balié et al., 2017).

We propose new measures of bilateral trade policy restrictiveness, taking into account the impacts of tariffs on different value-added components of trade flows. In addressing the question of how to measure trade protection within GVCs, our paper is related to the literature considering multiple stages of production in the traditional definition of the effective protection rate (Diakantoni and Escaith, 2012; Rouzet and Miroudot, 2013; Chen et al., 2016). However, these measures are based on the fixed production coefficients of input-output tables.

Our analysis is in the spirit of Anderson and Neary (1996, 2005) who develop index numbers for policy variables that are defined in a general equilibrium framework. The theoretical model provides a consistent aggregation procedure[2] which solves the endogeneity problem affecting a-theoretical weighting schemes (Cipollina and Salvatici, 2008; Anderson et al., 2013; Laborde et al., 2017). These theoretically sound measures provide indexes that are equivalent to the original data in terms of the variable of interest. Anderson and Neary (1994) assess the effect of the structure of trade policy on national welfare, defining the Trade Restrictiveness Index (TRI) as the uniform tariff that yields the same welfare as the original differentiated tariff structure. Anderson (1998) defines a Distributional Effective Rate of Protection (DERP) as the uniform tariff that yields the same sector specific factor income as the actual tariff structure. This can be used to measure the extent to which the level of protection is translated into sector-specific factor income. Anderson and Neary (2003; 2005) focus on import flows defining the Mercantilist Trade Restrictiveness Index (MTRI) as the uniform tariffs that maintain the value of trade at world prices.

We extend the previous behavioral models of tariff aggregation including the factor content approach of Neary and Schweinberger (1986). Moreover, we use Trefler and Zhu's (2010) analytical framework to calculate trade in intermediates and evaluate value added in intermediate trade, and adopt the approach of Foster-McGregor and Stehrer (2013) when measuring the value added in trade. The decomposition of trade flows into their value-added content by country of origin is applied at the bilateral level and is used to define different benchmarks against which to measure restrictiveness, according to where the value added originates. The resulting Value Added Trade Restrictiveness Indexes (VATRIs) are equivalent to the

[2] In the presence of very differentiated tariff structures (which is the rule), aggregation is required for policy purposes since the information on production and demand structures needed to make a full assessment of the implications of trade policy is available at a much higher level of aggregation than the information on tariffs and trade flows.

actual trade policies in terms of the impact on domestic or foreign (direct or indirect) value added embedded in imports.

The empirical analysis is performed using a modified version of the Global Trade Analysis Project (GTAP) model using the Multi-Regional Input-Output (MRIO)-GTAP Data Base. Results suggest that the use of the new trade metrics could improve the empirical information used to support policy making (Koopman et al., 2013). We find a significant impact of domestic trade policy on trade-related domestic value added due to the fact that import protection impacts domestic firms exporting intermediate inputs processed abroad and then imported back. This seems to suggest a *beggar thyself'* connotation of restrictive measures (IMF, 2013; Miroudot and Yamano, 2013). Furthermore, we find that bilateral protection has chain effects on *third* countries backwardly linked in the production of those bilateral flows (e.g., providing intermediate inputs which are used by the exporting country).

In the next section, we present the theoretical model underlying the definition of the indexes of trade restrictiveness in value-added terms. Subsequently, the CGE model is presented as well as the MRIO-GTAP Data Base, built on the GTAP Data Base used for the empirical application. In Section 4, we present the results for three countries, namely the European Union, United States and China. Section 5 concludes.

2. Theoretical model

The economy is assumed to be in competitive equilibrium with no distortions other than tariffs. The representative consumer maximizes utility, $U(x)$, subject to the budget constraint, $px \leq E$, where E represents income and p are prices. We firstly characterize the behavioral model to be used in the analysis, summarizing all consumption and production decisions within the economy by means of the indirect trade utility function (Woodland, 1980):

(1) $$H(p, b, f) \equiv U[p, g(p, f) + b],$$

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

(2) $$H_p(p,b,f) = -H_b(p,b,f)m(p,b,f),$$

that is, its derivatives with respect to prices are proportional to the net import demand functions, $m(p,b,f)$, the constant of proportionality being the marginal utility of income.

Trade in goods can be considered indirect trade in factors. Following Neary and Schweinberger (1986), embodied factor trade could substitute commodity trade in terms of 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 technology of the representative firm can be expressed by means of the unit cost function $c(\omega)$ which is non-decreasing, concave, twice differentiable and homogenous of degree one with respect to factor prices, ω. The unit cost function also depends on prices of intermediate inputs; however, since these prices are kept constant throughout, they are not included as arguments. The condition which allows this treatment is the assumption of separability implying that the conditional demand for primary inputs is independent of the prices of intermediate inputs.

In a competitive equilibrium, unit costs equal prices[3]; the *indirect factor trade utility function*, W, can therefore be defined by substituting $c(\omega)$ for p in the indirect trade utility function. Hence:

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

Differentiating the cost function with respect to the factor prices using Shephard's Lemma, we get the conditional demand for input:

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

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

The 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 (4) can be expressed as:

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

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

By substitution,

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

where D is the matrix of direct factor requirement coefficients[4]. Setting aside the scalar $-H_b$, the right-hand-side of (6) represents the Marshallian import demand *factor content*. More specifically, the k-th element of the Marshallian import demand *factor content* function can be expressed as:

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

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.

We now need to consider trade in intermediate goods and allocate the value added therein contained according to its geographical origin. Within GVCs the *effective* techniques of production are a combination of domestic and foreign technologies. According to 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 the factor content based on domestic coefficients whenever techniques of production differ among countries. When techniques of production are allowed to differ internationally, the cost minimizing derives from the marginal productivity factor pricing.

[4] The formal proof of the generalization of Roy's Identity to the factor content functions is given by Neary and Schweinberger (1986).

Intermediate trade is accounted for using the algorithm given by Trefler and Zhu (2010). They assume that the Hawkins-Simons condition is satisfied and use the Leontief coefficients (l_{ij}^{sr}) to compute the indirect absorption of intermediate inputs. Then, the factor content of net trade in (7) 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. Bilateral trade flows are given by:

$$M_{k\_tot}^{s}(\omega,b,f) = \sum_{r}\sum_{i,j} d_{ki}^{r}(\omega_k^r) l_{ij}^{sr} m_j^{s*}[c(\omega_k^r),b,f] - \sum_{r}\sum_{t\neq s}\sum_{i,j} d_{ki}^{r}(\omega_k^r) l_{ij}^{rt} m_j^{ts}[c(\omega_k^r),b,f] \ . \tag{8}$$

The first term of equation (8) represents the amount of factor k directly or indirectly employed worldwide to produce sector j country s' exports to the world (m_j^{s*}), and the second term is the factor k content of s' imports from all other countries ($\sum_{t\neq s} m_j^{ts}$)[5].

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 physical input coefficients in (8) (Johnson and Noguera, 2012; Foster-McGregor and Stehrer, 2013)[6]. L is the matrix of the Leontief coefficients and V is the diagonal matrix with elements equal to the share of direct domestic value added in total output in each sector of each country. 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's value added originated in sector i of goods produced by country r sector j. The multiplier matrix provides a breakdown of the flows of value added across country/sector of production since diagonal (off-diagonal) sub-blocks represent domestic (foreign) value added in domestic production.

[5] In what follows, subscripts denote sectors and superscripts denote countries.

[6] The statistical inter-country input-output (ICIO) tables are the principal source of information on the input requirements used in applied analysis; they contain transactions of intermediates within and between countries at the sector level, the direct value added and the gross output at the country/sector level.

In what follows, the analysis is restricted to the import component of equation (8). Accordingly, we specify the trade vector as a diagonal matrix containing positive entries for imports and zero otherwise. Using 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 equal to one (since all value added must be domestic or foreign), country s's imports can be decomposed in terms of value added according to the source. In the case of sector j:

$$(9) \qquad M_j^{*s} = \sum_r \sum_i v_i^r l_{ij}^{r*} m_j^{*s} = \sum_{r \neq s} \sum_i v_i^r l_{ij}^{r*} m_j^{*s} + \sum_i v_i^s l_{ij}^{s*} m_j^{*s}.$$

Equation (9) splits country s' imports of sector j from the rest of the world in a portion containing *foreign value added* (first term) and in a portion embedding *domestic value added* which is first exported and successively imported back after being processed 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 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 ($fvai\_imp$). Formally:

$$(10) \qquad M_j^{rs} = \underbrace{\textstyle\sum_i v_i^r l_{ij}^{rr} m_j^{rs}}_{fvab\_imp} + \underbrace{\textstyle\sum_i v_i^s l_{ij}^{sr} m_j^{rs}}_{dva\_imp} + \underbrace{\textstyle\sum_{t \neq r,s} \sum_i v_i^t l_{ij}^{tr} m_j^{rs}}_{fvai\_imp}.$$

The three components of (10) are used as a benchmark against which to measure trade policies, defining the uniform tariff equivalents yielding the same value of 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:

$$(11) \qquad \check{T}_{FVAB,j}^{rs}: \sum_i v_i^r \, l_{ij}^{rr} m_j^{rs} \left[\left(1 + \mathrm{T}_j^{(\mu)rs}\right) p^*(T), b^0, \omega\right] = \sum_i v_i^r \, l_{ij}^{rr} m_j^{rs} [p^0, p^*(T), b^0, \omega] \, .$$

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

(12)
$$\check{T}^{rs}_{DVA,j}\colon \sum_i v^s_i\, l^{sr}_{ij} m^{rs}_j \left[\left(1+\mathrm{T}^{(\mu)rs}_j\right) p^*(T), b^0, \omega\right] = \sum_i v^s_i\, l^{sr}_{ij} m^{rs}_j [p^0, p^*(T), b^0, \omega]\ ;$$

and:

(13)
$$\check{T}^{rs}_{FVAI,j}\colon \sum_{t\neq r,s}\sum_i v^t_i l^{tr}_{ij} m^{rs}_j \left[\left(1+\mathrm{T}^{(\mu)rs}_j\right) p^*(T), b^0, \omega\right] = \sum_{t\neq r,s}\sum_i v^t_i l^{tr}_{ij} m^{rs}_j\, [p^0, p^*(T), b^0, \omega].$$

In equations (11)-(13), superscript0 refers to the reference period, so that b^0 expresses the equilibrium at the point of reference which has to be maintained once the uniform tariff replaces the initial tariff structure and p^0 are the initial prices. International prices (p^*) are expressed as a function of the tariff vector (T) in order to allow for endogenous world prices thus dropping the small country assumption (Salvatici, 2001; Antimiani and Salvatici, 2005). The right-hand side in each equation is the total value originated in the exporting country (eq. 11), in the importing country (eq. 12), and in third countries (eq. 13) which is embedded in bilateral imports at the initial non-uniform tariffs. The left-hand side maintains the same values when applying a uniform (product-generic) tariff.

3. The empirical model

3.1. 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). Expenditure by regional households who receive factor rewards is 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[7]. 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. (2016a) in reallocating imports for government and private households according to the origin of these imports. Firm behavior is depicted in Figure 1.

Figure 1. Production structure in the GTAP model (Version 6.2-SC which introduces sourcing of imports by agent).

```
                    --------------------
                          qo(j,r)
                            /\
              /  \<----- CES(ESUBT=0)
                          /    \
                         /      \
                        /        \
               qva(j,r)         qf(i,j,r)
               /|\                   /\
CES(ESUBVA)->/ |  \                /  \<---CES(ESUBD)
             /  |   \             /     \
            /   |    \           /       \
           /    |     \         /         \
       Land   Labor  Capital  Domestic     Foreign
   qfe(i,j,r)        qfd(i,j,r)     qfm(i,j,r)
                                        |
                                        |
                                        | <------
                                        | CES(ESUBM)
                                   qifs(i,j,s,r)
```

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

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

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 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 is now 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 introduced previously. Namely, the original coefficient for bilateral imports evaluated at world prices ($VIWS$) is split into three sub-components (Figure 2): the foreign value added of direct exporter ($FVAB\_imp$), the total reflected domestic value added (DVA_imp), and the redirected foreign value added ($FVAI\_imp$).

Figure 2. Bilateral imports decomposition.

```
                 VIWS
                (i,r,s)
              _/   |   \_
            _/     |     \_
          _/       |       \_
        _/         |         \_
FVAB_imp +  DVA_imp   +   FVAI_imp
 (i,r,s)    (i,r,s)         (i,r,s)
```

The value-added multipliers, which combine 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 2. They are obtained from the cost structure of firms which combines primary factors of production and intermediate inputs. In country r, the total firms' purchases of intermediate inputs (Z_{ij}^{sr}) is obtained by adding the domestic component to imports from country $s\,(VIFMS_{ij}^{sr})$, that is, the value of purchases of domestic i for use by j in country r ($VDFM_{ij}^{r}$):

$$(14) \qquad Z_{ij}^{sr} = \begin{cases} VIFMS_{ij}^{sr} + VDFM_{ij}^{r} & if\ r = s \\ VIFMS_{ij}^{sr} & if\ r \neq s \end{cases}.$$

The zero-profit condition implies that revenues must be exhausted on expenditures, once accounting for all (tradable) intermediate inputs and primary factors of production (endowments):

$$(15) \qquad VODM_j^r = \sum_{i,trad} \sum_{s} Z_{ij}^{sr} + \sum_{i,end} VFM_{ij}^{r},$$

whereVFM_{ij}^{r} is the producer expenditure on endowment i by j in r valued at market prices. The sum over all payments for primary factors gives the composite valueadded originated in each producing sector for each economy. $VODM_j^r$represents the value of j's output in region r at domestic market prices (e.g., excluding intermediate input taxes, taxes on endowments, and taxes on output).

The delivery of intermediates used in the production of the receiving country can be expressed as a share of destination country r's sectoral output, thus:

$$(16) \qquad A_{ij}^{sr} = \frac{Z_{ij}^{sr}}{VODM_j^r},$$

where A_{ij}^{sr} is an element of the A matrix of technical (or structural) coefficients, giving the share of intermediate i originated in region s which is used by sector j in country r on j's output in r.

We also define Ias the identity matrix, with one in the main diagonal and zero in the off-diagonal elements. $L = (I - A)^{-1}$is the global Leontief inverse (or multiplier) matrix, already introduced in equation (8), giving total requirement of output directly *and* indirectly required worldwide to produce one unit of consumption.

Next, we turn to the value-added component and define the sectoral value-added shares for country r as:

$$(17) \qquad VSH_j^r = \frac{\sum_{i,endw} VFM_{ij}^{r}}{VODM_j^r}$$

We also define a diagonal matrix $\widehat{VSH}$ with value-added shares in the main diagonal and zero in the off-diagonals. The value-added contributions associated with unit final demand level is obtained by post-multiplying

$\widehat{VSH}$bythe Leontief inverse which generates the value-added multiplier matrix, providing a breakdown of the flows of value-added across sectors:

$$(18)\qquad \widehat{VSH}L = \begin{bmatrix} \widehat{VSH}^1 L^{11} & \widehat{VSH}^1 L^{12} & \cdots & \widehat{VSH}^1 L^{1c} \\ \widehat{VSH}^2 L^{21} & \widehat{VSH}^2 L^{22} & \cdots & \widehat{VSH}^2 L^{2c} \\ \vdots & \vdots & \ddots & \vdots \\ \widehat{VSH}^c L^{c1} & \widehat{VSH}^c L^{c2} & \cdots & \widehat{VSH}^c L^{cc} \end{bmatrix}$$

The $\widehat{VSH}L$ is the key matrix in the value-added trade literature. It contains all the information on the partition of value-added by country/sector sources in the production process. Since all value embedded in the production of a unit of output must be either domestic or foreign, the sum over all sector/country sources in the value-added multipliers (sum by column of the $\widehat{VSH}L$ matrix) must give unity. For the generic column referred to the production of j in country, the following is true:

$$(19)\qquad \sum_i \sum_s \widehat{VSH}_i^s L_{ij}^{sr} = 1$$

The condition in (19) ensures that consistency is maintained when post-multiplying by the bilateral import vectors. This recovers the value-added content of bilateral trade, both direct and indirect. Specifically, the value-added which originates (in sector i) of country t and is embedded in country r's imports (in sector j) from country $s(VAIT_{ij}^{tsr})$ is given by:

$$(20)\qquad \begin{aligned} VAIT_{ij}^{trs} &= \sum_i \widehat{VSH}_i^r L_{ij}^{rr} * VIWS_j^{rs} + \sum_i \widehat{VSH}_i^s L_{ij}^{sr} * VIWS_j^{rs} + \\ &+ \sum_i \sum_{t \neq s,r} \widehat{VSH}_i^t L_{ij}^{tr} * VIWS_j^{sr}. \end{aligned}$$

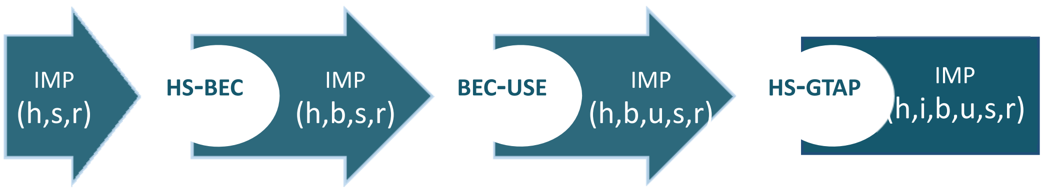
Equation (20) reflects within the GTAP model the main equation in the theoretical model defining the benchmarks for the value-added trade restrictiveness indexes (eq. 10).

Finally, in order to compute the uniform tariff, we define a new variable, $\mathrm{tr}(\mathrm{r},\mathrm{s})$, as the *product-generic tariff levied on imports from region r into region s*.

3.2. The MRIO-GTAP Data Base

In order to implement the VATRI, a four-dimensional information level on source and destination country-sector is required. For the purpose of our simulations, we use a recent GTAP Data Base, the MRIO-GTAP. It is derived from the reconciliation of trade data with the input-output structure available for each region, starting from the GTAP Data Base version 9 (Aguiar et al., 2016b)[8]. The key aspect in the construction of a full MRIO table is that import sources must be attributed for intermediate and final demand to individual source countries and sectors. The standard GTAP Data Base traces imports to specific agents (i.e., private households, government, and firms) in the domestic economy, but it aggregates these flows at the border (Narayanan et al., 2012) whereas bilateral trade data are not distinguished by end use. In order to obtain sourcing information, the standard GTAP Data Base 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 Data Base 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 shows this process.

Figure 3. 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

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

between HS and BEC revision 4. This concordance maps from 5052 HS codes at the six-digit level to 19 BEC categories, 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 map the 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 so that they are compatible with the GTAP Data Base in order 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[9].

Finally, the tariff data in the GTAP 9 Data Base 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

[9] 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 evaluated at market prices, $VIMS\ (i,r,s)$. 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 $\sum_r VIPMS(i,r,s) = VIPM(i,s)$.

computing averages at aggregate levels[10]. One caveat is that we do not take into account tariff exemptions granted in export processing zones and through inward and outward processing trade regimes. These regimes introduce a differential tariff treatment of imports depending on the sectors and the firms to which they are destined since imported goods entering into the production of exports are not subject to import duties. They are particularly relevant in the case of China trade flows (Yu and Tian, 2012).

4. Simulations and results

4.1. The value-added content of gross imports

In this section we give summary statistics on the value-added composition of bilateral trade for three major economies, namely the European Union (EU), the United States of America (USA) and China, which account for more than half of world exports and imports.

Table 1 reports the value-added shares in gross sectoral bilateral imports for each of the three components of equation (10) for each of the three regions/economies considered. 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 of Table 1), while in both the European Union and the United States, around 85% of the value of their exports originate in the exporting country.

The sector level provides a more interesting picture. As expected, the extractive industries (e.g. coke, petroleum products, processing of nuclear fuel) account for the highest share (around 50%) of foreign value added originating in a ‘third’ country, 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.

[10] For the documentation, see Guimbard et al. (2012).

The 'reflected' component is around 2% at the aggregate level; however, differences arise at the sectoral level for the various importing countries. In the case of the EU, the highest percentage is registered for motor vehicles (around 5%). About 6% of the value that is imported by China from both the European Union and the US in electronic equipment originates from China itself; the textiles sector also has a relatively high share of reflected value added, particularly in the case of Chinese imports from the United States (almost 5%). Finally, the US share of value added re-imported back after further processing abroad is slightly higher for motor vehicles and electronics imported from the European Union.

Table 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 (%)	Foreign value added: indirect (%)
Agriculture	6,547	2.0	90.2	7.8
Extraction	8,266	1.5	93.6	4.9
Food	7,914	2.3	88.1	9.6
Textiles	3,385	3.6	80.6	15.7
Wood	7,317	2.1	88.9	9.0
Petroleum	36,016	2.2	46.9	50.9
Chemicals	76,247	4.1	81.1	14.8
Metals	27,074	2.8	84.7	12.5
MotorVehi	47,607	4.6	79.5	15.9
ElecEquip	18,434	4.0	72.2	23.7
Machinery	63,664	2.7	86.6	10.7
Manufacture	8,477	3.2	83.6	13.2
Services	185,799	1.5	93.5	5.1
Total	496,746	2.6	84.2	13.1

Exporter: China

Sector	Gross imports (US $, mio)	Domestic value added (%)	Foreign value added: bilateral (%)	Foreign value added: indirect (%)
Agriculture	3,054	0.9	92.6	6.5
Extraction	1,284	1.7	86.9	11.4
Food	6,668	1.5	85.7	12.9
Textiles	90,380	2.0	84.1	13.8
Wood	18,099	2.8	80.8	16.5
Petroleum	3,260	2.2	45.7	52.1
Chemicals	31,695	2.9	75.9	21.1
Metals	35,466	2.5	75.9	21.6
MotorVehi	15,303	5.2	75.8	19.0
ElecEquip	96,269	3.3	71.0	25.7
Machinery	80,110	3.6	76.5	19.9
Manufacture	29,424	2.0	85.7	12.3
Services	33,937	1.6	87.9	10.5
Total	444,950	2.8	78.4	18.8

(*Continued*)

(*Continued*)

United States' imports (market prices)

Exporter: European Union				
	Gross	Domestic	Foreign value added	
	imports	value added	bilateral	indirect
Sector	(US $, mio)	(%)	(%)	(%)
Agriculture	1,680	1.3	90.4	8.3
Extraction	1,715	1.2	91.3	7.5
Food	21,282	1.6	89.0	9.5
Textiles	10,551	1.7	85.6	12.6
Wood	9,076	1.6	90.2	8.2
Petroleum	16,374	1.3	47.1	51.7
Chemicals	102,011	3.0	82.6	14.4
Metals	27,478	2.1	83.7	14.1
MotorVehi	66,665	3.4	83.1	16.5
ElecEquip	10,069	3.3	78.3	18.3
Machinery	90,293	2.6	84.8	12.5
Manufacture	13,647	2.1	86.3	11.6
Services	156,442	1.4	91.4	7.2
Total	527,283	2.3	85.1	12.6

Exporter: China				
	Gross	Domestic	Foreign value added	
	imports	value added	bilateral	indirect
Sector	(US $, mio)	(%)	(%)	(%)
Agriculture	1,351	1.0	92.6	6.4
Extraction	793	1.0	86.9	12.1
Food	6,505	2.4	85.7	11.9
Textiles	82,911	2.1	84.1	13.8
Wood	27,152	2.4	80.8	16.8
Petroleum	1,201	1.2	45.7	53.1
Chemicals	33,060	2.3	75.9	21.7
Metals	28,295	1.6	75.9	22.5
MotorVehi	12,349	2.2	75.8	22.0
ElecEquip	135,234	2.9	71.0	26.2
Machinery	83,400	2.1	76.5	21.4
Manufacture	34,873	1.5	85.7	12.8
Services	14,643	1.1	87.9	11.0
Total	461,768	2.2	77.6	20.2

(*Continued*)

(*Continued*)

China's imports (market prices)

Exporter: European Union

Sector	Gross imports (US $, mio)	Domestic value added (%)	Foreign value added bilateral (%)	Foreign value added indirect (%)
Agriculture	1,935	0.7	90.4	8.8
Extraction	3,352	0.7	91.3	8.0
Food	5,478	0.9	89.0	10.2
Textiles	5,263	2.9	85.6	11.4
Wood	6,494	1.2	90.3	8.6
Petroleum	786	0.6	47.1	52.3
Chemicals	29,089	1.4	82.6	16.0
Metals	21,494	1.5	83.7	14.8
MotorVehi	56,085	2.2	83.1	14.7
ElecEquip	7,839	5.4	78.3	16.3
Machinery	75,891	2.4	84.8	12.8
Manufacture	1,804	2.1	86.3	11.6
Services	33,304	0.7	91.4	7.9
Total	248,814	1.9	85.0	13.0

Exporter: United States

Sector	Gross imports (US $, mio)	Domestic value added (%)	Foreign value added bilateral (%)	Foreign value added indirect (%)
Agriculture	22,318	0.9	90.2	8.9
Extraction	4,695	0.8	93.6	5.6
Food	5,551	0.9	88.1	11.0
Textiles	1,848	4.6	80.6	14.8
Wood	7,821	1.7	88.9	9.4
Petroleum	2,199	0.8	46.9	52.3
Chemicals	24,736	1.7	81.1	17.3
Metals	11,644	1.5	84.7	13.8
MotorVehi	16,576	3.0	79.5	17.5
ElecEquip	10,362	6.9	72.3	20.9
Machinery	27,161	2.2	86.6	11.3
Manufacture	1,042	2.0	83.7	14.3
Services	10,916	0.7	93.4	5.9
Total	146,870	2.0	84.5	13.5

4.2. The protection on value added

The computation of trade restrictiveness indexes is performed employing the previously introduced modified GTAP model with all the GTAP sectors and six regions - "European Union 28", "United States", "China", "high income countries", "middle income countries"[11], 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. In the following, we present the results for 12 aggregate goods sectors. See Table 2 for details of the aggregation procedure. The baseline refers to 2011.

To compute uniform tariffs, we remove all taxes on imports from region r into s and swap the value-added component of interest with a uniform tariff levied on imports from region r into s. This is 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 initial level. We performed our simulations for the bilateral trade relationships between the three disaggregated regions and for each bilateral link, we calculated the VATRI for each of the value-added components.

Table 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). The last two columns report the ad valorem import tariff rates by sector (VII) and the trade-weighted average tariff (VIII). Values in the rows, unless they refer to the ad valorem import tax, represent the contribution of each sector in the index.

[11] "Middle income countries" includes upper and lower middle income countries.

Table 2. *GTAP Data Base 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.

** 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. Value added trade restrictiveness indexes.

European Union 28 imports from China

	Uniform tariff equivalents						Ad valorem	Weighted average
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)
	τ_fvab	τ_dva	τ_fvai					
Country/region. origin of VA	(chn)	(eu)	(usa)	(hics)	(mics)	(lics)		
Sector-generic	3.5	2.9	3.3	2.6	3.0	2.8		3.4
Agriculture	0.0	0.0	0.0	0.0	0.0	0.0	4.0	
Extraction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Food	0.1	0.0	0.1	0.0	0.1	0.0	11.0	
Textiles	1.7	1.1	1.7	1.0	1.1	0.9	10.0	
Wood	0.0	0.0	0.0	0.0	0.0	0.1	1.0	
Petroleum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Chemicals	0.3	0.3	0.3	0.3	0.4	0.5	4.0	
Metals	0.3	0.2	0.2	0.2	0.4	0.3	3.0	
MotorVehi	0.1	0.2	0.1	0.1	0.1	0.1	3.0	
ElecEquip	0.3	0.3	0.4	0.5	0.3	0.2	1.0	
Machinery	0.5	0.6	0.5	0.5	0.6	0.5	2.0	
Manufacture	0.1	0.1	0.1	0.0	0.1	0.1	2.0	

European Union 28 imports from United States

	Uniform tariff equivalents						Ad valorem	Weighted average
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)
	τ_fvab	τ_dva	τ_fvai					
Country/region. origin of VA	(usa)	(eu)	(chn)	(hics)	(mics)	(lics)		
Sector-generic	1.9	1.9	1.7	1.9	1.9	1.9		1.3
Agriculture	0.1	0.0	0.0	0.0	0.0	0.0	3.0	
Extraction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Food	0.2	0.1	0.0	0.1	0.1	0.1	13.0	
Textiles	0.1	0.1	0.2	0.1	0.1	0.0	7.0	
Wood	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Petroleum	0.1	0.1	0.0	0.4	0.5	0.9	2.0	
Chemicals	0.5	0.6	0.3	0.5	0.4	0.4	2.0	
Metals	0.2	0.2	0.2	0.2	0.2	0.1	2.0	
MotorVehi	0.4	0.5	0.5	0.4	0.3	0.2	3.0	
ElecEquip	0.0	0.1	0.1	0.1	0.1	0.0	1.0	
Machinery	0.4	0.2	0.3	0.2	0.2	0.1	1.0	
Manufacture	0.0	0.0	0.0	0.0	0.0	0.0	1.0	

(*Continued*)

(*Continued*)

United States imports from China

	Uniform tariff equivalents						Ad valorem	Weighted average
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)
	τ_fvab	τ_dva			τ_fvai			
Country/region. origin of VA	(chn)	(usa)	(eu)	(hics)	(mics)	(lics)		
Sector-generic	2.2	2.0	1.7	1.4	1.8	1.9		2.8
Agriculture	0.0	0.0	0.0	0.0	0.0	0.0	1.0	
Extraction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Food	0.0	0.0	0.0	0.0	0.0	0.0	3.0	
Textiles	1.1	1.0	0.7	0.6	0.7	0.6	12.0	
Wood	0.0	0.0	0.0	0.0	0.0	0.1	1.0	
Petroleum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Chemicals	0.2	0.2	0.2	0.2	0.3	0.4	3.0	
Metals	0.2	0.1	0.1	0.1	0.2	0.2	3.0	
MotorVehi	0.1	0.1	0.1	0.1	0.0	0.0	2.0	
ElecEquip	0.1	0.1	0.1	0.1	0.1	0.1	0.0	
Machinery	0.4	0.3	0.4	0.3	0.4	0.4	1.0	
Manufacture	0.1	0.1	0.1	0.0	0.1	0.1	2.0	

United States imports from European Union 28

	Uniform tariff equivalents						Ad valorem	Weighted average
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)
	τ_fvab	τ_dva			τ_fvai			
Country/region. origin of VA	(eu)	(usa)	(chn)	(hics)	(mics)	(lics)		
Sector-generic	1.3	1.1	1.2	1.2	1.4	1.4		0.9
Agriculture	0.0	0.0	0.0	0.0	0.0	0.0	2.0	
Extraction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Food	0.1	0.0	0.0	0.0	0.1	0.1	2.0	
Textiles	0.2	0.2	0.4	0.2	0.2	0.2	8.0	
Wood	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Petroleum	0.0	0.0	0.0	0.2	0.3	0.3	2.0	
Chemicals	0.3	0.4	0.2	0.3	0.3	0.3	1.0	
Metals	0.1	0.1	0.1	0.1	0.2	0.2	2.0	
MotorVehi	0.1	0.1	0.1	0.1	0.1	0.1	1.0	
ElecEquip	0.3	0.0	0.0	0.0	0.0	0.0	0.0	
Machinery	0.0	0.2	0.3	0.2	0.2	0.2	1.0	
Manufacture	0.0	0.0	0.0	0.0	0.0	0.0	1.0	

(*Continued*)

(*Continued*)

China imports from European Union 28

	Uniform tariff equivalents						Ad valorem	Weighted average
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)
	τ_fvab	τ_dva		τ_fvai				
Country/region. origin of VA	(eu)	(chn)	(usa)	(hics)	(mics)	(lics)		
Sector-generic	6.5	6.2	6.2	6.3	6.2	5.9		7.0
Agriculture	0.1	0.0	0.0	0.1	0.1	0.0	13.0	
Extraction	0.0	0.0	0.0	0.0	0.0	0.0	1.0	
Food	0.2	0.1	0.1	0.1	0.1	0.2	12.0	
Textiles	0.2	0.3	0.3	0.2	0.2	0.3	10.0	
Wood	0.1	0.0	0.0	0.0	0.0	0.0	2.0	
Petroleum	0.0	0.0	0.0	0.0	0.1	0.1	5.0	
Chemicals	0.8	0.5	0.5	0.8	1.0	0.9	6.0	
Metals	0.4	0.3	0.3	0.4	0.5	0.5	4.0	
MotorVehi	2.2	2.2	2.2	2.4	2.1	1.9	16.0	
ElecEquip	0.1	0.3	0.3	0.2	0.1	0.1	2.0	
Machinery	2.4	2.5	2.5	2.2	1.9	1.8	6.0	
Manufacture	0.1	0.1	0.1	0.1	0.1	0.1	16.0	

China imports from United States

	Uniform tariff equivalents						Ad valorem	Weighted average
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)
	τ_fvab	τ_dva		τ_fvai				
Country/region. origin of VA	(usa)	(chn)	(eu)	(hics)	(mics)	(lics)		
Sector-generic	4.6	4.1	4.7	4.5	4.6	4.6		4.8
Agriculture	0.3	0.1	0.2	0.1	0.1	0.2	3.0	
Extraction	0.0	0.0	0.0	0.0	0.0	0.0	1.0	
Food	0.3	0.1	0.2	0.2	0.2	0.2	10.0	
Textiles	0.1	0.2	0.1	0.1	0.1	0.1	7.0	
Wood	0.1	0.0	0.0	0.0	0.0	0.0	1.0	
Petroleum	0.0	0.0	0.0	0.1	0.2	0.5	4.0	
Chemicals	1.0	0.7	1.3	1.2	1.2	1.6	6.0	
Metals	0.3	0.2	0.3	0.3	0.3	0.4	4.0	
MotorVehi	1.0	1.5	1.5	1.3	1.3	0.8	12.0	
ElecEquip	0.1	0.2	0.1	0.1	0.1	0.1	1.0	
Machinery	1.3	1.1	1.0	0.9	0.9	0.7	5.0	
Manufacture	0.1	0.1	0.1	0.1	0.1	0.1	14.0	

Our results show 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 level of protection whereas for Chinese exports to the United States and Chinese imports from both the United States and the European Union, it overestimates the level of protection. Domestic value added faces a significant level of protection (column II) relative to total foreign value added, direct and indirect (column VII) and this confirms 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 (3.5 to the European Union, and 2.2 to the United States) is higher than the value which maintains constant its indirectly exported value added (1.7 and 1.2, respectively). This reflects the sectoral specialization involved in the different trade links. Textiles is a major direct exporting sector for China and it has high levels of nominal protection. Indirect value added exports are particularly relevant for motor vehicles since they represent 12% and 15% of total value added (directly and indirectly) exported by China through motor vehicles in the EU and US markets, respectively.

European Union exports to China face high levels of protection, both directly (6.5) and indirectly through the United States (4.7). 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. Machinery (mainly in direct trade) and chemicals (mainly in indirect trade) are also 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 value added exports, both direct and indirect, to China.

The indexes obtained for the domestic value-added component in imports (6.20 and 4.13) indicate that the tariff structure in China has a heavy impact on domestic Chinese firms producing intermediate inputs for European Union and US production, mainly in machinery and motor vehicles sectors, exporting to China. The most affected EU upstream domestic sectors providing inputs that are processed in China and then re-imported are used in the production of textiles and machinery. The overall protection faced by United States in EU market impacts the European Union's value added mostly through imports of chemicals and motor vehicles. Further, Unite.2d States domestic inputs that enter the Chinese production of textiles for re-export are the most affected by United States trade policy.

Finally, the value added originated in low-income countries seems to face relatively lower barriers when it is indirectly exported through EU or US exports. This may be evidence that developing countries value added is embedded in products that face lower tariffs and/or more elastic import demands.

5. Policy implications and conclusions

In this work, we extend the set of trade restrictiveness indexes originally proposed by Anderson and Neary to assess the effects of trade policies on GVC-related trade. The input-output structure underlying the VATRIs provides insights into the impact of bilateral protection on different segments of globally fragmented productive processes.

We are still in a world trade where tariffs strongly affect vulnerable poor countries (Evenett and Fritz, 2015) and where the total impact of tariffs can have a significant cumulative impact because of the trade in intermediates (Yi, 2003). The main policy implication of our analysis is that bilateral nominal tariffs and trade flows are not sufficient to provide an accurate picture of the impact of protectionist measures through backward and forward linkages. On the one hand, the value of the index for the domestic value-added (reflected) component relative to the foreign direct value added is indicative of the harm inflicted to domestic producers providing inputs to the exporting sectors of the foreign country. This shows the *beggar thyself* content of protectionism.

On the other hand, the value added is exported both directly and indirectly. This implies that the importer's tariffs towards third countries also play a very significant role in assessing the overall protection faced. Accordingly, there are significant benefits to be reaped or costs to be incurred even if there are no actual changes in bilateral trade policies.

Our results are only indicative due to the standard structure of the model and the high level of aggregation of the data, However, they show that VATRIs represent a potentially useful addition to the tools available for trade policy analysis.

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