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Abstract: Trade costs such as applied tariffs, transportation and insurance costs are amplified as they pass through the multiple production steps associated with modern supply chains. This so-called "cascade effect" arises since trade costs accumulate as intermediate goods are imported and then re-exported further downstream, going through different processing nodes before reaching the final consumer. Moreover, the financial impact of these trade costs is magnified in the "trade in tasks" rationale which governs global value chains (GVCs). Specialised processing firms need to recoup the associated trade cost applying to the full value of the good from the smaller fraction of value-added created at each consecutive productive stage. This large relative weight of transaction expenses on the profitability of individual business operations explains why trade along GVCs is particularly exposed to trade costs. The paper reviews the implications of trade costs on competitiveness at industry, national and global levels. The financial implications of trade costs at firm and sectoral level are based on trade in value-added data for 2011. The multilateral welfare effects of reducing discrete trade costs are identified using a network analysis approach, which goes beyond the traditional bilateral dimension of international trade and identifies where trade facilitation investment would have the highest social returns from a GVC perspective. The authors conclude that while the *direct benefits* of trade facilitation will be proportionally higher for those countries that are not well integrated into international trade because of their high trade costs, the *global benefits* of trade facilitation investments will also be high if they are undertaken by key traders that lie at the core of global value chains.

Key words: Global Value Chains, trade in value-added, international input-output analysis, trade costs, trade facilitation, competitiveness, effective rate of protection
JEL: C67, F13, F14, F23, F61

Table of Contents

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1 SYNTHESIS AND CONCLUSIONS

Trade is subject to the "tyranny of distance". Transaction costs tend to rise as distance increases between trading partners and are, together with the relative size of the exporting and importing economies, among the main determinants explaining bilateral trade patterns. Through the years, the progressive decline in tariff duties and other customs barriers, the reductions in transportation costs and the progress in information and communication technology connectivity have "flattened the planet". Falling transactions costs have thus facilitated the expansion of global trade.

Johnson and Noguera (2016), in their review of the evolution of trade in value added from 1970 to 2009, point that trade frictions (as trade costs are called in gravity models) explain the five stylised facts they were able to identify: (i) the ratio of world value-added to gross exports (an indicator of GVC trade) has fallen over time by roughly ten percentage points; (ii) this ratio has fallen for manufacturing but actually risen outside of manufacturing; (iii) changes have been heterogeneous across countries, with fast growing countries seeing larger declines in the ratio of their value-added to gross exports; (iv) and (v) facts concern bilateral trade where the authors show that declines in value-added to export ratios have been larger for proximate partners and country pairs that entered into regional trade agreements.

Yet, trade costs remain an issue, especially when considered from the perspective of global value chains. Anderson and van Wincoop state in their 2004 comprehensive survey of trade costs that "The death of distance is exaggerated. Trade costs are large, even aside from trade policy barriers and even between apparently highly integrated economies." Indeed, the objective of reducing transaction costs and facilitating trade has been given a new emphasis over the last decade. In the geographically fragmented production networks which emerged since the mid-1990s, trade in intermediate goods represents more than half the volume of international transactions. More than in "traditional trade" in basic commodities and in final goods, transaction costs (border and behind the border costs of trade) are crucial components of the competitiveness of firms and determine in large part their ability to participate in global production networks.

Transaction costs on domestic and international markets are also at the core of the existence of domestic and international supply chains, according to a Coasian vision of the firm. In his 1937 paper, Ronald Coase (1910-2013) posited that corporations exist to economize on the transaction costs of markets. Beyond some threshold size, organizational complexity becomes overwhelming and the firm faces diseconomies of scale and scope. The optimal size of the firm, according to Coase, is the point at which the incremental benefit from transaction cost savings is offset by the incremental cost of complexity. Value chains were born out of a decrease in transaction costs, first on the domestic market when large firms started out-sourcing their non-core activities to first-tier suppliers. When international transaction costs in turn went down, international outsourcing and offshoring began and has since taken even greater hold.

Undeniably, trade and other transaction costs are key elements to understand the evolution of GVCs and their limits: the point at which the transaction costs offset the gains from trade. Trade costs such as applied tariffs, transportation and insurance costs or other border taxes and fees are amplified as they pass through the multiple steps associated with modern supply chains. This so-called "cascade effect" arises since trade costs accumulate as intermediate goods are imported and then re-exported further downstream, going through different processing nodes before reaching the final consumer. Moreover, the financial impact of these trade costs is magnified in the "trade in tasks" rationale which governs global value chains (GVCs). In contrast to a large integrated firm concentrating most of the production processes under the same roof, specialised processing firms that spread their manufacturing over multiple locations need to recoup the associated trade costs. They do this by applying to the full value of the good from the smaller fraction of value-added created at each consecutive productive stage. This larger relative weight of transaction expenses on the profitability of individual business operations explains why trade along GVC is particularly exposed to trade costs.

The "acc*umulation and magnification"* effects of cascading tariffs explain why complex GVCs cannot develop when tariffs reach above some threshold value (Yi, 2003). Lowering trade costs has changed not only "how much" trade has grown, but also "who" trades and "how". Hummels (2007) mentions that besides cost considerations, improvements in transportation services—like greater speed and reliability—allowed a reorganization of global networks of production and new ways of coping with uncertainty in foreign markets.

Like tariffs, non-tariff trade costs tend to be high for agriculture and for complex manufactured products. The distribution of nominal tariffs between unprocessed and processed goods -- a feature of nominal schedules known as tariff escalation -- has a particular importance for GVC trade and industrialisation policies. When the production of a final good is fragmented across several countries, trade costs increase the purchase price of inputs, parts and components. The additional production cost is reflected in a higher sale price and transmitted to the next production step. Those cost accumulate through the supply chain through a cascading effect and are ultimately embodied into the higher final price paid by the final consumer.

The results obtained for 2011 —latest year for which TiVA data were available at the time of undertaking this research— show that the direct additional production cost due to tariffs on average of the economies covered by the OECD-WTO TiVA database is low, about 2% at MFN and 0.4% once preferential treatments on trade in intermediate inputs are taken into consideration. The low incidence of tariffs on inputs reflects both the impact of tariff escalation (commodities and unprocessed manufactured being less imposed than final goods; in addition, tariffs on IT components being bound at 0 under WTO IT Agreement) and the fact that GVCs are concentrated in free-trade zones such as the EU or NAFTA. Most of the trade frictions within GVC transactions result from transportation costs and deficient logistic and trade facilitation conditions: their incidence is estimated at an ad-valorem tariff equivalent of 17%. While some of these non-tariff costs fall outside the realm of national policy makers (e.g., geographic distance with the trading partner or sharing a common language), many of them fall under the control of domestic policy (logistic performance, cost of doing business, etc.).

Trade costs vary by sector and country. Outside agriculture, the most costly sectors, as measured with the extended effective protection margin, are Motor vehicles, Transport equipment, Petroleum products, Computers and Machinery. Primary sectors carry the lowest trade cost as they require few inputs in the production chain. Low income countries tend to suffer more and Cambodia ranks first as the most expensive country in terms of additional trade costs on inputs in some sectors such as Textiles, Chemicals and Computers. But some high income economies are also facing considerable trade friction for some sectors. In the Textiles sector Singapore emerges as the third most expensive country next to some European countries, such as Iceland, Cyprus and Hungary. Brazil, India, China, Thailand and Denmark show the lowest trade costs for this particular sector.

Cascading trade costs not only penalise the final consumer, they erode the competitiveness of domestic industry and lower the effectiveness of export-led industrialisation strategies. Steep trade cost escalation creates a significant anti-export bias on complex manufactured goods when "value added" is the traded "commodity". This bias, measured through extended effective protection rates (EEPRs), creates additional obstacles for export diversification and GVC upgrading. Besides tariff and transportation, non-monetary costs, in particular delays and uncertainty are relevant when the manufacture of merchandise goods is fragmented across several countries. Delays in a "just-in-time" business model disrupt the whole supply chain and render the process inoperable.

The results obtained in the study show that in some countries, trade costs can increase the average domestic price of tradable products by as much as 80%, once tariff and non-tariff costs are taken into consideration. This is more than the double of what was observed for the most efficient economies in our survey. High trade costs affect sectors that are mainly focused on the domestic market, such as Agriculture and Food products, but some industries highly integrated in GVCs, such as vehicles, transport equipment and other manufacture are also affected by high procurement expenses. The typical Motor vehicle industry operating at an average of the domestic costs observed in 2011 would suffer a loss of competitiveness equivalent to 27% of its value-added compared to the best international benchmark.

Many developing countries intend lowering their trade costs by setting up Export Processing Zones (EPZ) and duty draw-back schemes. Draw-backs improve the gross margin of domestic exporters by an average of 4 to 5%. But the effect of such schemes is limited in time and scope, because they compensate the exporting firms for the additional production costs only when they use imported inputs. The study demonstrates that such strategies tend to price-out second-tier domestic firms as long as the national suppliers of a first-tier domestic exporting firm are not able to draw back the duties they had to pay on their own inputs. Even in this case, they still have to pay the non-tariff trade costs on their inputs if they are not established in a free zone with improved trade facilities.

One of the conclusions is therefore that mitigating arrangements commonly used in developing countries, such as EPZs or draw-back schemes, have limited effects and are only second best alternatives to fully-fledged Trade Facilitation when GVC up-grading through deeper domestic inter-industrial linkages is the policy-makers' main objective. The cascading effect of tariffs and other trading costs on domestic production cost outweighs the tax incentives that the government is able to offer to exporting firms. This price differential is particularly relevant from the typical GVC outsourcing perspective, where "*buy*" decisions arising from a "*make or buy*" assessment implies arbitraging between domestic and foreign suppliers. Indeed, unless the policy makers eventually improve the trade costs suffered by all domestic industries, the "oasis" effect of special industrial zones turns into an "enclave" effect.

Finally, in a production network, bilateral trade costs only tell part of the story. In a close-knit network, one's competitiveness depends also on the costs faced by trade partners and by trade competitors. Network analysis used in this paper underscores that poor trade facilitation performance among countries that are important trade partners (i.e. that lie at or close to the heart of regional networks) impose a systemic cost both to themselves and also to the rest of the trade community. By extension, the welfare benefits from improved trade facilitation in terms of gains from trade will be felt by the implementing economy itself, by its direct trade partners and will also be beneficial for the entire community. The welfare benefits of the WTO Trade Facilitation Agreement in terms of gains from trade will be felt by the implementing economy itself, by its direct trade partners and will also be beneficial for the entire community. This is directly attributable to the way in which trade costs accumulate in GVCs.

The benefits of trade facilitation may be further explained as follows:

- At a country-level, benefits may be focused on those economies with the most progress to make on trade facilitation. The WTO World Trade Report found that successful implementation of the TFA would boost developing-country exports by between $170 billion and $730 billion per year – with those benefits focused most on the countries with the worst TF scores. An UN-ECA report finds that, thanks to tariff reduction and trade facilitation, the share on intra-African trade would double over the next decade and export diversification would be particularly reinforced. From a global perspective, the OECD has calculated that the implementation of the TFA could reduce worldwide trade costs by between 12 percent and 17 percent. A 1% reduction in trade costs is estimated to increase bilateral trade by about 3% to 5%.

- In the case of GVC trade in intermediate goods, the benefits of trade facilitation apply to products that are processed and re-exported to a third destination, either embodied in final goods or in new intermediate products. The benefits of facilitating trade are felt by the entire value chain, from the producers of the basic inputs to final assembly and end consumers. At the level of suppliers, lead firms and their contractors within time-sensitive sectors may benefit more than other firms, but the effects should also be evident for their suppliers too. The study identifies six key economies (Indonesia, Russia, Brazil, India, China and Italy) that play an important role as regional or global GVC hubs, but are somewhat behind in terms of trade costs relative to their international trade status. Trade facilitation investments in these countries would not only benefit their domestic industries but would have positive spill-over for their regional and global trade partners.

2 TARIFFS, TRANSACTION COSTS AND COMPETITIVENESS

Trade costs are not only related to distance, transportation costs or tariffs, but include many other factors, some of them not directly measurable, such as uncertainty. Those trade costs, which result from a mix of policy decisions (tariffs and non-tariff measures, customs and other cross-border administrative requirements) and structural conditions (distance from main markets, situation of the transport infrastructure) act as a nominal protection by shielding domestic producers from the competitions of imported products. But they also increase production costs, and reduce their competitiveness. This second part will first proceed to a formal analysis before reviewing the results obtained on the trade partners covered in the TiVA database.

2.1 The analytical framework

The most visible effect of trade costs is reducing trade, as in the standard gravity model (Box 1). One way of understanding these costs is to associate these factors to the set of "frictions" that tends to reduce trade. Samuelson's famous representation depicts trade shrinking under the effect of frictions in the same way that an iceberg melts while moving through the sea.

Besides the quantitative impact on reducing trade flows, trade costs affect also the prices at which domestic firms can sell their output on the domestic market as well as the price they pay when purchasing the inputs required for production. This less visible impact of trade costs on prices and how it affects the pattern of relative incentives or disincentives within the domestic economy has generate a lot of interest since the 1960s, especially through the theory of effective protection rate. Most research, in particular the seminal work from Corden (1966) focus on policy induced trade costs, but natural barriers to trade, such as geographical distance or landlockedness, are relatively more important in terms of impact on trade margins (Milner, 1996; Greenaway and Milner, 2003).

Among all cross-border transaction costs, nominal tariffs are certainly the most visible. Tariff duties increase the domestic price of tradable goods by adding a tax to their international or free market price. When duties are specific (in particular for agricultural products), analysts compute ad-valorem equivalents. When it comes to non-tariff trade costs, the situation is more complex. International economics has overwhelmingly relied on Samuelson's (1954) hypothesis that they are proportional to value and distance (ad-valorem "iceberg transport cost").

Yet this remains an over-simplification. For example, transportation costs depend on (i) the nature of the good (e.g., perishable or not; bulky or not, etc.) (ii) the distance between producers and consumers and (iii) the mode of transport. Besides freight costs, Lewis (1994) identifies various additional factors contributing to logistics costs, among them: interest charges on goods awaiting shipment, on goods in transit and on goods held as safety stock; loss, damage or decay of goods between manufacture and sale.

Because tariffs have become a less frequent barrier to trade, the contribution of transportation to total trade costs —shipping plus tariffs— has become not only more evident, but also relatively more important. Hummels (2007) records that median transport expenditures were half as much as tariff duties for U.S. imports in 1958, equal to tariff duties in 1965 and three times higher than aggregate tariff duties paid in 2004.

BOX 1: Trade Frictions and the Gravity Model

By analogy with Newton's Law of Universal Gravitation, the model predicts that trade between two countries is proportional to their economic mass and inversely proportional to the 'distance' separating them. In economic terms, this distance refers to all the 'frictions' impeding trade, such as transportation costs, transactions costs, customs duties and other restrictive trade policy measures, as well as a "home bias". The geographic distance between two countries is generally well-correlated with these trade frictions. [1]

The gravity model aims at measuring the strength of these restrictions. It was initially based on a purely statistical specification following Jan Tinbergen's original formulation. Gravity received a micro-economic foundation with Anderson and van Wincoop (2003). This theoretical contribution was also helpful in improving the specification of the statistical model (e.g., coping for omitted variable bias). In the simplest case of two countries *a* and *b*, we can express the gravity equation as:

$$X_{ab} = \frac{Y_a Y_b}{Y d_{ab}^2} \qquad [1]$$

where X_{ab} are exports from *a* to *b*, Y_a is *a*'s economic size from the supply-side perspective (the mass of products supplied at origin *a)*, Y_b is *b*'s market size (the mass of products demanded at destination b), *Y* is total income and d_{ab} is the economic distance between *a* and *b* (a measure of the trade frictions that impede pure free trade). The model does not have to be limited to two countries; we can define as $s_i = Y_i/Y$ the share of any country *i* in world income and generalise the model to *N* countries:

$$X_{ab} = \frac{Y_a Y_b}{Y d_{ab}^2} = \frac{s_a s_b Y}{d_{ab}^2} \qquad [2]$$

In the absence of any trade friction (no trade and transportation costs), if products and consumer preferences are homogeneous across countries, consumers in *a* and in *b* are expected to buy products in the same proportion based on their share of world income. Distance and borders do not play any role and frictionless exports from *a* to *b* are simply:

$$\tilde{X}_{ab} = s_a s_b Y \qquad [3]$$

The difference $\tilde{X}_{ab} - X_{ab}$ between frictionless and actual trade flows measures the effect of trade frictions:

$$d_{ab} \approx \sqrt{\tilde{X}_{ab}/X_{ab}} \qquad [4]$$

The results from [4] are submitted to a series of statistical analysis using regression models. Because observable monetary trade costs (tariffs, transportation, etc.) can be directly specified in the regression equation, the "unexplained" variance can be attributed to (non-directly observable) obstacles. Many gravity models include also 'multilateral resistance terms, which can be expressed as:

$$(\Pi_i)^{1-\sigma} = \sum_j \left(\frac{d_{ij}}{P_j}\right)^{1-\sigma} \frac{Y_j}{Y} \qquad [5]$$

$$(\mathrm{P}_j)^{1-\sigma} = \sum_i \left(\frac{d_{ij}}{\Pi_i}\right)^{1-\sigma} \frac{Y_i}{Y} \qquad [6]$$

Π_i^k is the outward multilateral resistance and aggregates the incidence of all bilateral trade costs borne by the producers in country *i*. P_j^k is the inward multilateral resistance and accounts for the incidence of all bilateral trade costs on buyers in country *j*. These multilateral resistance terms are not directly observable. But it is possible (Novy, 2013) to obtain a reduced form τ_{ij} which is the geometric mean of barriers to trade in both directions:

$$\tau_{ij} \equiv \left(\frac{t_{ij} t_{ji}}{t_{ii} t_{jj}}\right)^{\frac{1}{2}} - 1 = \left(\frac{X_{ii}.X_{jj}}{X_{ij}.X_{ji}}\right)^{\frac{1}{2(\sigma-1)}} - 1 \qquad [7]$$

Gravity takes a new twist when analysed from the perspective of global value chains. Noguera (2012) finds that bilateral trade cost elasticity of value added exports is about two-thirds of that for gross exports. As we see in the second part of the study, the multilateral trade resistances fall short of reflecting the strength and length of GVC interconnections: new indicators derived from network analysis provide additional information on the length and strength of multilateral interrelations.

[1] The paper focuses on international trade costs but domestic constraints can seriously restrict the potential for export diversification. Freund and Rocha (2010) find, for example, that transit delays are the most important constraint to exports for African countries. These domestic hurdles result in higher trading costs and are negatively correlated with average income; due to this deficit in in-land transport facilitation, gains from trade are much harder to harvest for the poorest countries.

2.1.1 Transaction costs and domestic value-added

From a consumer perspective, trade costs reduce real income by increasing the domestic price of final goods compared to its equivalent world price. However, for a domestic producer of this final good, measuring the impact of trade costs is multifaceted. On the one hand, trade costs and other restrictions on competing imports raise the prices in the home market and are beneficial to domestic producers. On the other hand, trade costs induce also an increase in the domestic price of inputs. By raising the production cost, they are harmful to the producers. The net impact of trade costs depends on their effects on prices of both outputs and inputs. In the example presented in Table 1, the net effect on gross profits of the nominal protection granted by trade costs is positive. In this simulation, the firm gains from protection because the additional benefit derived from the nominal protection granted by trade costs is larger than the related additional production cost. As we will see, this is not always the case. [2]

This net effect of trade costs is more complex to assess when the production of the final good is organised along global value chains. Trade in tasks is often called "trade in value-added", because what firms exchange in their business-to-business (B2B) transactions along global value chains are not products but value-added. The processing firms contributing to GVCs need to recoup all trade costs applying to the gross value and weight of the processing goods, not from the full commercial value of the gross output, but from the share of value-added they create (their "processing fees"). This value being much smaller than the full commercial value of the good to which trade costs apply, the financial impact of these costs on the processing firm competitiveness and profitability in a GVC context is said to be "amplified".

When firms are price takers and the cost of labour is fixed, the impact of trade costs is magnified on what truly matters for the firm: on the part of value-added related to gross profits. In the simulation of Table 1, a 25% trade cost lead to a 50% reduction in gross profit if the firm exports (Table 1). Furthermore, as we shall see later, costs cascade through the production network.

Table 1 Amplification effect of trade cost on value-added and profit margin

	Domestic Market		***Export Market***	
	No trade costs	With trade costs	No trade costs	With trade costs
Imported intermediate input	40	40	40	40
Trade cost on inputs	0	10	*0*	10
Value added	60	75	*60*	*50*
- Labour	40	40	40	40
- Profit	***20***	***35***	***20***	***10***
Export Price (FOB)	…	…	100	100
Domestic Market Price	100	125	…	…

Note: example based on hypothetical values, for illustrative purpose only. The ad-valorem trade margin (25%) is the same for input and output.
Source: Authors' elaboration

On the other hand, trade costs act as a nominal protection allowing the domestic producer to sell at higher prices: if the ad-valorem trade costs are the same for the inputs and the outputs, the net profit increases 75% to 35.

This example illustrates the importance of measuring the impact of trade costs not only in proportion of the gross value of traded inputs and outputs (the "iceberg" analogy) but also in proportion of the value-added generated at each step of the supply chain. The method used here derives from the Effective Protection Rate theory introduced by Balassa (1965) and Corden (1966). As we shall see, monetary trade costs (tariffs, transportation and other financial costs identified by Lewis 1994)

[2] This simple simulation take the labour costs as exogenous. Obviously, in presence of high tariff and trade costs inflating cost of living, wages will also tend to increase in order to maintain purchasing power parity.

increase the domestic "price" of the value-added. Not only do trade costs deter international competitiveness, but they also act as a currency over-valuation, by increasing the profitability of domestic sales over exports. The domestic "price" of the value added being higher for the domestic industry, it creates a strong anti-export bias in a trade in tasks perspective. Similarly, foreign investment (FDI) flows will aim at capturing this protection rent by targeting sales on the domestic market rather than looking at exports.

In their original formulation, effective protection rates are calculated by deducting the additional production cost that the manufacturers had to pay because of the tariff charged on tradable inputs from the additional benefit generated by selling its product at a price higher above that of the free-trade market price, thanks to the duties charged on competitive imports. The result gives the rate of value-added at domestic prices (selling price minus cost of intermediate inputs required for the production) and is compared with the hypothetical value-added that would have resulted from the operation if no custom duties had been levied.

The effective rate of protection on tradable good "j" is the difference between V_j the value-added obtained on domestic market (with process influenced by trade costs) and V^*_j the value-added that would be generated in absence of policy and natural trade barriers, expressed in proportion of the frictionless value-added. It is given by the expression:

$$EEPR_j = (V_j - V^*_j) / V^*_j \qquad [8]$$

Substituting products for industries, the expression [8] can be expressed in terms of standard input-output notation:

$$EEPR_j = \frac{p_j . t_j - \sum_i (t_i . a_{ij})}{p_j - \sum_i a_{ij}} - 1 \qquad [9]$$

With

- p_j nominal price of output *j* at frictionless trade price;
- a_{ij} : elements of the matrix A of technical coefficients in an input-output matrix at frictionless trade price of inputs *i*. [3]
- t_j : 1+ rate of *ad valorem t&t* nominal protection on sector "j", $t_j \geq 1$
- t_i : 1+ rate of *ad valorem* nominal *t&t* protection on inputs purchased from sector "i", $t_i \geq 1$ Note that "i" can be equal to "j" when a firm purchases inputs from other firms of the same sector of activity. In an inter-country framework, "i" includes also the partner dimension [c] as inputs from sector "i" might be domestic or imported.

In the trade literature, this expression is often simplified into:

$$EEPR_j = \frac{t'_j - \sum_i (t'_i . a_{ij})}{1 - \sum_i a_{ij}} \qquad [10]$$

With t'_i and t'_j the rates of ad valorem protection ($t'_{i,j} \geq 0$; $\forall$ i,j).

To simplify, we can consider that the *t&t* protection for a given product is represented by the MFN tariff applied to the weighted average of CIF value (FOB plus freight and insurance costs) of goods imported from different geographical origins. If the tariff schedule is flat and the FOB/CIF margin is similar for all products, the rate of effective *t&t* protection on the value added is equal to the nominal rate of *t&t* protection. In the presence of tariff escalation (MFN tariffs rising with the degree of

[3] In practice, input coefficients a_{ij} are calculated by dividing input values of goods and services used in each industry by the industry's corresponding total output, i.e. $a_{ij} = z_{ij} / X_j$ where z_{ij} is a value of good/service *i* purchased for the production in industry *j*, and X_j is the total output of industry *j*. Thus, the coefficients represent the direct requirement of inputs for producing just one unit of output of industry *j*. As we discuss in Annex 3, technical coefficients in IO tables are not calculated at free trade prices and the text-book formula needs to be adapted.

processing; transportation and insurance costs increase more than proportionally to the unit value of the goods), downstream domestic industries producing final goods will benefit from a higher effective protection. Upstream industries producing inputs will have, on the contrary, a lower *t&t* protection margin (first element of the right hand side of equation [8]) and possibly a negative one if the sum of *t&t* margins paid on the inputs is higher than the margin of protection received on the output.

If domestic industries were able to export at the price they sell domestically (meaning that firms are price makers and demand is price inelastic), a positive *t&t* effective protection would mean an increase in exported value-added. Yet this is usually not the case, unless the exporting firm has global market power —not a common situation for most firms, especially those located in developing countries. So, the most frequent situation is that the exporting firm is a price taker and will have to compete on the global market at international prices. For the exporting firm, the export price should be lower than the domestic one by the amount of nominal *t&t* protection received. [4]

The calculation of EPRs as expressed in equation [8] is made possible by the availability of the same international input-output matrices that are used to measure trade in value-added, as in the OECD-WTO TiVA database. The calculation relies also on the simplifying hypothesis of perfect competition and substitutability between imported and domestic products (see Annex 4 for a discussion). Domestic industries are expected to raise their price in order to benefit from the additional costs due to tariff and freight costs applied to the imported goods that compete with its products. In such a situation, international transaction costs influence the domestic price of all inputs, be they imported or domestically produced. We will refer to this ad-valorem increase in the price of competing goods as the extended "*tariff and transport*" (*t&t*) nominal protection.

Assuming that all applied tariffs are MFN (most favoured nation) and do not discriminate between trade partners, and transportation costs are of the "iceberg type" (i.e. proportional to the value of the imported good), the extended *t&t* effective protection is the difference between the nominal *t&t* protection enjoyed on the output minus the weighted average of *t&t* paid directly (imported goods) or indirectly (domestic goods) on the inputs required for production. The weights applied to the additional *t&t* costs on inputs are derived from the technical coefficients of the input-output matrix.

When the firm exports and pays all international trade costs (t_i >1) on its inputs, the value added it receives will be lower:

$$\left(1-\sum_i\left(t_i\ .\ a_{ij}\right)\right) < \left(1-\sum_i a_{ij}\right) \qquad [11]$$

If the exporting firm have also to pay for the transportation costs to the country of destination, the difference is even higher:

$$\left((1-d_j)-\sum_i\left(t_i\ .\ a_{ij}\right)\right) \ll \left(1-\sum_i a_{ij}\right) \qquad [12]$$

With d_j the ad valorem transport cost of output *j;* d_j>0.

Therefore, a high *t&t* EPR, resulting for example from high nominal duties, high transportation costs and steep tariff escalation, reduces incentives to export, as the rate of return on the domestic market is higher than what can be expected on the international one. It is a well-known result that high EPRs discourage benefiting firms from exporting their output.

This anti-export bias becomes even more relevant when analysing trade policy from a "trade in value added" perspective (Diakantoni and Escaith, 2012). Cost competitiveness is particularly critical in a

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[4] Alternatively, the exporting firm may decide to charge higher price but will face a lower demand, depending on the value of the price elasticity. We do not analyse this option, which belongs to the economic analysis of EPRs through partial or general equilibrium approaches.

GVC context, when foreign lead-firms base their "make or buy" decisions as well as the choice of offshore localization from tight cost arbitraging (Kohler, 2004). Even if the typical arrangements in a supply chain contract is for the lead-firm to cover the international costs of procurement (equation [11]) an exporting firm will be in an inferior position vis à vis a competitor in the home market of the lead-firm and operating in a free trade environment, because its value-added when selling at world price (left hand side of equation [11]) is lower than its competitor (right hand side).

Even more importantly from the perspective of GVC up-grading in developing countries, the high *t&t* protection will limit the possibility of developing domestic inter-industry linkages (second-tier domestic suppliers) in the case that an exporting firm at home would be able to join an international supply chain. The negative impact of high *t&t* EPRs on second-tier domestic suppliers derives from the fact that tariff and transportation costs influence the domestic price of all inputs, including domestically produced ones (goods but also services). Domestic suppliers of tradable goods will be able to raise their own prices up to the level of the international price plus the *t&t* ad-valorem charge on the competing imports, without running the risk of being displaced by them. As discussed in Box 2, tariffs and other transaction costs on tradable goods have also implications for services and non-tradable products, with serious implications in terms of international competitiveness.

Box 2. Services and inefficiency spill-overs

Albeit all the discussion so far referred to merchandise goods, the additional production cost is also valid for services providers. Up to very recently, the literature on EPRs did not include services, which were traditionally treated as "non-tradable" in the early literature (illustratively, Corden —one of the pioneers of EPR theory treated services as primary inputs and incorporated them in the domestic value-added). Today, services are not only increasingly traded, but they represent a large share of the final production cost of manufactured goods. [5] Moreover, the cost and quality of GVC-related services, both embodied and imbedded, is a key component for defining the competitiveness of any given industry and its capacity for up-grading the value-chain (Low, 2013).

For the services providers who have to support a higher cost of tradable inputs but cannot benefit from tariff protection, EPRs are negative. More importantly, their situation in terms of international competitiveness, as described by the left-hand side of equation [11], deteriorates: unless they accept to operate at lower gross margins than their international competitors, they are not competitive on the international market and the exporting firms making use of their services suffer a disadvantage equivalent to the inefficiency spill-over. [6]

This aspect of inefficiency spill-over is also increasingly relevant when looking at GVCs from a "trade and development" perspective: a productive chain is as strong as its weakest link. Following a GVC approach to industrialization, policy-makers should design "smart industrial policies" that, at distinct from old-style vertical industrial policies, look at value creation by reducing inefficiencies. Accounting for inter-industry linkages and sectoral inefficiencies leads to the identification of inefficiency spill-overs that arise when (distorted) intermediate inputs prices comparing domestic inter-industrial linkages for a given country against its main trade partners. As observed by Cella and Pica (2001), sectoral inefficiencies measured through the inter-industry linkages in the OECD were largely due to inefficiencies imported from other sectors via intermediate input prices, rather than to internal factors. Overpriced inputs may be due to technical inefficiencies affecting the upstream industrial sectors or the effect of distorting trade policies.

This is a clear indication that tariff policy and transport and trade facilitation have a clear bearing on competitiveness: high effective protection through high tariffs and high transaction costs result, at best in higher domestic prices than what they could have been and, at worst, inflates prices much higher than international ones. Therefore, by increasing the relative price of non-tradable with respect to tradable products, tariffs and other trade frictions act here as a kind of catalyst to an over-valued real exchange rate.

[5] Using OECD-WTO TiVA database, it was possible to estimate that, once the value of services embodied in the production of goods is taken into consideration, the share of commercial services in world trade in value-added duplicates its Balance of Payments value.

[6] Domestic firms are supposed to operate with production technologies similar to their competitors' ones. Obviously, a domestic firm may remain competitive on the international market despite higher costs if it benefits from other advantages, be they natural (access to cheap resources such as land or energy) or resulting from an industrial policy (subsidies and soft financing).

2.1.2 Trade costs, competitiveness and export-led growth strategies

If the tariff and trade cost schedules are flat, EPR is equal to the nominal rate of *t&t* protection. In the presence of *t&t* cost escalation (MFN tariffs rising with the degree of processing; transportation and insurance costs increase more than proportionally to the unit value of the goods), downstream domestic industries producing final goods will benefit from a higher effective protection. Upstream industries producing inputs and basic parts and components will have, on the contrary, a low EEPR and possibly a negative one if the sum of *t&t* margins paid on inputs is higher than the margin of protection received on the output.

Therefore, industries registering a high EPR on their production, resulting for example from high nominal duties, high transportation costs and steep tariff escalation, will have little incentive to export because the rate of return on the domestic market is higher than what can be expected on the international one. [7] Incidentally, this result explains why small firms do not export as much as large firms in the more realistic situation where some of the trade costs are not "iceberg" ad-valorem fees but are sunk costs.

In order to analyse more precisely the different impacts of trade costs on competitiveness as well as some mitigating measures that the exporting country could implement, it is important to distinguish between the costs of domestic (superscript "*h*") and foreign inputs (superscript "*f*"). EEPR can be written as:

$$EEPR_j \;=\; \frac{t_j - [\sum_i (t_i \,.a^f{}_{ij}) + \sum_i (t_i.a^h{}_{ij})]}{1-\sum_i a_{ij}} - 1 \qquad [13]$$

With a^f_{ij} and a^h_{ij} the intermediate consumption "i" from, respectively, foreign and home country required to produce one unit of output "j".

Let us revert back to the most favourable case of a first-tier supplier operating in an international supply chain from an Export Processing Zone (EPZ) where the foreign lead-firm covers the costs of transportation of the intermediate inputs and the re-export of the processed good. In such a situation, the first-tier supplier does not have to pay any transaction cost. [8]

Yet, even when duty draw-backs or tariff exemptions (as in EPZs) correct for trade frictions and allow domestic producers to purchase inputs at international prices, export-oriented firms still have a disincentive to purchase inputs internally as their second-tier domestic suppliers (represented by the sum $[\sum_i (t_i.a^h_{ij})]$ in equation [13]) would not be able to benefit from the duty exemption. Thus, despite draw-backs, the first-tier domestic suppliers exporting their products to other participants of the international supply chain remain at a disadvantage compared to their free-trade competitors (right hand side of equation [14] and also the denominator of [13]) when they source some of their inputs from other local suppliers or outsource part of their tasks to them: [9]

$$\left(1 - \left[\sum_i a^f{}_{ij} + \sum_i \left(t_i.a^h_{ij}\right)\right]\right) < \left(1 - \sum_i a_{ij}\right) \qquad [14]$$

[7] We consider here that the exporting firm is a "price taker" which cannot impose its higher prices and will have to compete on the global market at international prices. See Annex 4 for a discussion.

[8] Gereffi, Humphrey and Sturgeon (2005) identify five types of GVC coordination, ranging from lax (market) to vertical (multi-national firm). Modern days complex International Supply Chains involving B2B contractual arrangements are often organised in a vertical or hierarchical manner, where suppliers tend to be dependent on larger, dominant buyers. The dominant buyer is referred to as "Lead Firm", while suppliers can be organised as "First-Tier suppliers" (direct contractual relationship with the Lead-Firm) or "Second-Tier suppliers" when they work for first-tier suppliers. The asymmetric market relationship in those hierarchical networks creates strong and complex linkages. While lead-firms select their suppliers on strict cost/quality criteria and push costs down the chain, they may also finance the coordination expenses, including trade costs, or provide credit.

[9] Unless home firms substitute high-tariff domestic inputs for lower ones (negative correlation between changes in t_i and a^h_{ij}). Diakantoni and Escaith (2012) show that almost no substitution took place in East Asia.

EPZs or duty draw-back schemes will compensate the exporting firm for the additional production costs caused by tariffs only when it uses imported inputs, and the transportations costs only if these imported inputs are those specified by the GVC Lead-Firm. In this case, $\sum_i \left(t_i . a^h_{ij}\right) = 0$ and inequality [14] becomes an identity because all trade costs are covered by the Lead Firm (*id est*, $a^f_{ij} \equiv a_{ij}$; $\forall$ i,j).

But such a strategy prices-out domestic suppliers when nominal tariffs and trade costs are high. The national suppliers of these domestic firms, because they sell on their home market, will not be able to draw back the duties they had to pay on their own inputs. Even if they were able to do so, through what are often complex and arcane administrative mechanisms, domestic suppliers using non-imported inputs would still be put at a disadvantage because nominal tariff protection raised the domestic price of all tradable products, be they actually imported or not. As far as other trade costs included in the FOB-CIF margin, the only possibility for second-tier domestic suppliers to avoid them would be to join the supply-chain itself, with the agreement of the foreign Lead-Firm (*id est*, substituting, with the agreement of the Lead-Firm, other GVC suppliers and "capturing" their value-added).

To summarize the main implications of our formal model, even in absence of *t&t* cost escalation and flat EEPR, trade frictions reduce the competitiveness of domestic firms in the most frequent situation where they are price takers and compete on the global market at international prices. When a domestic firm exports, it loses the additional benefit due to the nominal protection it receives on its output while still paying the additional cost on inputs purchased domestically. The only way to compensate for the additional costs and lower profits at export would be to reduce the value-added cost, for example by paying lower wages or retaining less profit. [10]

This loss of cost competitiveness is particularly critical in a GVC context, when the customers on the export market are foreign lead-firms that make their "make or buy" decisions as well as the choice of offshore localization on the basis of tight cost and profit margins. Even if the typical arrangements in a supply chain contract is for the lead-firm or supply-chain manager to cover the international costs of procurement, an exporting firm will still have to face the higher cost of purchasing domestically its inputs. For this reason, the policy makers have developed several strategies, from duty draw-backs (the exporter can redeem the value of the tariff duties and other indirect taxes paid on inputs used for exports) to free export processing zones (industrial parks installed in fiscal enclaves).

Such schemes (i.e. duty drawbacks and export processing zones), nevertheless fall short of providing a first-best policy when the policy makers' ultimate objective is to use GVCs as a path towards industrialization. Actually, the high *t&t* protection in place outside the EPZs will limit the possibility of developing domestic inter-industry linkages (second-tier domestic suppliers), even in the case where a domestic firm was able to join an international supply chain. It may also exert downward pressure on wages as companies seek to remain competitive and compensate the high EEPR costs.

The negative impact of high EEPRs on second-tier domestic suppliers and the perspective of GVC up-grading in developing countries, derives from the fact that tariff and transportation costs influence the domestic price of all inputs, including domestically produced ones (goods, but also services). This effect is due to the fact that high trade costs raise the domestic market price of all products, be they imported or domestically produced. Domestic suppliers of tradable goods have the possibility of raising their own prices up to the level of the international price plus the *t&t* ad-valorem charge on the competing imports, without running the risk of being displaced by them. In a situation of profit maximization, they will jump at the opportunity, if only to recoup the additional production costs they had to pay on the inputs.

[10] This tactic may be used to gain a contract, but is not sustainable in the long term if the firm wishes to retain skilled staff or invest and expand its production capacity.

Let us take the most favourable case of a first-tier supplier operating from an Export Processing Zone (EPZ) in a typical international supply chain where the foreign lead-firm covers the costs of transportation of the intermediate inputs and the re-export of the processed good. In such a situation, the first-tier supplier does not have to pay any transaction costs. Yet, even when duty draw-backs or tariff exemptions (as in EPZs) correct for trade frictions and allow domestic producers to purchase inputs at international prices, export-oriented firms still have a disincentive to purchase inputs internally as their second-tier domestic suppliers would not be able to benefit from the duty exemption.

EPZs or duty draw-back schemes will compensate the exporting firm for the additional production costs caused by tariffs only when it uses imported inputs. In turn, these imported inputs are those specified and procured by the GVC Lead-Firm. Such a strategy effectively prices-out domestic suppliers when nominal tariffs and trade costs are high. Alternatively, it may exert downward pressure on labour costs among domestic suppliers as they struggle to recoup lost competitiveness.

Any national supplier of a domestic exporting firm located outside the EPZ will not be able to draw back the duties they had to pay on their own inputs. Even if it was able to do so, through what are often complex and arcane administrative mechanisms, a domestic supplier using non-imported inputs would still be put at a disadvantage because nominal tariff protection raises the domestic price of all tradable products, be they actually imported or not. The only possibility for second-tier domestic suppliers to avoid *t&t* costs would be to use only imported inputs.

While the anti-export bias is a well-known result from a traditional trade in final goods perspective, our new corollary is relevant only from the vertical specialization perspective typical of GVCs, where a "*buy*" decision arising from a "*make or buy*" assessment implies arbitraging between domestic and foreign suppliers.

2.2 Stylised facts: Trade costs per country and sector

The section reviews the results obtained on the OECD-WTO *TiVA* 61 economies. After presenting the data sources, the section presents the role of trade costs in providing nominal protection to the domestic producers but also increasing their production costs.

2.2.1 Data sources

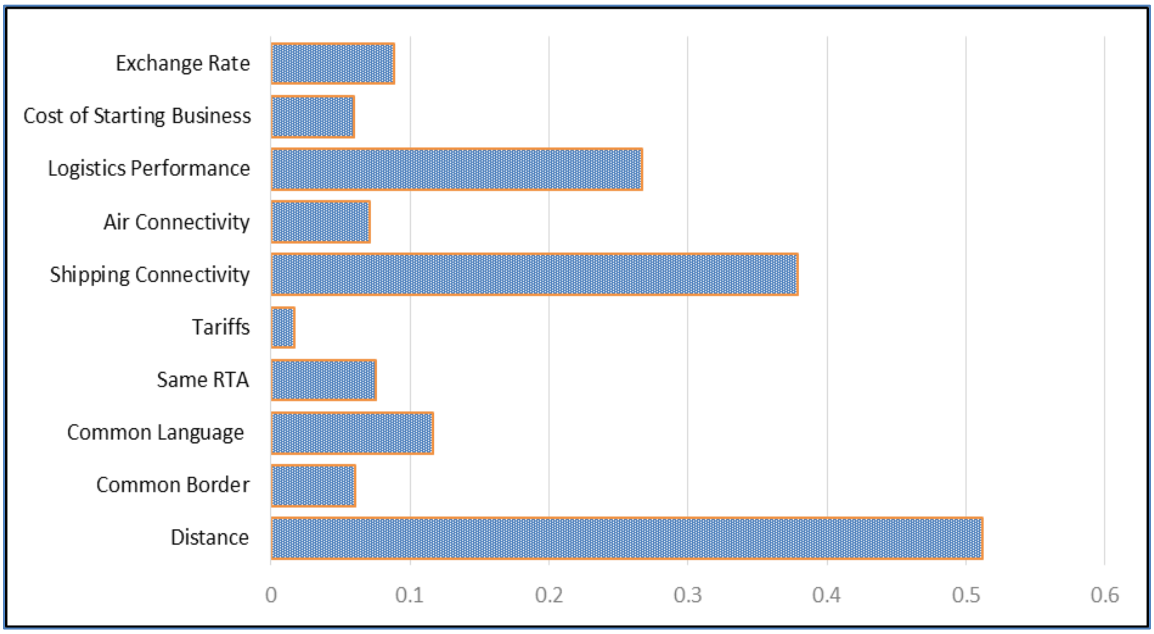
Technical coefficients are sourced from TiVA's underlying OECD Inter-Country Input-Output (ICIO) Tables. The detailed tariff data for the year 2006 and 2011 are sourced from the WTO IDB database and the WTO-ITC-UNCTAD World Tariff Profiles database, aggregated at the Harmonized System (HS) nomenclature product subheading level (HS-6 digit). Applied tariffs distinguish most favoured nation treatment (MFN) and preferential. Information on bilateral trade flows at tariff line level is sourced from the WTO Integrated Data Base and complemented by the UN Comtrade database.

There are several ways for estimating trade costs (for a review, see Fortanier and Miao, 2016). Instead of a direct measure of trade margin, such as the FOB/CIF difference, we opted for an indirect estimate made on trade in value-added data taken from Duval, Saggu and Utoktham (2015). The non-tariff trade costs by Duval et al. are derived from an application of the "Gravity Model" on the OECD-WTO TiVA database. Those trade costs have a monetary dimension (e.g., transportation, insurance and other fees) but also a more subjective dimension: information costs; non-monetary barriers (regulation, licensing, etc.); consumer taste differences; insecure contracts and weakness in trade governance leading to uncertainty.

Trade costs measured through the indirect gravity model approach have two main components. The first one is mainly bilateral. It reflects the geographical and economic separation between the exporter and the importer and covers the geographical distance, freight and insurance costs, but also the trade friction/facilitation effect of features such as language, common history, common border and/or regional trade agreement participation. The second component of trade costs is proper to the exporter or the importer, irrespective of the bilateral trade aspects. They represent the administrative and economic costs of crossing the border either at export or at import stage. These costs are often referred as border "thickness" (G-20, 2016) and include tariffs and nontariff measures, logistic and trade facilitation performances at the ports of origin or destination, but also trade policy uncertainty which may increase the perceived cost of doing business.

Therefore, not all of the bilateral trade costs as measured through indirect methodologies such as the ESCAP-World Bank database have a direct incidence on the EPR measured in monetary terms. Figure 1 disaggregates those costs in various components according to their influence. [11] In truth, the indirect trade costs computed in Duval et al. (2015) do not pretend to be actual costs and should be understood as relative measures. Those costs should therefore be calibrated to reflect more closely the monetary cost of trade margins. Pooling HS chapter data across all countries, partners and 6 digit product categories, Fortanier and Miao (2016) report FOB/CIF margins ranging from 2.7% for HS75 (nickel and its products) to 28% for HS 25 (salt, sulphur, earth & stone, lime & cement). These results are much lower than what is extrapolated from the indirect measure in Duval et al. (2015). On the other hand, de Palma, Lindsey, Quinet and Vickerman (2011, p. 85) state that the direct FOB/CIF measure seriously underestimates the actual transportation costs. Because the monetary bilateral trade costs (excluding tariffs) are expected to be proportional to distance, a 30% weight was attributed to the overall trade cost to impute the non-tariff trade margins in the EPR calculation. [12]

Figure 1 Relationship between overall trade costs and specific variables



Source: adapted from G-20 (2016)

2.2.2 Trade costs and the international competitiveness of the Domestic Value Chain

This section provides an estimate of the impact of trade costs as measured on the TiVA countries for year 2011. In order to calculate EEPR as in equation [10], we need an estimate of the hypothetical value added of the representative firm operating at world prices. We opted to use as international benchmark the German industries: the country has among the lowest ad-valorem tariff and non-

[11] The graph pictures the elasticity of trade costs respective to each of the components (i.e. to what extent are trade costs affected by distance, or exchange rate)

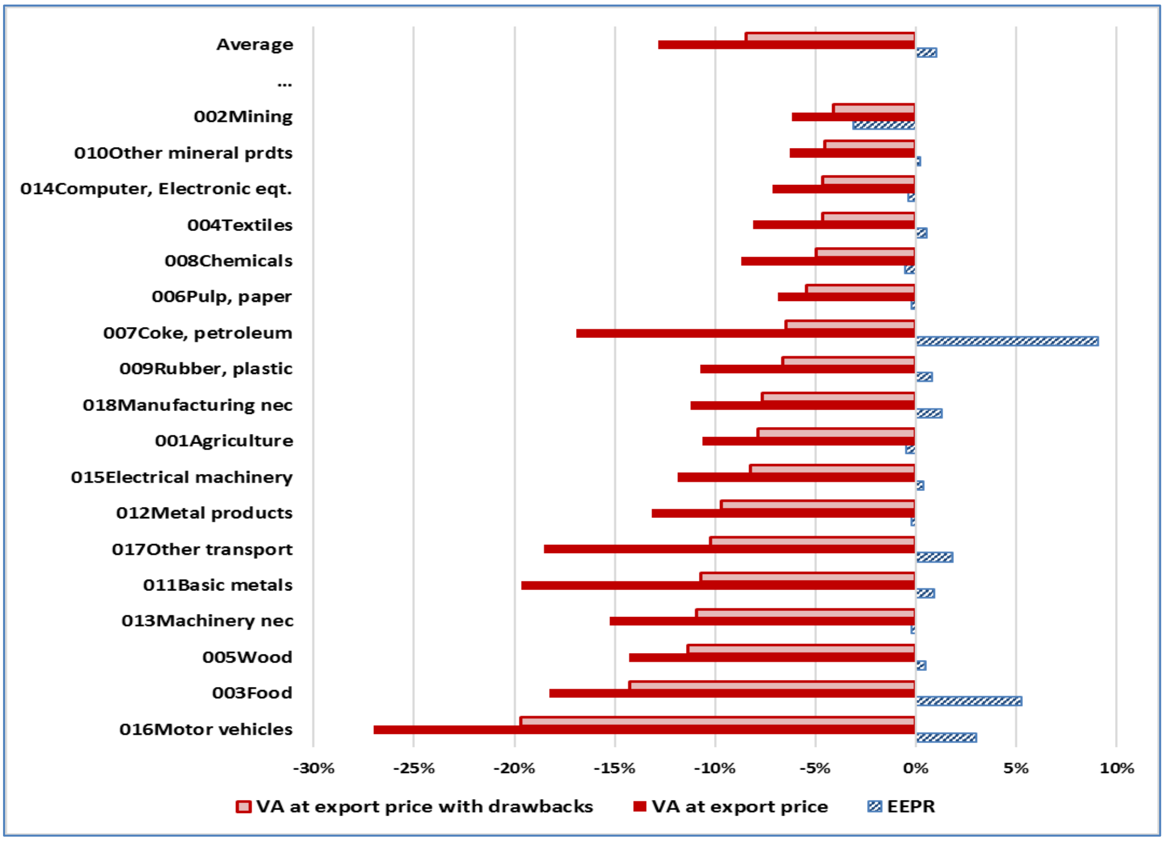
[12] This weight results from discussion with the authors of the original ESCAP trade cost database used in this paper, but it remains a very approximate estimation.

tariff trade costs among the TiVA economies. Moreover, the German industries are among the most competitive internationally, as demonstrated by the country's large trade surplus in recent years.

We compared this benchmark with what would be the hypothetical situation of an "average domestic industry" which, while having the same production function than its counterpart in Germany, would have to support additional trade costs (preferential tariffs and non-tariff trade costs) on its inputs equal to the average observed for the TiVA sample. This hypothetical firm would, when selling on its home market, benefit from the nominal protection on its output these costs add to the price of competing imports. The relative difference between the value-added at domestic price and at world price gives EEPR. When exporting, the industry loses the protection on its output but still has to pay the additional trade costs on its inputs (VA at export price, as in [11]) unless it can benefit from draw-backs and recoup the trade costs on the inputs that are imported. Yet, even in this case, the price of inputs purchased on the domestic market will still remain inflated by trade costs (see equation [14]).

Figure 2 shows that most industries register low positive of negative effective protection, with the exception of Mining and quarrying on the negative side and Coke and Petroleum, Food products and Motor vehicles on the positive one.

Figure 2 Extended effective protection and international competitiveness, simulation results (2011)



Note: The simulation is based on German industries as a benchmark for international production function and the average trade costs (based on preferential tariffs) observed for the 61 TiVA economies. Following the usual convention, only inputs of merchandises are included in the calculation of effective protection; inputs of services are implicitly considered as domestic value-added.
Source: Authors' construct.

But even when the EEPR is low or negative, exporting the output while still paying the home trade costs on inputs can seriously affect the domestic firms' competitiveness. This is the case of the Mining sector, where trade frictions reduce the competitiveness of domestic firms by 6%. The domestic Motor vehicle industry, which registers a moderate positive EEPR of 3%, would register a gross margin 27% lower than the benchmark German firm operating at world price. Benefiting from draw-backs would reduce this loss, but the home industry would still lag behind the international competitor by a margin of about 20% if it continues sourcing other inputs domestically. Food industries have also little incentive to export, their value-added being lower by 18% compared to the benchmark (14% in presence of draw-backs). When the industry relies heavily on imported inputs, as in the case of petroleum products, draw-back schemes can yield an improvement of 10 points .[13] But this remains an exception, and in average, draw-backs will improve the competitiveness of domestic exporters by a margin of 4 to 5 percentage points.

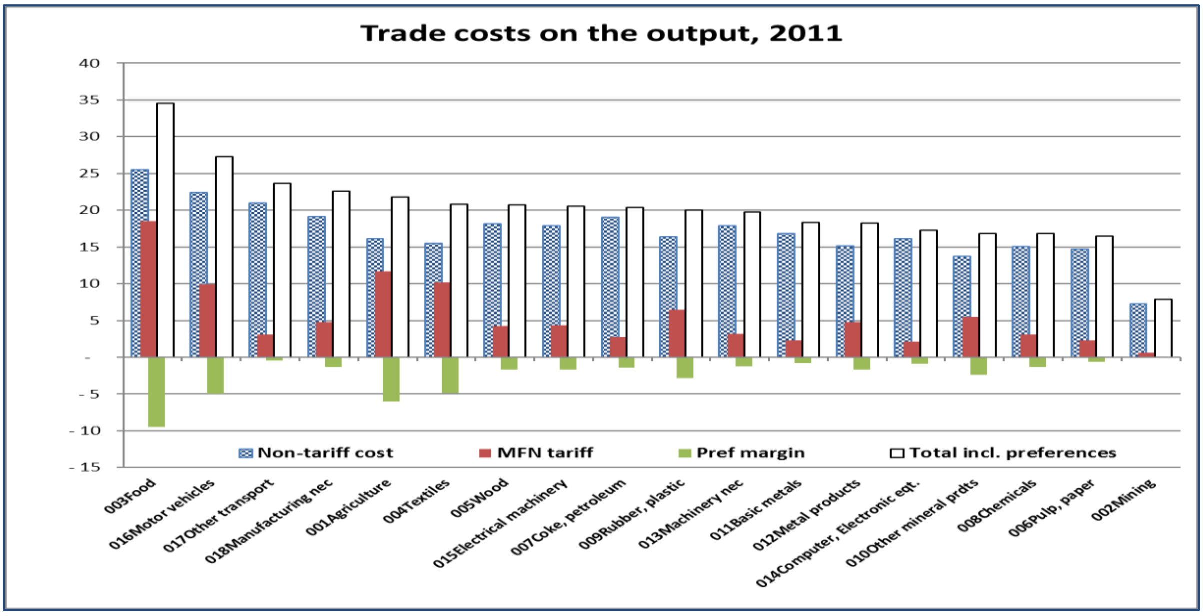
Interpreting those results from a GVC perspective, we can conclude that, despite draw-backs, the first-tier domestic suppliers exporting their products to other participants in the international supply chain remain at a disadvantage compared to their free-trade competitors. This disadvantage is about 8% in average of the sectors. It corresponds to the additional production costs formally identified by the sum $[\sum_i (t_i . a_{ij}^h)]$ in equation [7] and creates a disincentive for export-oriented firms to purchase inputs to second-tier domestic suppliers. In our simulation, the bias against sourcing inputs from the domestic value chain rather than purchasing competitive imported inputs is particularly important for the automotive industries. The only way to compensate for the additional production costs and lower profit margin at export would be to reduce the domestic cost of domestic products, for example by paying lower wages or retaining less profit. But this strategy would run against the objectives of GVC economic and social up-grading.

2.2.3 Trade costs on the inputs and on the output

- **Trade costs as nominal protection for domestic producers**

The first effect of tariff and non-tariff trade costs is to protect domestic producers from competitive imported products, by increasing the import price by a trade margin. Figure 3 shows that the sectors most protected by tariff and non-tariff trade costs falling on imports, are food and agricultural products, or manufactures such as transport and motor vehicles.

Figure 3 Trade costs and nominal protection of output, 2011



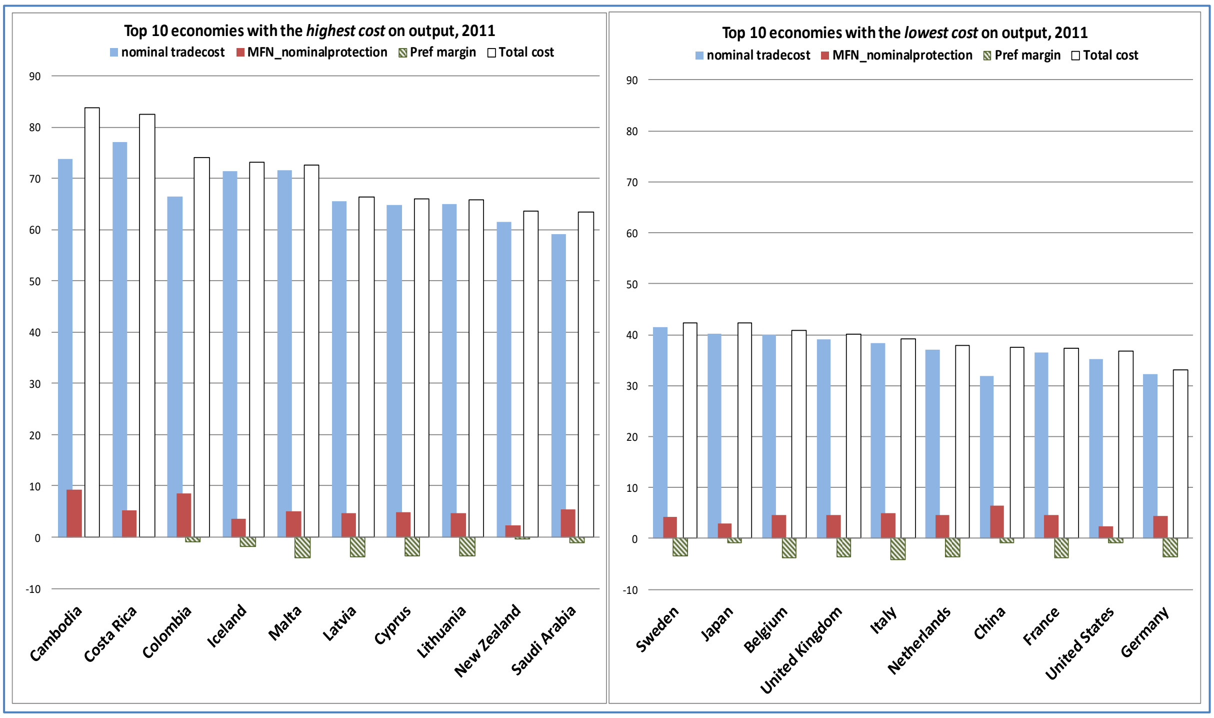
Note: Ranked according to total trade cost, including preference margin. See Annex 5 for sector definition.
Source: Authors' calculations.

[13] Even when EEPR is negative, as in the case of the Mining sector, trade frictions still reduce the competitiveness of domestic firms when they compete on the global market at international prices while still paying their inputs at domestic price.

Trade costs for these products add up to 35% to the price international of competing imports. Commodities or primary goods such Mining, Wood or Paper imported products face the lowest trade cost: tariffs are usually low and the products are shipped in bulk, using sea freighters. Nevertheless, the average trade and tariff nominal protection for all sectors is 20% (17% for non-tariff costs and 3% for tariff, including 2.5% preference margin). Considering that the protection received on output translate also in an increase in the production cost of the users of those intermediate products, the weight on competitiveness is significant.

The situation varies greatly from country to country. Figure 4 compares the top and bottom 10 countries in terms of tariff and non-tariff trade costs. The highest trade costs are found in developing countries, but small developed countries can also face high costs when they are relatively isolated from the main markets, as it is the case for small islands like Malta or Cyprus. With the exception of China, the economies facing the lowest import cost are all developed economies.

Figure 4 Top/bottom ten countries, highest and lowest trade cost (2011, all sectors)

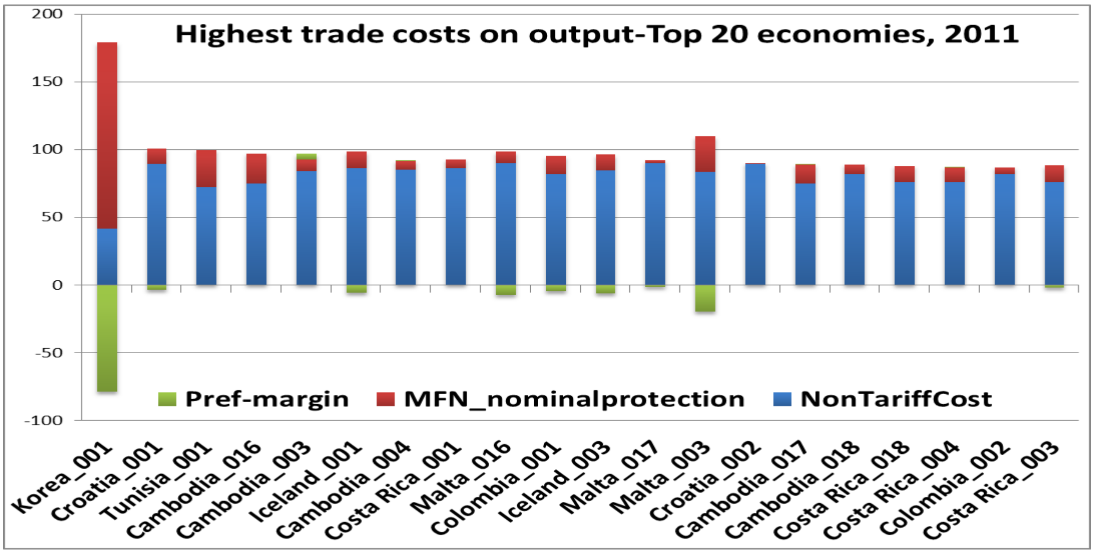


Note: Ranked according to total trade cost, including preference margin.
Source: Authors' calculations.

As expected, trade costs vary from country to country and from sector to sector. Figure 5 shows that Agriculture (sector 001) and Food products, beverages and tobacco (003) are usually the most protected sectors, because of tariffs or non-tariff trade costs. [14] Sector 16, 17 and 18 (transport equipment and other manufacture) are also well represented. The lowest sectoral costs (not represented here) are mainly found in one country (Germany).

[14] Agricultural products are often subject to demanding Non-Tariff measures (SPSS, etc.) and the transportation of perishable products is costly.

Figure 5 Top 20 highest trade costs per output and economy, 2011

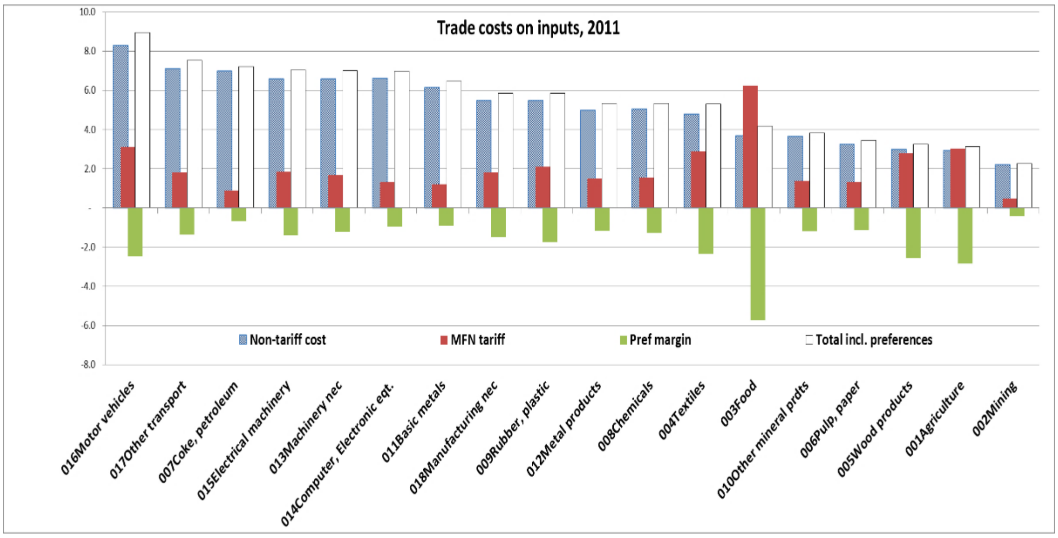


Note: Ranked according to total trade cost, including preference margin. Sector codes are detailed in Figure 2 and Annex 5.
Source: Authors' calculations.

- **Trade costs and additional production expenses**

While trade costs offer a nominal protection to domestic producers and allow them to increase their selling price by the trade cost margin, they also entail additional production costs by inflating the price of imported and domestically produced inputs. There is a correlation between nominal protection received on output (Figure 3) and nominal protection paid on inputs (Figure 6) because most industries are using in their production process parts and components originating from firms classified in the same industrial sector. Nevertheless, this is not the case for Food products, Agriculture and Textile sectors which rank higher in terms of protection than in terms of additional production costs.

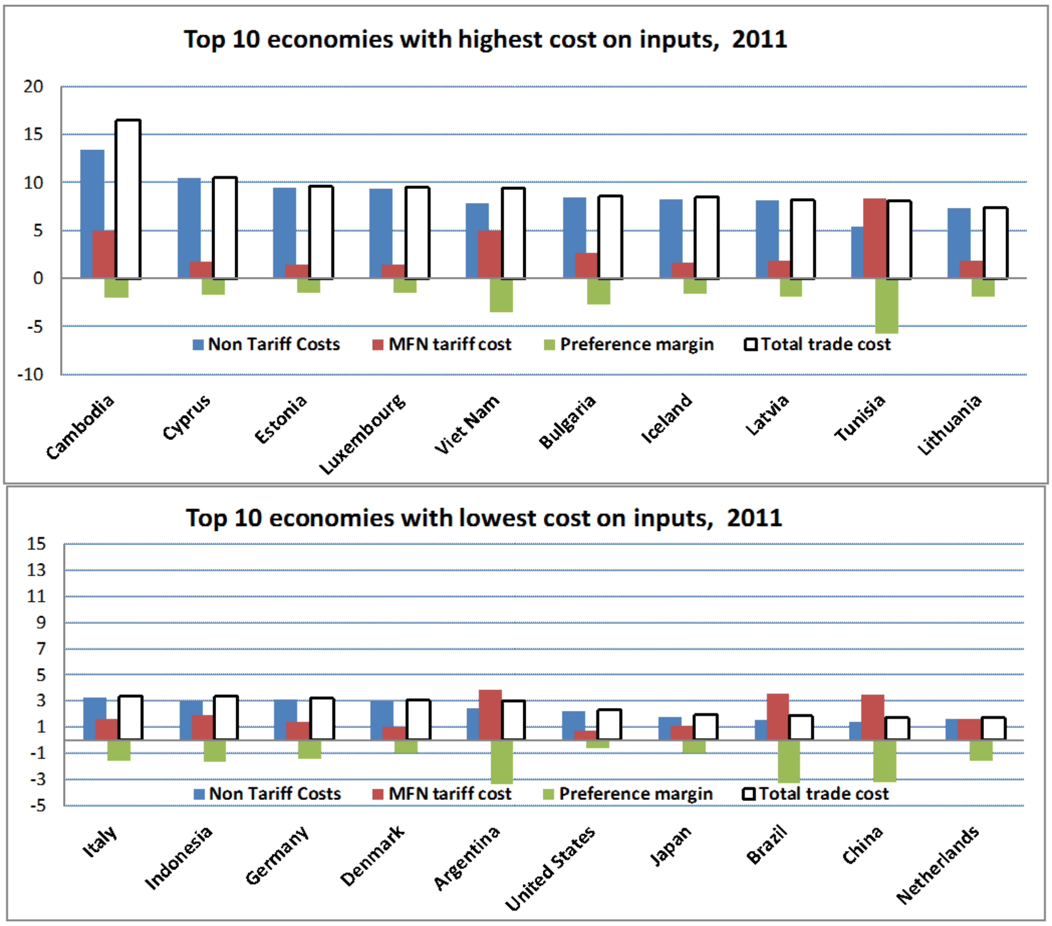
Figure 6 Trade costs and additional input prices, 2011



Source: Authors' calculations.

The situation varies also from country to country, small economies being more affected by high unit trade costs than large ones.

Figure 7 Top/bottom ten countries, highest and lowest trade cost (2011, all sectors)



Source: Authors' calculations.

Unless compensated by saving on other aspects of production (either unsustainable aspects such as low remuneration of labour and investment or export subsidies; or welfare enhancing ones such as high total factor productivity), those higher costs reduce the international competitiveness of the industries located in these countries. Some of these costs fall under the control of domestic policy (logistic performance, cost of doing business, etc.) and can be improved unilaterally; others are exogenous, such as distance with the trading partner or sharing a common language.

Some of those exogenous costs can be overcome in the long run by appropriate policy: freight costs can be lowered by promoting more competitive international shipping market (e.g., Open Sky policy for air freight) and even language barriers can be lowered: Costa Rica, a successful GVC player and dependent upon exports to the US market, included many years ago the teaching of English in primary schools.

While tariff costs have decreased between 2006 and 2011, in particular the MFN ones, non-tariff trade costs have slightly increased (see Table 2). The net impact remains negative in the case of nominal *t&t* protection on output (minus one percentage point) but nil in the case of imported inputs.

Table 2 Trade costs: incidence on output and input prices, 2006-2011

Trade Costs [a b]	Non-Tariff				MFN Tariff				Preferential Tariff				Total including preferences.			
	Outputs		Inputs [c]		Outputs		Inputs [c]		Outputs		Inputs [c]		Outputs		Inputs [c]	
	2011	Var/2006	2011	Var/2006	2011	Var/2006	2011	Var/2006	2011	Var/2006	2011	Var/2006	2011	Var/2006	2011	Var/2006
001Agriculture	16.1	0.4	2.9	0.1	11.7	-3.9	3.0	-0.7	5.6	-2.4	0.2	0.0	21.8	-2.0	3.1	0.0
002Mining	7.3	0.1	2.2	0.0	0.6	-0.5	0.5	-0.1	0.8	-0.5	0.1	0.0	8.1	-0.4	2.3	0.0
003Food	25.5	1.1	3.7	0.2	18.5	-2.2	6.3	-1.4	9.0	-3.7	0.5	-0.2	34.5	-2.6	4.2	0.1
004Textiles	15.5	0.2	4.8	0.2	10.2	-1.5	2.9	-0.5	5.4	-1.9	0.5	-0.1	20.8	-1.7	5.3	0.1
005Wood	18.2	0.2	3.0	0.1	4.3	-1.1	2.8	-0.7	2.5	-1.3	0.3	-0.1	20.7	-1.1	3.3	0.0
006Pulp, paper	14.7	0.1	3.3	0.1	2.3	-1.0	1.3	-0.4	1.7	-0.8	0.2	-0.1	16.5	-0.7	3.5	-0.1
007Coke, petroleum	19.0	0.2	7.0	0.2	2.8	-0.7	0.9	-0.3	1.3	-0.8	0.2	-0.1	20.3	-0.6	7.2	0.1
008Chemicals	15.1	0.1	5.0	0.1	3.1	-0.6	1.6	-0.4	1.7	-0.7	0.3	-0.1	16.8	-0.6	5.3	0.0
009Rubber, plastic	16.4	0.1	5.5	0.1	6.5	-1.3	2.1	-0.5	3.6	-1.5	0.4	-0.1	20.0	-1.3	5.8	0.0
010Other mineral prdts	13.7	0.1	3.6	0.1	5.5	-0.1	1.4	-0.2	3.1	-1.2	0.2	-0.1	16.8	-1.0	3.8	0.0
011Basic metals	16.9	0.0	6.1	0.1	2.3	-0.9	1.2	-0.4	1.5	-0.9	0.3	-0.1	18.4	-0.9	6.5	0.0
012Metal products	15.2	0.0	5.0	0.1	4.8	-1.2	1.5	-0.5	3.0	-1.2	0.4	-0.2	18.2	-1.2	5.3	-0.1
013Machinery nec	17.9	0.1	6.6	0.1	3.2	-0.6	1.7	-0.4	1.9	-0.7	0.4	-0.1	19.8	-0.5	7.0	0.0
014Computer, Electronic eqt.	16.1	0.2	6.6	0.1	2.1	-0.4	1.3	-0.3	1.2	-0.6	0.4	-0.1	17.3	-0.4	7.0	0.0
015Electrical machinery	17.9	0.2	6.6	0.2	4.3	-0.8	1.8	-0.4	2.6	-1.1	0.5	-0.2	20.5	-0.8	7.0	0.0
016Motor vehicles	22.4	0.5	8.3	0.2	9.9	-2.0	3.1	-0.7	4.9	-1.9	0.7	-0.2	27.3	-1.4	9.0	0.0
017Other transport	21.0	0.5	7.1	0.2	3.1	-0.3	1.8	-0.3	2.6	-1.1	0.4	-0.1	23.6	-0.5	7.6	0.0
018Manufacturing nec	19.2	0.4	5.5	0.2	4.7	-1.3	1.8	-0.5	3.4	-1.2	0.4	-0.1	22.5	-0.8	5.9	0.1
Average [a]	***17.1***	***0.2***	***5.2***	***0.1***	***5.5***	***-1.1***	***2.1***	***-0.5***	***3.1***	***-1.3***	***0.4***	***-0.1***	***20.2***	***-1.0***	***5.5***	***0.0***

Note: a/Simple average across countries or sectors; b/ variation between 2006 and 2011 in percentage points, using 2011 as base year for weights; c/ imported products only, using the 2011 technical coefficients of international input-output matrix as weights.
Source. Authors' calculations.

3 CASCADING TRANSACTION COSTS IN THE WORLD TRADE NETWORK

After looking at the magnification effect on *t&t* costs on country and individual firms' value-added and competitiveness, this section examines trade costs as a cascading source of trans-border cost-push transmission. This occurs when manufacturing is geographically segmented and organized as an international production network. The impact of tariffs and other additional transaction costs is amplified as intermediate goods are further processed by importing countries then re-exported.

3.1 Accumulation of trade costs along international supply chains

Yi (2003), Ma and Van Assche (2010) and Ferrantino (2012) highlight the existence of non-linearity in the way in which transaction costs negatively affects trade-flows in a trade in tasks perspective, where goods have to travel through several nodes before reaching their final destination. The impact of tariffs and other additional transaction costs is amplified as intermediate goods are further processed by importing countries then re-exported. Yi (2003) indicates that a small decrease in tariffs can induce a tipping point at which vertical specialization (trade in tasks) kicks in, where it was previously non-existent. When tariffs decrease below this threshold, there is a large and non-linear increase in international trade. The cascading and non-linear impact of tariff duties when countries are vertically integrated can be extended to other components of the transaction cost. When supply chains require semi-finished goods to cross international borders more than once, the effect of a marginal variation in trade costs everywhere in the supply chain is much larger than would be the case if there were a single international transaction.

Ferrantino (2012) shows that, when trade costs apply in proportion to the value of a good, the total cost of delivering the product through the supply chain down to the final consumer increases exponentially with the number of production stages. For example, if the average ad valorem transaction cost is ten per cent, accumulated transaction costs in a supply chain of five-stages of equal additions lead to an ad valorem tariff equivalent of 34 per cent. Doubling the number of stages by slicing up the supply chain more than doubles the total delivery costs, as the tariff equivalent is 75 per cent.

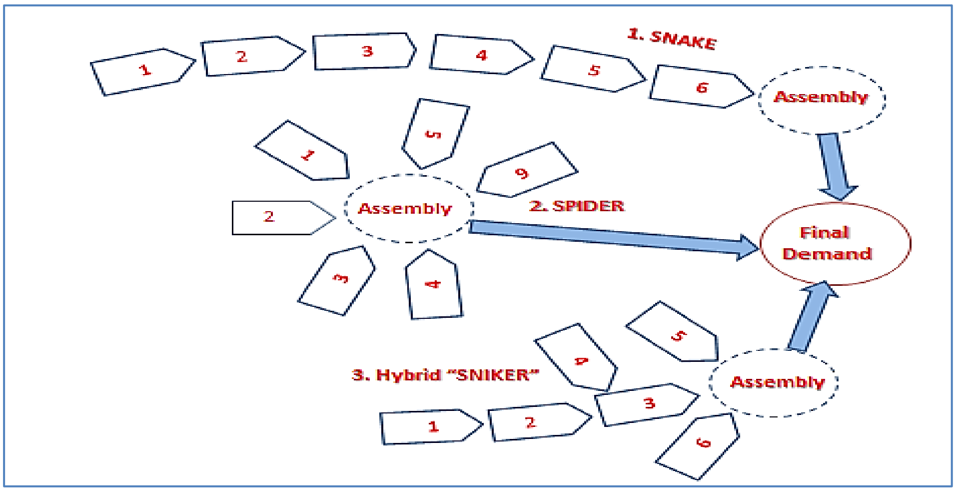
3.2 Mitigating factors

In practice, the accumulation effect may be lower than what a simple exponential formula suggests. We review two of the main mitigating factors at work: the topology of GVCs and their endogeneity to trade costs.

- **The taxonomy of GVCs**

While the image of a chain implicitly projects the idea of a succession of sequential steps ("snakes", in the zoological taxonomy of GVCs), most supply chains are not linear but are defined by a hub and spoke pattern ("spiders"). In the spider case (Figure 8), first tier suppliers of parts and components are arranged around a central assembly plant which ships the end product to its final destination. Unbundling costs are lower in the "hub and spoke" configuration: inputs cross a border at most twice, once as a part and once embodied in final output.

Figure 8: The zoology of GVCs: Spider, Snakes and Snikers

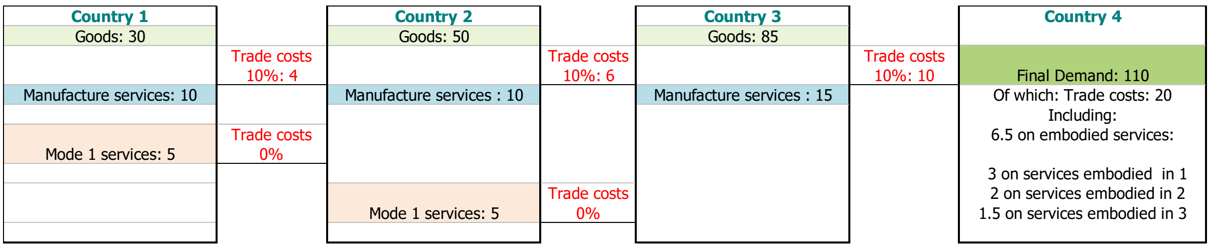


Source: Freely adapted from Baldwin and Venables, 2010

In a snake, each task is embodied into goods in processing that are shipped again to the next production stage. At each stage, the gross commercial value of the good in process increases, leading to cascading transaction costs. In real life, actual supply chains will be a mix of spiders and snakes, as suggested by Baldwin and Venables. The zoological classification of the GVC (a "*snake*", a "*spider*" or the hybrid we call "*sniker*" in Figure 8), its length (as measured by the number of border crossings) and the associated trade costs determine the extent of cumulative trade costs embodied in the value of the final goods.

Adapting from Murakov (2016), a sequence of cumulative trade costs in a "snake" can be described as in Figure 9. Cross border exports of business services (Mode 1) do not support trade costs, as long as they are not embodied into manufactured goods. Manufacture services that are embodied into exports of goods paying taxes and other trade costs (a flat 10% in our example). The final consumer pays 110 for the final good (including international trade costs but excluding domestic margins), of which 20% relate to accumulated trade costs (10 direct, 10 embodied in the FOB commercial value of the imported goods). [15] It should be noted that services do pay trade costs if they are embodied into a good which crosses a border. In our example, the $5 Mode 1 services exported from 1 to 2 didn't pay trade costs from 1 to 2, but served as the basis for an *ad valorem* taxation after being embodied as manufacture services at stage 2.

Figure 9 Cumulative trade costs in a 3 borders snake



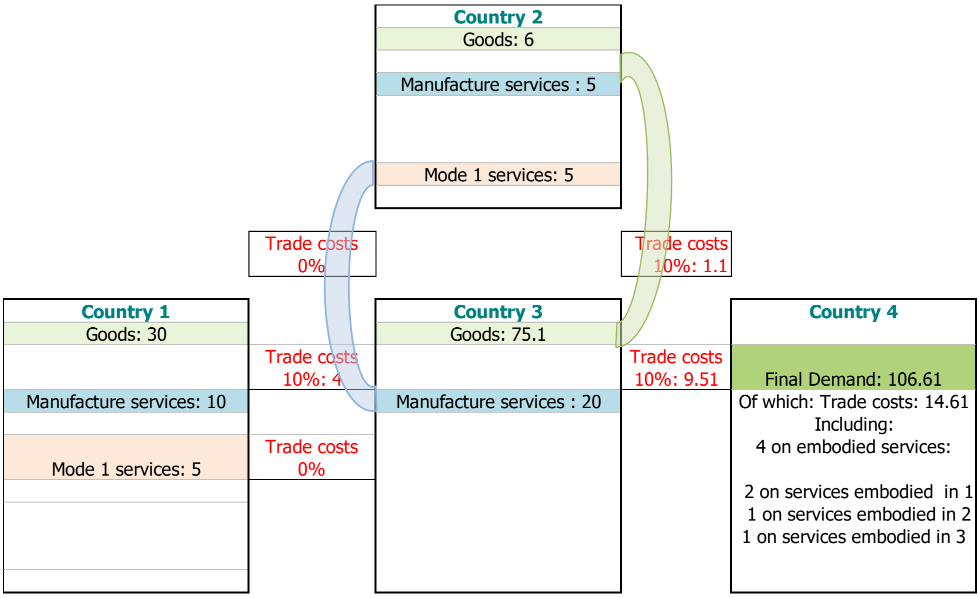
Source. Authors' calculations.

The accumulation of trade costs does not only depend of the number of border crossings, but also of the topology of the supply chain. Figure 10 shows the same example of a 3 country supply chain,

[15] This taxation of trade in embodied services (called 'Mode 5' by the authors) is analysed in Cernat and Kutlina-Dimitrova (2014). Using the TiVA database, the paper finds that the weight of 'mode 5' exports is considerable and varies between 20% in China and 34% in the EU27. While cross-border services are not supposed to pay duties, those 'mode 5' services exports are subject to fairly complex trade rules.

organised as a hub and spoke (or 'spider').The difference with the previous case is minimal, only one intermediate step is removed, part of the manufacturing services which were previously done in country 2 are now executed in the country 3 of final assembly. Yet, even with this small change, the direct and indirect trade costs of importing the product in country 4 are reduced by 27%, translating into a lower consumer price.

Figure 10 Cumulative trade costs in a 3 borders spider



Source. Authors' calculations.

Muradov (2016) finds that the direct impact of tariffs (paid on imports) is almost always more important than the accumulated tariffs embodied in the cost of production of these products. The largest indirect tariffs are found for Indonesia (3.76% direct; 1.33% indirect); Australia (2.44%; 1.30%), Chinese Taipei (2.52%; 1.28%) and Japan (1.39%; 1.28%). The only cases where the indirect cost due to tariffs was higher than the direct one were found in in countries with low nominal protection: Luxembourg ((0.18%; 1.02%), Malta (0.38%; 0.69%), Russia (0.73%; 1.27%) and Greece (0.72%; 0.92%).

The calculation of GVC length and other GVC related indicators will be made more difficult in the future with the spread of the new National Accounts and Balance of Payments conventions, which artificially shorten GVCs, irrespective of their true topology (see Box 3).

Box 3. When National Accounts change Snakes into Spiders

Since the 2008 revision of the UN System of National Accounts (SNA2008), many linear GVCs are now reported as spiders, artificially shortening the length of international supply chains. When trade in intermediate inputs –the main type of inter-industry flows– does not involve a change in ownership, the new SNA2008 does not report the resulting transactions as trade in goods and records only the processing fees paid by the Lead Firm to its suppliers.

Even when the physical trade in intermediate goods undertakes successive processing as in the "snake" type, the SNA and Balance of Payments data will report only the bilateral financial flows between the lead-firm and its suppliers. At the difference of actual trade flows, the monetary track is purely bilateral ("spider" style) and will not show any accumulation effect along the physical GVC, even in the "snake" type, unless a change of ownership is recorded.

This new accounting convention ignores most trade costs (manufacturing is treated as trade in services) and results –*inter alia*- in an artificial shortening of the GVCs. It may even confuse the true origin and destination of processing value-added when firms have distinct localizations for their production plants, their distribution hubs and their financial headquarters, a situation that is increasingly common for large multinational enterprises. Attributing to its respective countries of origin the value-added embodied into a final good may lead to an over-representation of financial centres and tax heavens when the new accounting convention is used.

This is unfortunate at a time where trade between related firms (be they part of the same conglomerate or linked through GVC contracts) is shaping regional and international economics. Trade statisticians, in the 2010 version of International Merchandise Trade Statistics: Concepts and Definitions, decided to keep track of the physical flows of goods, irrespective of change in ownership. But conciliating Main Street (trade flows) and Wall Street (financial flows) under the new SNA2008 complicates the compilation of international input-output tables that serve as a basis for the measure of trade in value-added and the calculation of related GVC indicators.

The shortening of GVCs observed after 2011 by Timmer, Los, de Vries and Stehrer (2016) may be due, at least partially, to the fact that the 2015 release of the WIOD database uses the SNA2008 convention. The OECD-WTO TiVA database aims at correcting for this accounting bias, at the cost of a series of additional imputations.

- **Trade costs and the endogeneity of GVC length**

The other important mitigating factor is endogenous to the development of GVCs: supply chains can only prosper and progress when trade costs are low. It is when these costs are reduced beyond a certain threshold that a lead-firms will find profitable to internationally outsource part of their production. [16] As a matter of facts, GVCs are Coasian constructs that exist only if the incremental benefit from improved complexity (GVC length) is higher than the increased transaction cost. [17] This means that (i) the total accumulated trade cost along the GVC is bounded by the GVC performance in terms of efficiency but also that, (ii) for a given structure of efficiency gains, the length of the GVC is negatively correlated to trade costs. As Yi (2003) shows, the relationship is not lineal and trade costs have to be significantly reduced before GVCs start expanding.

It is therefore unrealistic to extrapolate accumulating trade costs along longer GVCs in situations where ad valorem trade costs do not go down, unless efficiency increases for some exogenous reason and compensates for the additional trade costs. Excluding those supply shocks on efficiency (be they exogenous or endogenous, such as improved learning by doing), the net result between the decrease in ad valorem trade costs (the exogenous factor) and the resulting increase in GVC length should lead to relatively small increases in total accumulated costs ex post facto.

Figure 11 shows the results of a simple simulation exercise based on the hypothesis that, for a given product, GVC expansion is endogenous to trade costs. When trade costs are above a certain threshold, the length of the GVC measured in terms of border crossing is 0: there is coincidence between the place of production and consumption, without border crossing.

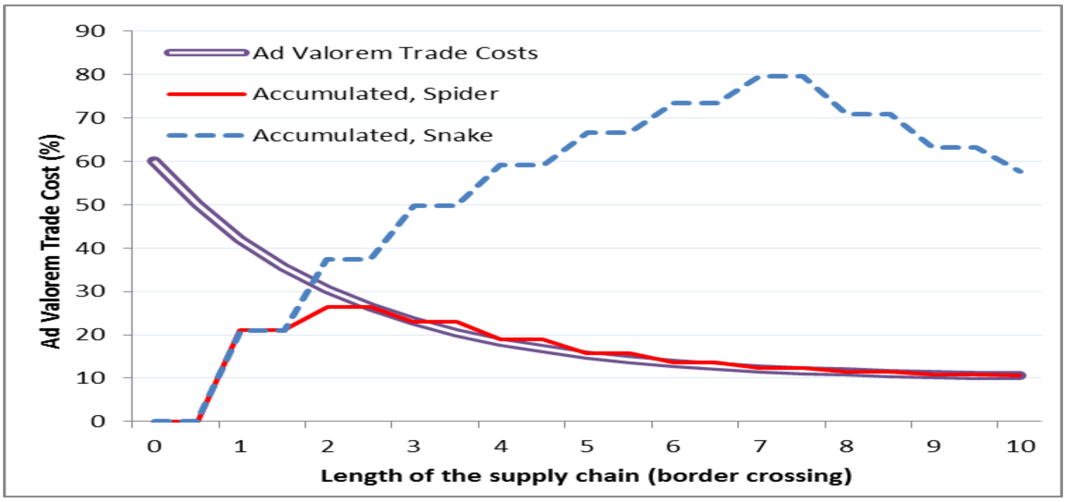
It is only when trade costs go down beyond certain thresholds that it becomes to be profitable to shift part of the production to another country which offers efficiency gains larger than the additional trade cost incurred. When trade costs are further reduced, new outsourcing opportunities may be found to increase production efficiency. It will be the case when the efficiency gain is high but the supplier is far away, or when the efficiency gain is moderate but the supplier is closer. The net effect between increased efficiency minus accumulated trade costs is transferred to the Lead Firm (increased gross margin) and/or to the final consumers (lower prices).

When GVCs are of the spider type, the marginal decrease in the ad valorem trade costs may compensate the additional cost of further fragmenting the chain. In our simulation, this happens at the third split. When GVCs are snakes, the decreasing ad valorem trade cost applies on an increasing

[16] In practice, the lead-firm may have other strategic objectives in international outsourcing that go beyond pure cost-efficiency, but this essay focuses only on value-added and production costs.
[17] Ronald Coase posited that corporations exist to economize on the transaction costs of markets. After some size is achieved, organizational complexity becomes overwhelming and the firm faces diseconomies of scale and scope.

accumulated value of trade in intermediate goods. In this case, the mitigating effect of lower ad valorem trade costs is not as strong as in the spider type because the trade costs accumulate exponentially (Ferrantino, 2012). But the additional unit cost is decreasing and the net effect becomes negative after a certain point (the 7th split in our simulation). [18] Thus, even in the case of a snake-type linear supply chain, there cannot be an exponential accumulation of trade costs: the accumulated cost profile is parabolic. [19]

Figure 11 Ad-Valorem and Accumulated trade costs in snakes and spider

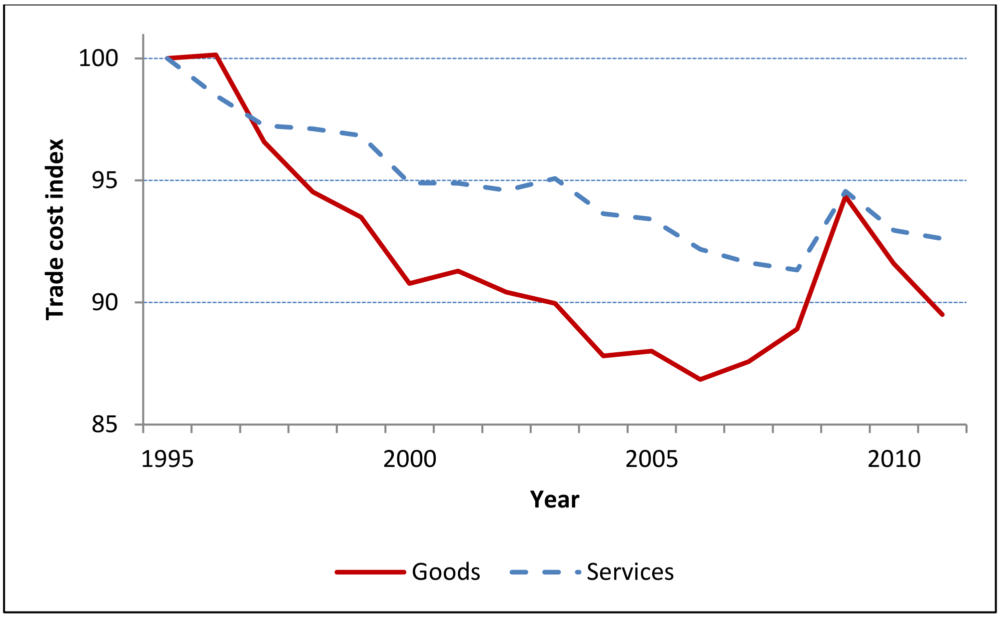


Note: When trade costs are high, all value is produced by the lead-firm in 0 where it is consumed (no trade takes place). At step 1, the VA is split in 2 between the country of final consumption and a first-tier supplier. When ad valorem trade costs decrease by a sufficient margin, an additional fragmentation takes place in step 2, the VA being now split in 3. In the snake configuration, the accumulated trade cost increases following an exponential function of the (diminishing) ad-valorem trade cost. In a spider topology where the VA is split equally between final destination and an increasing number of first-tier suppliers, the total trade cost is simply the sum of the outsourced VA multiplied by the (diminishing) ad-valorem cost.
Source: Authors' calculations based on simulated data

This said, the figure tells us also that established GVCs are also vulnerable to a reversion in the decreasing trend in ad valorem trade costs. If the ad valorem trade costs start increasing again, the GVC length is gradually shortened. Moreover, at the difference of pure monetary costs that were influencing international competitiveness in the analysis presented in section 2.2 , non-monetary trade frictions, such as policy uncertainty and macroeconomic risks have to be included in the calculation. And these costs increased during the 2008-2009 global crisis without returning to their minimum value afterwards. This increase in overall trade costs may explain the shortening of GVC length observed after 2011 (Timmer, Los, de Vries and Stehrer, 2016).

[18] This apparently paradoxical result can be intuitively explained as follows: when trade costs are very high, accumulated cost is 0 because no trade takes place; when trade is frictionless, accumulated trade costs are also 0 because there are no trade costs. So, in-between these two extreme positions, there is an inflexion point: accumulated trade costs increase with the length of the GVC up to the inflexion point and start decreasing afterwards.
[19] In theory, if trade costs tend to 0 (frictionless trade), the length of the supply chain may extend up to the total number of countries, each one specializing in a specific task. Here again, the Coasian theory of the firm tells us that this will not be the case as long as organizational costs increase with the complexity of coordinating such complex GVCs.

Figure 12 Trade frictions in goods and services, 1995-2011



Source: Escaith and Miroudot, 2015

In practice, most attempts at measuring the length of GVCs and the resulting accumulation of trade costs are based on international input-output calculations, even if the data fall short of providing a good representation of trade along global value chains. [20] Rouzet and Miroudot (2013) formalize a measure of the cumulative tariffs embodied in trade in intermediates along international supply chains. Their results reveal that although nominal tariffs are low in most OECD economies, indirect tariffs can add a significant burden by the time a good reaches its final user. For example, products imported from India into the EU have paid a series of tariffs totalling 3.7%. 52% of this amount is directly levied at the EU border and 48% results from duties on intermediate inputs imported by India at previous production stages. Using a different method to compute the inverse matrix, Muradov (2016) obtains an estimate of border crossings and shows that they tend to increase while cumulative tariffs decline: the reduction in direct import tariffs neutralized the indirect accumulation of embodied duties.

3.3 Cascading costs and trade facilitation: a World Trade Network perspective

The accumulation of trade costs from beginning to end of production networks goes against the "raison d'être" of global value chains, which require participants to operate in time-critical, decentralized systems. To realize the cost savings associated with production networks, intermediate products must be worked and shipped between production locations and onwards into retail distribution systems (and thence to the final consumer) as efficiently and quickly as possible.

Time lost waiting at borders (and related costs of storage etc.) are deadweight economic costs within the network. Djankov, Freund and Pham (2010) found that each additional day a product was delayed by border formalities equated to adding 70 km on average to the distance between trade partners. The effect was particularly pronounced for time sensitive agricultural goods where a day's delay reduced a country's relative exports by 6 per cent. In a trade network, this bilateral effect is compounded as the efficient organization of production flows between two trade partners also

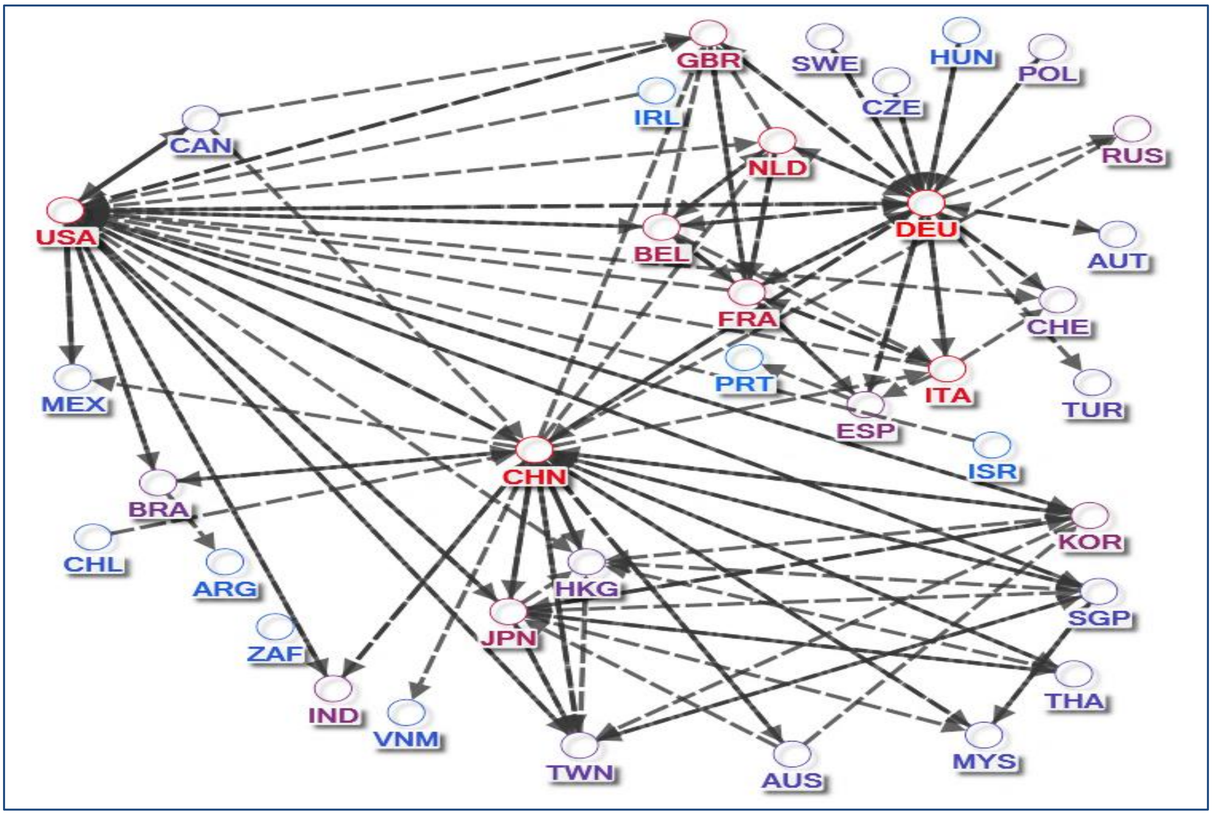
[20] Without entering into a very technical debate, a fundamental limitation of the international input-output calculus is the large aggregation bias that is created when all firms, small and large, export-oriented or not, are aggregated into a single "representative industry". Because the input-output table aggregates domestic oriented and export oriented firms into a single piece of data, with the former being much more numerous than the latter, the probability of successive border crossings calculated using a Leontief setting (or the H matrix in Muradov, 2016) is much smaller than what it would be in the reality of GVC trade.

depends on the efficiency of upward and downward GVC partners: the production chain will be as swift as its slowest link. Bilateral trade frictions should therefore be analysed from a multi-player perspective. Improving the effectiveness in processing trade with a minimum of frictions will not have the same impact on the world trade network that improving logistic and trade facilitation in a country playing the role of a GVC hub.

3.3.1 World Trade Network and GVC Hubs

The graph in Figure 13 is based on trade flows on intermediate goods (a marker of GVC trade) excluding oil. It shows clearly that GVC trade in intermediate inputs is organised along three large regional clusters (East Asia, centred on China; Europe, centred on Germany and North America, with the US as central hub and dense extra-regional exchanges). The East Asia and Europe regional value-chains include several smaller clusters organised around, for example, Japan or the UK.

Figure 13 Graph representation of trade in intermediate goods, 2011



Note: Graph based on the 61 TiVA economies and the value of their bilateral gross trade flows in intermediate goods, excluding oil. The figure shows only the most important flows (higher ones being shown as plan arrows). The colour coding indicates the node' s centrality (PageRank), ascending from blue to red.
Source: Based on COMTRADE data and BEC classification.

Network and graph analysis allows also quantifying the role of key players by computing "betweenness and centrality indicators". The former indicate the role as a hub facilitating exchanges between each other pairs of trade partners, which gives to the hub the capacity to broker contacts among other partners, for example to capture trade margins and charge logistic services. Centrality conveys include in addition the idea of having influential role through the trade partners. The intuition behind their calculation is that if a trade partner (a node or a vertex, in network analysis) "influences just one other node, who subsequently influences many other nodes (who themselves influence still more others), then the first node in that chain is highly influential" (Borgatti, 2005).

A player's centrality is therefore not only a function of its own importance in the world trade economy, but also a function of the centrality of its trade partners. In order to assess the contribution of each economy as a GVC trade facilitator, the "PageRank" centrality indicator is computed for each partner, based on all TiVA economies (including Rest of World) and all trade flows in intermediate goods (excluding oil). Table 3 presents, for the top 20 hubs, their main network indicators.

Table 3 Between-ness and centrality indicators for a selection of trade hubs, 2011

Hub Label (ISO3)	In-Degree	Out-Degree	Between-ness Centrality	Closeness Centrality	Eigenvector Centrality	Page-Rank
DEU	43	50	375.2	0.015	0.034	2.51
CHN	41	44	248.4	0.014	0.034	2.26
NLD	40	30	200.9	0.013	0.032	2.04
ITA	38	38	178.0	0.014	0.032	2.16
USA	42	40	176.0	0.014	0.033	2.09
FRA	32	37	118.1	0.013	0.030	1.90
BEL	33	32	85.0	0.013	0.029	1.74
RUS	22	19	72.5	0.011	0.023	1.40
JPN	30	32	61.9	0.012	0.030	1.66
GBR	36	35	56.3	0.013	0.030	1.74
KOR	26	28	37.8	0.012	0.027	1.47
ESP	25	23	34.3	0.011	0.024	1.41
HKG	24	21	32.3	0.011	0.022	1.23
IND	28	24	25.7	0.012	0.027	1.46
SWE	16	21	23.3	0.011	0.021	1.15
POL	21	20	22.7	0.011	0.021	1.20
BRA	23	26	22.7	0.011	0.024	1.30
THA	18	22	21.5	0.011	0.020	1.10
AUS	18	18	19.4	0.011	0.020	1.10
TUR	22	15	16.1	0.011	0.021	1.13

Note: Graph based on the 61 TiVA economies and the value of their bilateral gross trade flows in intermediate goods, excluding oil.
Source: Authors' calculation based on COMTRADE data and BEC classification.

The 61 trade partners included in TiVA are ranked according to their "network centrality". The score as "GVC Hub" is compared with their relative performance in terms of timeliness (as measured by the Logistic Performance Index (LPI), a trade facilitation index). An ideal situation would be to have a perfect fit between GVC centrality and trade cost efficiency. If not, the analysis identifies where trade facilitation investments would have the largest global impact. The hypothesis is that investment in upgrading trade facilitation performance will have a large positive spill-over and be highly profitable in terms of global welfare when they improve the situation of a key player.

As indicated in Table 3, the ranking is relatively robust to a change in the type of network indicator used, with the exception a series of cases (among the Top 20, it is the case for Russia, Thailand, Australia, Sweeden, India and Brasil). Our first preference goes for the Page Rank indicator. Citing the creators of this indicator (Brin, S. and Page, L. 1998) and putting their words in a trade context, PageRank can be thought of as a model of trader behaviour: Assuming there is a "random trader" who is given an upstream GVC supplier at random and moves along the trade network, never hitting "back" before eventually reaching the country of final destination. The probability that the random trader deals through a given node is its PageRank. A trading node can have a high PageRank if there are many trade flows that point to it, or if there are only a few nodes that point to it but these nodes have high PageRanks and are very influential. On a more practical basis, we also note that Page Rank tend to be a compromise between other alternatives when there is a large divergence in ranking. For example, the rank based on Page Rank for Russia is 13 compared to the ranking of 8 obtained with "Between-ness" and the ranking of 15 given by "Eigenvector Centrality",

Table 4 Ranking of Top20 GVC hubs according to selected network indicators, 2011.

Hub Label (ISO3)	Rank Betweeness	Rank Closeness	Rank Eigenvector Centrality	Rank PageRank	Memo item: Rank LPI
DEU	1	1	1	1	4
CHN	2	2	2	2	25
NLD	3	5	5	5	5
ITA	4	3	4	3	23
USA	5	4	3	4	9
FRA	6	6	7	6	12
BEL	7	8	9	7	7
RUS	8	13	15	13	57
JPN	9	9	8	9	8
GBR	10	7	6	8	10
KOR	11	10	11	10	20
ESP	12	12	12	12	19
HKG	13	16	16	16	2
IND	14	10	10	11	43
SWE	15	19	20	19	13
POL	16	17	19	17	29
BRA	17	13	13	14	42
THA	18	22	25	22	36
AUS	19	22	24	23	17
TUR	20	19	18	20	26

Source: elaborated on the basis of Table 3

The relative "hub" roles in the world trade network are not set in stone and are expected to reflect global and regional comparative advantages. Some countries may specialize in trading certain type of intermediate products and the relative importance of trade partners may change through time. Similarly, a small country may gain influence by investing in trade and transport facilitation, becoming a key regional or global player.

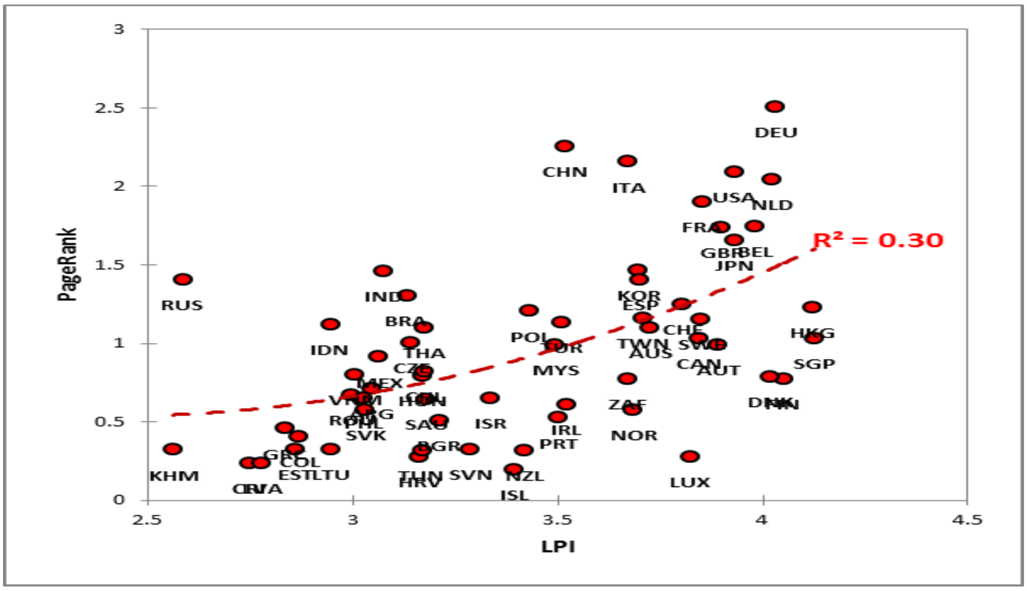
3.3.2 Gains from Trade Facilitation in the World Trade Network

In this section, the centrality indicator calculated on the total trade in intermediate inputs is compared to the Logistic Performance Index (LPI) computed by the World Bank. [21]

The relationship between a high score on LPI and a central role in world trade is positive, but loose (the coefficient of correlation is 0.3). This means that some countries that rank highly in terms of trade do not score very well in terms of overall trade facilitation, imposing both a systemic cost to themselves and to the rest of the trade community (remember that PageRank takes also into account the indirect trade flows to and from direct trade partners). Intuitively, the economies located above the trend curve in the graph have a more important role as GVC hub than their LPI score would predict. They are potential candidates for receiving trade and transport facilitation attention, not from their individual perspective only, but also because of the potential large spill-over effect a bettering of their Trade Facilitation would entail.

21 Logistics Performance Index data are collected through an online survey of operators in charge of moving and trading goods. The international LPI used in this paper analyzes countries in six components: (1) The efficiency of customs and border clearance (2) The quality of trade and transport infrastructure; (3) The ease of arranging competitively priced shipments; (4) The competence and quality of logistics services (trucking, forwarding, and customs brokerage) (5) the ability to track and trace consignments and (6) The frequency with which shipments reach consignees within scheduled or expected delivery times. The six indicators are summarized into the LPI index by using a Principal Component Analysis. The index goes from 1 (worst score) to 5 (best score). Source: World Bank LPI 2015

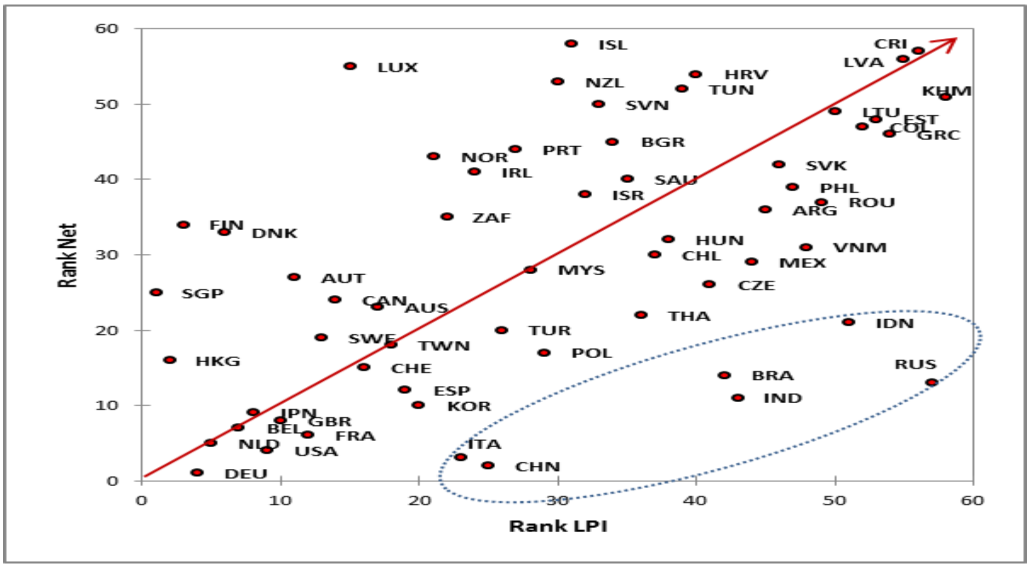
Figure 14 PageRank on trade in intermediate goods vs. LPI index, 2011



Note: the trend line in red colour fits LPI on PageRank for descriptive reasons only and does not imply any causality between the two indicators.
Source: Based on COMTRADE and Wold Bank data.

To provide a clearer idea of the relative positions of economies with regard to their role as GVC-hub vs. their trade facilitation score, economies are ranked according to their respective scores. Ideally, a perfect fit between centrality and trade facilitation would show all countries aligned on the 45° diagonal of Figure 15. This is far from being the case. There is a significant mismatch between the quality of trade and transport facilitation and the role of each economy in the World Trade Network.

Figure 15 PageRank scores vs. LPI index, arranged by rank, 2011



Note: The red line shows the 45° diagonal of equal ranking according to LPI and to PageRank. The dotted ellipse indicates outliers in terms of the PageRank/LPI score matching.
Source: Based on COMTRADE and Wold Bank data.

Improving the LPI score for the economies located below the 45° line would benefit the entire trade community by reducing cumulated trade costs, the farther the point being from the line, the higher the expected benefits. Six countries (among the 61 currently included in the TIVA database) are particularly relevant from this perspective: Indonesia, Russia, Brazil, India, China and Italy. Obviously, this should be considered a secondary priority: the main one remains on the individual country where the highest trade costs have been identified (see section 2.2), where those high additional costs affect the international competitiveness of domestic firms and their capacity to join GVCs and upgrade.

- **Robustness checks**

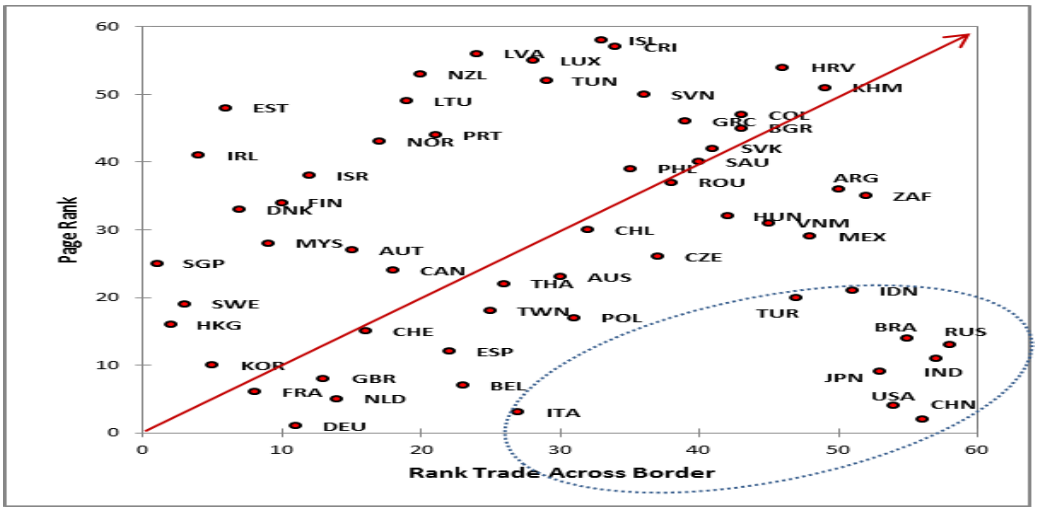
The results obtained in the previous section were checked against alternative indicators for both GVC-trade centrality and trade and transport facilitation. Page Rank was retained because it is based on probabilistic properties that fit better the underlying features of the world trade network (Kandiah, Escaith and Shepelyansky, 2015). An alternative trade and transport facilitation index used was the Trading Across Borders (TAB) indicator, produced by the World Bank as part of its "Doing Business" project. This indicator records the time and cost associated with the logistical process of exporting and importing goods and is based on the time and cost (excluding tariffs) associated with three sets of procedures—documentary compliance, border compliance and domestic transport—within the overall process of exporting or importing a shipment of goods.

There is no significant correlation between Page Rank and TAB (it was 0.3 in the case of the LPI). Therefore, comparing Page Rank and TAB ranks (Figure 16) is much less informative. We still have Indonesia, Russia, Brazil, India, China and (but to a lesser degree) Italy as outliers, but the group is joined by Turkey, Japan and the USA.

Due to the low statistical basis for including those additional three countries, it is safer to remain with Indonesia, Russia, Brazil, India, China and (but to a lesser degree) Italy as good candidates for a short list of countries where additional investments in trade facilitation would bring not only benefits for the country itself and its bilateral trade partners, but also for the entire community.

The expected benefits of implementation of the WTO's Trade Facilitation Agreement (TFA) are significant. The bilateral benefits of trade cost reduction from a "full" implementation of the TFA has been estimated by OECD at 16.5% of total costs for low income countries, 17.4% for lower-middle income countries, 14.6% for upper-middle income countries; and 11.8% for OECD countries. Taken together, these estimates imply that a 1% reduction in trade costs has the potential to increase bilateral trade by between 2.8% and 4.5% (WTO, 2015; G20 TIWG, 2016).

Figure 16 PageRank scores vs. Trading Across Border index, arranged by rank, 2011



Note: The red line shows the 45° diagonal of equal ranking according to Trade Across Border and to PageRank scores. The dotted ellipse indicates outliers in terms of the PageRank/TAB score matching.
Source: Based on COMTRADE and Wold Bank data.

The impact would be even more important for regions suffering from low trade integration due to high intra-regional trade costs. Africa is known to suffer from high trade costs, but unfortunately the TiVA database we used in estimating them does not cover, so far, most African countries. But we can refer to Mevel and Karingi (2012) who estimate, using a CGE model, that intra-African trade would be strongly impacted with the adoption of trade facilitation measures. Indeed, the creation of regional free trade agreements accompanied by more efficient customs procedures and reduction in delays that merchandise spend at African ports, would lead in 2022 to a 128.4% (or $85.0 billion) increase in intra-African trade, as compared to the 2004 simulation baseline. Consequently, the share of intra-African trade would in fact more than double over the next decade passing from 10.2% in 2010 to 21.9% in 2022. Diversification out of traditional exports in intra-African trade would also be significantly expanded, as intra-continental trade in industry would grow the fastest with the trade reforms.

In conclusion, actions taken to reduce trade costs are expected to have significant positive effects on increasing trade flows. While the direct benefits of trade facilitation will be proportionally higher for those countries that are not well integrated into international trade because of their high trade costs, our data suggests also that the global benefits will be higher if trade facilitation investments are undertaken by key traders that lie at the core of global value chains. Akin to lead firms, these are the countries that lie close to the centre of the spider's web of trade in intermediate products. In an increasingly globalized and networked world, facilitating trade in these hub countries would matter as a determinant of the pattern of bilateral trade within and beyond their region as well as of the geographical distribution of investment and production.

BIBLIOGRAPHY

Anderson, J. and E. van Wincoop (2004) 'Trade Costs' NBER Working Paper 10480

Anderson, J. and E. van Wincoop (2003) "Gravity with Gravitas: A Solution to the Border Puzzle," American Econ. Review 93:1, pp. 170-192.

Balassa, B. (1965) 'Tariff Protection in Industrial Countries: An Evaluation' The Journal of Political Economy, vol LXXIII, pp. 573-594, December.

Baldwin, R. and A. Venables (2010) 'Spiders and Snakes: Offshoring and Agglomeration in the Global Economy', Working Paper 16611, NBER.

Borgatti, S. (2005) 'Centrality and network flow', Social Networks Volume 27, Issue 1, Pages 55–71.

Brin, S. and Page, L. (1998) 'The anatomy of a large-scale hypertextual Web search engine'. Computer Networks and ISDN Systems 30: 107–117.

Cella, G. and G. Pica (2001) 'Inefficiency Spillovers in Five OECD Countries: An Interindustry Analysis' Economic Systems Research, 13:4, 405-416

Cernat, L. and Z. Kutlina-Dimitrova (2014) 'Thinking in a Box: a 'Mode 5' Approach to Service Trade' EU-Trade, Chief Economist Note #1, March

Corden, W.M (1966) 'The structure of a tariff system and the effective protection rate' The Journal of Political Economy, vol LXXIV, pp. 221-237, June.

de Palma, A. , R. Lindsey, E. Quinet and R. Vickerman (editors) (2011) 'Handbook of Transport Economics' Edward Elgar Publishing.

Diakantoni, A. and Escaith, H. (2012) 'Reassessing Effective Protection Rates in a Trade in Tasks Perspective: Evolution of trade policy in Factory Asia' WTO Working Paper ERSD-2012-11.

Diakantoni, A. and Escaith, H. (2014) 'Trade in Tasks, Tariff Policy and Effective Protection Rates ' WTO Working Paper Series 2014-22.

Dietzenbacher, E. and I. Romero. (2007) "Production Chains in an Interregional Framework: Identification by Means of Average Propagation Lengths", in International Regional Science Review, 30: 362.

Djankov, S., C. Freund; C-S. Pham (2010) 'Trading on Time' The Review of Economics and Statistics February Vol. 92, No. 1, Pages 166-173.

Duval, Y., A. Saggu and C. Utoktham (2015) 'Value Added Trade Costs in Goods and Services', ESCAP Trade and Investment Working Paper 01

Escaith (2015) 'Closing the gaps between trade theories, trade policies and global production statistics: a practitioner's perspective' Conference of European Statisticians, Geneva, 7 July

Escaith, H. and H. Gaudin (2014) "Clustering Value-Added Trade: Structural and Policy Dimensions", WTO Staff Working Paper ERSD-2014-08.

Escaith, H. and S. Miroudot (2015) 'World Trade and Income Remain Exposed to Gravity', CPER/VoxEU eBook on "The Global Trade Slowdown: A New Normal?" edited by B. Hoekman.

Ferrantino, M. (2012) "Using Supply Chain Analysis to Examine the Costs of Non-Tariff Measures (NTMs) and the Benefits of Trade Facilitation". WTO Staff Working Paper ERSD-2012-02 (Geneva, Switzerland, World Trade Organization).

Fortanier, F. and G. Miao (2016) 'Estimating CIF-FOB margins on international merchandise trade flows', OECD STD/CSSP/WPTGS

Fujimoto, T. and Y. Shiozawa (2011 and 2012) 'Inter and Intra Company Competition in the Age of Global Competition: a Micro and Macro Interpretation of Ricardian Trade Theory' Evolutionary and Institutional Economics Review 8(1) pp. 1-37 for the 2011 volume and 8(2) pp. 193-231 for the 2012 one.

G-20 TIWG (2016) 'Discussion Paper on Monitoring and Reducing Trade Costs', Second Meeting of the Trade and Investment Working Group; 4-5 April, Nanjing, China

Gaulier, G., D. Mirza, S. Turban and S. Zignago (2008) 'International Transportation Costs Around the World: a New CIF/FoB rates Dataset' CEPII, March.

Gereffi, G., J. Humphrey and T. Sturgeon (2005) 'The governance of global value chains' Review of International Political Economy 12:1 February 2005: 78–104

Greenaway, D. and C. Milner (2003) 'Effective Protection, Policy Appraisal and Trade Policy Reform' Research Paper 2003/06, Nottingham University.

Hummels, D. (2007) 'Transportation Costs and International Trade in the Second Era of Globalization' Journal of Economic Perspectives 21-3 pp 131-154

Hummels, D. and G. Shaur (2012) 'Time as a Trade Barrier' NBER Working Paper 17758

Inomata, S. (2008) 'A New Measurement for International Fragmentation of the Production Process" IDE Paper 175, IDE-JETRO
Johnson, R. and G. Noguera (2016) 'A Portrait of Trade in Value Added over Four Decades' NBER Working Paper 22974
Kandiah V., H. Escaith and D. Shepelyansky (2015) 'Google matrix of the world network of economic activities' The European Physical Journal B, pp. 88-186.
Kohler W. (2004) 'International Outsourcing and Factor Prices with Multistage Production' The Economic Journal, Vol. 114, No. 494 Conference Papers pp. C166-C185
Koopman, R., W. Powers, Zhi Wang and Shang-Jin Wei (2010) 'Give Credit Where Credit Is Due: Tracing Value Added in Global Production Chains' NBER w1426
Lavoie, M. (2014) "Post-Keynesian Economics: New Foundations", Edward Elgar.
Lewis, D (1994) 'Freight Mode Choice: Air Transport Versus Ocean Transport in the 1990's' Flight Transportation Laboratory; Massachusetts Institute of Technology.
Los, B. and U. Temurshoev (2012)'Distance-Based Measures of Globalization in a World with Fragmented Production' presentation at the WIOD Conference on Causes and Consequences of Globalization, Groningen, 24-26 April
Low, P. (2013) 'The Role of Services in Global Value Chains', Fung Global Institute, June.
Ma, Alyson C. and Ari Van Assche (2010) 'The Role of Trade Costs in Global Production Networks Evidence from China's Processing Trade Regime' World Bank Working Paper 5490
Mayer, Th. and S. Zignago (2011) 'Notes on CEPII's distances measures: The GeoDist database' CEPII 2011-25
Mevel, S. and S. Karingi (2012) 'Deepening Regional Integration in Africa: A Computable General Equilibrium Assessment of the Establishment of a Continental Free Trade Area followed by a Continental Customs Union' 7th African Economic Conference, Kigali.
Milner, C. 'On natural and policy-induced sources of protection and trade regime bias' Review of World Economics, Vol 132-4 pp. 740-752
Miroudot, S. and H. Nordström (2015) "Made in the World", European University Institute Working Paper RSCAS 2015/60
Muradov, K. (2016) 'Trade costs and borders in the world of global value chains', 19th Annual Conference of Global Economic Analysis, Washington 15-16 June.
Noguera, G. (2012) 'Trade Costs and Gravity for Gross and Value Added Trade', Berkeley and Columbia University Job Market Paper.
Novy, D. (2013) 'Gravity redux: Measuring international trade costs with panel data', Economic Inquiry 51(1), pp. 101-121.
OECD-WTO (2012) 'Trade in value-added: concepts, methodologies and challenges' e-document in 'Made in the World' website.
OECD-WTO *TiVA* database
Rouzet, D. and S. Miroudot (2013) 'The Cumulative Impact of Trade Barriers Along The Value Chain: An Empirical Assessment Using the OECD Inter-Country Input-Output Model', OECD, June.
Samuelson, P. (1954) 'The transfer problem and the transport costs' The Economic Journal 64, 264–289.
Streicher, G. and Stehrer, R. (2015) 'Whither Panama? Constructing a consistent and balanced SUT system including trade and transport margins' Economic Systems Research 27, 213-237
Tamamura C. (2010) 'Cost Reduction Effects of "pseudo FTAs" in Asia -Application of a price model based on a multilateral I/O table' IDE Discussion Papers No 226
Timmer, M P, B Los, R Stehrer and G J de Vries (2016) 'An Anatomy of the Global Trade Slowdown based on the WIOD 2016 Release' GGDC research memorandum number 162, University of Groningen
Wang, Z., S-J Wei, X. Yu and K. Zhu (2015) 'Characterizing Global and Regional Value Chains' preliminary version, mimeo, December
WTO (2015) 'World Trade Report 2015; Speeding up trade: benefits and challenges of implementing the WTO Trade Facilitation Agreement'
WTO 'Integrated Data Base' http://www.wto.org/english/res_e/statis_e/statis_e.htm
WTO 'World Trade Profiles' http://www.wto.org/english/res_e/statis_e/statis_e.htm
WTO; IDE-JETRO (2011) 'Trade patterns and global value chains in East Asia: From Trade in Goods to Trade in Tasks' (Geneva, Switzerland, World Trade Organization and Tokyo, Japan, IDE-JETRO).
Yi, K-M. (2003) 'Can Vertical Specialization Explain the Growth in World Trade?' in *Journal of Political Economy* 111: 52-102.

ANNEX 1 – INPUT-OUTPUT MEASURE OF TRADE IN VALUE ADDED

Measuring Trade in Value-Added is a "simple" extension of the method used to calculate Gross Domestic Product from the supply (production) side of the GDP identity. GDP is the sum of the value-added produced by each industrial sector and calculated by identifying and subtracting from the sectoral output the value of all intermediate consumptions, be they purchased from other domestic industries or imported. Identifying the sectoral origin of these intermediate consumption allows to build Supply-Use Tables (product x industry) and Input-Output Matrices (industry x industry). Value-Added is the difference between the cost of intermediate inputs and the sale of the output. Value-Added covers the remuneration of employees and investors, plus the net effect of indirect taxes and subsidies.

The coefficients of the Input-Output Matrix, called technical coefficients, are derived by normalizing the value of intermediate consumption Z_{ij} by the value of total production

$$(a_{ij} = Z_{ij}/X_i) \qquad \text{[A1.1]}$$

Where Z_{ij} is the intermediate consumption of products from sector i by j (i and j being possibly in different countries) and X_i is the total production of sector i. Those technical coefficients form the basis of the calculation of the EPRs presented above in the paper. They represent the direct requirements of inputs from "i" for producing one unit of output of industry "j". For example, to produce one unit of output, sector *2* will require a_{12} units from sector *1*.

The technical coefficients tell only part of the story of the productive chain. In order to be able to produce the a_{12} units demanded by sector *2*, the productive sector *1* will need inputs from other sectors. To satisfy this endogenous demand created by one additional unit of output in sector *2*, individual firms in each other connected sectors will also require inputs produced by suppliers operating from other sectors. And so on and so forth, as the indirect demands generated at each step create in turn additional requirements.

Provided that $a_{ij} \geq 0, \forall\, i \; and \; j$ and $\sum_i a_{ij} < 1$ the feedback sequence resulting from the initial demand injection can be obtained by the series

$$\boldsymbol{I} + \boldsymbol{A} + \boldsymbol{A}^2 + \boldsymbol{A}^3 + \ldots + \boldsymbol{A}^n = [\mathbf{I}\text{-}\mathbf{A}]^{-1} \qquad \text{[A1.2]}$$

Where $\boldsymbol{I}$ is an identity matrix representing the initial demand injection and $\boldsymbol{A}^n$ is the progressive impact of initial demands at the n^th stage of the production chain. When n tends to infinity, the series has a limit equal to $\boldsymbol{L}$**.** The coefficients of the Leontief Inverse $[I\text{-}A]^{-1}$ measure the depth (intensity) of the backward linkages between sectors. They describe entirely the direct and indirect flows of intermediate products involved by the productive chains.

Producing final goods (Y) requires intermediate goods, themselves requiring other inputs and so on and so forth, as in equation [A1.2]. Total production (X) is the sum of those final goods and the required inputs. Starting from a single country perspective (OECD-WTO, 2012):

$$\mathbf{X} = \mathbf{AX} + \mathbf{Y} \qquad \text{[A1.3]}$$

Often written (after rearranging terms):

$$\mathbf{X} = [\mathbf{I}\text{-}\mathbf{A}]^{-1}\,\mathbf{Y} \qquad \text{[A1.4]}$$

where:

X: is an n*1 vector of the output of n industries within an economy.

A: is an n*n technical coefficients matrix; where a_{ij} is the ratio of inputs from domestic industry i used in the output of industry j.

I: is the diagonal n*n identity matrix

Y: is an n*1 vector of final demand for domestically produced goods and services (final demand includes consumption, investment and exports) and AX results in a vector of direct and indirect intermediate inputs required for producing Y.

A country's total value added can be split in two parts: one is the VA embodied in goods and services absorbed domestically (consumption and investment), the other is the VA embodied in its exports. One can estimate the total indirect and direct contribution of exports to domestic value-added as :
VAE: $\mathbf{V}\,(\mathbf{I\text{-}A})^{-1}\mathbf{E}$ [A1.5]

V: vector of value-added ratio, with $V_j = [1 - \sum_i a_{ij}]$.
E: vector of exports by industry to the rest of the world.

ANNEX 2 – MEASURING THE LENGTH OF GLOBAL VALUE CHAINS AND THE NUMBER OF BORDER CROSSINGS

The analysis of trade costs embodied into multi-stage international production processes is often carried out using international input-output models. The calculation has been made possible by the availability of the underlying IO tables: Koopman, Powers, Wang and Wei (2010) estimate the cumulated effect of transportation and tariff margins GTAP Multi-Country Input-Output tables; Tamamura (2010) uses the IDE-JETRO international tables to estimate the impact of regional trade agreements. Length is most often estimated using the concept of average propagation length (APL) applied at the international level in Dietzenbacher and Romero (2007) for major European countries and by Inomata (2008) for Asia.

APL represents the average number of production stages lining up in every branch of all the given supply chains. It is a short hand representation for an industry's level of fragmentation which relies on the weighting of "distance index" by successive powers "k" of the technical coefficient matrix **A**. **A**^{k}s are regarded as progressive impacts of the initial demand when supply chains are sliced at the kth stage of the production process. APL is defined as:

$$APL_{j-i} = 1 * \frac{a_{ij}}{(l_{ij}-\delta_{ij})} + 2 * \frac{[A^2]_{ij}}{(l_{ij}-\delta_{ij})} + 3 * \frac{[A^3]_{ij}}{(l_{ij}-\delta_{ij})} + \cdots \qquad [A2.1]$$

where l_{ij} is Leontief inverse coefficients $[I-A]^{-1}$, δ_{ij} is a Kronecker delta product which is $\delta_{ij} = 1$ if $i = j$ and δ_{ij} =0 otherwise.

In other words, APL is the weighted average of the number of production stages, where an impact from industry j goes through until it ultimately reaches industry i, using the strength of an impact at each stage as a weight. By construction, APL shows a rapidly decaying effect after the second round, due to the low value of the non-diagonal coefficients in the Leontief. As a result, the value of the additional element of the APL suite [A1.7] falls rapidly to zero after the second production stage. Actually, the fact that the **A**^{k}s tend to zero when k increases is actually a condition for the suite to converge to the Leontief inverse [**I**-**A**]$^{-1}$, a results central to most GVC indicators. The smaller the value of extra-diagonal technical coefficients, the faster is the convergence to zero.

This is particularly true for the international coefficients (those outside the block-diagonal matrices representing the domestic inter-industrial exchanges) and reflects the fact that most nations are largely self-sufficient in terms of intermediate inputs. Therefore, the foreign component of **A**^{k} (coefficients outside the bloc-diagonal of domestic industries) is rapidly insignificant from an economic perspective when k increases. [22] Even in China or Mexico, two economies that built their

[22] This is true for the industry average which is represented in an input-output matrix. This average is prone to aggregation bias and export-oriented industries may be much more reliant on imported inputs than the

export diversification strategy on GVCs, the weight of foreign inputs in their gross exports is about 32%. At k=3, the resulting weight in $\mathbf{A}^k$ is barely above 1% and falls almost to 0 at k=4. [23] This is also true for other measures of GVC length derived from the input-output matrix.

The length of the GVCs can be factored in by using geographic distance or monetary transportation costs between two inter-related industries instead of counting production stages as in the APL formulation shown in [A1.7]. This calculation was suggested by Los and Temurshoev in 2012. Once we know the distance between the supplying firm and its clients (d_{ij}), we can use a vector of input-weighted distance from customers to suppliers to provide a geographical distance (d_{ij} is in kilometres) or an economic one (if d_{ij} is in monetary terms). The distance covered by the global value chain between its initiation and the final consumer is given by:

$$\mathbf{D}: \quad (\mathbf{I}\text{-}\mathbf{A'})^{-1}\, \mathbf{D}^* \qquad [A2.2]$$

D* being a diagonal input-weighted matrix of supplier-to-client distance by industry and country.[24]

Miroudot and Nordstöm (2015) adapt this methodology to measure the length of the external network of suppliers, sourcing the distance from the GeoDist database maintained by CEPII (Mayer and Zignago, 2011). Wang et al. (2015) intend a synthesis of the various backward and forward measures by defining a GVC position index based on a thorough decomposition of the contribution of each production stage to the total value. Their index measures the distance from any production stage between the final demand and the initial factor inputs in a production line by a combination of production linkages based on both forward and backward linkages. Actually, the length of the international part of supply chains (the one being subject to cumulative tariff and transportation costs) varies from country to country and sector to sector. Muradov (2016) proposes a new approach to quantify the accumulation of trade costs and the average number of backward and forward border crossings. His methods relies on the use of an alternative to the Leontief matrix to compute a "global" inverse, disaggregating ex-ante (intead of ex-post, as in other approaches) the diagonal and off-diagonal blocks corresponding to, respectively, domestic and international transactions in the **A** matrix.

Overall, the total number of production stages (i.e., involving the participation of several industries) using backward and forward linkages is relatively small (the TiVA average is about 2 stages when all good and services industries are covered, 12% of the second stage taking place in a foreign country). Yet, as mentioned in Box 3, the weight of the international share in the case of vertically specialised exporting firms may be much underestimated because traditional input-output tables aggregate both export-market and domestic-market oriented firms.

The more complex decomposition proposed by Wang et al. (2015) goes further by distinguishing between pure domestic, directly traded, and indirectly traded production activities. Their index redefines both the forward and backward participation index by considering not only export production, but also production that satisfies domestic final demand through international trade. While the total production length mains relatively low (2.05 in 2011), the part which is specific to a GVC goes almost to 5 and has been increasing steadily since 2002 (except for a break in 2008-2009). Murakov (2016) tries also to overcome the shortcomings of the tradition approach and

average domestic firm. This can be observed in the TiVA database that distinguish several types of firms in the case of China and Mexico.

[23] And our back-of-envelope calculation raising to power k the sum of foreign weights "*aij*" is already optimistic: $(\sum aij)^k > (\sum aij^k)$

[24] For each domestic industrial sector, an average distance to international supplier is calculated, weighting the distance to the supplier's country by its share in the total inputs imported by the domestic industry. From a purely international trade perspective, domestic inter-industry commerce should be set to 0 (the distance between two domestic firms is nil), but this is an oversimplification when it comes to some developing countries, where most population lives on the coastal area and in-land transportation is more expensive than international freight.

estimates that the average number of border crossings rose from 1.8 in 2001 to 1.9 in 2010. The longest chains are those travelled by mining products and basic metals (about 2.4 border crossings) while food and beverage or footwear products remain fundamentally done in short supply chains (about 1.5 border crossing).

ANNEX 3 MEASURING PRICES AND IMPUTING TRADE MARGINS IN AN INTERNATIONAL INPUT-OUTPUT FRAMEWORK

The input-output system as described by national accounts does not distinguish quantities and prices: the technical coefficients are values (quantity x prices) measured at basic prices. Those basic prices reflect as closely as possible the factory-gate prices and, in an international input-output context, do not include international and domestic trade margins or indirect taxes (tariff duties and other indirect taxes). [25] Muradov (2016) extends Streicher and Stehrer (2015) to disaggregate the full chain of calculation for an imported good between factory-gate basic price at the origin and purchasers' price at the destination market:

> The chain starts with a basic producer price at the gate of the exporting country factory, to which are applied indirect taxes (less subsidies) when the product is sold domestically (those taxes are usually drawn-back if the product is exported). Domestic freight costs within the country of origin are added to the producer price to obtain the FOB price. The product is then shipped, adding international trade and transport margins to the FOB price to obtain the CIF valuation. In the country of destination, this CIF price is augmented by tariff duties applying on imports plus net domestic taxes (less subsidies). Domestic trade and transport margins are added to this price at the border in order to obtain the purchasers' price.

According to the international standards used for the compilation of the data used to build input-output, imported goods are valuated at their FOB prices and additional cost due to tariffs is not reflected in the related input-output coefficients. So, foreign inputs (superscript "f" in equation [13]) are measured at their international "frictionless" cost (if we discard the trade margins generated in the country of origin). On the other hand, the EPR theory assumes that the domestic prices of tradable goods are influenced by the rate of nominal protection on competing inputs. Therefore, the farm-gate (or basic) price of these domestic goods embodies the effect of these trade margins. So we need to correct the price of domestic inputs and outputs in order to estimate the hypothetical prices in absence of trade cost in order to compute the denominator of equation [13] (value added at international prices, or V^*_j). Similarly, we need to add the effect of trade margins on the cost of imported inputs in the numerator of equation [13] but not add them on the unit cost of output or domestic inputs, which should remain equal to 1 at domestic prices.

The different implications on imputed prices when the input-output coefficients are calculated at basic prices lead to rewriting equation [13] in the following way:

Let's call $\hat{a}^f_{ij}$ and $\hat{a}^h_{ij}$ the *observed* value at basic domestic price of intermediate consumption "i", from, respectively, foreign and home country required to produce one unit of output "j". From the way basic prices are calculated, and under the hypothesis of a full pass-through of nominal trade protection to domestic prices, we can relate the observed $\hat{a}_{ij}$ to the purchaser price a_{ij} and a^*_{ij} at, respectively, domestic and international prices.

$$\hat{a}^f_{ij} = a^{*f}_{ij} = a^f_{ij} / t_i \quad \text{and} \quad \hat{a}^h_{ij} = a^{*h}_{ij} \,.\, t_i = a^h_{ij} \;;\; t_i \geq 1 \qquad [A3.1]$$

- a^{*h}_{ij} being the hypothetical purchase cost of domestic inputs if the competing imported products had entered the domestic economy without tariff and non-tariff trade (*t&t*) cost.

[25] In a purely national IO table, the cost of imports would be calculated on a CIF. When compiling international IO tables, the FOB/CIF margin is redistributed between trade partners and imports are imputed at their FOB value.

- t_i being the nominal *t&t* protection coefficient (one plus the ad-valorem rate) on inputs purchased from sector "i".

Because $t_i \geq 1$ (tariff duties are not negative), $a^{*h}_{ij} \leq a^{h}_{ij}$ **.** Similarly, the implicit producer price p_j of output "j" is the international price plus the nominal *t&t* protection coefficient. Without this nominal protection, the price of "j" would become:

$p^*_j = p_j / t_j, \; t_j \geq 1$ [A3.2]

In other words, under normal market conditions, because of nominal protection, the domestic firm would not be able to sell it product at the same price on the international market. It would have to reduce its mark-up margin in proportion of the protection received. Distinguishing between the costs of domestic (superscript "*h*") and foreign inputs (superscript "*f*") the estimated EEPR expressed in terms of observed input-output basic prices becomes:

$$\widehat{EEPR}_J = \frac{1-\left[\sum_i \llbracket(t\rrbracket_i . \hat{a}^{f}_{ij}) + \sum_i \llbracket \hat{a}^{h}_{ij})\right]}{\frac{1}{t_j} - \left(\sum_i \hat{a}^{f}_{ij} + \sum_i \frac{\hat{a}^{*h}_{ij}}{t_i}\right)} \qquad \text{[A3.4]}$$

$\hat{a}_{ij}$ being the observed input-output coefficient at basic prices and $1/t_j$ the internal price of the one unit of domestic output.

ANNEX 4 - METHODOLOGICAL SHORTCOMINGS

This annex, based on Diakantoni and Escaith (2012) discusses some of the theoretical shortcomings affecting the use of tariff and transportation costs in evaluating competitiveness.

- **EPR's theoretical shortcoming in a general equilibrium context**

After their formulation in the 1960s, EPRs gained rapidly a wide audience, and became regarded not only as a key indicator of the structure of protection, but also as a predictor for policy appraisal, in particular in developing countries. Yet, theoretical criticisms arose almost as quickly as the EPR theory had emerged. A key assumption of EPRs when used as predictors (and not as descriptors) is the Leontief hypothesis of fixed coefficients in the production function, as it is implicitly the case in the Leontief model, which assumes perfect complementarity between production factors. While this assumption has some validity in short-term economics, it is no more the case when long-term effects have to be modelled.

In a general equilibrium context, two forces counteract to reduce the "effectiveness" of EPRs as predictors: substitution and scale effects. The possibility of substitution widens the choices open to each industry. When the domestic price of a domestic product rises, its demand will be lower; the greater the substitution effects, the faster demand shifts to lower-priced products. The situation is even more complex when traded and non-traded goods and services are substitutes. [26] Thus, the effective positive protection provided to the priority sectors will be overstated by the EPR formula, while it will be the opposite for negative EPRs. Moreover, when primary and intermediate inputs are substitutes, effective protection may lead to changes in the relative costs of labour and capital across the board, inducing further substitution effects. Finally, in the presence of significant scale effects, the lower demand resulting from higher nominal protection may reduce production volumes and

[26] For example, in agriculture production, it is possible to replace the use of herbicides used for controlling weeds by employing more labour.

increase production costs per unit in such a way as to considerably mitigate (or even reverse) the intended subsidy on the sectorial value added. [27]

Despite these shortcomings, effective rate of protection remains widely used by practitioners and policy analysts. There are several reasons behind EPR resilience:

- First, EPRs remain a synthetic descriptor of the past or present arbitrages caused by the applied tariff schedule on each sector of the economy. The Input-Output (I-O) matrix observed at a certain point of time is the outcome of the resources and technology available at that time, plus the end result from all the substitution effects that took place due to changes in relative prices and in the nominal tariff structure.
- Second, the standard definition can still apply to partial equilibrium economic models, often used by applied economists, which legitimizes the approach for trade policy analysis (Ruffin, 2008).

- **EPR's microeconomics shortcomings**

A key assumption for measuring the implication of trading costs is that those costs are (i) fully reflected in the selling price (full pass-through) and (ii) domestic competitors will raise their own price to increase their profit margin. Heterodox economists would rather criticise the implicit assumption of a single "market price" for internationally tradable goods and the underlying hypothesis of profit maximization which means that the price of domestically produced tradable goods will rise in line with the nominal *t&t* protection granted against the competition of substitutable imported goods.

For most heterodox economists, in particular the Post-Keynesian school (Lavoie, 2014) or Neo-Ricardian ones (Fujimoto and Shiozawa, 2011/2012), prices are formed by adding a mark-up to production costs. Therefore, the domestic price of locally produced goods should increase only in proportion of the additional production cost of imported inputs. This cost-push effect is expected to be considerably lower than the full nominal protection granted on competing imports: The sum $[\Sigma t_{i.} a^{h}_{ij}]$ in the EPR equation is now close or equal to zero and the resulting EPR is higher than in the conventional "mainstream" approach.

Confronted to higher tariffs and non-tariff costs on their market of destination, lead firms may decide to lower their profit margin (no impact on the domestic price of the imported goods). Similarly, domestic competitors may decide to forego the possibility of inflating their gross margin (value-added) by the amount of nominal protection and increase their market share by under-pricing the competing imports. In the extreme, situation may vary from industry to industry and no general conclusion can be derived from trade costs and tariff schedules.

This heterodox view may not be far away from the mainstream new "new" trade theory that emphasizes firm heterogeneity and the semi-oligopolistic market structure of "trade in varieties". Here too, the economists' contribution boils down to empirical research based on micro-data at firm level. Nevertheless, most economists would probably agree that firms in semi-industrialised countries act more as price takers and adjust their output price in function of the competing imports. Thus, EPRs would remain empirically valid at least in the case of developing economies.

[27] Remember that value added is a residual, calculated as the difference between the market value of the output and the cost of production, excluding primary inputs (labour and capital). When there are positive returns to the scale of production, the value added by unit of product increases as production expands.

ANNEX 5 –SECTORS AND PARTNERS USED IN THE OECD ICIO TABLE 2015

Sector	Industry Description
001	Agriculture, hunting, forestry and fishing
002	Mining and quarrying
003	Food products, beverages and tobacco
004	Textiles, textile products, leather and footwear
005	Wood and products of wood and cork
006	Pulp, paper, paper products, printing and publishing
007	Coke, refined petroleum products and nuclear fuel
008	Chemicals and chemical products
009	Rubber and plastics products
010	Other non-metallic mineral products
011	Basic metals
012	Fabricated metal products
013	Machinery and equipment, nec
014	Computer, Electronic and optical equipment
015	Electrical machinery and apparatus, nec
016	Motor vehicles, trailers and semi-trailers
017	Other transport equipment
018	Manufacturing nec; recycling

Country	ISO
Argentina	ARG
Australia	AUS
Austria	AUT
Belgium	BEL
Brazil	BRA
Brunei Darussalam	BRN
Bulgaria	BGR
Cambodia	KHM
Canada	CAN
Chile	CHL
China	CHN
Colombia	COL
Costa Rica	CRI
Croatia	HRV
Cyprus	CYP
Czech Republic	CZE
Denmark	DNK
Estonia	EST
Finland	FIN
France	FRA
Germany	DEU
Greece	GRC
Hong Kong, China	HKG
Hungary	HUN
Iceland	ISL
India	IND
Indonesia	IDN
Ireland	IRL
Israel	ISR
Italy	ITA
Japan	JPN

Country	ISO
Korea, Republic of	KOR
Latvia	LVA
Lithuania	LTU
Luxembourg	LUX
Malaysia	MYS
Malta	MLT
Mexico	MEX
Netherlands	NLD
New Zealand	NZL
Norway	NOR
Philippines	PHL
Poland	POL
Portugal	PRT
Romania	ROM
Russian Federation	RUS
Saudi Arabia, Kingdom of	SAU
Singapore	SGP
Slovak Republic	SVK
Slovenia	SVN
South Africa	ZAF
Spain	ESP
Sweden	SWE
Switzerland	CHE
Chinese Taipei	TWN
Thailand	THA
Tunisia	TUN
Turkey	TUR
United Kingdom	GBR
United States of America	USA
Viet Nam	VNM

Source: OECD ICIO