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Trade costs, trade performance and global value chains

Arnold Njike Oya

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DE L'UNIVERSITÉ PSL

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Trade costs, Trade performance and Global value chains

Soutenue par

Arnold NJIKE

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L'Université Paris-Dauphine n'entend donner aucune approbation ni improbation aux opinions émises dans les thèses; ces opinions doivent être considérées comme propres à leurs auteurs.

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General Introduction

In 1970, according to World bank data, the total exports of goods and services represented approximately 13.5 % of world GDP. Since then, this share has continuously increased to represent 30 % in 2018. As international transport costs, tariffs and other commercial barriers decreased throughout this period, countries found it more and more profitable to trade with each other. This is no surprise since all the theoretical models demonstrate that trade is more profitable than autarky. The asserted gains of trade are generally in term of price and variety. Said otherwise, through trade, countries can consume more of the same goods they could have produced in autarky and also different other varieties of goods that they could not have produced their selves.

Many authors tried to quantify the magnitude of these gains in recent years. [Bernhofen and Brown \(2005\)](#), for instance, used as a natural experiment the opening of Japan to world trade in the 19th century to assess the magnitude of the gains from trade. They estimated that the gains from the trade liberalization were at most 8 to 9 % of GDP. [Irwin \(2005\)](#) did a similar exercise in assessing the welfare cost of the Jeffersonian trade embargo between December 1807 and March 1809 in the United States. He estimated the welfare loss to be about 5 % of GNP. One of the most comprehensive work is the paper of [Costinot and Rodríguez-Clare \(2014\)](#) who, assuming different market structures and taking into account the existence of multiple sectors and trade in intermediate goods, estimated that a move to autarky would imply on average between 27 % and 40 % of real income decrease for the 33 countries of their data set.

The welfare gains from trade are thus undeniable. This justifies the reduction in tariff and non-tariff barriers that we observed in the last 30 years following the vague of unilateral and multilateral trade liberalizations triggered notably by the Tokyo round or the Uruguay round, and which led us to the current era of globalization. One of the main consequences of this phenomenon is the fragmentation of the production process. If countries were specialized in products in the past, thanks to low tariffs, low transports costs and differences in technology, they are rather specialized in specific tasks as of today. It means that many firms find it more profitable to outsource or externalize some tasks

required to produce a good to other firms in other countries so that they focus on a core activity realized with the highest degree of efficacy.

As goods became increasingly complex, the necessity of fragmenting the production process for many firms has become an imperative because of the cost and the difficulty to master every step of the production process of a good from the upstream to the downstream. This explains the wave of offshoring that has occurred since the end of the 20th century for many western companies to take profit from low labour costs, notably in East Asia. The extent of this phenomenon has been quite significant, especially in Europe, Asia and America, but less in Africa. As a matter of facts, according to [Johnson and Noguera \(2012\)](#), the value-added to gross exports ratio, which is the share of value-added in a unit of good that is exported, was on average 78 % for the 16 African countries of their data set in 2004, while it was 64 % for East-Asian countries and 70 % for western European countries. It means that on average, 30 % of the value of the exported goods from Western Europe come from other countries, while it is only 22 % for Africa.

This lower participation of African countries in the global value chains and more generally to international trade is often explained by many factors among which the importance of their level of trade costs. Whether it is the lack of qualitative transport infrastructures tied to the geography of the continent, the time in transit from the factory to the gate of expedition or even the remoteness from the most extensive economic markets, African countries are known for their high level of trade costs. See [Bosker and Garretsen \(2012\)](#), [Freund and Rocha \(2011\)](#), [Buys et al. \(2006\)](#), [Limao and Venables \(2001\)](#), [Amjadi and Yeats \(1995\)](#).

High trade costs are even more critical when it comes to being involved in the international fragmentation of the production process. As [Koopman et al. \(2014\)](#) or [Yi \(2003\)](#) showed, a small reduction in tariffs can have magnified and non-linear effects on the growth of trade. This is due to the fact that for a good to reach its final state, its components need to cross the borders of many countries as many times as required to complete the production process. A one-percentage-point tariff reduction on trade is, therefore, logically amplified.

Low tariffs and transport costs thus represent critical requirements to participate effectively in the world production network and consequently, increase the level of exports. While decreasing tariffs is a matter of political will and can be implemented with more or less ease, decreasing transport costs is much more complicated, especially for countries suffering from a blatant lack of transport infrastructures or huge geographical constraints. Are the countries facing this kind of difficulties, therefore, condemned to low levels of exports? Said differently, is it possible to export as much as other countries despite facing higher levels of trade costs? Furthermore, as participating more in the global value chains

is among the key priorities of policymakers in many developing countries today, what can they precisely expect in term of welfare gains?

Providing answers to these questions is essential for many reasons. First of all, extreme poverty is still a widespread issue in many developing countries. While the most recent estimates of the world bank indicate that only 10 % of the world's population lived under 1.90 \$ per day in 2015 in comparison to 36 % in 1990, this reduction has not been even across regions. In fact, the number of extreme poor has increased instead of diminishing in Sub-Saharan Africa, which is now home to more than half of the extreme poor. In East-Asia, though, this number has substantially decreased along with an increasing integration through trade in the global economy and sustained economic growth. As have shown [Frankel et al. \(1996\)](#) specifically for the case of East-Asia and many other studies in general (See [Singh \(2010\)](#) for a survey), trade is highly likely among the main drivers of this economic growth and consequently of poverty reduction in this part of the world. If condemned to low levels of trade because of their high level of trade costs, tackling extreme poverty would, therefore, be even more difficult for the concerned countries.

Secondly, as theoretical trade models predict, trade is inversely proportional to the distance between countries. As a result, in most regions in the world, intra-regional trade represents the highest share of their total trade. For instance, according to data from UNCTAD 69 % of European exports were sent to fellow European countries, while the share is 56 % for America, 61 % for Asia but only 15 % for Africa in 2018. The lack of qualitative transport infrastructures, as mentioned earlier, certainly plays a role in explaining this low share of intra-regional trade in Africa. Specifically, the road quality is pretty bad in most African countries, especially sub-Saharan African countries¹. With 16 landlocked countries in the continent over 54 countries, the road transport network undoubtedly plays a critical role in explaining the low intensity of intra-regional trade.

Improving it is thus essential to stimulate intra-regional trade in Africa. Except this continent, other regions in the world face high intra-regional trade costs but need for various reasons a good level of intra-regional trade. It is for instance the case of Brazil, which has a vast territory and needs strong economic linkages between its states to occupy and ensure control over its whole territory. This is especially critical for its Amazonian region which is often perceived by the international community as an ecological reserve for humanity. Developing economic linkages through trade between this region and the rest of the country is thus of geostrategic interest. However, as it is far from the economic

¹According to the world economic forum, in 2017, 15 out of the 37 worse countries in term of road quality were from sub-Sahara Africa.

centre and not very well served by transport infrastructures, this could be complicated to achieve. Due to all these considerations, it is, therefore, interesting to determine whether it is possible to be internationally or intra-regionally export efficient despite facing a high level of trade costs.

Thirdly, although the international production network is increasingly fragmented, it is not straightforward to determine accurately up to what extent this phenomenon increase the welfare gains of trade. Most of the studies that are interested in this matter use a framework in which they allow for trade in intermediate goods to calculate the welfare gains of trade. We can cite, for instance, [Caliendo and Parro \(2015\)](#) or [Costinot and Rodríguez-Clare \(2014\)](#). By using their framework, the welfare gains thereby obtained embed the share related to international fragmentation. However, the net share of fragmentation in the welfare gains cannot be properly determined. As the welfare gains of trade are inversely proportional to the share of domestic trade in intermediate goods, one should be able to determine properly this share in order to assess reliably the contribution of international fragmentation in the welfare gains.

Standard trade models as those presented in the two previous papers generally highlight the share of direct domestic trade in intermediate goods, however, international fragmentation implies also an indirect share which appears when a country exports its intermediate inputs to third countries which are later exported back by the latter to the origin country embedded in their final goods exports. Calculating the net contribution of international fragmentation in the welfare gains of trade would requires identifying this share of indirect domestic trade in intermediate goods which is not highlighted in the previous models. [Fally and Hillberry \(2018\)](#) use an approach that allow them to quantify the impact of fragmentation on the welfare gains of upstream and downstream countries, but they do not explicitly estimate the net contribution of fragmentation in the welfare gains of trade. Providing a clear answer to this question is, therefore, of great interest.

We discuss these questions in three different chapters. In the first one, we study the intranational trade performance of the state of Amazonas in Brazil, divided into two distinct entities among which one host a Free trade zone. More precisely, as this state is located far from the economic centre of the country and not well served by transport infrastructures, we try to determine whether despite these considerations it succeeds in exporting intranationally at least as much as other Brazilian states. To do so, we build upon stochastic frontier analysis; an econometric method developed independently by [Aigner et al. \(1977\)](#) and [Meeusen and van Den Broeck \(1977\)](#). This method allows us to determine the trade performance of each Brazilian state as regards their exports to each of their partners, thus avoiding the fairly criticized method of calculating trade potentials. We also use more

conventional estimators such as the Poisson pseudo maximum likelihood estimator in order to assess the intensity of intra-national exports in comparison to international exports for each Brazilian state, which is another measure of intra-national trade performance; or to measure the real level of trade costs for each state.

In the second chapter, we assess the trade performance of African countries. As we mentioned earlier, many studies² have already established that African countries export less than the other countries of the world and that it is related to their lack of qualitative transport infrastructures. We reassess these conclusions using the latest advances in the literature regarding the estimation of trade flows to check whether they still hold. Specifically, we use the Poisson pseudo maximum likelihood estimator to estimate the trade equation for bilateral gross trade flows and, after disentangling these flows into intermediate and final goods bilateral exports, we assess whether there is a penalty regarding African trade flows. On top of that, as policymakers are more interested in value-added trade flows which are directly related to GDP, we formulate and estimate a model for value-added exports so as to assess whether with this variable the trade performance of African countries remains low in comparison to other countries.

In the last chapter, considering the fact it is difficult to determine reliably the net contribution of international fragmentation in the welfare gains of trade using standard trade models that are based upon gross exports³, given that they do not explicitly allow the identification of the share of indirect domestic trade in intermediate goods, we propose a model based upon value-added exports that allows us to do so. More precisely, using the gravity model for value-added exports developed in the previous chapter as a building block, we formulate a general equilibrium model that is solved in change following the exact hat algebra of [Dekle et al. \(2008\)](#). Then, we calculate the welfare gains of trade in comparison to a move to autarky or following any given trade shock and we obtain the net contribution of fragmentation in the welfare gains. This net contribution is calculated as the sum of the gains related to direct trade in intermediate goods and indirect trade in intermediate goods in the total welfare gains of trade. The model also allows us to assess how trade costs influence the participation of countries in the global production chain and their position as upstream or downstream countries.

Our results suggest that a high level of trade costs is not redhibitory for trade performance. Particularly, we found that despite facing among the highest levels of trade costs in Brazil

²See, for instance, [Freund and Rocha \(2011\)](#), [Buys et al. \(2006\)](#), [Lima and Venables \(2001\)](#), [Amjadi and Yeats \(1995\)](#).

³By standard trade model, I refer to [Anderson and Van Wincoop \(2003\)](#), [Chaney \(2008\)](#), [Eaton and Kortum \(2002\)](#) or other variants such as [Caliendo and Parro \(2015\)](#).

as evidenced by their exporter multilateral resistance terms, Manaus and RAM (Rest of Amazonas), the two entities composing the state of Amazonas, were among the top performers in term of intra-national exports in Brazil in 2008. We also found evidence that a high share of manufactured value-added as a percentage of GDP exerts a positive impact on trade efficiency. As Manaus, where the free trade zone (FTZ) is implanted, presents the highest share of manufactured value-added as a percentage of GDP in Brazil, a share mainly attributable to the firms of the free trade zone, it suggests that the FTZ plays a role in explaining this situation.

In addition, we found that African countries exports are not as weak as it is suggested by the literature despite the high level of trade costs they undoubtedly face. In fact, when it comes to gross exports, our results suggest that they do not export less than the average country in the world when the Poisson pseudo maximum likelihood is used. The same conclusion goes for their intermediate goods exports, but not for their final goods exports for which they are clearly under-performing. Moreover, we found that the impact of trade costs on African countries exports is higher, especially as regards their final goods exports. Nevertheless, when the independent variable is expressed in value-added terms, this supplementary impact is 6 times lower; meaning that African value-added trade flows are less sensitive to trade costs than their final goods trade flows. This result is due to the integration of the “cost of fragmentation” in the value-added trade equation, that is the sum of trade costs of third countries through which the value-added of the origin country passes to reach its final destination. This “cost of fragmentation” plays a critical role in the third chapter as it allows us to identify the net contribution of fragmentation in the welfare gains of trade.

As our evidence suggests, the net contribution of fragmentation in the welfare gains of trade is not that high, at least in comparison to the gross contribution. By defining this net contribution as the sum of the gains related to direct trade in intermediate goods and indirect trade in intermediate goods, which is related to the above-mentioned cost of fragmentation; we show that turning off trade in intermediate goods would reduce welfare by approximately 3.5 percentage points on average only, a figure way lower than what would suggest a classical trade model. This represents 24 % of the average welfare gains of trade, while a classical trade model would predict a share of 51 % for the gains related to international fragmentation. We also show that the total welfare gains from trade are different using our model than what could predict a classical one, especially for upstream and downstream countries. Specifically, they are 8.5 percentage points higher for the most downstream countries and 5 percentage points lower for the most upstream ones; a result in line with the findings of [Fally and Hillberry \(2018\)](#).

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Chapter 1

Import Processing zones : Tools for regional economic integration ? The case of the Free Trade Zone of Manaus (Brazil)

Abstract: Characterised by low-quality transport infrastructures and located quite far from the country economic centre, the Amazonian region in Brazil was almost wholly disconnected from the rest of the country for several decades. In conjunction with other factors, this motivated the creation of a Free Trade Zone in the region by Brazilian authorities to foster economic linkages with the country's other states. We examine in this chapter whether this challenging goal of connecting an isolated region marked by low-quality transport infrastructures to a distant economic centre has been accomplished and if the Free Trade Zone (FTZ) has played a role in the process. Using a gravity model to assess each Brazilian state trade performance and level of trade costs, we found that the two entities representing the state of Amazonas (Manaus where the Free Trade Zone is implanted and the rest of Amazonas) were among the most effective intra-national exporters in Brazil in 2008 despite facing the highest level of trade costs in the country. These apparently counter-intuitive findings indicate a potentially significant role of the FTZ in this process of integration.

Keywords: stochastic frontier analysis, regional integration, trade costs, Import processing zones

JEL classification code : F150

1.1 Introduction

The world economy as of today is characterised by the prominence of international trade flows that have increased considerably in the last 30 years. As attested by the extensive literature on this subject pioneered by [Tinbergen \(1962\)](#), the pattern of bilateral trade flows depends on the economic size of the two trading partners. However, it is subjected to substantial and varied impediments, ranging from man-made restrictions to geographical barriers. [Limao and Venables \(2001\)](#) insisted on the role of infrastructures and “land-lockedness”, showing that a representative landlocked country will trade approximately 60 % less than a median coastal economy. They also showed that the poor performance of African countries in their intra-national or international exports could be explained solely by the bad quality of their infrastructures.

The Amazonian region in Brazil is subjected to these strong impediments. Located quite far from the economic centre of the country and not very well served by the low-quality Brazilian transport network, this region has experienced a lot of difficulties, especially with the rubber production decline at the beginning of the 20th century. Despite Brazilian authorities’ efforts, this remote zone with low population density was almost wholly disconnected from the rest of the country, a real problem because of its size and substantial wealth in natural resources. Besides its increasingly widespread perception as an ecological reserve for humanity by the international community throughout time could have been detrimental to Brazil sovereignty in this region ([Nunes, 1990](#)). It explains the various policies implemented from the thirties until today to connect it with the rest of the country, consolidate the sovereignty of Brazil and therefore preserve this geostrategic asset.

Among these policies, the creation of the Free Trade Zone of Manaus in 1957 (ZFM) is of great importance. The official objective of this zone effectively implemented in 1967 was twofold as stated by SUFRAMA (Superintendencia de la Zona Franca de Manaus). Create an economic hub in West Amazonia and promote socioeconomic integration with the rest of Brazilian states to reduce the regional disparities and guarantee the country’s national sovereignty on its whole territory. As we can imagine, these objectives are very challenging, especially socioeconomic integration which implies connecting an isolated region to a distant economic centre knowing that the transport network is far from excellent. It is therefore very interesting for at least three reasons to determine whether this goal has been accomplished and if the Free Trade Zone (FTZ) played a role in the process.

First of all, a lot of regions in the world are in this situation, that is to say with low-quality transport infrastructures and trying most of the time unsuccessfully to stimulate

the level of their international and intra-regional trade integration by different means. Some authors, as well as international organisations, promote the somewhat natural solution of improving the quality of transport infrastructures to stimulate their exports. However, this solution could be quite expensive, especially in some regions where the lack of infrastructures is very pronounced. For example, [Buys et al. \(2006\)](#) estimated that upgrading the level of the transport network in Africa for overland trade to an acceptable level would require about \$20 billion for initial upgrading and \$1 billion annually for maintenance. On top of the fact that these improvements probably need a lot of time to be efficiently implemented because of coordination matters or other considerations, the amounts mentioned above are quite important and raise the question of their opportunity in comparison to the expected trade benefits only. If there is an alternative solution that could stimulate trade in the short to medium term at a reasonable cost before the implementation of these necessary improvements, it could be very interesting for the concerned countries.

Secondly, the theoretical and empirical literature on FTZs has focused on export processing zones (EPZs) which most of the time impose restrictions on domestic sales. The case of (ZFM) is quite different since local sales have been widely encouraged by tax incentives following the objectives detailed above. Thus, this FTZ has been excluded from several empirical analyses because of its alleged inward orientation.

Finally, as explained by [Madani \(1999\)](#) the locational choice of a Free Trade Zone is an essential factor of success. According to him, a lot of Free Trade Zones failed to accomplish their goals like the “Zone Franche d’Inga” in former Zaire or the Puerto Limon Zone on Costa Rica’s Atlantic/Caribbean coast because of a poor locational choice as it is the case for the Free Trade Zone of Manaus. It is therefore very interesting to determine whether in these particular conditions the ZFM succeeded or at least contributed to the improvement of the state of Amazonas economic linkages with the rest of Brazilian states.

[Yücer et al. \(2014\)](#) provide preliminary insights on this matter. Questioning the existence of internal vertical specialization in the Brazilian production system, they show that the state of Amazonas is quite well connected to the rest of the country. Precisely, they show that this state presents the highest import content from other Brazilian states in its international exports, and also exports more indirectly than directly its value-added notably through other Brazilian states. As interesting as these results are, they unfortunately do not provide insights on the singular role of Manaus to explain this phenomenon, nor on the existence of a potential catalytic effect of Manaus on the Rest of Amazonas.

To solve this problem, we use a data set developed by [Guilhoto \(2014\)](#) that separates the

state of Amazonas in two entities, Manaus and the rest of Amazonas. Instead on relying upon input-output analysis as [Yücer et al. \(2014\)](#), we provide answers to our questions by using a gravity model that helps us to determine the real level of trade costs faced by each state or entity in its trade relationships and also to derive different measures of trade performance. We notably calculate the intensity of intra-national trade with respect to the benchmark for international trade regarding each Brazilian entity; and derive using stochastic frontier analysis a measure of bilateral export efficiency for these states.

Our results suggest that Manaus and the Rest of Amazonas present the highest level of trade costs among Brazilian states, but despite this, are among the most efficient intra-national exporters in Brazil. Their trade performance scores are indeed among the highest of the set of Brazilian states. It is therefore plausible that the Free Trade Zone of Manaus is the missing link to explain this situation. This idea is not devoid of sense since we found evidence using stochastic frontier analysis that a high percentage of manufactured value-added in comparison to total value-added has a positive effect on export efficiency. The fact that Manaus presents the highest manufactured value-added as a percentage of GDP in Brazil (a value-added principally attributable to the firms of the FTZ) supports this idea.

The main contribution of this paper is, therefore, to rigorously show that Manaus and the Rest of Amazonas are among the most efficient intra-national exporters in Brazil, this suggesting that a good set of tax incentives can offset the disadvantages associated with remoteness and high transport costs, and substantially stimulate a given country exports. It also enriches the conclusions of [Yücer et al. \(2014\)](#) by providing insights on the singular role of the Free Trade Zone of Manaus to explain this phenomenon.

The remainder of this paper is organised as follows. Section [1.2](#) presents the ZFM and its system of tax incentives before going to its economic results. In section [1.3](#), we slightly modify the Anderson and Van Wincoop structural gravity model to suit our problem and present different estimations methods with an emphasis put upon stochastic frontier analysis. Section [1.4](#) and [1.5](#) are devoted to the results and section [1.6](#) to some concluding remarks.

1.2 The Free Trade Zone of Manaus, specificities and economic results

The concept of Free Trade Zone may have different meanings and refer to different situations depending on the objectives and policies established by the government that builds

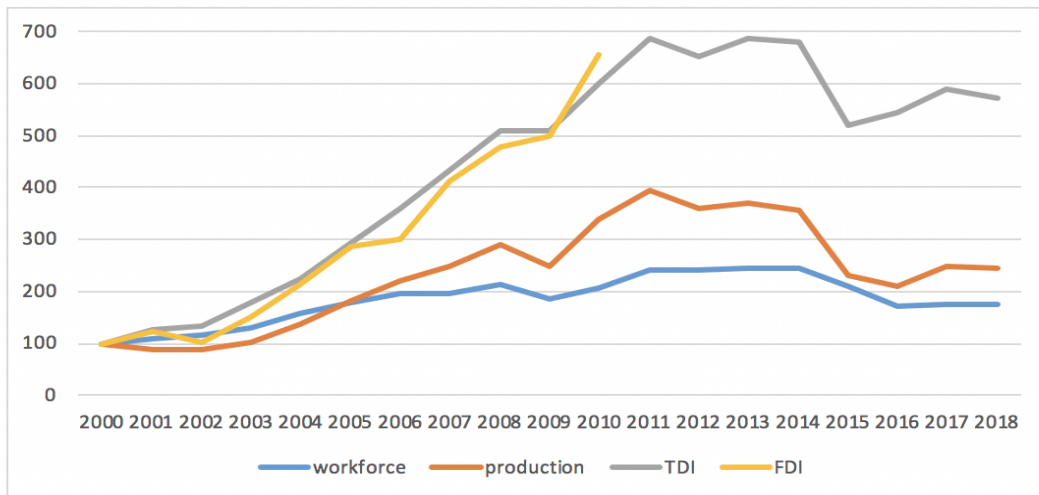
them. They can nevertheless be defined broadly as geographical areas within the borders of a country where regulation is more business-friendly than in the rest of the national territory according to [Farole and Akinici \(2011\)](#). These rules concern especially the investment climate, customs duties and taxes or international trade.

In most cases, FTZs around the world are export-oriented. The Free Trade Zone of Manaus however does not seem to abide by this trend since the stylized facts show a concentration of its sales in the Brazilian market. The fact that contrarily to most EPZs across the world which have restricted access to the internal markets of their host countries, the one of Manaus is also set to stimulate trade relationships with the other Brazilian states by mean of a wide range of incentives could be an explanation. This is a fundamental distinction, which led [Johansson and Nilsson \(1997\)](#) to brand it an “Import Processing Zone”.

Precisely, the incentives granted to ZFM can be divided into two main categories: federal incentives, and state level incentives. The first are the most important in value and have to do with custom duties and legal entities income tax, but also some Brazilian specific taxes as the tax on industrial products or some social contributions. For example, in 2008, these incentives reached \$R 14 billion, approximately 16% of the total amount of tax incentives provided by the Brazilian government to the entire country according to the finance department. It represented nearly one-third of Manaus GDP in 2008 which was R\$ 38 billion (IBGE).

State level incentives are weaker but significant enough to be mentioned. The main incentive is a tax called ICMS (Imposto sobre circulação de mercadorias e prestação de serviços), a value-added tax perceived by each state and which is the primary source of tax revenues for many of them. In 2008, the state of Amazonas renounced to R\$ 3 billion of ICMS revenues but collected R\$ 4.6 billion, about 70 % of the state budget revenue. It is R\$ 500 million more than the ICMS collected by the state of Para whose GDP was R\$ 58 billion at the same time, and which do not provide the same level of ICMS incentives to its firms. The tax incentives effect on the state revenue therefore appears to be more than compensated by its effect on firms’ activity in Amazonas.

With all these tax incentives, the results of the FTZ are noteworthy, particularly regarding foreign direct investment, production or employment. We can see it in [figure 1.1](#) which presents the evolution of some economic indicators of the industrial pole of Manaus, 2000 being the year of reference. It shows a strong progression of FDI, with a six-fold increase from \$ 1021 million in 2000 to \$ 6688 million in 2010. Besides, even if this figure is not shown in the chart, they represented 60% of total investment (TDI) in the industrial pole of Manaus in this period, a clear indicator of the attractiveness of the FTZ for



Source : Suframa, **Fonte :** SAP/CGPRO/COISE

Figure 1.1: Evolution of some economic indicators of the industrial pole of Manaus (PIM) (Base 100 in 2000)

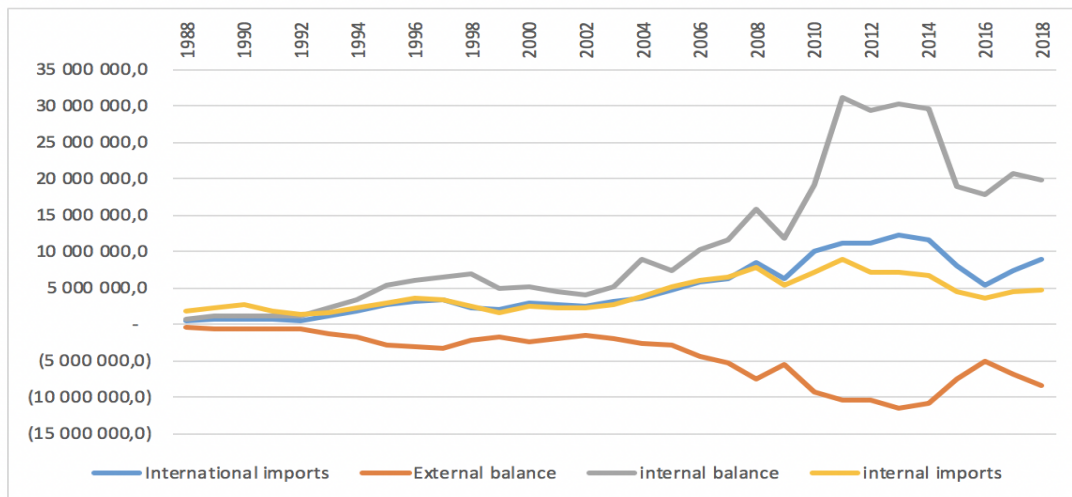
international firms.

After 2010, the data on FDI are not reported any more by SUFRAMA, but as we can see, total investment remained approximately the same until 2014 before a steep decline related to a political turmoil in the country. Just as foreign direct investments, the industrial pole of Manaus (PIM) production increased steeply in the early 2000s after a brief decline a few years before. It has thus quadrupled between 2000 and 2011 from \$ 10 billion to \$ 41 billion, what has also been felt on employment. These figures are quite exceptional and reflect the success of PIM.

They are however tarnished by the political instability and economic crisis experimented by Brazil from 2014 to 2016. In fact, the Brazilian GDP decreased by 3.54 % and 3.3 % respectively for 2015 and 2016 and increased only by 0.5 % in 2014. Our figures show that this crisis severely affected investment, production and employment in PIM with a 35 % decrease of production in US \$ between 2014 and 2015 and a 25% decrease of total investment.¹ It has also been felt on PIM exports to the rest of the country with a 40 % decrease of the internal balance surplus as shown in figure 1.2.

The figure presents PIM's internal and external trade balance for the period 1988/2018 in thousands dollar and shows that the increase in production since 2000 or earlier did not result in a proportional increase of PIM external exports. Even if they grew, they remained well below exports to the rest of Brazil which sharply soared as illustrated in

¹The decline is however less pronounced in the Brazilian currency than in dollar as we could expect.



Source : Suframa, **Fonte :** SAP/CGPRO/COISE

Figure 1.2: PIM's internal and external trade balance (\$ US 1000))

the chart. It is shown in particular that the foreign trade deficit and international imports were almost of the same scale, which suggests weak international exports.

Despite the recent disappointing results related to the political instability in Brazil, these stylized facts suggest that Manaus, a municipality which represents 80% of Amazonas GDP is an outstanding performer in term of intra-national exports with the help of PIM, at least relative to international exports. However, without a comparison with other Brazilian states, it is quite difficult to determine whether the goal of socioeconomic integration with the rest of the country has been satisfactorily achieved for the state of Amazonas. To clarify this matter, a gravity model can be used to assess each Brazilian state export performance.

1.3 Model specification

The gravity model has been widely used in the economic literature to explain bilateral trade relationships and has become the standard workhorse for doing so because of its empirical success. It has many uses that range from counterfactual simulation analysis to the assessment of countries' trade performance. It is for this latter use that we decided to work with this model. We want to assess each Brazilian state trade performance, Manaus and the Rest of Amazonas being considered as states, in order to decide whether these two entities export performance is similar to other Brazilian states and good enough to achieve socio-economic integration with the rest of the country.

Measuring trade performance has generally been done by deriving measures of trade

potentials from the difference between predicted trade flows (that is to say by the empirical model) for each bilateral relationship, and flows that actually occurred. This kind of measures can be helpful to determine for example whether Amazonas exports are in line with those of other Brazilian states. However, this method has driven some criticism from [Egger \(2002\)](#), regarding the inappropriateness of in-sample projections of trade potentials. He argued that a well-specified model should not present systematic differences between observed and in-sample predicted trade flows. [De Benedictis and Vicarelli \(2005\)](#) took Egger’s remark a step further noting that out-of-sample predictions also are not immune to the eventuality of misspecification of the estimated model since the potential bias in the coefficients is also transmitted to the out-of-sample predicted flows. In other words, the trade potentials predicted for countries that were not in the sample originally used to obtain the parameters of the model will also be affected by the bias inherent to these parameters. To avoid these considerations, we use a different strategy than the calculation of trade potentials to obtain our measures of trade performance. Doing so requires a slight modification of [Anderson and Van Wincoop \(2003\)](#) structural gravity model.

1.3.1 The structural gravity Model

Despite the empirical success of the gravity model to explain bilateral trade, it has been criticized for a long time because of its lack of theoretical underpinnings. Many attempts have been made to address this problem beginning with [Anderson \(1979\)](#) or [Bergstrand \(1989\)](#) although the complexity of their models impeded their use as an everyday toolkit for trade economists. An essential contribution of [Anderson and Van Wincoop \(2003\)](#) simplified the expressions derived in the previous works, therefore allowing the thus theoretically founded gravity model to be used with more ease as a workhorse for trade economists. One of this work core added values is the demonstration of the relative trade costs importance in the explanation of bilateral trade. This is based on the idea that for a given bilateral barrier between two regions, say A and B for example, a rise of trade barriers with all other trading partners for A decreases the relative trade cost for B and thus increase trade between them. This justifies the integration of what they called multilateral resistance indexes (MR) in the gravity model and thus prevents the gold medal mistake mentioned by [Baldwin and Taglioni \(2006\)](#), generally observed in previous works on the estimation of this equation.

Anderson and Van Wincoop’s model has the following form:

$$X_{ij} = \frac{Y_i Y_j}{Y_w} \left(\frac{T_{ij}}{\Pi_i P_j} \right)^{1-\sigma} \quad (1.1)$$

$$\text{With } P_j^{1-\sigma} = \sum_i \frac{Y_i}{Y_w} \frac{T_{ij}^{1-\sigma}}{\Pi_i^{1-\sigma}} \quad (1.2)$$

$$\text{And } \Pi_i^{1-\sigma} = \sum_j \frac{Y_j}{Y_w} \frac{T_{ij}^{1-\sigma}}{P_j^{1-\sigma}} \quad (1.3)$$

And where Y_w is the world GDP, Y_i and Y_j respectively the GDP's and expenditures of countries i and j and T_{ij} the trade costs factor between the two countries. $1 - \sigma < 1$ is the trade costs elasticity, and Π_i and P_j represent the exporter and importer outward and inward multilateral resistance terms respectively. This model stems from a problem of maximisation under constraints. To address our specific question, we derive a similar kind of model. Specifically, we have the following utility function:

$$\left(\sum_i \beta_{ij}^{\frac{1-\sigma}{\sigma}} c_{ij}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \quad (1.4)$$

subject to the budget constraint:

$$\sum_i p_{ij} c_{ij} = Y_j \quad (1.5)$$

Where c_{ij} is the consumption of region i goods by region j , p_{ij} the price of region i goods for region j consumers and $\beta_{ij} = \alpha_i \gamma_{ij}$ a positive distribution parameter. Contrarily to AVW, we assume that this parameter is composed of an idiosyncratic component α_i and a bilateral component γ_{ij} instead of being solely specific to i . This assumption of bilateral preferences is also made by authors as [Combes et al. \(2005\)](#) or [Costinot and Rodríguez-Clare \(2014\)](#). However, as in the original AVW article, $p_{ij} = p_i t_{ij}$ where p_i is the exporter's supply price net of trade costs and t_{ij} the trade cost factor between i and j . The nominal value of exports from i to j is therefore $x_{ij} = p_{ij} c_{ij}$ and the total income of region i which stems from the market clearing condition is $Y_i = \sum_j p_{ij} c_{ij}$. A simple maximisation of the utility function under the budget constraint yields:

$$x_{ij} = \frac{(\beta_{ij} p_i t_{ij})^{1-\sigma} Y_j}{P_j^{1-\sigma}} \quad (1.6)$$

$$\text{With } P_j^{1-\sigma} = \sum_i (\beta_{ij} p_i t_{ij})^{1-\sigma} \quad (1.7)$$

The market clearing condition implies that:

$$Y_i = \sum_j \frac{(\beta_{ij} p_i t_{ij})^{1-\sigma} Y_j}{P_j^{1-\sigma}} \quad (1.8)$$

As AVW, we solve for the scaled price $\alpha_i p_i$. It follows that:

$$\begin{aligned} (\alpha_i p_i)^{1-\sigma} &= \frac{Y_i}{\sum_j \left(\frac{\gamma_{ij} t_{ij}}{P_j} \right)^{1-\sigma} Y_j} \\ &= \frac{Y_i}{Y_w \sum_j \left(\frac{\gamma_{ij} t_{ij}}{P_j} \right)^{1-\sigma} \frac{Y_j}{Y_w}} \\ &= \frac{Y_i}{Y_w \sum_j \left(\frac{\gamma_{ij} t_{ij}}{P_j} \right)^{1-\sigma} \theta_j} \end{aligned} \quad (1.9)$$

with $\theta_j = \frac{Y_j}{Y_w}$ and $Y_w = \sum_j Y_j$ the world income.

$$\text{By defining } \Pi_i^{1-\sigma} = \sum_j \left(\frac{\gamma_{ij} t_{ij}}{P_j} \right)^{1-\sigma} \theta_j \quad (1.10)$$

We get: $(\alpha_i p_i)^{1-\sigma} = \frac{\theta_i}{\Pi_i^{1-\sigma}}$ and thus,

$$P_j^{1-\sigma} = \sum_i \left(\frac{\gamma_{ij} t_{ij}}{\Pi_i} \right)^{1-\sigma} \theta_i \quad (1.11)$$

Finally, we obtain:

$$x_{ij} = \frac{Y_i Y_j}{Y_w} \left(\frac{\gamma_{ij} t_{ij}}{\Pi_i P_j} \right)^{1-\sigma} \quad (1.12)$$

which is the Anderson and Van Wincoop's structural gravity equation scaled by the parameter $\gamma_{ij}^{1-\sigma}$. This parameter plays a prominent role in our model as it represents a bilateral preference that region j has on region i goods, or said differently region i's effectiveness in selling its goods to region j. Its range is $[0,1[$ such that the more region j appreciates region i goods, the closer is $\gamma_{ij}^{1-\sigma}$ to 1 and inversely.

1.3.2 Empirical strategy

Given its nonlinear nature, many authors estimate a log-linear version of this equation. It gives:

$$\ln X_{ij} = a_0 + a_1 \ln Y_i + a_2 \ln Y_j + (1 - \sigma) \ln T_{ij} - (1 - \sigma) \ln \Pi_i - (1 - \sigma) \ln P_j + (1 - \sigma) \ln \gamma_{ij} + v_{ij} \quad (1.13)$$

Where a_0 is the constant, and v_{ij} the error term. Regarding trade costs, they are usually approximated by different types of variables. The equation is often as follows:

$$T_{ij} = d_{ij}^{\delta_1} \cdot \exp(\delta_2 cont_{ij} + \delta_3 lang_{ij} + \delta_4 ccol_{ij} + \delta_5 col_{ij} + \delta_6 smctry_{ij} + \delta_7 wto_{ij} + \delta_8 RTA_{ij}) \quad (1.14)$$

With d_{ij} representing the bilateral distance, and $cont_{ij}$, $lang_{ij}$, $ccol_{ij}$, col_{ij} , $smctry_{ij}$, wto_{ij} , RTA_{ij} representing dummies respectively for the presence of a common border, a common official language, a common colonizer, if the territory is or has been one of its partner colonies in the past, for the country's trade with itself, if the trading partners are members of WTO, and finally if there is a trade agreement between the two partners.

δ_6 is thus a parameter that quantifies the average intensity of internal trade with regards to international trade for the regions of the set, or in other words, the border effect. In equation 1.14, this parameter is the same for all the regions, but we could render it region specific. As suggested by [Combes et al. \(2005\)](#), it should have a positive value because the informational transaction cost is lower inside a country than between two countries, or because consumers have systematic preferences for local goods. It means that we could have model our bilateral preference parameter γ_{ij} as a function of the border effect. As it is not the case, γ_{ij} is therefore region i 's efficacy in selling its goods to region j conditionally on not being member of the same country. This distinction between country and region is critical because as we will make clear in the data section, our database embed inter-state Brazilian trade flows and international trade flows.

Regarding the multilateral trade resistance terms, they are generally not directly observable. Many authors used remoteness indexes as proxies for them, but because of their discordance with theory, exporter and importer fixed-effects are more advisable ([Head and Mayer, 2014](#)). When using cross-sectional data, the latter option makes impossible the integration of other idiosyncratic variables such as GDP because of perfect collinearity. We can therefore only estimate parameters from dyadic variables.

Since [Silva and Tenreyro \(2006\)](#) raised concerns regarding the consistency of parameters obtained by estimating log-linearized trade equations via ordinary least squared, the Poisson Pseudo maximum likelihood estimator is more and more used. It allows the model to

be estimated in level, therefore, dealing better with zero trade flows in trade data. The model estimated becomes :

$$X_{ij} = \exp(a_0 + a_1 \ln Y_i + a_2 \ln Y_j + 1 - \sigma \ln T_{ij} - (1 - \sigma) \ln \Pi_i - (1 - \sigma) \ln P_j + (1 - \sigma) \ln \gamma_{ij}) + n_{ij} \quad (1.15)$$

with X_{ij} representing exports in value from country i to country j, the other variables remaining unchanged.

Fally (2015) goes further by advocating that there is only one estimator of the pseudo maximum likelihood (PML) category, namely the Poisson pseudo maximum likelihood which is fully consistent with structural gravity when fixed effects are included in the estimation. This is because its first order conditions automatically satisfy the equilibrium constraints imposed to derive the multilateral resistance (MR) terms in equations (1.10) and (1.11). Accordingly, these terms can be obtained from the fixed effects estimates after some manipulations. More formally, it can be shown that for a model formulated as following:

$$X_{ij} = \exp(a_i + \ln T_{ij}^{1-\sigma} + \ln \gamma_{ij}^{1-\sigma} + b_j) \quad (1.16)$$

Where $\ln \gamma_{ij}^{1-\sigma}$ is the bilateral preference parameter as in equation (1.12), the equilibrium conditions $Y_i = \sum_j X_{ij}$ and $Y_j = \sum_i X_{ij}$ can be rewritten as:

$$Y_i = \sum_j \exp(a_i + \ln T_{ij}^{1-\sigma} + \ln \gamma_{ij}^{1-\sigma} + b_j) \quad (1.17)$$

$$Y_j = \sum_i \exp(a_i + \ln T_{ij}^{1-\sigma} + \ln \gamma_{ij}^{1-\sigma} + b_j) \quad (1.18)$$

$$\begin{aligned} \Rightarrow \sum_j T_{ij}^{1-\sigma} \gamma_{ij}^{1-\sigma} Y_0 \exp(b_j) &= Y_0 Y_i \exp(-a_i) \\ \Rightarrow \sum_i T_{ij}^{1-\sigma} \gamma_{ij}^{1-\sigma} Y_0^{-1} \exp(a_i) &= Y_0^{-1} Y_j \exp(-b_j) \end{aligned}$$

We define:

$$\Pi_i^{1-\sigma} = Y_0 Y_i \exp(-a_i) \quad (1.19)$$

$$P_j^{1-\sigma} = \frac{Y_j}{Y_0} \exp(-b_j) \quad (1.20)$$

where b_j and a_i are respectively estimates of the importer and exporter fixed effects, and

Y_0 the income of the reference country. By incorporating them into equations (1.17) and (1.18), we find the expressions of $\Pi_i^{1-\sigma}$ and $P_j^{1-\sigma}$ derived from the previous theoretical model (equations (1.10) and (1.11)). It proves that (1.19) and (1.20) are their solutions. As we may have noticed, because of the equilibrium conditions, these equations are valid only under the requirement of consistent data that is to say a data set where output equals the sum of outward trade, and expenditures equal the sum of inward trade. This requirement is generally met by inter-country input-output matrices, which unfortunately are very scarce.

But beyond that, there is a concern with our empirical model. In practice, preferences are not easily observable. When they are not explicitly controlled in the estimation, the estimated model is the traditional AVW model (equation (1.1), (1.2), (1.3)). In an empirical formulation, they logically represent a component of the error term. For the log-linear case, the estimated model therefore becomes:

$$\ln X_{ij} = a_0 + a_1 \ln Y_i + a_2 \ln Y_j + 1 - \sigma \ln T_{ij} - (1 - \sigma) \ln \Pi_i + \varepsilon_{ij} \quad (1.21)$$

with $\varepsilon_{ij} = v_{ij} - u_{ij}$

and $u_{ij} = (\sigma - 1) \ln \gamma_{ij}$

Estimating this kind of equation is straightforward using stochastic frontier analysis.

1.3.3 Stochastic frontier analysis

Independently developed by [Aigner et al. \(1977\)](#) and [Meeusen and van Den Broeck \(1977\)](#) for cross-sectional data, the initial purpose of the stochastic frontier model is to estimate firms' efficiency in their production. For this, a maximum production achievable by a firm is firstly predicted by the model based on its production factors. Any gap between the actual and predicted levels of production is explained by a composite error term (ε_i) formed by a two-sided component v_i (alternatively positive or negative) and a one-sided strictly positive component u_i . The two-sided component captures outside influences beyond the control of the producer and the one-sided captures the degree of firm's inefficiency such that $\varepsilon_i = v_i - u_i$. The basic stochastic production frontier model is thus as follows:

$$C_i = f(A_i, \beta) + v_i - u_i \quad (1.22)$$

With C_i representing the dependent variable, A_i the vector of explanatory variables with β as the vector of coefficients, and $v_i - u_i$ the components of the error term ε_i . The model

can be estimated by maximum likelihood under some assumptions on the distribution of the composite error term. The literature generally assumes a half-normal distribution $N^+(0, \sigma_u^2)$, a truncated normal distribution in u $N^+(u, \sigma_u^2)$, or exponential and gamma distributions for the inefficiency term u_i because it is supposed to be strictly positive and a normal distribution for the two-sided term v_i . The estimation gives us the variance of the error term for the whole sample ($\sigma^2 = \sigma_v^2 + \sigma_u^2$), and the observation specific inefficiency is obtained by calculating the conditional expectation of u_i knowing ε_i as proposed by [Jondrow et al. \(1982\)](#). Assuming a half-normal distribution for u_i , these authors showed that the conditional density function of u_i knowing ε_i is $f(u_i | \varepsilon_i) \sim N^+(u_{*i}, \sigma_*^2)$ with:

$$u_{*i} = \frac{-\varepsilon_i \sigma_u^2}{\sigma_v^2 + \sigma_u^2} \text{ and } \sigma_*^2 = \frac{\sigma_v^2 \sigma_u^2}{\sigma_v^2 + \sigma_u^2} \quad (1.23)$$

It implies that the conditional mean is:

$$E[u_i | \varepsilon_i] = u_{*i} + \frac{\sigma_* \phi\left(\frac{u_{*i}}{\sigma_*}\right)}{\Phi\left(\frac{u_{*i}}{\sigma_*}\right)} \quad (1.24)$$

where $\phi(\cdot)$ and Φ are respectively the normal probability density function and the normal cumulative distribution function. Using the same method, [Battese and Coelli \(1988\)](#) derived an observation specific conditional efficiency term which ranges between 0 and 1, the most efficient observations being naturally close to 1. We have:

$$E[\exp(-u_i) | \varepsilon_i] = \exp(-u_{*i} + \frac{1}{2}\sigma_*^2) \frac{\Phi\left(\frac{u_{*i}}{\sigma_*} - \sigma_*\right)}{\Phi\left(\frac{u_{*i}}{\sigma_*}\right)} \quad (1.25)$$

These results are founded on the assumption of a half-normal distribution for u_i , but we could have used different distributions. [Kumbhakar and Lovell \(2003\)](#) showed besides that regardless of the distribution chosen for u_i , the results remain consistent as long as we are only interested in a ranking of the most efficient observations. However, there is less flexibility regarding heteroskedasticity. According to the previous authors, ignoring the two-sided error term heteroskedasticity only biases the constant, but it is better not to ignore the inefficiency term heteroskedasticity to avoid biased parameter estimates. To address this, [Caudill et al. \(1995\)](#) proposed to estimate a model where the variance of u_i , σ_u^2 is a function of covariates. We thus get $u_i \sim N^+(0, Z_i\alpha)$. It allows the inefficiency term to be heteroskedastic and also highlights the variables Z_i that are its determinants.

Before considering the use of this method, we need to test its applicability. We hence

need to check if our assumption on the error term form that is to say $\varepsilon_i = v_i - u_i^2$ with u_i a positive real number and v_i distributed symmetrically around 0 is credible. If this assumption is correct, ordinary least squares residuals should be asymmetrical and left skewed. To test this, we can use a sample-moment based statistic following [Schmidt and Lin \(1984\)](#)³ and a skewness- kurtosis test of normality. If the null hypothesis of no skewness is rejected, we can hence estimate the stochastic frontier model. An alternative way is to perform a likelihood ratio test between the stochastic frontier and the OLS estimations, which amounts to testing the hypothesis that $\sigma_u^2=0$. See [Kumbhakar et al. \(2015\)](#).

Authors like [Ravishankar and Stack \(2014\)](#) or [Kang and Fratianni \(2006\)](#) have already used this kind of empirical model to estimate gravity equations. It is especially useful when it comes to the determination of bilateral trade potentials. Contrarily to the conventional method which estimates the benchmark level of trade achievable by a country with its trading partners and defines the trade potential as the deviation with this benchmark, the stochastic frontier model calculates the maximum level of trade achievable by a country with a given partner. The level of trade efficiency or inefficiency can consequently be determined via the deviation with this maximum and serve as an indication of trade potential. This measure is better than a simple difference between actual and predicted trade flows because the two-sided noise term, which in principle captures outside influences beyond the control of the exporter has been singled out.

1.4 Data and econometric results

1.4.1 Data

Our dataset is composed of aggregate bilateral trade flows for 222 importing countries and entities (including the different Brazilian states and 217 exporting countries and entities from three different sources, the COMTRADE database, the Brazilian external trade and development department and the 2008 Brazilian inter-regional input-output matrix estimated by [Guilhoto and Sesso Filho \(2010\)](#). The COMTRADE database is the main source for international trade flows but does not provide Brazilian states trade data. Besides, some countries did not report their exports for the year 2008 although their imports were recorded. It explains the difference between the number of exporters

²This is the form of a production-type stochastic frontier model, but there are other forms

³The statistic is computed like this: $\sqrt{b} = \frac{m_2}{m_3\sqrt{m_2}}$ where m_2 and m_3 are respectively the second and the third sample moments of the OLS residuals

and importers.⁴ The Brazilian external trade and development department provides trade flows for each Brazilian state with their international partners but does not propose trade flows between Brazilian states. It is worth mentioning that these data include exports to Brazilian states from countries that are absent in the COMTRADE database, and also that both imports and exports are provided in their FOB value. The 2008 Brazilian inter-regional input-output matrix estimated by [Guilhoto and Sesso Filho \(2010\)](#) provides trade flows between Brazilian states. In this database, we have 26 Brazilian states + the state of Amazonas which is divided into two entities, Manaus and the rest of Amazonas. We restricted our samples to 2008 because of Brazilian intra-national trade data availability. 2008 flows aside, the more recent are from 1999. The sources of the other variables used in our estimations are reported in table 1.1. For instance, we obtained the geographic distance between each pair of countries/states by using a generator built by the Centre for Biodiversity and Conservation of the American Museum of Natural History (AMNH). The distance of a country to itself is calculated following [Redding and Venables \(2004\)](#): $d_{ii} = 0.33\sqrt{\frac{area}{\pi}}$. Whenever necessary, we converted Brazilian data in US dollar using the average exchange rate in 2008 1\$= 1.8346\$R.

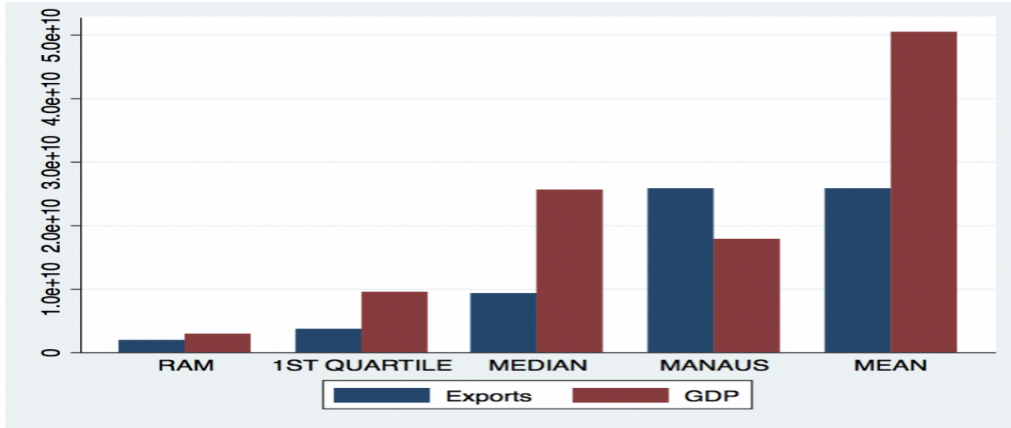
Table 1.1: Sources of different variables used in our estimations

Variables	Source
Exporter / importer GDP	Brazilian system of national accounts World development indicators
Distance	Geographic distance Matrix generator (American museum of natural history)
Contiguity	Cepii/Author calculations
Common official language	Cepii/Author calculations
Colony	Cepii/Author calculations
Common colonisator	Cepii/Author calculations
Regional trade agreement	WTO RTA information system.
WTO membership	WTO website

Before going to the econometric results, it would be interesting to present some descriptive statistics. Figure 1.3 presents summary statistics on Brazilian states intra-national exports and GDPs, Manaus and the Rest of Amazonas being considered as states. As we can see, Manaus total exports to other Brazilian states are very close to the average of the sample, and way above the median. It is not the case for its GDP which is inferior to the mean and the median of the sample. This fact already suggests that Manaus is a good performer

⁴It should be noted that zero trade flows are not reported in this data set; we must therefore add them. To ensure that the added flows are truly null, and not just unreported, we do not consider as zero the missing flows of countries that appear as importers but not as exporters in the COMTRADE database.

in term of internal exports. However, as we can see, the value of its internal exports is superior to its GDP, which means that a share of the said internal exports comes from somewhere else. We should therefore pay attention to this if we want to determine the export performance of Manaus rigorously.



Source: SUFRAMA, Brazilian national accounts

Figure 1.3: Selected states total internal exports and GDP

Regarding the rest of Amazonas (RAM) the situation is entirely different as its exports are lower than its GDP and both are inferior to the first quartile. It is therefore difficult to make a preliminary conclusion regarding its trade performance in comparison to other Brazilian states. The econometric results analysis should provide more insights.

1.4.2 Econometric Results

In this sub-section, we present the econometric results obtained using different estimators among which ordinary least squares, Pseudo Poisson maximum likelihood, and the stochastic frontier estimator. To ease the analysis, table 1.2 presents the different variables used in the estimations, their definitions and expected signs.

For each estimator, we used the following empirical models:

- OLS: $\ln X_{ij} = a_i + b_j + (1 - \sigma) \ln T_{ij} + v_{ij}$
- PPML: $X_{ij} = \exp (a_i + b_j + (1 - \sigma) \ln T_{ij}) + n_{ij}$
- Stochastic frontier: $\ln X_{ij} = a_i + b_j + (1 - \sigma) \ln T_{ij} + \varepsilon_{ij}$
 - with $\varepsilon_{ij} = v_{ij} - u_{ij}$
 - and $u_{ij} = (\sigma - 1) \ln \gamma_{ij}$

Where a_i and b_j represent respectively exporter and importer fixed effects.

Table 1.2: Variables of the estimated models and their definitions

Variable	Definition	Expected sign
ldist	Distance	Negative
contig	Dummy for sharing a common border	Positive
comlang_off	Dummy for entities with the same official language	Positive
smctry	Dummy for trade between Brazilian states	Positive
comcol	Dummy for entities sharing a common colonizer	Positive
colony	Dummy for colonial ties between two entities	Positive
RTA	Dummy for Regional trade agreements	Positive
both_wto	Dummy for trading partners both WTO members	Positive
lva_indr	Share of Manufactured goods in exporter value added	-
lva_indp	Share of Manufactured goods in importer value added	-

We also used two different specifications for the trade costs indices. The first one is similar to equation 1.14 where we estimate a single average parameter δ_6 for the Brazilian border effect.

- $T_{ij} = d_{ij}^{\delta_1} \cdot \exp(\delta_2 cont_{ij} + \delta_3 lang_{ij} + \delta_4 ccol_{ij} + \delta_5 col_{ij} + \delta_6 smctry_{ij} + \delta_7 wto_{ij} + \delta_8 RTA_{ij})$

In the second specification, we estimate 28 different parameters δ_i for each Brazilian state border effect including Manaus and the rest of Amazonas.

- $T_{ij} = d_{ij}^{\delta_1} \cdot \exp(\delta_2 cont_{ij} + \delta_3 lang_{ij} + \delta_4 ccol_{ij} + \delta_5 col_{ij} + \delta_i border_{ij} + \delta_7 wto_{ij} + \delta_8 RTA_{ij})$

$border_{ij}$ is, therefore, a dummy equal to one for the trade of a given Brazilian entity, Manaus, RAM or any other state with all other Brazilian entities and zero otherwise whereas $smctry_{ij}$ is a dummy equal to one whenever a Brazilian state trades with another one and zero otherwise. More precisely, with $border_{ij}$ each Brazilian entity has a dummy for its exports to other Brazilian entities and with $smctry_{ij}$ we only have one dummy for the inter-Brazilian entities trade. Also, as mentioned in the data section, we have internal trade flows only for Brazil.

Distinguishing between these two trade costs specifications has critical implications for the assessment of trade performance that will follow in the next section. The idiosyncratic parameters δ_i as they represent the intensity of internal trade in comparison to international trade for each Brazilian state are per se measures of intra-national export performance. As we analyse them in more detail in the following section, we do not show them in table 1.3 that presents our preliminary econometric results.

The first 3 columns present results obtained using the second specification of trade costs while the last three columns use the first specification. The PPML estimations have 41,586 observations while it is 24,564 for the others because of zero trade flows. Importer and

exporter fixed effects parameters are not shown in this table to save space. As regards the stochastic frontier estimations, the variables U_{σ} and V_{σ} represent respectively the log of the variance regarding the inefficiency component of the error term u_{ij} and the two-sided component v_{ij} . The estimations have been made on the assumption of a normal distribution for the two-sided noise term, and an exponential distribution for the inefficiency term. We also assumed homoskedasticity for the two components of the error term. We will relax this assumption in the following section.

Table 1.3: The determinants of Bilateral gross exports

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	PPML	OLS	Frontier	PPML	OLS	Frontier
ldist	-0.764*** (0.0475)	-1.611*** (0.0281)	-1.536*** (0.0258)	-0.762*** (0.0474)	-1.599*** (0.0283)	-1.527*** (0.0258)
smctry				2.715*** (0.222)	3.593*** (0.149)	3.016*** (0.137)
contig	0.300*** (0.0876)	0.450*** (0.122)	0.594*** (0.110)	0.297*** (0.0872)	0.434*** (0.125)	0.592*** (0.112)
comlang_off	0.199** (0.0786)	0.766*** (0.0556)	0.633*** (0.0500)	0.201** (0.0785)	0.768*** (0.0557)	0.638*** (0.0500)
comcol	0.341** (0.162)	0.708*** (0.0778)	0.632*** (0.0678)	0.343** (0.162)	0.702*** (0.0778)	0.630*** (0.0678)
colony	0.212 (0.138)	1.043*** (0.121)	1.069*** (0.102)	0.213 (0.138)	1.047*** (0.121)	1.073*** (0.102)
RTA	0.577*** (0.0832)	0.733*** (0.0588)	0.644*** (0.0520)	0.580*** (0.0831)	0.751*** (0.0590)	0.655*** (0.0520)
both_wto	-0.0556 (0.439)	0.268 (0.174)	0.204 (0.164)	-0.0567 (0.438)	0.262 (0.174)	0.200 (0.164)
Constant	19.43*** (0.695)	40.95*** (0.359)	41.09*** (0.331)	19.41*** (0.694)	40.82*** (0.363)	41.01*** (0.331)
Usigma ($\ln\sigma_u^2$)			0.948*** (0.0328)			0.955*** (0.0325)
Vsigma ($\ln\sigma_v^2$)			0.609*** (0.0290)			0.619*** (0.0286)
Observations	41,586	24,564	24,564	41,586	24,564	24,564
R-squared	0.896	0.726		0.896	0.724	
Reporter FE	YES	YES	YES	YES	YES	YES
Partner FE	YES	YES	YES	YES	YES	YES
Border effect	YES	YES	YES	-	-	-

Cluster-robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

As we can see, the distance coefficient is close to what is observed in the literature. When the PPML estimator is used, we have a coefficient around 0.75 whereas the coefficient is above unity when OLS or stochastic frontier are used. Furthermore, we see that Brazilian states trade far more with themselves than with their international partners as the parameters related to the variable “smctry” show. According to the PPML estimation in column 4, they traded approximately 15 times more “exp (2.715)” between each other than with foreign countries in 2008, a coefficient at least twice lower than that obtained by [Daumal and Zignago \(2010\)](#) for 1999 data. We should however mention that OLS

suggest a significantly higher intra-Brazilian level of trade.

Roughly, all the other variables in these estimations have expected signs and coefficients. As this work is not about determining their true value, we will not pay much attention to their analysis and will focus more on the stochastic frontier results presented in columns 3 and 6. It appears that the log of the inefficiency term variance is significant at the 1% level no matter the specification of trade costs, thus suggesting the existence of an inefficiency component in the error term. This idea is confirmed by a likelihood ratio test between the OLS and the stochastic frontier estimation presented in appendix 1.1 which amounts to test the hypothesis that $\sigma_u^2=0$ as said in section 1.3.3. With the help of the results presented above, we derived different measures of trade costs and trade performance to carry out our analysis on Manaus and the rest of Amazonas level of trade integration in Brazil.

1.5 Manaus and the rest of Amazonas trade performance

To asses properly the trade performance of the two entities composing the state of Amazonas in our sample, we carry out an analysis that is organized in three parts. Firstly, we show that Manaus and the rest of Amazonas are among the most efficient intra-national exporters in Brazil. Then, we show that despite their intra-national export efficiency these two entities levels of trade costs are among the highest of the subset of Brazilian states. This apparently counter-intuitive result leads us to our third point which is to envisage the tax incentives provided by the Free Trade Zone of Manaus as one of the main explanations to the state of Amazonas trade performance.

To substantiate our first point, we analyse two different measures of trade performance namely the intensity of intra-national trade in comparison to international trade for each Brazilian state, and the score of export performance derived from the stochastic frontier analysis. As regards the intensity of intra-national trade in comparison to international trade or framed differently the border effect, we obtain it as said earlier with the three estimations whose results are presented in the three first columns of table 1.3 respectively for the PPML estimator, OLS and the stochastic frontier estimator. Table 1.4 displays these parameters for the 28 Brazilian entities of our sample.

Manaus and the rest of Amazonas are represented in this table respectively by “MANAUS” and “RAM”. As we can see, according to all the estimators used, the rest of Amazonas is the Brazilian entity that has the highest export intensity toward other Brazilian states

in comparison to the benchmark for international exports. Depending on the estimator, Manaus is either ranked sixth or third, therefore suggesting that these entities are among the most efficient intra-national exporters in Brazil.

Table 1.4: Border effect coefficients of Brazilian states⁵

States	(1) PPML	(2) OLS	(3) Frontier
RAM	6.409***	6.793***	5.631***
AC	6.123***	6.078***	5.383***
RR	5.742***	5.419***	4.814***
SE	5.292***	3.962***	3.272***
DF	5.208***	5.092***	4.207***
MANAUS	5.169***	5.754***	4.845***
PI	4.371***	4.346***	3.738***
RN	4.367***	4.689***	3.994***
PB	4.326***	4.053***	3.561***
PE	4.173***	3.674***	3.092***
CE	3.978***	3.818***	3.405***
TO	3.866***	5.214***	3.065***
RO	3.792***	3.859***	3.236***
AP	3.145***	2.832***	1.343
SP	2.939***	2.570***	2.513***
GO	2.895***	2.604***	2.135***
AL	2.887***	2.359***	1.146***
MA	2.873***	4.659***	3.344***
MS	2.813***	2.475***	2.061***
BA	2.622***	3.092***	2.513***
SC	2.541***	2.253***	2.154***
RS	2.505***	2.120***	2.052***
MT	2.495***	2.551***	1.881***
PR	2.445***	2.379***	2.295***
RJ	2.292***	4.366***	3.827***
MG	2.043***	2.240***	1.889***
ES	1.846***	2.274***	1.542***
PA	1.808***	2.602***	1.794***

*** p<0.01, ** p<0.05, * p<0.1

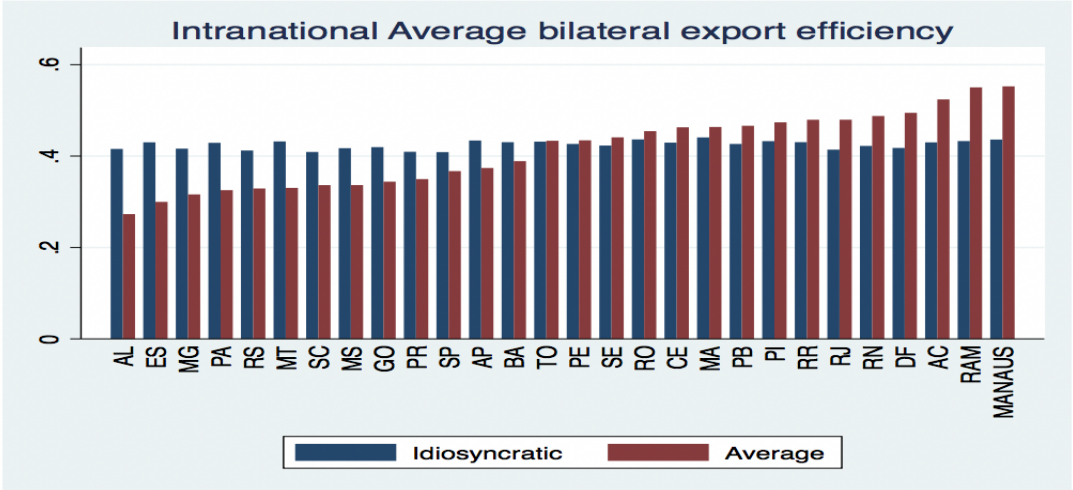
It is worth to note that 10 of the 14 largest states in term of economic size are also among the 14 states presenting the lowest border effect coefficient, which suggest that smaller states tend to trade more with their Brazilian counterparts than with other countries in the world. However, as interesting as these results are, they present the weakness

⁵Appendix 1.2 displays the list of Brazilian States.

to display an aggregate intra-national trade performance for each Brazilian state and do not provide insights regarding the bilateral intra-national export efficiency. A state could therefore export a lot to two or three states and few to the other states, but this measure would still suggest that the intra-national export performance is high. To solve this problem, we rely upon stochastic frontier analysis to obtain measures that reflects more the bilateral intra-national export performance of each Brazilian state.

More precisely, we estimate the parameter $\gamma_{ij}^{1-\sigma}$ that derives from our theoretical model. As mentioned earlier, we assumed that preferences have the following form $\beta_{ij}^{1-\sigma} = (\alpha_i \gamma_{ij}^{1-\sigma})$ with two components, an idiosyncratic one “ $\alpha_i^{1-\sigma}$ ” that we interpreted as country i’s efficacy in selling its goods to all its partners and a bilateral one $\gamma_{ij}^{1-\sigma}$ that we interpreted as country i’s efficacy in selling its goods to country j specifically. The first component is naturally captured by the exporter fixed effects since it is idiosyncratic. Estimating the second component $\gamma_{ij}^{1-\sigma}$ requires the use of stochastic frontier analysis as discussed in section 1.3.3.

From the estimations in table 1.3 columns 3 and 6 representing the specifications with an idiosyncratic border effect for each Brazilian state and an average one respectively, we calculated this bilateral component of trade efficiency. The results are displayed in the following figure that presents the average bilateral efficiency regarding the intra-national exports of the different Brazilian states.



Source: Author’s estimations

Figure 1.4: Brazilian states intra-national export performance

As explained in section 1.3.3, we obtained the scores of bilateral export efficiency by using equation 26 (the conditional expectation of efficiency knowing the error term ε_{ij}) after estimating the stochastic frontier model. We then calculated an average bilateral

trade efficiency for each Brazilian state intra-national exports. It appears that when the specification with an idiosyncratic border effect is used (table 1.3 column 3), there is no significant difference in the average bilateral trade efficiency scores of Brazilian states. However, when the specification with an average border effect is used, Manaus and RAM are the most efficient intra-national exporter of the set of Brazilian states.

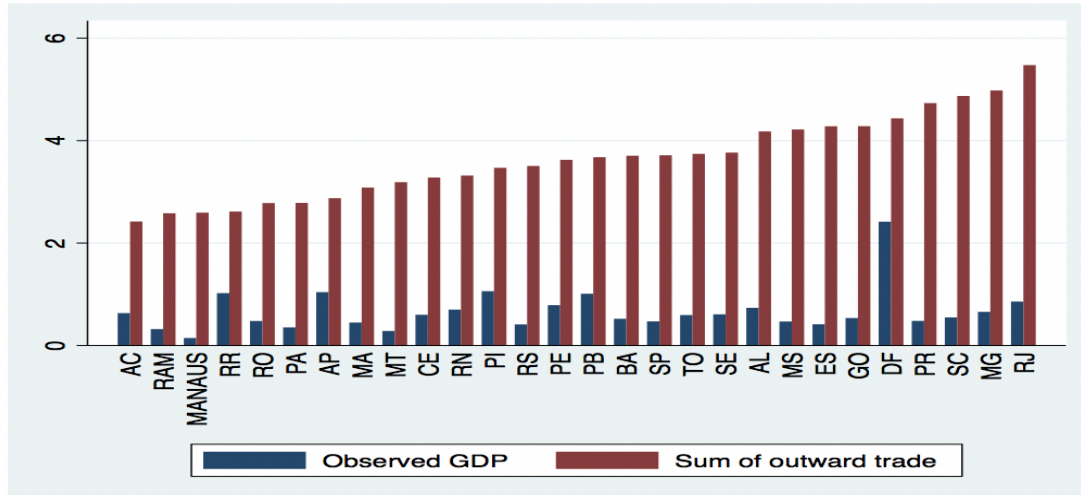
This result is sensible because as said earlier, the idiosyncratic border effect parameters presented in table 1.4 for each Brazilian state capture their aggregate intra-national trade performance. When we use a single average parameter to control for the border effect of each state (Table 1.3 column 6), the states that trade more than the average with their Brazilian counterparts have a higher average bilateral export efficiency in comparison to the other specification and inversely. All these findings confirm the idea that Manaus and RAM are among the best performers in term of intra-national exports in Brazil. Despite that, their respective level of trade costs does not seem to be among the lowest in the country.

In fact, the level of trade costs of these two entities is among the highest in the subset of Brazilian states. We show this by calculating each exporting state multilateral resistance term, which represents the sum of trade costs with all the trading partners (see equation 1.3). More specifically, we use the PPML parameter estimates of exporter fixed effects from the regression in table 1.3 column 4⁶, and we solve for the multilateral resistance term using equation 1.19 as Fally (2015). The following table presents some descriptive statistics about the calculated multilateral resistance terms. As shown in equation 1.19, our measures are obtained using the following formula “ $\Pi_i^{1-\sigma} = Y_0 Y_i \exp(-a_i)$ ”, Where $\Pi_i^{1-\sigma}$ is the variable of interest, Y_0 the GDP of the reference country (USA) in our case, Y_i the GDP of the exporting country, and a_i the estimated exporter’s fixed effects.

As we mentioned earlier, estimating the multilateral resistance term with this method requires that the sum of exports (including trade with self) equals GDP to comply with structural gravity. Unfortunately, it is not the case with our data set because some countries did not report their exports to all destinations, and also, the trade data are not expressed in value-added contrarily to GDP. Besides, our trade data do not include trade with self except for intra-Brazilian trade flows. To take this into account, we calculated two measures of our variable of interest. The first with the observed GDP (blue), and

⁶We do not use the PPML fixed-effects parameter estimates of column 1 table 1.3 because this specification with an idiosyncratic border effect for each Brazilian state amounts to exclude intra-national trade flows from the regression. Thus, the obtained fixed-effects parameter estimates are the same as for a regression with no intranational trade flows. This is a problem because multilateral resistance is supposed to affect all trade flows in the same way while this regression suggests a different multilateral resistance for each state intranational flows.

the second with the sum of exports for each state. As we can see in the chart below, the results are approximately the same for Manaus and RAM regardless of the formula chosen.



Source: Author's calculations

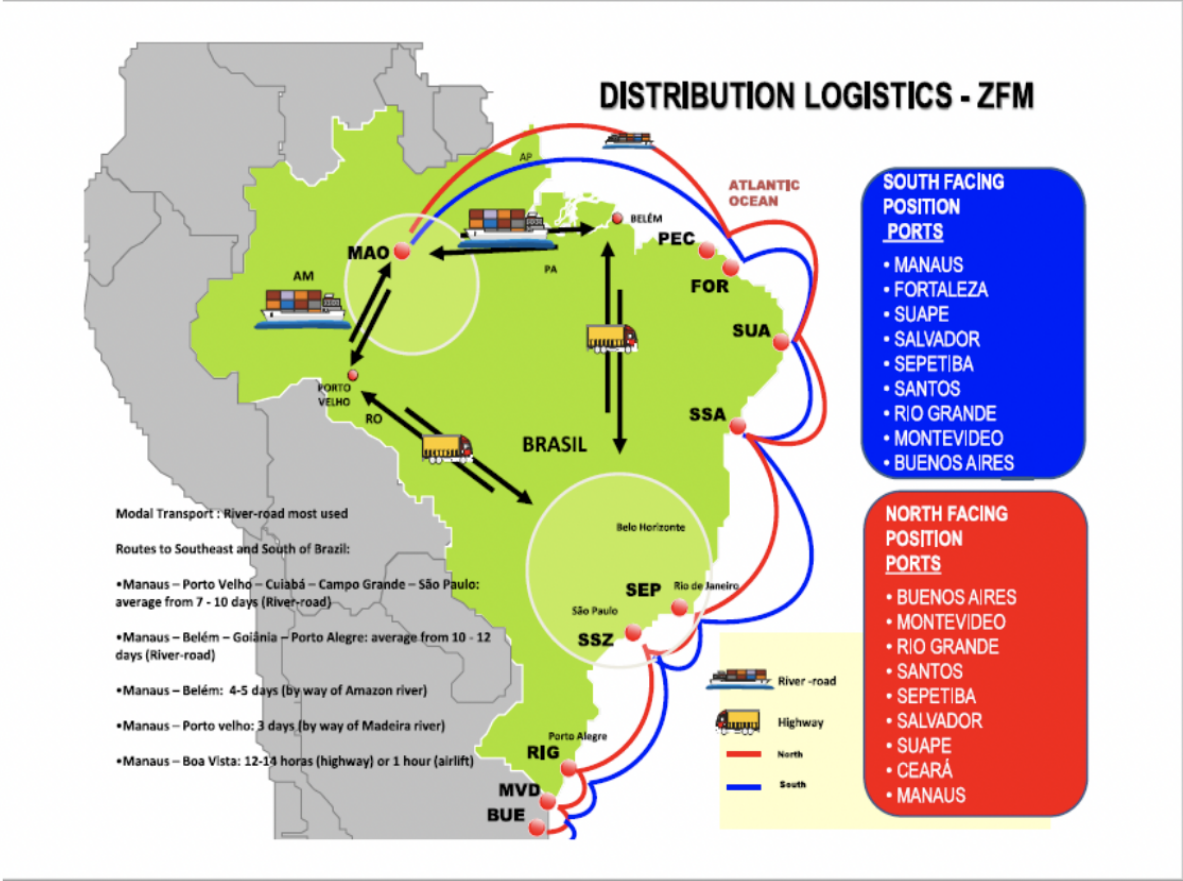
Figure 1.5: Brazilian states exporter multilateral resistance

We should note that we are interested in Π_i and not $\Pi_i^{1-\sigma}$. As $\sigma > 1$, a high $\Pi_i^{1-\sigma}$ means a low Π_i . In this regard, Manaus is among the entities with the highest level of trade costs in the subset of Brazilian states since its $\Pi_i^{1-\sigma}$ is well below the average, and close to the minimum in each case. The rest of Amazonas also presents a below-average $\Pi_i^{1-\sigma}$ which means that its multilateral resistance term is also among the highest in Brazil. The geographical situation of Manaus certainly plays a prominent role in explaining this situation.

It is the case because the only differences between Amazonas and the other Brazilian states trade costs factors are 2 geographical variables notably distance and the contiguity dummy (See equation 1.14). It suggests that the states located in the northern part of Brazil as Amazonas are relatively far from the economically large Brazilian states, but also from the economically large countries in the world. The following map of Manaus' transport network provided by SUFRAMA confirms the consistency of this idea.

This map shows that Manaus (MAO) is among the entities located the farthest from Sao Paulo (SSZ), the economic hearth of the country. On top of that, because of the lack of direct connections with the rich southern states, the goods from Manaus need to bypass by other states as Rondonia (RO) or Para (PA) which are also far from the economic centre, implying longer distances to cover and therefore higher transports costs. This effect is nevertheless not accounted in our multilateral resistance term since we simply

used the direct geographic distance between each state’s capital. Still, as we can see, the estimated multilateral resistances for states like Para or Rondonia which are nearly as far as Manaus from the economic hearth of the country are also among the highest of the Brazilian sample (See table 1.4).



Source: Suframa

Figure 1.6: Amazonas inter-state transport network

To sum up, the second point was to say that Manaus and RAM level of trade costs were among the highest in the subset of Brazilian states. Despite this fact it appears that they are also among the top performers in term of intra-national exports in Brazil. In other words, the high level of trade costs does not impeach these two entities to outperform the average Brazilian state in term of intra-national exports. It is therefore very likely that another factor is at play here.

This leads us to our third point, which is to envisage the tax incentives provided by the Free Trade Zone of Manaus as one of the main explanations to the state of Amazonas trade performance. To assess the relevance of this idea, we carried out a stochastic frontier estimation with a specification allowing the inefficiency term to be heteroskedastic. As explained in section 1.3.3, this kind of specification is very interesting because it also

permits to determine the variables that influence the inefficiency term. We therefore estimated a fixed-effects stochastic frontier model, and we modelled the variance of the bilateral inefficiency term as a function of bilateral man-made restrictions such as the existence of trade agreements between the two partners, and WTO membership. Besides, considering that manufactured goods are among the more traded goods in term of value,⁷ and also less sensitive to transport costs than primary goods as Xu (2015) for example showed, a high share of manufactured goods in GDP should have a positive influence on trade performance. We therefore assumed that the variance of the bilateral inefficiency term also depends on the exporter's manufactured goods share in GDP.

It is important to note that in Brazil in 2008, the entity that had the highest manufactured goods share in its GDP was Manaus. This manufactured production was essentially attributable to the companies installed in the Free Trade Zone, and which directly benefit from the Brazilian authorities' tax incentives. We can therefore argue that this ratio captures at least a share of the Free Trade Zone impact on Manaus production. The following table displays the results of the regression. The first column presents the independent variables.

Table 1.5: Determinants of the bilateral trade efficiency variance

VARIABLES	(1) lexport	(2) Usigma	(3) Vsigma
Ldist	-1.513*** (0.0254)		
Contig	0.520*** (0.110)		
comlang_off	0.631*** (0.0496)		
Smctry	2.918*** (0.136)		
Comcol	0.637*** (0.0674)		
Colony	1.006*** (0.100)		
RTA	0.110* (0.0617)	-1.350*** (0.104)	
both_wto	0.156 (0.178)	-0.486*** (0.0515)	
lva_indr		-0.765*** (0.0401)	
Constant	40.92*** (0.330)	-0.114 (0.104)	0.521*** (0.0294)
Exporter fixed effects	YES		
Importer fixed effects	YES		
Observations	24,556	24,556	24,556

Cluster-robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Except ldist and lva_indr (the log of the manufactured value-added share in GDP), all

⁷According to WTO, the share of manufactured goods in total merchandise exports was 70 percent in 2015

these are dummy variables. They are all described in table 1.2. The second column presents the coefficients associated to the independent variables that determines the log of exports, whereas columns $U\sigma$ and $V\sigma$ represent respectively the inefficiency component and the two-sided noise component of the error term variance. As said earlier in section 1.3.3, the variance of the error term is ($\sigma^2 = \sigma_v^2 + \sigma_u^2$).

The estimation is made in one step on the assumption of a normal distribution for the two-sided noise component and an exponential distribution for inefficiency. We can see in the table that $V\sigma$ is constant since it does not depend on any covariates unlike $U\sigma$. It appears that except for the constant, all the variables explaining the inefficiency variance are significant at the 1% level and have a negative sign. It means that a trade agreement for example has a negative impact on the variance of trade inefficiency, and therefore a positive impact on the efficiency variance.

As discussed by Parmeter et al. (2014) the sign of the inefficiency variance covariates coefficients is also informative about the sign of their effect on the expected value of inefficiency. We can thus say that an increase of the exporter's share of manufactured goods in GDP exerts a negative impact on its trade inefficiency, and therefore a positive impact on its trade efficiency. The magnitude of the coefficients however tells us nothing about their marginal effects on inefficiency, since the relationship between the expected value of inefficiency and the covariates is nonlinear. Still, if the level of Manaus manufactured goods share in GDP is the result of the tax incentives provided by the Free Trade Zone (which is probably the case to some extent), it would mean a positive impact of the Free Trade Zone on Manaus intra-national export performance. All these results therefore suggest that the goal of fostering the state of Amazonas economic linkages with other Brazilian states that motivated the creation of Manaus FTZ has been achieved, and that this Free Trade Zone played a role in the process.

1.6 Concluding remarks

The goal of this paper was to determine Manaus and the Rest of Amazonas level of integration into the Brazilian economy and to examine the eventual role of the Free Trade Zone of Manaus to explain their situation. To do so, we used a structural gravity model and derived some measures of trade costs and trade performance in order to compare Manaus and RAM with the other Brazilian states. We showed that these two entities presented in 2008 the highest level of trade costs among Brazilian states, but despite this fact, were among the most efficient intra-national exporters in Brazil. To explain this puzzle, we envisaged the free trade zone of Manaus as the main explanation because of

the wide range of tax incentives it provides to firms in this region. To support this idea, we established that the manufactured value-added share in total value-added has a positive impact on the trade efficiency scores. As manufactured goods are the main products fabricated by the firms in this FTZ which besides, amounts to a high share of Manaus GDP; we judged that this idea was not devoid of sense. It therefore appears that a good set of tax incentives as those of Manaus FTZ could offset the disadvantages associated with remoteness and high transport costs, and stimulate a given country exports. Examining the conditions that led to this outcome and the potential impact of this FTZ type of tax incentives on intra-regional trade in other regions of the world could hence be an interesting future direction of research.

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Appendices

1.1 LR tests on the existence of inefficiency in the data

As [Kumbhakar et al. \(2015\)](#) explain, a LR test for a stochastic frontier normal-half normal model with OLS as the restricted model amounts to testing the hypothesis that the inefficiency variance $\sigma_u^2=0$. According to them, the LR test statistic has a mixture of chi-square distribution with 1 degree of freedom since only σ_u^2 is restricted. The critical values of this distribution are as follows:

Table 1.6: Critical values of the mixed chi-square distribution

Degree of freedom	Significance level						
	0.25	0.1	0.05	0.025	0.01	0.005	0.001
1	0.455	1.642	2.705	3.841	5.412	6.635	9.500

Source : Table 1, Kodde and Palm (1986, Econometrica).

More precisely, if there is no inefficiency, in the data, the OLS residuals are described by the following equation:

$$\varepsilon_{ij} = v_{ij} + E(v_{ij}), \text{ With } E(v_{ij}) = 0$$

Otherwise, if there is inefficiency, the residuals are better described by

$$\varepsilon_{ij} = v_{ij} - u_{ij} + E(u_{ij}) + E(v_{ij}), \text{ With } E(u_{ij}) \geq 0$$

We can estimate the latter model by applying the standard stochastic frontier model presented earlier, assuming a standard normal distribution $N(0, \sigma_v^2)$ for v_{ij} and an exponential distribution $N+(\sigma_u^2)$ for u_{it} both being i.i.d. The former model is estimated via OLS, and we perform the likelihood ratio test to determine which model better explains the error term. The likelihood ratio test statistic is $-2[L(H_0) - L(H_1)]$ where $L(H_0)$ and $L(H_1)$ are likelihood values of the restricted model (OLS) and the unrestricted model (stochastic frontier).

Following the test, we obtain a LR statistic equal to 1503.06 which means a significance at the 1% level. This test thus confirms the existence of inefficiency in the estimated model.

1..2 List of Brazilian states

Acronym	Name of State
RAM	Rest of Amazonas
AC	ACRE
RR	RORAIMA
SE	SERGIPE
DF	DISTRITO FEDERAL
MANAUS	MANAUS
PI	PIAUI
RN	RIO GRANDE DO NORTE
PB	PARAIBA
PE	PERNAMBUCO
CE	CEARA
TO	TOCANTINS
RO	RONDONIA
AP	AMAPA
SP	SAO PAULO
GO	GOIAS
AL	ALAGOAS
MA	MARANHAO
MS	MATO GROSSO DO SUL
BA	BAHIA
SC	SANTA CATARINA
RS	RIO GRANDE DO SUL
MT	MATO GROSSO
PR	PARANA
RJ	RIO DE JANEIRO
MG	MINAS GERAIS
ES	ESPIRITO SANTO
PA	PARA

Chapter 2

Are African exports that weak ? A trade in value-added approach

Abstract: African countries are known to export less than any other group of countries in the world. Numerous studies have pointed out the high level of transport costs related to the lousy quality of transport infrastructures in the African continent to be the main explanation of this situation. We first show that depending on the estimator used, African countries on aggregate do not trade necessary less than the average country in the world when it comes to gross exports, even if they underperform clearly as regards final goods exports. We also formulate a model for trade in value-added by adapting the Anderson and Van Wincoop's gravity equation to take into account the structure of value-added exports. The proposed model highlights the importance of indirect trade costs, which are trade costs of third countries through which the exported value-added of the origin country passes to reach its final destination. When we control for these indirect trade costs, it appears that the penalty on the direct trade costs between African countries' and their partners is at least two times lower for value-added exports than what is predicted for gross exports and even six times lower in comparison to final goods exports.

Keywords: Global value chains, Gravity model, trade costs, African trade

JEL classification code : F100

2.1 Introduction

The weakness of African exports is a long-standing concern. The continent's share of world exports has never been known to top 8% since African independence, and has actually posted a virtually steady downward trend despite a few episodes of growth. WTO data estimate Africa's share of world exports at just 2% today. This diminutive share presents a real problem for a number of reasons. First, it has been shown that exporting firms in many countries, including Africa, pay higher wages and are larger employers than non-exporting firms (Bernard et al., 2007; Rankin et al., 2006). From this point of view, an increase in exports is potentially welfare-improving for a continent on which extreme poverty remains rife.

Second, given that African countries are generally small economies, an increase in exports could offset their weak domestic demand. This explains the many trade agreements signed by African countries with their regional and international partners since the early 1990s to gain access to larger markets. However, these trade agreements do not appear to have done anything to increase African countries' exports or their share in world exports as presented by the above stylized facts. Yet are these countries' exports as weak as they seem? More formally, do African countries' exports fall short of a benchmark level?

This question has been widely discussed in the literature. There is a consensus among researchers that these countries trade less than others with similar characteristics, despite other findings presented by a few studies.¹ Limao and Venables (2001), for example, support this view. They show that there is a penalty on intra-sub-Saharan African (SSA) trade flows and that this penalty is overturned once the level of transport infrastructure is controlled for. They therefore conclude that transport infrastructure plays a key role in explaining the transport cost penalty borne by intra-SSA trade.

Freund and Rocha (2011) reach a similar conclusion regarding the weakness of African exports compared to the benchmark. However, they find a different trade obstacle, albeit related to transport infrastructure, in the form of transit time from factory to port of shipment. They find that halving average transit time to 3.5 days would raise African trade by 30%. The negative impact of transport infrastructure on African trade is also highlighted by Buys et al. (2006).

Although the results of these studies are interesting, they raise certain concerns with respect to the estimation methods used for the theoretical model. The literature has

¹Foroutan and Pritchett (1993) find that African countries do not trade less than countries with similar economic characteristics. Rodrik (1998) explains the weakness of African exports by the low-income growth in this continent in the period studied.

largely discussed how to properly estimate the gravity model, the framework on which all these findings are based. For example, it is acknowledged that the use of ordinary least squares to estimate this model, as commonly seen in the above studies, is not risk free in the presence of heteroskedasticity, something highly likely in trade data ([Silva and Tenreyro, 2006](#)).

In addition, most of the studies on the trade performance of African countries use exporter and importer GDP to control for mass variables. When bilateral gross exports are the dependent variable and trade in intermediate goods is present, GDP is clearly not the appropriate mass variable. This is because bilateral gross exports embed previously imported intermediate inputs used to produce the exported final goods, while GDP covers solely domestic value-added. Using an inappropriate mass variable can alter the trade performance scores, as countries using more imported intermediate inputs to produce their exported goods display a higher level of exports than possible given their GDP.

Moreover, exporter fixed-effects are rarely included in the estimations. Rigorous model estimation calls for the inclusion of exporter and importer fixed-effects to adequately control for all idiosyncratic variables, such as multilateral resistance. Yet it is hard to assess the trade performance of different countries with the presence of fixed-effects, because they capture part of our parameter of interest. It is thus worthwhile to determine whether the alleged weakness of African exports compared to the benchmark continues to be found when the gravity model is estimated correctly and rigorously.

We take a threefold approach to address the above-mentioned concerns. First, we use appropriate mass variables rather than GDP to estimate the model. Second, we use the Poisson pseudo maximum likelihood estimator (PPML) instead of ordinary least squares to prevent heteroskedasticity issues. Third, in addition to using gross exports as our dependent variable, we calculate each country's value-added exports and reformulate the gravity model to take into account the particularity of these trade flows before estimating it.

This approach substantially improves the estimation of the gravity equation, because it determines the real increase in international demand that a country can expect after reducing its trade costs with its trading partners. In fact, trade costs probably have a differential impact on value-added exports and gross exports due mainly to the inclusion of domestic and foreign content in gross exports. A trade cost could therefore impact more on the foreign than the domestic content of gross exports. This is, for instance, suggested by [Johnson and Noguera \(2012b\)](#), who find a steady downward trend in the ratio of value-added to gross exports from 1970 to 2009, along with a sharp decrease in bilateral trade costs over the period.

Estimating the model with value-added exports thus enables us to assess the real impact of trade costs on this variable, and naturally eases the identification of the real contribution that a change in trade costs could make to an economy's material well-being in terms of real income. Some authors, such as [Guilhoto et al. \(2015\)](#) and [Johnson and Noguera \(2012b\)](#), have already used classical gravity equations to estimate models with bilateral value-added exports as the dependent variable. However, because of their more complex structure, these traditional models – such as that of [Anderson and Van Wincoop \(2003\)](#) and other variants such as [Eaton and Kortum \(2002\)](#) and [Chaney \(2008\)](#)– are not entirely suitable to explain this type of trade flow. This is because, unlike the direct bilateral exports that these models explain, a given country's value-added exports to a particular destination depend on third country exports of final goods to that same destination ([Koopman et al., 2014](#)). A better modelling strategy therefore needs to take this into account.

In this sense, [Aichele and Heiland \(2018\)](#) derive a structural expression for value-added exports that they use to perform a counterfactual analysis in general equilibrium, but they do not estimate a reduced form gravity equation. [Noguera \(2012\)](#) proposes an approach that combines the gross trade equation with a log-linear Taylor approximation of bilateral value-added exports around a benchmark equilibrium. This produces an equation that relates bilateral value-added exports in change to gravity variables. Although his interesting method takes into account third countries' trade costs with the destination of final consumption, it presents the caveat of estimating a log-linear gravity equation. With heteroskedastic data, as shown by [Silva and Tenreyro \(2006\)](#), estimating this kind of log-linearized gravity model using ordinary least squares, as conducted by [Noguera \(2012\)](#), could produce biased parameter estimates.

We propose a framework that preserves the non-linearity of the model and thus gets around this potential problem. Unlike [Noguera \(2012\)](#), who finds that the bilateral trade cost elasticity of value-added exports is about two-thirds that of gross exports, we find that only the standard errors of the trade cost parameters' are lower for value-added exports than for gross trade flows. It suggests that inter-country heterogeneity in magnitudes of trade cost parameters is lower for value-added exports.

For instance, African countries bear a sizeable penalty on their trade cost coefficients compared to the benchmark when the dependent variable is final goods exports. However, this penalty is six times lower with value-added exports. This means, for example, that an improvement in transport infrastructures, which can considerably reduce African transport costs, could significantly increase their exports of final goods, but have less of an impact on their value-added exports.

This result has many policy implications, because policymakers are more concerned with the exported value-added for the reasons detailed above. We thus contribute to the literature by highlighting this differential impact of trade costs on African value-added exports and final goods exports, but also by proposing an appropriate model to estimate the gravity equation for value-added export flows. The remainder of this paper is organized as follows. Section 2.2 presents the structural gravity model developed by [Anderson and Van Wincoop \(2003\)](#) and discusses certain considerations regarding its empirical estimation. Section 2.3 proposes a gravity model for value-added exports. Sections 2.4 and 2.5 present respectively the data and the empirical results. Finally, section 2.6 contains some concluding remarks.

2.2 The structural Gravity Model and its estimation

Anderson and Van Wincoop's model has the following form:

$$X_{sj} = \frac{Y_s D_j}{Y} \left(\frac{t_{sj}}{\Pi_s P_j} \right)^{1-\sigma} \quad (2.1)$$

$$\text{With } P_j^{1-\sigma} = \sum_s \frac{Y_s t_{sj}^{1-\sigma}}{\Pi_s^{1-\sigma}} \quad (2.2)$$

$$\Pi_s^{1-\sigma} = \sum_j \frac{D_j t_{sj}^{1-\sigma}}{P_j^{1-\sigma}} \quad (2.3)$$

$$\text{And } Y_s = \sum_{j=1}^N X_{sj} \quad (2.4)$$

where X_{sj} represents bilateral exports from country “s” to country “j”, Y is the world's GDP, Y_s and D_j respectively the GDP² and expenditures of countries “s” and “j”, and t_{sj} country “j” import costs for goods from country “s”. $1 - \sigma < 1$ is the trade-cost elasticity of trade, and Π_s and P_j represent respectively the exporter and importer outward and inward multilateral resistance terms. Given its nonlinear nature, a log-linear version of

²GDP here is the sum of value-added created within a country, which also includes net taxes on intermediate inputs. See [Timmer et al. \(2015\)](#)

this equation is often estimated. We have:

$$\ln X_{sj} = a_0 + a_1 \ln Y_s + a_2 \ln D_j + (1 - \sigma) \ln t_{sj} - (1 - \sigma) \ln \Pi_s - (1 - \sigma) \ln P_j + \varepsilon_{sj} \quad (2.5)$$

Where a_0 is the constant, and ε_{sj} is the error term. We use the following equation for the trade cost factor:

$$T_{sj} = d_{sj}^{\delta_1} \cdot \exp(\delta_2 cont_{sj} + \delta_3 lang_{sj} + \delta_4 ccol_{sj} + \delta_5 col_{sj} + \delta_6 rta_{sj} + a_i border_{sj}) \quad (2.6)$$

With d_{sj} representing the bilateral distance, and $cont_{sj}$, $lang_{sj}$, $ccol_{sj}$, col_{sj} , $border_{sj}$ representing dummies respectively for the presence of a common border, a common official language, a common colonizer, if the territory is or has been one of its partner colonies in the past and for the country's trade with itself. The best way to control for exporter and importer multilateral trade resistance, which is generally unobservable, is to use exporter and importer fixed-effects ([Baldwin and Taglioni, 2006](#)).

Estimating a log-linearized model is not a flawless exercise, particularly because it raises the issue of Jensen inequality [$E(\ln y) \neq \ln E(y)$], which biases the estimates in the presence of heteroskedasticity. As [Silva and Tenreyro \(2006\)](#) point out, the expected value of the logarithm of a random variable is a function of its mean, but also of the higher-order moments of the distribution. So, for instance, if the error term variance in equation (2.5) is a function of the independent variables, as is generally the case in trade data³, the exogeneity assumption $E(\varepsilon_{sj}|x) = 0$ required for the consistency of OLS will be violated. The authors, therefore, advocate using the Poisson Pseudo maximum likelihood estimator instead, an estimation method that avoids log-linearization and has several other interesting features in line with some of the characteristics of trade data, such as the existence of zero trade flows. The estimated model thus becomes:

$$X_{sj} = \{ \exp(a_0 + a_1 \ln Y_s + a_2 \ln D_j + (1 - \sigma) \ln T_{sj} - (1 - \sigma) \ln \Pi_s - (1 - \sigma) \ln P_j) + \varepsilon_{sj} \} \quad (2.7)$$

With X_{sj} representing exports in value from country “s” to country “j”, and the other variables remaining unchanged. When we include importer and exporter fixed-effects to control for the multilateral resistance terms, we obtain the following empirical model:

$$X_{sj} = \exp(u_s + \ln T_{sj}^{1-\sigma} + u_j) \quad (2.8)$$

³The authors state that the higher the conditional expectation of trade flows, the higher the probable variance of trade flows with respect to the regressors.

where u_j and u_s are respectively estimates of the importer and exporter fixed-effects, and Y_0 the income of the reference country.

Originally designed for gross trade flows, the [Anderson and Van Wincoop \(2003\)](#) gravity model is not necessarily suitable to analyse value-added trade flows as we will see in the next section.

2.3 A gravity model for value-added exports

Trade flows between countries are generally analyzed using data on bilateral gross exports. As we know, these data are obtained by recording the gross value of goods as they cross borders. With a fragmented production process involving many countries, inputs cross borders many times before reaching their destination, and it is impossible to determine exactly where the value-added embedded in the flows comes from and where it is ultimately consumed. This poses a problem when seeking to explain trade flows using a standard gravity model, because the ratio of value-added to gross exports is highly heterogeneous across countries and time ([Johnson and Noguera, 2012b](#)). These data cannot therefore be relied on to properly analyze how value-added is exchanged between countries. This has prompted the development of new methods to obtain better measures of trade in value-added such as in [Daudin et al. \(2011\)](#), [Johnson and Noguera \(2012a\)](#) or [Koopman et al. \(2014\)](#).

Following [Koopman et al. \(2014\)](#), for example, a given country's value-added exports to a particular destination depend on third country exports of final goods to that same destination. In other words, bilateral value-added exports (v_{ij}) from country "i" to country "j" are obtained by computing the sum of weighted exports of final goods from each country $s \in S$ in the world to the importing country, where the weights are proportional to the importance of the origin country "i" in the production structure of the other countries ($s \in S$). S represents the set of countries in the world including "i". We take this definition to derive a gravity model for value-added exports, using the structural model developed by [Anderson and Van Wincoop \(2003\)](#) as a starting point. In appendix 2.1, we derive our model by posing a problem of maximisation under constraints, and we obtain the same results as in this section.

More formally, we have:

$$v_{ij} = \left(\sum_{s=i}^S \pi_{is} X_{sj} \right) \tag{2.9}$$

Where X_{sj} is defined as in (2.1), π_{is} the fraction of country “i” value-added required to produce a unit of final goods in country “s” and v_{ij} bilateral value-added exports.

By combining equations (2.9) and (2.1), it follows that:

$$\begin{aligned}
v_{ij} &= \sum_{s=i}^S \frac{Y_s D_j}{Y_w} \left(\frac{t_{sj}}{\Pi_s P_j} \right)^{1-\sigma} \pi_{is} \\
&= \left(\frac{Y_i D_j}{Y_w} \left(\frac{t_{ij}}{\Pi_i P_j} \right)^{1-\sigma} \pi_{ii} \right) + \left(\sum_{s \neq i}^S \frac{Y_s D_j}{Y_w} \left(\frac{t_{sj}}{\Pi_s P_j} \right)^{1-\sigma} \pi_{is} \right) \\
\Rightarrow v_{ij} &= \left(\frac{Y_i D_j}{Y_w} \left(\frac{t_{ij}}{\Pi_i P_j} \right)^{1-\sigma} \pi_{ii} \right) \left(\frac{\frac{Y_i D_j}{Y_w} \left(\frac{t_{ij}}{\Pi_i P_j} \right)^{1-\sigma} \pi_{ii} + \sum_{s \neq i}^S \frac{Y_s D_j}{Y_w} \left(\frac{t_{sj}}{\Pi_s P_j} \right)^{1-\sigma} \pi_{is}}{\frac{Y_i D_j}{Y_w} \left(\frac{t_{ij}}{\Pi_i P_j} \right)^{1-\sigma} \pi_{ii}} \right) \\
&= \left(\frac{Y_i D_j}{Y_w} \left(\frac{t_{ij}}{\Pi_i P_j} \right)^{1-\sigma} \right) \left(\frac{\sum_{s=i}^S \frac{Y_s D_j}{Y_w} \left(\frac{t_{sj}}{\Pi_s P_j} \right)^{1-\sigma} \pi_{is}}{\frac{Y_i D_j}{Y_w} \left(\frac{t_{ij}}{\Pi_i P_j} \right)^{1-\sigma}} \right) \\
&= \left(\frac{Y_i D_j}{Y_w} \left(\frac{t_{ij}}{\Pi_i P_j} \right)^{1-\sigma} \right) \left(\frac{\sum_{s=i}^S \pi_{is} Y_s \left(\frac{t_{sj}}{\Pi_s} \right)^{1-\sigma}}{Y_i \left(\frac{t_{ij}}{\Pi_i} \right)^{1-\sigma}} \right) \\
\Rightarrow v_{ij} &= \left(\frac{Y_i D_j}{Y_w} \left(\frac{t_{ij} t_{iSj}}{\Pi_i P_j} \right)^{1-\sigma} \right) \tag{2.10}
\end{aligned}$$

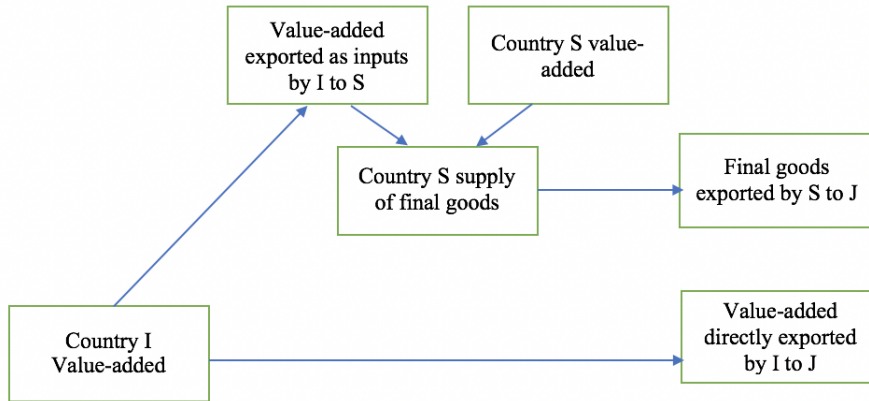
$$\text{Where } t_{iSj} = \left(\frac{\sum_{s=i}^S \pi_{is} Y_s \left(\frac{t_{sj}}{\Pi_s} \right)^{1-\sigma}}{Y_i \left(\frac{t_{ij}}{\Pi_i} \right)^{1-\sigma}} \right)^{\frac{1}{1-\sigma}} \tag{2.11}$$

This term t_{iSj} is a function of bilateral trade costs between “i” and “j”, and of the weighted sum of bilateral trade costs between “j” and all its trading partners including “i”. This is very similar to Anderson and Van Wincoop’s multilateral resistance, except for the fact that it is associated with a bilateral relationship instead of being idiosyncratic to a country. It represents the relative trade cost of indirectly exported value-added from country of origin “i” to destination country “j” through third countries “ $s \in S$ ” in terms of directly exported value-added from “i” to “j”. Furthermore, we can see that equation (2.10) is close to the Anderson and Van Wincoop’s gravity equation with the difference that it is scaled by this new term that we label “Cost of fragmentation”.

As bilateral trade costs, this term exerts a negative effect on bilateral value-added exports. However, it decreases with the amount of indirectly exported value-added by the origin

country, that is to say, $\frac{\partial t_{iSj}}{\partial \pi_{is}} < 0$. It means that the more connected a country is to the world production network via its intermediate inputs' exports, the lesser its cost of fragmentation will be, and the higher will be its exported value-added to a given partner comparatively to a less connected country.

Figure 2.1: Schematic description of bilateral value-added exports



For example, consider a three-country case with countries “i”, “s” and “j”, as in the chart above. The exported value-added from “i” to “j” depends on its direct exports to “j”, but also its indirect exports via country “s” exports of final goods to “j.”⁴ This is because, in order to produce a unit of final good, country “s” needs intermediate goods and thus value-added from “i”. This example also clearly illustrates that the trade costs incurred by the exported value-added from “i” to “j” are not only direct trade costs, but also indirect trade costs incurred by the indirectly exported value-added via exports of final goods from “s” to “j”.

Estimating a model of trade in value-added without taking into account these indirect trade costs therefore gives rise to an omitted variable bias, with its undesirable repercussions on the estimated coefficients. As should now be clear, value-added exports are not readily available common data on trade between countries. They therefore need to be calculated using an inter-country or multi-country input-output matrix. The following section describes the dataset used for this work.

⁴Bear in mind that B_{is} represents the total quantity of country “i” output required to produce a unit of final good in country “s”, and that will be consumed either in “s” or outside “s”. $B_{is}Y_s$ therefore represents the fraction of country “i” output required to produce supply of final goods to country “s” for consumption either in “s” or outside “s”.

2.4 Data

This work draws on the GTAP 9 Database, which is a multi-country input-output table. The table comprises 57 sectors and 140 entities, within which are found 26 African countries and six aggregated regions for the rest of Africa. The dataset released in 2015 has three base years, from among which we choose 2011 to conduct our analysis. We obtain our measure of value-added exports using the methodology developed by [Koopman et al. \(2014\)](#). As our table is a multi-country table, intermediate consumption imports are not broken down by countries of origin, nor are final demand imports. This poses a problem because we need the complete set of bilateral intermediate and final demand imports in order to calculate the bilateral value-added exports of each country. Two options are available to solve this problem.

First, a proportionality assumption can be applied. Specifically, we assume that for a given destination country, the imported share of intermediate goods from a country of origin is the same as the share of that country in the total imports of the destination country. This assumption has been somewhat criticized for its poor performance in capturing the real share of a given country of origin in the inputs used by a given sector in a destination country or in the final goods consumed by the said destination country ([Koopman et al., 2014](#); [Puzzello, 2012](#)).

To solve this problem [Koopman et al. \(2014\)](#) recommend using the UN Broad Economic Classification of products by end-use category with HS6 digit level COMTRADE data to split commodities into intermediate and final goods. Taking the trade shares thereby obtained, a reconciliation exercise is conducted to ensure that the new set of intermediate and final goods flows is consistent with the GTAP Database aggregates. In order to perform this reconciliation exercise, we draw on a quadratic mathematical programming model proposed by [Tsigas et al. \(2012\)](#). Appendix 2.3 provides more details.

[Koopman et al. \(2014\)](#) make a comparison between the results obtained from this method using version 7 of the GTAP Database to build an inter-country input-output table for 2004 and the 2005 inter-country input-output table developed by the Institute of Development Economics in Japan for nine East Asian economies and the United States. Given that the latter is based on a survey of firms, it reports true data regarding the use of intermediate goods from a given country by a given sector. The authors show that the UN BEC method performs much better than the proportionality assumption in approximating these true data.

For this reason, we privileged the UN BEC method to obtain our data on value-added exports and perform our analysis. The results obtained with the proportionality assumption

can nevertheless be found in Appendix 2.2.

As mentioned earlier, the GTAP Database level of aggregation is very high. This is problematic due to our focus on African countries. We have only 26 of the continent’s 54 countries. The other 28 countries are represented by six aggregated regions. This implies that intra-African trade considerations cannot realistically be analyzed in this study. In addition, this level of aggregation implies having to make assumptions regarding certain gravity variables such as “common border” and “common official language”. In effect, if one country in an aggregate of countries shares a border with another outside of the aggregated entity, that does not mean that the entire entity shares a border with the said external country. We therefore need to take this into account and we arbitrarily consider that a given aggregation of countries shares a common border with a state if at least 80% of its component countries share a border with it. Having said that, to ensure the robustness of our results, we also conduct our empirical analysis taking two other scenarios whereby:

- We consider that a given aggregation of countries shares a common border with a state if 100% of its component countries share a border with it;
- We consider that a given aggregation of countries shares a common border with a state if at least 60% of its component countries share a border with it.

Table 2.1: Presentation of the different variables used in our estimations

Variables	Source	Methodology/rule/formula
Value-added exports	Author’s calculations	Koopman Wang and Wei (2014)
Distance	American museum of natural history	Distance of an entity to itself: $d_{ii} = 0.33\sqrt{\frac{area}{\pi}}$
Common border	Cepii/Author’s calculations	
Common official language	Cepii/Author’s calculations	1 if 80% of the countries of an aggregated entity share the characteristic in the first column
Colony	Cepii/Author’s calculations	share the characteristic in the first column
Common colonizer	Cepii/Author’s calculations	with a given country, zero otherwise.
Regional trade agreement	Mario Larch	
Cost of fragmentation (t_{isj})	Author’s calculations	$\left(\frac{\sum_{s=i}^S \pi_{is} Y_s \left(\frac{t_{sj}}{\pi_s}\right)^{1-\sigma}}{Y_i \left(\frac{t_{ij}}{\pi_i}\right)^{1-\sigma}} \right)^{\frac{1}{1-\sigma}}$

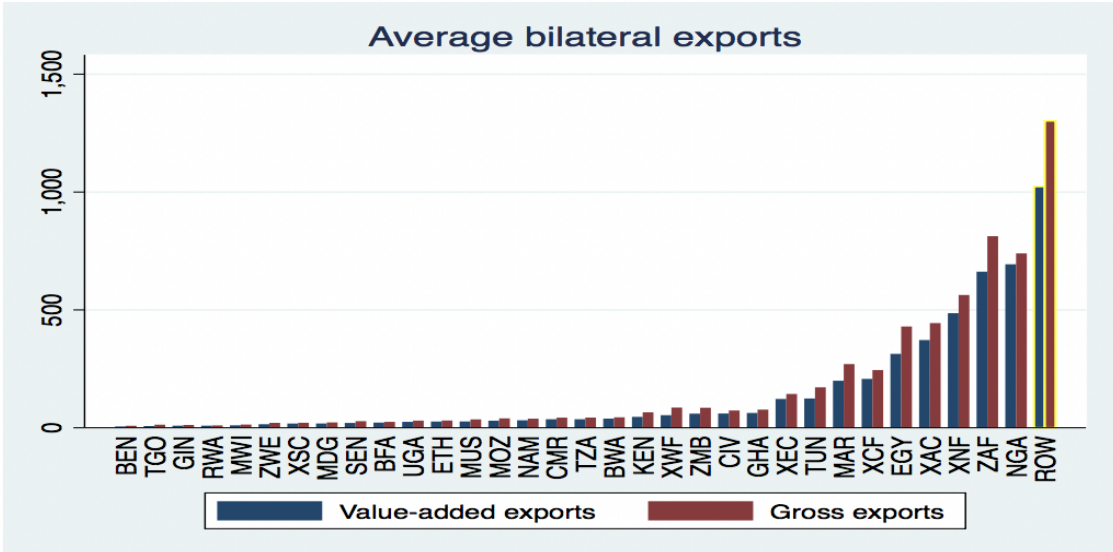
Table 2.1 presents some of the variables used in our estimations, their sources and the rules or methodology applied to obtain them. As can be seen, we obtain the geographic distance between each pair of countries using a generator built by the Centre for Biodiversity and Conservation at the American Museum of Natural History (AMNH). The distance of a country to itself is calculated using the formula in column 3. The proxy for the cost of fragmentation is obtained as follows: we estimate equation (2.8) with the trade costs function in equation (2.6) to obtain the trade costs parameters that will allow us to get a proxy of final goods exports’ bilateral indexes of trade costs ($t_{ij}^{1-\sigma}$). Exporter multilateral

resistance $\Pi_i^{1-\sigma}$ is then obtained using the fixed-effects estimates as in Fally (2015) and finally, using equation (2.11), we solve for the cost of fragmentation.

It is important to note that this procedure does not obtain t_{iSj} , but $t_{iSj}^{1-\sigma}$. This implies that the effect of the obtained term on value-added exports will not be $(1 - \sigma)$, as would have been the case had we been able to calculate t_{iSj} directly, but unity instead (at least theoretically). $t_{iSj}^{1-\sigma}$ is therefore more like an inverse cost of fragmentation, and we label it as such hereafter. The econometric results will clarify this point. However, before going moving on to these results, it is worth presenting a brief description of the data on value-added and gross exports and on the cost of fragmentation.

Chart 2.2 presents the average data on bilateral value-added and gross exports for African countries compared to the rest of the sample (ROW). It shows unsurprisingly that the African countries' bilateral export flows are lower compared to other countries, be it for value-added exports or gross exports.

Figure 2.2: African countries average bilateral exports (2011)

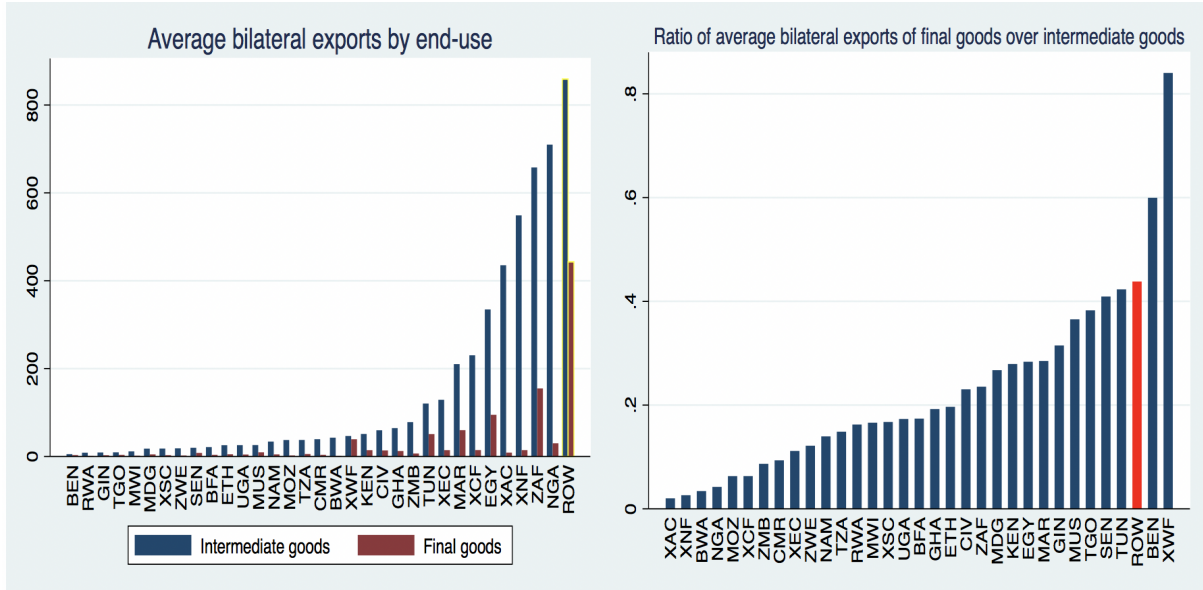


Source: Authors calculations, GTAP 9 database

When we further disentangle gross exports into intermediate and final goods using the method based on the UN Broad Economic Classification of products by end-use category (UN BEC method thereafter), the result remains the same, i.e. African export flows are lower compared to other countries, as shown in chart 2.3. Interestingly, this chart also points up a significant difference between the two kinds of trade flows.

It appears that intermediate goods exports are higher on average than final goods trade flows for every country in the sample, as shown in the left panel of the chart. This is

Figure 2.3: African countries average bilateral exports by end use (2011)



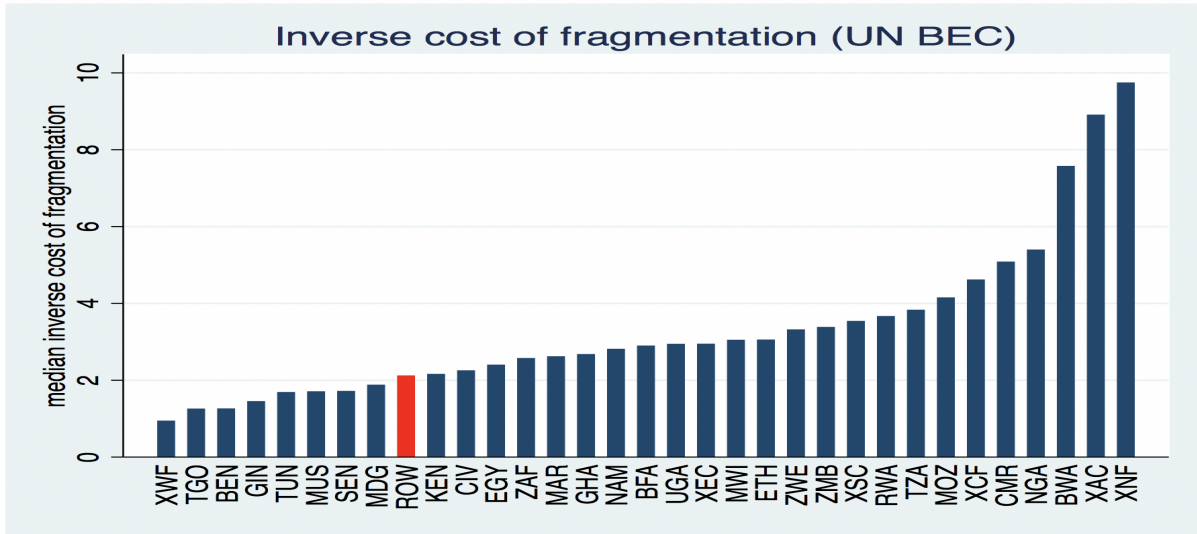
Source: Author's calculations, GTAP 9 database

not surprising, because the emergence of global value chains in recent decades has led to an important surge of trade in intermediate goods. What is worth noting is that this situation is more pronounced for African countries. The right panel of the chart shows that the ratio of average bilateral exports of final goods over intermediate goods is lower for African countries than for other countries (ROW). It suggests that African countries are mainly located in the primary stages of the production process, more specialized in the supply of inputs for the production of final goods in other countries than producing the latter themselves.

This result should also be reflected by the cost of fragmentation of these countries. As said earlier, it represents the relative trade cost of indirectly exported flows from country of origin “i” to destination country “j” through third countries “ $s \in S$ ” in terms of directly exported flows from “i” to “j”. The lower this cost, the more a country exports indirectly its flows than directly. Chart 2.4 presents the measures of the inverse cost of fragmentation ($t_{ijs}^{1-\sigma}$).

The chart shows that the median inverse cost of fragmentation is higher for most African countries (75%) than for other countries. As mentioned earlier $\frac{\partial t_{ijs}}{\partial \pi_{is} Y_s} < 0$, and therefore, $\frac{\partial t_{ijs}^{1-\sigma}}{\partial \pi_{is} Y_s} > 0$ (where $\pi_{is} Y_s$ is the amount of value-added indirectly exported by country “i” via third country “s”). A higher inverse cost of fragmentation, i.e. lower cost of fragmentation, would therefore mean that African countries export more value-added indirectly than the rest of the set and vice versa. The analysis of the mode by which

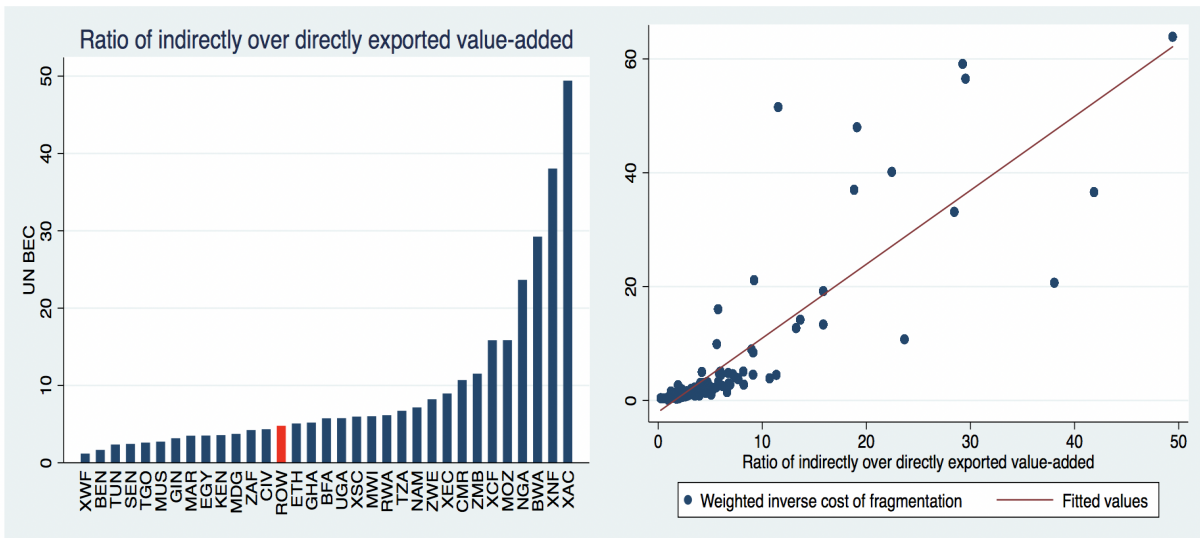
Figure 2.4: African countries median inverse cost of fragmentation



Source: Author's calculations, GTAP 9 database

African flows are exported in chart 2.5 lends support to this hypothesis.

Figure 2.5: African countries trade flows' mode of export



Source: Author's calculations, GTAP 9 database

The left panel of the chart shows that African countries bearing a lower median inverse cost of fragmentation than other countries export less value-added indirectly. This is confirmed by the scatter plots in the chart's right panel comparing the ratios of indirectly to directly exported value-added and weighted inverse costs of fragmentation.⁵ We can

⁵The weighted inverse cost of fragmentation is obtained as follows for each country: $\sum_j \frac{v_{ij}}{Y_i} t_{iS_j}^{1-\sigma}$

clearly see that there is a good correlation between the two variables, of the order of 0.84 to be accurate.

2.5 Econometric results

This section is organized into two parts. First, using the latest gravity model estimation advances, we review the alleged weakness of African countries' exports compared to countries with similar characteristics. We then evaluate the real role played by trade costs in the export performance of these countries.

2.5.1 The alleged weakness of African countries exports

As mentioned earlier, many studies have found that African countries export less than others with similar characteristics (Freund and Rocha, 2011; Buys et al., 2006; Limao and Venables, 2001). Most of these studies obtain their results using ordinary least squares. This poses a problem because, as shown by Silva and Tenreyro (2006), this estimator is inconsistent where the condition of homoskedasticity is not met, which is more than likely with trade data. Furthermore, the way the model's key variables are approximated, namely the mass variables and multilateral resistance terms, can also give cause for concern. Since Baldwin and Taglioni (2006), the literature generally controls for these variables by including exporter and importer fixed-effects in the estimations. However, it is hard to assess the trade performance of different countries by including fixed-effects, because they fundamentally capture our parameter of interest.

Most studies of African countries' trade performance hence exclude them from their estimations, taking the exporter and importer's respective GDP to control for the mass variables. This is problematic because a country's gross exports, unlike its GDP, include a share of value-added from other countries. When a country is well-integrated into the world production network, for example, when its exports present a large import content, GDP is not a good proxy for its size. This is because the share of foreign goods in its exports is by definition a share of other countries' GDP. The appropriate proxy is total output, which is the sum of GDP and intermediate consumption (local and imported).

Failing to use the appropriate proxy can significantly alter the trade performance scores for countries with a high ratio of value-added to gross exports, as is the case with African countries. It is thus extremely important to determine whether African exports continue to appear weak compared to the benchmark when the gravity model is estimated using the proper estimator and mass variables. The following two tables present the results of our estimations.

Table 2.2: Explanation of bilateral gross exports (PPML estimator)

VARIABLES	Gross exports	Gross exports
Exporter GDP	0.831*** (0.0138)	
Exporter total output		0.834*** (0.0128)
Distance	-0.719*** (0.0335)	-0.698*** (0.0327)
Common border	0.203** (0.0791)	0.224*** (0.0814)
Common language	0.240*** (0.0773)	0.250*** (0.0762)
Colony	-0.0520 (0.0979)	-0.0172 (0.0962)
Common colonizer	0.438*** (0.118)	0.451*** (0.120)
RTA	0.0987* (0.0597)	0.103* (0.0579)
aftrade	-0.168** (0.0835)	-0.0757 (0.0883)
Constant	5.730*** (0.323)	4.878*** (0.322)
Observations	19,182	19,182
R-squared		
Exporter FE	NO	NO
Importer FE	YES	YES

Robust standard errors in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

aftrade is a dummy that is equal to 1 for African countries' exports and 0 otherwise.

RTA is a dummy that is equal to 1 when the countries are members of a regional trade agreement and zero otherwise.

The first, table 2.2, presents regressions with bilateral gross exports as the dependent variable using the Poisson pseudo maximum likelihood estimator. In keeping with [Silva and Tenreyro \(2006\)](#), we performed a test to check whether the pattern of heteroskedasticity in the data satisfies the condition required for the consistency of ordinary least squares. This test, presented in appendix 2.2, shows that the OLS estimator is unsuitable for our estimations.⁶ For this reason, we relegated the results obtained with ordinary least squares

⁶There is no need to perform the same test to determine whether the pattern of heteroskedasticity

in appendix 2.2. The two regressions of table 2.2 feature two different mass variables, the log of GDP (Exporter GDP) for column 1 and the log of total output (Exporter total output) for column 2. In each regression, we do not control for exporters' multilateral resistance but include importers' fixed-effects along with other variables to control for trade costs. The non-inclusion of a proxy for exporters' multilateral resistance allows us to capture a penalty on African exports which should be higher than with a proxy, as the latter would capture part of our parameter of interest.

The trade cost variables include the log of bilateral distance (Distance) and dummies to control respectively for the existence of a common border (Common border), a common official language (Common language), a colonial link (Colony), a common colonizer (Common colonizer), and a common trade agreement (RTA). Also included is a dummy that is equal to 1 for African countries' exports and 0 otherwise (Afrtrade) in order to check whether there is a penalty on their exports. As explained by Freund and Rocha (2011), given that this specification is clearly inconsistent with trade theory due to the absence of exporter fixed effects, the penalty on African exports should be at its highest level. Note that we drop the countries' internal trade flows, which is tantamount to including dummies to control for trade within a country.

As shown by the table, the African dummy coefficient is negative and significant at the 1% threshold for the first column. Specifically, when the mass variable used is the exporter's GDP (column 1), African countries export approximately 15% less ($e^{-0.168} - 1 = -0.15$) than expected. However, when the appropriate mass variable is used, namely total output (column 2), the penalty no longer exists since the African dummy coefficient is no longer significant.⁷ Thus, we can conclude that African countries do not export less than expected in terms of bilateral gross exports. It could be interesting to determine whether this result holds at a more detailed level differentiating between final and intermediate goods.

Authors like Antràs and De Gortari (2017) have suggested that trade costs have a more detrimental effect on downstream than upstream production stages. As the alleged weakness of African exports is generally explained by the higher level of trade costs borne by these countries, it would not be surprising to find a lower penalty on their trade in intermediate goods than on their trade in final goods.

corresponds to that assumed by the PPML estimator, because this estimator is consistent in our case, even if the variance function is misspecified, unlike OLS. It may, however, not be efficient.

⁷Freund and Rocha (2011) find a penalty of a higher magnitude using ordinary least squares and GDP as the mass variable(See footnote 12 in their article), a result that we also find in appendix 2.2. Thus, the alleged weakness of African countries' exports depends on the estimator used, but clearly, the PPML results should be preferred as suggests the test on the pattern of heteroskedasticity presented in appendix 2.2.

Table 2.3: Explanation of bilateral final and intermediate goods exports (PPML estimator)

	Intermediate goods exports	Final goods exports
Distance	-0.649*** (0.0386)	-0.798*** (0.0443)
Common border	0.234** (0.0956)	0.206** (0.0974)
Common language	0.308*** (0.0923)	0.0800 (0.0870)
Colony	0.0408 (0.104)	-0.0405 (0.133)
Common colonizer	0.447*** (0.134)	0.385** (0.175)
RTA	0.0655 (0.0650)	0.232*** (0.0801)
aftrade	0.0649 (0.106)	-0.730*** (0.106)
Exporter_supply1	0.770*** (0.0118)	
Exporter_supply2		0.990*** (0.0306)
Constant	5.377*** (0.364)	3.246*** (0.417)
Observations	19,182	19,182
Exporter FE	NO	NO
Importer FE	YES	YES

Robust standard errors in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

aftrade is a dummy that is equal to 1 for African countries' exports and 0 otherwise.

RTA is a dummy that is equal to 1 when the countries are members of a regional trade agreement and zero otherwise.

For each regression, the exporter mass variable (Exporter_supply) is the log of sum of exports regarding the relevant trade flows.

The suggestive evidence is presented in table 2.3, where the estimations are performed using the PPML estimator. This table features two columns of regressions respectively for intermediate and final goods export flows obtained using the above-mentioned UN BEC method. The regressions are performed using the same econometric specification as in table 2.2, where we control for importer fixed-effects but do not include exporter fixed-effects. For each regression, the exporter mass variable (Exporter_supply) is the log of the sum of exports for the relevant trade flows. The variable of interest is again the African trade dummy, equal to 1 for African exports and zero otherwise.

As can be seen, the African dummy coefficient is not significant for intermediate goods exports, which means that African countries do not export fewer intermediate goods than expected. However, the story is different for exports of final goods, which post 52% less than expected ($e^{-0.73} - 1 = -0.518$).

Thus, according to this econometric specification, although the African countries' aggregate bilateral trade is no lower on average than expected, final goods appear to underperform while intermediate goods appear to be unaffected. Note, however, that this specification intentionally designed to reveal the highest possible penalty on African exports is inconsistent with trade theory, since our estimation does not take into account the exporters' multilateral resistance.

To rigorously estimate the model, we need to control for these variables by including exporter fixed-effects in the regressions. However, doing so makes it hard to assess the African countries' export performance due to perfect multicollinearity between the exporter fixed-effects and the dummy for African exports. Nevertheless, it is possible to check whether there is a difference in the impact of trade costs on these countries' trade flows compared to others. In principle, a lower trade performance than a reference group should be reflected by higher trade costs or a higher impact of trade costs on trade flows.

Moreover, up to this point, we have been interested in the export performance of African countries in terms of their gross trade flows. However, as mentioned earlier, what is relevant for policymakers is not necessarily growth in gross trade, since bilateral gross exports embed a share of value-added that comes from foreign countries. These exports could therefore increase due to an increase in this share of foreign value-added. Value-added exports, on the other hand, do not embed a foreign component and comprise solely local value-added. An increase in this variable thus has a direct impact on GDP growth, a core concern for policymakers. In the next series of regressions, we examine whether trade costs have a greater impact on African countries' bilateral gross exports and value-added exports.

Finally, it is worth noting that the above results are based on Hubert-White robust standard errors. However, in these econometric specifications for bilateral trade flows, disturbances could be correlated across different non-nested clusters, namely across exporter, importer or country-pair. Disregarding these different dimensions of correlations could give rise to drastically biased standard errors of the coefficients of interest regardless of whether fixed-effects are included or not; see [Cameron et al. \(2011\)](#), and [Egger and Tarlea \(2015\)](#) or [Larch et al. \(2019\)](#) specifically for the case of structural gravity estimations. In the following set of regressions, the standard errors are clustered by exporter, importer and country-pair using the stata package developed by [Correia et al. \(2019\)](#).

2.5.2 Trade costs and African countries' trade performance

Many studies consider high trade costs as one of the main explanations for Africa's weak trade and economic performance (Amjadi and Yeats, 1995; Limao and Venables, 2001; Freund and Rocha, 2011; Bosker and Garretsen, 2012). We assess the relevance of this assertion by performing a series of regressions based on theoretically consistent econometric specifications using the PPML estimator. The results are reported in tables 2.4 and 2.5. To be more precise, we include exporter and importer fixed-effects to control for exporter and importer multilateral resistance terms as required by the theory. Consequently, we can no longer assess the trade performance of African countries using the previous dummy variable equal to 1 for African exports and zero otherwise due to perfect multicollinearity.

Instead, we create two interaction variables: the first between the previous dummy equal to one for African exports or zero otherwise and bilateral distance (*afldist*), and the other between bilateral distance and a dummy equal to 1 for African imports and zero otherwise (*af2ldist*). This solves the matter of perfect multicollinearity and enables us to determine whether the distance coefficient is significantly higher for African exports than for imports or vice versa. The trade costs function remains the same as before as regards bilateral gross exports, including for intermediate and final goods exports. However, there is a difference when it comes to value-added exports. In line with the model developed in section 2.3, a new variable appears in the form of what we have called the inverse cost of fragmentation. This variable, as explained earlier, captures the sum of bilateral trade costs with a given destination of the third countries through which a country of origin's value-added transits before reaching the said destination.

Table 2.4 features four columns of regressions. The first presents the results for gross exports and Columns 2, 3, and 4 results respectively for final goods exports, intermediate goods exports and value-added exports obtained using the UN BEC method presented in appendix 2.3. Firstly, column 4 shows that $lt_{iSj}^{1-\sigma}$, the log of the inverse cost of fragmentation, has a positive and significant impact on value-added exports. As discussed earlier, the positive sign here is due to the fact that we are only able to obtain a proxy of⁸ $T_{iSj}^{1-\sigma}$ rather than T_{iSj} which is the real cost of fragmentation. This is because trade elasticity ($1 - \sigma$) is not readily observable. Had we used T_{iSj} , the impact would have been negative and equivalent to trade elasticity.

⁸To obtain $T_{iSj}^{1-\sigma}$, we first run a regression with final goods as the dependent variable using the PPML estimator with exporter and importer fixed-effects in order to obtain the trade cost coefficients. We then solve for $t_{ij}^{1-\sigma}$ using the trade costs function in equation (2.6) and exporter multilateral resistance $\Pi_i^{1-\sigma}$, is obtained using the fixed-effects estimates as in Fally (2015). Finally, we solve for $T_{iSj}^{1-\sigma}$ using equation (2.11).

Table 2.4: Additional impact of distance on African trade flows (PPML estimator)

VARIABLES	Gross exports	Final goods exports	Intermediate goods exports	Value-added exports
Distance	-0.689*** (0.0594)	-0.695*** (0.0760)	-0.692*** (0.0627)	-0.711*** (0.0215)
Common border	0.265** (0.121)	0.297** (0.135)	0.230* (0.123)	0.304*** (0.0446)
Common language	0.122 (0.0827)	0.249** (0.110)	0.0990 (0.0940)	0.273*** (0.0351)
Colony	0.0695 (0.149)	0.00763 (0.177)	0.103 (0.145)	-0.00817 (0.0504)
Common colonizer	0.325** (0.160)	0.509* (0.282)	0.256* (0.142)	0.548*** (0.0821)
RTA	0.176** (0.0877)	0.213* (0.110)	0.198** (0.0878)	0.222*** (0.0313)
$lt_{iSj}^{1-\sigma}$				1.142*** (0.0328)
afldist	-0.184 (0.175)	-0.630*** (0.181)	-0.138 (0.201)	-0.0932** (0.0426)
af2ldist	-0.123 (0.134)	-0.0836 (0.169)	-0.138 (0.178)	-0.0371 (0.0565)
Constant	15.00*** (0.509)	14.27*** (0.651)	14.55*** (0.536)	13.75*** (0.185)
Observations	19,182	19,182	19,182	19,182
Exporter FE	YES	YES	YES	YES
Importer FE	YES	YES	YES	YES

Cluster robust standard errors by exporter, importer and country pairs in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

RTA is a dummy that is equal to 1 when the countries are members of a regional trade agreement and zero otherwise.

$lt_{iSj}^{1-\sigma}$ is the log of the inverse cost of fragmentation.

afldist is an interaction variable between the dummy equal to one for African exports or zero otherwise and the log of bilateral distance.

af2ldist is an interaction variable between a dummy equal to one for African imports or zero otherwise and the log of bilateral distance.

The second interesting result is to find no additional effect of distance on African bilateral gross exports (afldist) and imports (af2ldist) in column 1, as the coefficients of the interaction variables are not significant. This is a consequence of the multi-way cluster-robust standard errors which, as mentioned earlier, are clustered by exporter, importer and country-pairs. The standard errors thereby obtained are higher than the Hubert-White robust standard errors, which gives rise to more conservative inferences for all estimates. In fact, the coefficients using the Hubert-White robust standard errors would be significant at the 10% threshold. That said, this result is consistent with the evidence

presented in table 2.2 i.e. that when the Poisson pseudo maximum likelihood estimator is used with the appropriate mass variable, African gross exports are not significantly lower than expected.

Turning to final goods exports (columns 3), it can be seen that the additional distance coefficient -0.63 is significant at the 1% threshold. This indicates that the impact of distance on African exports of final goods is approximately twice as high as for other countries ($-0.695-0.63$). This coefficient is non-significant for imports of final goods. In addition, distance does not seem to have a different impact on African trade flows of intermediate goods compared to other countries (column 4). This finding would appear to confirm the result found in table 2.3 that African countries underperform only in their exports of final goods. It also suggests that part of the additional distance coefficient for exports of final goods captures foreign countries' preferences for African goods.

We say this because intermediate goods are supposed to be more homogeneous than final goods. If distance does not have a greater effect on African imports of final goods or intermediate goods flows, but only has more of an effect on exports of final goods that are highly heterogeneous across countries, it is likely that this penalty actually reflects other countries' weak preferences for African final goods. In the same vein, the additional distance coefficient for African value-added exports (-0.0932) in column 5 is significant at the 5% threshold, albeit seven times lower than for final goods exports, while the coefficient for African value-added imports is not significant. This might suggest that African value-added exports are less sensitive to the weak preferences of foreign countries for African goods.

Whether weak preferences or the additional impact of distance, what is clear is that African value-added exports are less affected than African final goods exports. This result shares some similarities with the findings of [Noguera \(2012\)](#), who shows that the trade cost elasticity for value-added exports is about two-thirds of that of gross exports. In our case, however, the distance coefficient is approximately the same on average, whether for value-added exports or final goods exports.⁹ Only the additional distance coefficients for African countries are different for both trade flows. This is due to the fact that the standard errors are lower when the dependent variable is expressed in value-added terms, suggesting that there is less heterogeneity across countries in terms of the magnitude of the trade cost parameters. For instance, in the case of distance, the standard error is equal to 0.0215 when the dependent variable is expressed in value-added terms (column 5), while it is equal to 0.0760 for final goods exports, as shown in column 3.

⁹Note that it is more relevant to compare value-added trade cost coefficients with final goods trade cost coefficients than to compare them with gross exports trade cost coefficients because, as shown in section 2.3, bilateral value-added exports depend on exports of final goods by countries of origin and third countries, and thus on final goods trade costs.

Table 2.5: Additional impact of trade costs on African trade flows (PPML estimator)

VARIABLES	Gross exports	Final goods exports	Intermediate goods exports	Value-added exports
$lt_{ij}^{1-\sigma}$	1.017*** (0.0509)	0.992*** (0.0775)	1.016*** (0.0450)	0.997*** (0.0269)
$AFlt_{ij}^{1-\sigma}$	0.213 (0.210)	0.736*** (0.203)	0.133 (0.241)	0.114** (0.0494)
$AF2lt_{ij}^{1-\sigma}$	0.161 (0.174)	0.0882 (0.178)	0.188 (0.227)	0.0481 (0.0532)
$lt_{iSj}^{1-\sigma}$				1.142*** (0.0324)
Constant	15.17*** (0.275)	14.29*** (0.426)	14.70*** (0.239)	13.76*** (0.145)
Observations	19,182	19,182	19,182	19,182
Exporter FE	YES	YES	YES	YES
Importer FE	YES	YES	YES	YES

Cluster robust standard errors by exporter, importer and country pair in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

$lt_{iSj}^{1-\sigma}$ is the log of the inverse cost of fragmentation.

$lt_{ij}^{1-\sigma}$ is the log of bilateral costs to trade between countries “i” and “j”

taken to the power $1 - \sigma$.

$AFlt_{ij}^{1-\sigma}$ is an interaction variable between the dummy for African exports and $lt_{ij}^{1-\sigma}$.

$AF2lt_{ij}^{1-\sigma}$ is an interaction variable between the dummy for African imports and $lt_{ij}^{1-\sigma}$.

The results reported in table 2.4 only quantify the additional impact of distance on African trade flows. In table 2.5, we perform the same regressions using the full bilateral trade cost indices. To be more precise, using equation (2.6), and the trade cost parameters obtained from the previous regressions without the interaction variables between distance and the dummies respectively for African exports (afldist) and imports (af2ldist), we calculate the trade cost indices $t_{ij}^{1-\sigma}$. We then create two new interaction variables respectively between the dummies for African exports and imports and the trade cost indices in order to determine whether trade costs have a greater impact on African trade flows than on others.

In table 2.5, $lt_{ij}^{1-\sigma}$ is the log of bilateral costs to trade between countries “i” and “j” taken to the power of $1 - \sigma$. $AFlt_{ij}^{1-\sigma}$ is an interaction variable between the dummy for African exports and $lt_{ij}^{1-\sigma}$, $AF2lt_{ij}^{1-\sigma}$ is an interaction variable between the dummy for African imports and $lt_{ij}^{1-\sigma}$, and $lt_{iSj}^{1-\sigma}$ is the log of the inverse cost of fragmentation. Since $1 - \sigma$ is negative, $lt_{ij}^{1-\sigma}$ is inversely proportional to the level of trade costs.

As the reported results show, the previous conclusions still hold. Trade costs do not have a greater impact on African countries’ gross exports compared to other countries.

This is because, as shown in column 1, the additional trade costs coefficients for African gross exports and imports captured respectively by the interaction variables $AFlt_{ij}^{1-\sigma}$ and $AF2lt_{ij}^{1-\sigma}$ are not significant. We also find as before that trade costs have a greater impact on African final goods exports compared to other countries, since a 1% increase in trade costs reduces African exports by $1 - \sigma(0.992+0.736)\%$ (see column 3). As in the previous table, this greater impact of trade costs concerns neither African final goods imports nor intermediate goods trade flows (Column 4). As with value-added exports (column 5), the additional impact of trade costs “0.114” is six times lower when it is compared to the impact on final goods exports (column 3), such that a 1% increase in trade costs reduces African exports by just $1 - \sigma(0.997+0.114)\%$.

As explained earlier, all these findings suggest that the weakness of African exports and especially final goods exports, as established in table 2.3 is probably due more to weak preferences by non-African countries for the goods of our countries of interest than to the higher trade costs borne by these countries. In addition, value-added trade flows appear to be less impacted by these weak preferences, which implies that the export trade performance of our countries of interest is higher in value-added terms.

These results remain the same when different assumptions are made with respect to the gravity variables included in the trade costs function. Specifically, as mentioned earlier, we obtained the previous results by assuming that the aggregated regions in the GTAP multi-country database share a border or a common language with a non-aggregated region if at least 80% of their respective component countries share a border or a common language with that non-aggregated region. As shown in appendix 2.2, the results remain rigorously the same irrespective of whether we choose a 100% threshold or a 60% threshold to decide if an aggregated region shares a common border or a common language with a non-aggregated region.

2.6 Concluding remarks

The purpose of this paper was to question the virtual consensus in the literature regarding the relative weakness of African exports. We find that the results are more ambiguous. Taking the latest advances in international trade flow estimation, we first showed that, depending on the estimator used, African gross exports are not as weak as purported in the literature compared to a gravity model benchmark. More precisely, we showed that even though our countries of interest clearly underperform in terms of their final goods exports, the same does not hold true for their intermediate goods exports such that their trade performance in gross exports is similar on average to other countries.

We also showed that bilateral trade costs have a greater impact on African countries' trade flows, and especially on their final goods exports. Surprisingly, however, when the chosen dependent variable is expressed not in gross terms, but rather in value-added terms, the additional impact of bilateral trade costs is six times lower than their impact on final goods exports. African value-added exports are thus less sensitive than African final goods exports to bilateral trade costs.

Finally, we observed that the additional impact of bilateral trade costs concerns essentially exports, since it is non-existent with respect to imports. This differential impact suggests to us that, where it exists, the weakness of African exports is probably due more to other countries' weak preferences for African goods than to the continent's higher level of trade costs, as asserted in the literature.

Either way, be it weak preferences or bilateral trade costs, African countries' value-added exports – the trade flows that should matter the most to policymakers – are apparently less sensitive to these impediments than final goods exports. It appears, however, that the cost of fragmentation, which synthesizes the bilateral trade costs with a given destination of all the third countries through which a country of origin's value-added transits before reaching the said destination, plays a significant role in explaining value-added trade flows. It would therefore be interesting to analyze its determinants more thoroughly.

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Appendices

2.1 Derivation of the value-added exports gravity model (Maximisation under constraints)

We have the following expression for value added-exports from [Koopman et al. \(2014\)](#):

$$v_{ij} = n_i \left(\sum_{s=i}^S B_{is} X_{sj} \right) \quad (2.12)$$

where v_{ij} represents the exported value-added from country of origin “i” to destination country “j”. This expression is obtained by input-output analysis by breaking down a given country’s gross exports into regions of origin. As we know, a country needs inputs from other world regions in addition to its own inputs in order to produce a unit of intermediate or final good. Gross exports represent the sum of intermediate and final goods exported by a given country to its partners. That country’s exported value-added is solely the share of gross exports produced within it. In other words, it represents the payments made to workers and capital owners in the country of origin to produce the exported good. In this expression, $n_i = \frac{Y_i}{G_i}$ represents the ratio of GDP (Y_i) to total output (G_i). B_{is} is an element of the total requirement matrix derived from input-output analysis. It represents the amount of country “i” goods required to produce a unit of final goods in country “s” to be consumed either in “s” or abroad. Finally, X_{sj} represents the exports of final goods from country “s” to country “j”.

Equation (2.12) can be rewritten :

$$v_{ij} = n_i (B_{ii} X_{ij} + \sum_{s \neq i}^S B_{is} X_{sj}) \quad (2.13)$$

By rewriting the equation in this way, we show that the exported value-added from country “i” to country “j” depends on the directly exported value-added by “i” to “j” ($B_{ii} X_{ij}$), and on the indirectly exported value-added from i, via third states “s” to country “j” ($\sum_{s \neq i}^S B_{is} X_{sj}$). This indirectly exported value-added represents the intermediate goods sourced from “i” that are embedded in the final good exports of third countries “s” to destination country “j”.

Unlike classic export flows, we can see that value-added exports have a more complex structure. This needs to be taken into account when building a rigorous gravity model. If we denote as c_{ij} country “j” consumption of final goods (quantity) from country “i”, and

as $\alpha_{is} = n_i B_{is}$ the amount of value-added from country “i” required to produce a unit of final good in country “s”, the utility function to be maximized by country “j” consumers is:

$$\left(\sum_i \sum_{s=i}^S \beta_s^{\frac{1-\sigma}{\sigma}} (\alpha_{is} c_{sj})^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \quad (2.14)$$

subject to the budget constraint:

$$\sum_i \sum_{s=i}^S \alpha_{is} c_{sj} p_{sj} = Y_j \quad (2.15)$$

where $p_{sj} = p_s t_{sj}$ is the price of the exported good from country “s” to country “j” composed of the supply price of exporting country “ p_s ”, and the trade cost factor between the two countries “ t_{sj} ”. $c_{sj} p_{sj}$ therefore represents the nominal value of the exported final good from “s” to “j”.

We solve this problem for bilateral relationship “ij” by posing the Lagrangian function:

$$L = \left(\sum_i \sum_{s=i}^S \beta_s^{\frac{1-\sigma}{\sigma}} (\alpha_{is} c_{sj})^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} - \lambda \left(\sum_i \sum_{s=i}^S \alpha_{is} c_{sj} p_{sj} - Y_j \right) \quad (2.16)$$

$$\frac{\partial L}{\partial \alpha_{is} c_{sj}} = 0$$

$$\Rightarrow \frac{\sigma}{\sigma-1} \left(\sum_i \sum_{s=i}^S \beta_s^{\frac{1-\sigma}{\sigma}} (\alpha_{is} c_{sj})^{\frac{\sigma-1}{\sigma}} \right)^{\frac{1}{\sigma-1}} \beta_s^{\frac{1-\sigma}{\sigma}} \frac{\sigma-1}{\sigma} (\alpha_{is} c_{sj})^{\frac{-1}{\sigma}} - \lambda p_{sj} = 0 \quad (2.17)$$

$$\Rightarrow \frac{\left(\sum_i \sum_{s=i}^S \beta_s^{\frac{1-\sigma}{\sigma}} (\alpha_{is} c_{sj})^{\frac{\sigma-1}{\sigma}} \right)^{\frac{1}{\sigma-1}} \beta_s^{\frac{1-\sigma}{\sigma}} (\alpha_{is} c_{sj})^{\frac{-1}{\sigma}}}{p_{sj}} = \lambda$$

$$\Rightarrow (\alpha_{is} c_{sj})^{\frac{-1}{\sigma}} = \frac{\lambda p_{sj}}{\left(\sum_i \sum_{s=i}^S \beta_s^{\frac{1-\sigma}{\sigma}} (\alpha_{is} c_{sj})^{\frac{\sigma-1}{\sigma}} \right)^{\frac{1}{\sigma-1}} \beta_s^{\frac{1-\sigma}{\sigma}}}$$

$$\Rightarrow \alpha_{is} c_{sj} = \left(\frac{\lambda p_{sj}}{\left(\sum_i \sum_{s=i}^S \beta_s^{\frac{1-\sigma}{\sigma}} (\alpha_{is} c_{sj})^{\frac{\sigma-1}{\sigma}} \right)^{\frac{1}{\sigma-1}} \beta_s^{\frac{1-\sigma}{\sigma}}} \right)^{-\sigma}$$

We pose $\left(\sum_i \sum_{s=i}^S \beta_s^{\frac{1-\sigma}{\sigma}} (\alpha_{is} c_{sj})^{\frac{\sigma-1}{\sigma}} \right)^{\frac{1}{\sigma-1}} = A$ and $c_{sj} p_{sj} = x_{sj}$

$$\Rightarrow \alpha_{is} x_{sj} = \frac{\lambda^{-\sigma}}{A^{-\sigma}} (\beta_s p_s t_{sj})^{1-\sigma} \text{ with } p_s t_{sj} = p_{sj}$$

We thus have: $\sum_{s=i}^S \alpha_{is} x_{sj} = \frac{\lambda^{-\sigma}}{A^{-\sigma}} \sum_{s=i}^S (\beta_s p_s t_{sj})^{1-\sigma}$

$$\Rightarrow \alpha_{is} x_{sj} = \frac{(\beta_s p_s t_{sj})^{1-\sigma}}{\sum_{s=i}^S (\beta_s p_s t_{sj})^{1-\sigma}} \left(\sum_{s=i}^S \alpha_{is} x_{sj} \right) \quad (2.18)$$

$$\begin{aligned} \text{We also have } \sum_i \alpha_{is} x_{sj} &= \frac{(\beta_s p_s t_{sj})^{1-\sigma}}{\sum_{s=i}^S (\beta_s p_s t_{sj})^{1-\sigma}} \left(\sum_i \sum_{s=i}^S \alpha_{is} x_{sj} \right) \\ &= \frac{(\beta_s p_s t_{sj})^{1-\sigma}}{\sum_{s=i}^S (\beta_s p_s t_{sj})^{1-\sigma}} Y_j \end{aligned}$$

This finally gives:

$$\alpha_{is} x_{sj} = \left(\frac{\beta_s p_s t_{sj}}{P_j} \right)^{1-\sigma} \frac{\alpha_{is}}{\sum_i \alpha_{is}} Y_j \quad (2.19)$$

$$\text{Where } P_j = \left[\sum_{s=i}^S (\beta_s p_s t_{sj})^{1-\sigma} \right]^{\frac{1}{1-\sigma}} \quad (2.20)$$

In keeping with [Anderson and Van Wincoop \(2003\)](#) we impose market clearance to derive the gravity equation. This implies:

$$Y_s = \sum_i \sum_j \alpha_{is} x_{sj} \quad (2.21)$$

where $\sum_i \alpha_{is}$ equals 1, and where Y_s represents the total income of country ‘‘s’’.

We thus have:

$$\begin{aligned} Y_s &= \sum_j \left(\frac{\beta_s p_s t_{sj}}{P_j} \right)^{1-\sigma} \sum_i \frac{\alpha_{is}}{\sum_i \alpha_{is}} Y_j \\ &= \sum_j \left(\frac{\beta_s p_s t_{sj}}{P_j} \right)^{1-\sigma} Y_j \end{aligned} \quad (2.22)$$

We also solve for the scaled price $\beta_s p_s$ as (AVW) which gives:

$$(\beta_s p_s)^{1-\sigma} = \frac{Y_s}{\sum_j \left(\frac{t_{sj}}{P_j} \right)^{1-\sigma} \frac{Y_j}{Y_w}}$$

Replacing this in equation (2.19), we obtain:

$$\alpha_{is} x_{sj} = \frac{Y_s Y_j}{Y_w} \left(\frac{t_{sj}}{\Pi_s P_j} \right)^{1-\sigma} \frac{\alpha_{is}}{\sum_i \alpha_{is}} \quad (2.23)$$

$$\text{Where } \Pi_s = \left[\sum_j \left(\frac{t_{sj}}{P_j} \right)^{1-\sigma} \frac{Y_j}{Y_w} \right]^{\frac{1}{1-\sigma}} \text{ and } P_j = \left[\sum_{s=i}^S \left(\frac{t_{sj}}{\Pi_s} \right)^{1-\sigma} \frac{Y_s}{Y_w} \right]^{\frac{1}{1-\sigma}}$$

As mentioned earlier, the bilateral exported value-added from country “i” to “j” is:

$$v_{ij} = \left(\sum_{s=i}^S \alpha_{is} X_{sj} \right) \text{ with } \alpha_{is} = n_i B_{is} \text{ and } n_i = \frac{Y_i}{G_i}$$

It follows that:

$$\begin{aligned} v_{ij} &= \sum_{s=i}^S \frac{Y_s Y_j}{Y_w} \left(\frac{t_{sj}}{\Pi_s P_j} \right)^{1-\sigma} \frac{\alpha_{is}}{\sum_i \alpha_{is}} \\ &= \left(\frac{Y_i Y_j}{Y_w} \left(\frac{t_{ij}}{\Pi_i P_j} \right)^{1-\sigma} \alpha_{ii} \right) + \left(\sum_{s \neq i}^S \frac{Y_s Y_j}{Y_w} \left(\frac{t_{sj}}{\Pi_s P_j} \right)^{1-\sigma} \frac{\alpha_{is}}{\sum_i \alpha_{is}} \right) \\ \Rightarrow v_{ij} &= \left(\frac{Y_i Y_j}{Y_w} \left(\frac{t_{ij}}{\Pi_i P_j} \right)^{1-\sigma} \alpha_{ii} \right) \left(\frac{\frac{Y_i Y_j}{Y_w} \left(\frac{t_{ij}}{\Pi_i P_j} \right)^{1-\sigma} \alpha_{ii} + \sum_{s \neq i}^S \frac{Y_s Y_j}{Y_w} \left(\frac{t_{sj}}{\Pi_s P_j} \right)^{1-\sigma} \frac{\alpha_{is}}{\sum_i \alpha_{is}}}{\frac{Y_i Y_j}{Y_w} \left(\frac{t_{ij}}{\Pi_i P_j} \right)^{1-\sigma} \alpha_{ii}} \right) \\ &= \left(\frac{Y_i Y_j}{Y_w} \left(\frac{t_{ij}}{\Pi_i P_j} \right)^{1-\sigma} \right) \left(\frac{\sum_{s=i}^S \frac{Y_s Y_j}{Y_w} \left(\frac{t_{sj}}{\Pi_s P_j} \right)^{1-\sigma} \frac{\alpha_{is}}{\sum_i \alpha_{is}}}{\frac{Y_i Y_j}{Y_w} \left(\frac{t_{ij}}{\Pi_i P_j} \right)^{1-\sigma}} \right) \\ &= \left(\frac{Y_i Y_j}{Y_w} \left(\frac{t_{ij}}{\Pi_i P_j} \right)^{1-\sigma} \right) \left(\frac{\sum_{s=i}^S \beta_{is} Y_s \left(\frac{t_{sj}}{\Pi_s P_j} \right)^{1-\sigma}}{G_i \left(\frac{t_{ij}}{\Pi_i P_j} \right)^{1-\sigma}} \right) \end{aligned}$$

This equation is equivalent to the previous equation (2.10) (in the main text) and could be rewritten like this:

$$\begin{aligned} &= \left(\frac{Y_i Y_j}{G_i Y_w} \right) \left(\sum_{s=i}^S \beta_{is} Y_s \left(\frac{t_{sj}}{\Pi_s P_j} \right)^{1-\sigma} \right) \text{ or} \\ &= \left(\frac{Y_i Y_j}{Y_w} \left(\frac{t_{ij}}{\Pi_i P_j} \right)^{1-\sigma} \right) \left(\sum_{s=i}^S \frac{\beta_{is} Y_s}{G_i} \left(\frac{\frac{t_{sj}}{\Pi_s}}{\frac{t_{ij}}{\Pi_i}} \right)^{1-\sigma} \right) \end{aligned}$$

Bearing in mind that $\sum_i \alpha_{is} = 1$ and $\alpha_{is} = \frac{Y_i}{G_i} B_{is}$.

2..2 Robustness checks

2..2.1 Test of the pattern of heteroskedasticity

We drew on [Silva and Tenreyro \(2006\)](#) to test the appropriateness of each estimator for our data. Given that each estimator assumes a specific pattern of heteroskedasticity, its efficiency depends on how the variance of the dependent variable relates to its expected value. We have the following general case proposed by [Manning and Mullahy \(2001\)](#):

$$V[Y_i|X_i] = \lambda_0 E[Y_i|X_i]^{\lambda_1}$$

If $\lambda_1 = 1$, then Poisson PML is efficient. This case is a generalization of the Poisson variance assumption, i.e. equality between the conditional variance and the conditional mean. If $\lambda_1 = 2$, the Gamma PML is the optimal PML estimator. As we know, the Gamma PML first-order conditions are close to the OLS (logs) first-order conditions. The OLS estimator is also consistent in this case.

The results are presented in table 2.6¹⁰. These tests were conducted with conditional variance proxies obtained respectively from the estimation presented in table 2.2 column 2 of the main document for the PPML case and a variant where the dependant variable is the log of gross exports for the OLS case. Specifically, we estimated for the OLS case using a non-robust covariance estimator:

$$\ln(\text{Export}_{ij} - \widehat{\text{Export}}_{ij})^2 = \ln \lambda_0 + \lambda_1 \ln(\widehat{\text{Export}}_{ij}) + v_{ij} \quad (2.24)$$

and for the PPML case using a robust covariance matrix estimator.

$$(\text{Export}_{ij} - \widehat{\text{Export}}_{ij})^2 = \lambda_0 \widehat{\text{Export}}_{ij} + \lambda_0 (\lambda_1 - 1) \ln(\text{Export}_{ij}) \widehat{\text{Export}}_{ij} + e_{ij} \quad (2.25)$$

For the OLS case, we tested the null hypothesis $\lambda_1 = 2$, and for the PPML case $\lambda_0(\lambda_1 - 1) = 0$.

Table 2.6: Results of the test on the type of heteroskedasticity in the data (p-values)

Test (null hypothesis)	OLS	PPML
P-value	0.0000	0.300

As the table shows, this test lends credit to the suitability of the PPML estimator for our data, and thus reinforces the credibility of our results.

¹⁰See [Silva and Tenreyro \(2006\)](#) for more details on the tests

2..2.2 Econometric results with a 80% threshold for the determination of the aggregated regions trade costs variables

Table 2..7: Explanation of bilateral gross exports

VARIABLES	(1) OLS Log of gross exports	(2) OLS Log of gross exports	(3) PPML Gross exports	(4) PPML Gross exports
Exporter GDP	0.937*** (0.00454)		0.831*** (0.0138)	
Exporter total output		0.950*** (0.00438)		0.834*** (0.0128)
Distance	-0.730*** (0.0129)	-0.724*** (0.0124)	-0.719*** (0.0335)	-0.698*** (0.0327)
Common border	0.904*** (0.0620)	0.901*** (0.0598)	0.203** (0.0791)	0.224*** (0.0814)
Common language	0.382*** (0.0294)	0.412*** (0.0284)	0.240*** (0.0773)	0.250*** (0.0762)
Colony	0.382*** (0.0746)	0.372*** (0.0719)	-0.0520 (0.0979)	-0.0172 (0.0962)
Common colonizer	0.370*** (0.0356)	0.387*** (0.0343)	0.438*** (0.118)	0.451*** (0.120)
RTA	0.316*** (0.0225)	0.281*** (0.0217)	0.0987* (0.0597)	0.103* (0.0579)
aftrade	-0.530*** (0.0198)	-0.444*** (0.0192)	-0.168** (0.0835)	-0.0757 (0.0883)
Constant	4.050*** (0.158)	3.138*** (0.153)	5.730*** (0.323)	4.878*** (0.322)
Observations	19,182	19,182	19,182	19,182
R-squared	0.870	0.879		
Exporter FE	NO	NO	NO	NO
Importer FE	YES	YES	YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

aftrade is a dummy that is equal to 1 for African countries' exports and 0 otherwise.

RTA is a dummy that is equal to 1 when the countries are members of a regional trade agreement and zero otherwise.

Table 2..8: Explanation of bilateral final and intermediate goods exports (PPML estimator)

VARIABLES	Proportionality		UN BEC method	
	Intermediate goods exports	Final goods exports	Intermediate goods exports	Final goods exports
Distance	-0.677*** (0.0348)	-0.699*** (0.0295)	-0.649*** (0.0386)	-0.798*** (0.0443)
Common border	0.228** (0.0918)	0.276*** (0.0679)	0.234** (0.0956)	0.206** (0.0974)
Common language	0.265*** (0.0832)	0.201*** (0.0665)	0.308*** (0.0923)	0.0800 (0.0870)
Colony	0.0174 (0.0987)	-0.0229 (0.0999)	0.0408 (0.104)	-0.0405 (0.133)
Common colonizer	0.438*** (0.128)	0.467*** (0.121)	0.447*** (0.134)	0.385** (0.175)
RTA	0.109* (0.0620)	0.101* (0.0515)	0.0655 (0.0650)	0.232*** (0.0801)
aftrade	0.0227 (0.0946)	-0.221*** (0.0844)	0.0649 (0.106)	-0.730*** (0.106)
Exporter_supply1	0.829*** (0.0123)			
Exporter_supply2		0.828*** (0.0149)		
Exporter_supply3			0.770*** (0.0118)	
Exporter_supply4				0.990*** (0.0306)
Constant	4.821*** (0.343)	4.623*** (0.286)	5.377*** (0.364)	3.246*** (0.417)
Observations	19,182	19,182	19,182	19,182
Exporter FE	NO	NO	NO	NO
Importer FE	YES	YES	YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

aftrade is a dummy that is equal to 1 for African countries' exports and 0 otherwise.

RTA is a dummy that is equal to 1 when the countries are members of a regional trade agreement and zero otherwise.

For each regression, the exporter mass variable (Exporter_supply) is the log of sum of exports regarding the relevant trade flows.

The African dummy coefficient is not significant for intermediate goods exports irrespective of the way trade flows are obtained, which means as mentioned above that African countries do not export fewer intermediate goods than expected. This is not the case for exports of final goods, which post 20 % less than expected ($e^{-0.221} - 1 = -0.198$) when the proportionality assumption is used, and 52 % less ($e^{-0.73} - 1 = -0.518$) when the UN BEC method is used. This difference in magnitude stems directly from the proportionality assumption, which requires the trade shares to be the same for final goods and intermediate goods imports in each country. Still, as the total value of exported goods differs from the total value of imported goods, we can assess the differential trade performance between final and intermediate goods exports for African countries.

Table 2.9: Additional impact of distance on African trade flows (PPML estimator)

VARIABLES	Proportionality				UN BEC method		
	Gross exports	Final goods exports	Intermediate goods exports	Value-added exports	Final goods exports	Intermediate goods exports	Value-added exports
Distance	-0.689*** (0.0594)	-0.682*** (0.0602)	-0.692*** (0.0593)	-0.729*** (0.00719)	-0.695*** (0.0760)	-0.692*** (0.0627)	-0.711*** (0.0215)
Common border	0.265** (0.121)	0.281** (0.111)	0.260** (0.125)	0.291*** (0.00982)	0.297** (0.135)	0.230* (0.123)	0.304*** (0.0446)
Common language	0.122 (0.0827)	0.126 (0.0805)	0.121 (0.0841)	0.136*** (0.0160)	0.249** (0.110)	0.0990 (0.0940)	0.273*** (0.0351)
Colony	0.0695 (0.149)	0.101 (0.152)	0.0525 (0.148)	0.0172 (0.0195)	0.00763 (0.177)	0.103 (0.145)	-0.00817 (0.0504)
Common colonizer	0.325** (0.160)	0.363** (0.152)	0.305* (0.168)	0.385*** (0.0362)	0.509* (0.282)	0.256* (0.142)	0.548*** (0.0821)
RTA	0.176** (0.0877)	0.190** (0.0830)	0.175* (0.0910)	0.203*** (0.0105)	0.213* (0.110)	0.198** (0.0878)	0.222*** (0.0313)
$lt_{iSj}^{1-\sigma}$				1.498*** (0.0386)			1.142*** (0.0328)
afldist	-0.184 (0.175)	-0.152 (0.194)	-0.205 (0.170)	0.0390 (0.0339)	-0.630*** (0.181)	-0.138 (0.201)	-0.0932** (0.0426)
af2ldist	-0.123 (0.134)	-0.150 (0.152)	-0.109 (0.141)	-0.0316 (0.0335)	-0.0836 (0.169)	-0.138 (0.178)	-0.0371 (0.0565)
Constant	15.00*** (0.509)	13.82*** (0.520)	14.66*** (0.507)	13.72*** (0.0664)	14.27*** (0.651)	14.55*** (0.536)	13.75*** (0.185)
Observations	19,182	19,182	19,182	19,182	19,182	19,182	19,182
Exporter FE	YES	YES	YES	YES	YES	YES	YES
Importer FE	YES	YES	YES	YES	YES	YES	YES

Cluster robust standard errors by exporter, importer and country pairs in parentheses

*** p<0.01, ** p<0.05, * p<0.1

RTA is a dummy that is equal to 1 when the countries are members of a regional trade agreement and zero otherwise.

$lt_{iSj}^{1-\sigma}$ is the log of the inverse cost of fragmentation.

afldist is an interaction variable between the dummy equal to one for African exports or zero otherwise and the log of bilateral distance.

af2ldist is an interaction variable between a dummy equal to one for African imports or zero otherwise and the log of bilateral distance.

As regards final and intermediate goods exports obtained under the proportionality assumption (columns 2 and 3), it can be seen that the trade cost coefficients are approximately the same as for gross exports in column 1. This is an outcome of this assumption, which requires the bilateral import shares to be the same for both flows. The magnitude and non-significance of the additional distance coefficients also reflect this effect. The result is no different for value-added trade flows obtained using the proportionality method (column 4). The additional distance coefficients are also non-significant. What is interesting, however, is to note that the magnitude of the coefficients is lower and that the additional distance coefficient is even positive for value-added exports, suggesting that African value-added trade flows are less sensitive to distance than gross trade flows. It is clear from these results that using the proportionality assumption to disentangle gross trade flows into final and intermediate goods does not provide any information on the true breakdown of these flows. This gives ground to the above-mentioned criticism of this assumption and explains why the UN Broad Economic Classification of products by end-use category on detailed trade statistics is preferred to perform this breakdown.

Table 2.10: Additional impact of trade costs on African trade flows (PPML estimator)

VARIABLES	Proportionality				UN BEC method		
	Gross exports	Final goods exports	Intermediate goods exports	Value-added exports	Final goods exports	Intermediate goods exports	Value-added exports
$lt_{ij}^{1-\sigma}$	1.017*** (0.0509)	1.016*** (0.0521)	1.017*** (0.0508)	1.000*** (0.00634)	0.992*** (0.0775)	1.016*** (0.0450)	0.997*** (0.0269)
$AFlt_{ij}^{1-\sigma}$	0.213 (0.210)	0.167 (0.238)	0.244 (0.200)	-0.0458 (0.0397)	0.736*** (0.203)	0.133 (0.241)	0.114** (0.0494)
$AF2lt_{ij}^{1-\sigma}$	0.161 (0.174)	0.182 (0.203)	0.147 (0.180)	0.0391 (0.0403)	0.0882 (0.178)	0.188 (0.227)	0.0481 (0.0532)
$lt_{iSj}^{1-\sigma}$				1.499*** (0.0386)			1.142*** (0.0324)
Constant	15.17*** (0.275)	13.99*** (0.285)	14.83*** (0.274)	13.72*** (0.0463)	14.29*** (0.426)	14.70*** (0.239)	13.76*** (0.145)
Observations	19,182	19,182	19,182	19,182	19,182	19,182	19,182
Exporter FE	YES	YES	YES	YES	YES	YES	YES
Importer FE	YES	YES	YES	YES	YES	YES	YES

Cluster robust standard errors by exporter, importer and country pair in parentheses

*** p<0.01, ** p<0.05, * p<0.1

$lt_{iSj}^{1-\sigma}$ is the log of the inverse cost of fragmentation.

$lt_{ij}^{1-\sigma}$ is the log of bilateral costs to trade between countries “i” and “j” taken to the power $1 - \sigma$.

$AFlt_{ij}^{1-\sigma}$ is an interaction variable between the dummy for African exports and $lt_{ij}^{1-\sigma}$.

$AF2lt_{ij}^{1-\sigma}$ is an interaction variable between the dummy for African imports and $lt_{ij}^{1-\sigma}$.

2..2.3 Econometric results with a 100% threshold for the determination of the aggregated regions trade costs variables

Table 2..11: Explanation of bilateral gross exports

VARIABLES	(1) OLS Log of gross exports	(2) OLS Log of gross exports	(3) PPML Gross exports	(4) PPML Gross exports
Exporter GDP	0.938*** (0.00435)		0.831*** (0.0138)	
Exporter total output		0.951*** (0.00414)		0.834*** (0.0128)
Distance	-0.733*** (0.0143)	-0.728*** (0.0139)	-0.719*** (0.0337)	-0.699*** (0.0328)
Common border	0.904*** (0.0830)	0.900*** (0.0814)	0.200** (0.0795)	0.221*** (0.0819)
Common language	0.357*** (0.0330)	0.388*** (0.0322)	0.242*** (0.0780)	0.251*** (0.0769)
Colony	0.396*** (0.0747)	0.385*** (0.0731)	-0.0521 (0.0981)	-0.0171 (0.0965)
Common colonizer	0.436*** (0.0455)	0.448*** (0.0442)	0.447*** (0.119)	0.459*** (0.121)
RTA	0.308*** (0.0240)	0.274*** (0.0232)	0.0995* (0.0600)	0.104* (0.0582)
aftrade	-0.528*** (0.0223)	-0.442*** (0.0218)	-0.169** (0.0834)	-0.0760 (0.0883)
Constant	-0.929*** (0.139)	-1.830*** (0.136)	3.491*** (0.331)	2.638*** (0.325)
Observations	19,182	19,182	19,182	19,182
R-squared	0.862	0.871		
Exporter FE	NO	NO	NO	NO
Importer FE	YES	YES	YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

aftrade is a dummy that is equal to 1 for African countries' exports and 0 otherwise.

RTA is a dummy that is equal to 1 when the countries are members of a regional trade agreement and zero otherwise.

Table 2..12: Explanation of bilateral final and intermediate goods exports (PPML estimator)

VARIABLES	Proportionality		UN BEC method	
	Intermediate goods exports	Final goods exports	Intermediate goods exports	Final goods exports
Distance	-0.678*** (0.0349)	-0.700*** (0.0297)	-0.649*** (0.0388)	-0.798*** (0.0445)
Common border	0.224** (0.0923)	0.273*** (0.0683)	0.231** (0.0962)	0.201** (0.0975)
Common language	0.266*** (0.0837)	0.202*** (0.0673)	0.309*** (0.0930)	0.0822 (0.0880)
Colony	0.0173 (0.0989)	-0.0223 (0.100)	0.0409 (0.104)	-0.0408 (0.134)
Common colonizer	0.443*** (0.129)	0.479*** (0.122)	0.457*** (0.135)	0.383** (0.176)
RTA	0.109* (0.0622)	0.103** (0.0520)	0.0661 (0.0653)	0.234*** (0.0809)
aftrade	0.0228 (0.0945)	-0.221*** (0.0845)	0.0653 (0.106)	-0.731*** (0.106)
Exporter_supply1	0.829*** (0.0123)			
Exporter_supply2		0.828*** (0.0149)		
Exporter_supply3			0.770*** (0.0118)	
Exporter_supply4				0.990*** (0.0306)
Constant	2.711*** (0.338) (0.343)	2.226*** (0.296) (0.286)	3.310*** (0.353) (0.364)	0.717 (0.482) (0.417)
Observations	19,182	19,182	19,182	19,182
Exporter FE	NO	NO	NO	NO
Importer FE	YES	YES	YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

aftrade is a dummy that is equal to 1 for African countries' exports and 0 otherwise.

RTA is a dummy that is equal to 1 when the countries are members of a regional trade agreement and zero otherwise.

For each regression, the exporter mass variable (Exporter_supply) is the log of sum of exports regarding the relevant trade flows.

Table 2.13: Additional impact of distance on African trade flows (PPML estimator)

VARIABLES	Proportionality				UN BEC method		
	Gross exports	Final goods exports	Intermediate goods exports	Value-added exports	Final goods exports	Intermediate goods exports	Value-added exports
Distance	-0.690*** (0.0598)	-0.682*** (0.0607)	-0.693*** (0.0596)	-0.729*** (0.00721)	-0.695*** (0.0769)	-0.693*** (0.0630)	-0.711*** (0.0217)
Common border	0.258** (0.121)	0.274** (0.111)	0.252** (0.124)	0.291*** (0.00981)	0.291** (0.136)	0.222* (0.123)	0.302*** (0.0453)
Common language	0.128 (0.0830)	0.132 (0.0811)	0.127 (0.0844)	0.136*** (0.0160)	0.246** (0.110)	0.106 (0.0941)	0.271*** (0.0351)
Colony	0.0687 (0.150)	0.100 (0.153)	0.0516 (0.149)	0.0173 (0.0196)	0.0109 (0.178)	0.102 (0.146)	-0.00689 (0.0507)
Common colonizer	0.326** (0.161)	0.364** (0.153)	0.305* (0.169)	0.384*** (0.0363)	0.502* (0.282)	0.260* (0.144)	0.545*** (0.0817)
RTA	0.177** (0.0887)	0.194** (0.0841)	0.176* (0.0918)	0.203*** (0.0104)	0.219* (0.112)	0.198** (0.0885)	0.224*** (0.0315)
$lt_{iSj}^{1-\sigma}$				1.498*** (0.0386)			1.141*** (0.0328)
afldist	-0.185 (0.175)	-0.153 (0.194)	-0.206 (0.169)	0.0384 (0.0339)	-0.631*** (0.181)	-0.138 (0.201)	-0.0941** (0.0424)
af2ldist	-0.123 (0.134)	-0.151 (0.151)	-0.108 (0.142)	-0.0322 (0.0334)	-0.0844 (0.169)	-0.138 (0.179)	-0.0376 (0.0567)
Constant	15.00*** (0.513)	13.82*** (0.525)	14.68*** (0.510)	13.72*** (0.0669)	14.27*** (0.660)	14.56*** (0.538)	13.75*** (0.187)
Observations	19,182	19,182	19,182	19,182	19,182	19,182	19,182
Exporter FE	YES	YES	YES	YES	YES	YES	YES
Importer FE	YES	YES	YES	YES	YES	YES	YES

Cluster robust standard errors by exporter, importer and country pairs in parentheses

*** p<0.01, ** p<0.05, * p<0.1

RTA is a dummy that is equal to 1 when the countries are members of a regional trade agreement and zero otherwise.

$lt_{iSj}^{1-\sigma}$ is the log of the inverse cost of fragmentation.

afldist is an interaction variable between the dummy equal to one for African exports or zero otherwise and the log of bilateral distance.

af2ldist is an interaction variable between a dummy equal to one for African imports or zero otherwise and the log of bilateral distance.

Table 2..14: Additional impact of trade costs on African trade flows (PPML estimator)

VARIABLES	Proportionality				UN BEC method		
	Gross exports	Final goods exports	Intermediate goods exports	Value-added exports	Final goods exports	Intermediate goods exports	Value-added exports
$lt_{ij}^{1-\sigma}$	1.018*** (0.0510)	1.017*** (0.0522)	1.018*** (0.0509)	1.000*** (0.00631)	0.992*** (0.0777)	1.017*** (0.0451)	0.997*** (0.0269)
$AFlt_{ij}^{1-\sigma}$	0.214 (0.210)	0.167 (0.238)	0.244 (0.200)	-0.0458 (0.0396)	0.740*** (0.202)	0.133 (0.241)	0.115** (0.0494)
$AF2lt_{ij}^{1-\sigma}$	0.161 (0.174)	0.182 (0.203)	0.147 (0.180)	0.0396 (0.0400)	0.0852 (0.178)	0.188 (0.227)	0.0474 (0.0534)
$lt_{iSj}^{1-\sigma}$				1.499*** (0.0386)			1.141*** (0.0325)
Constant	15.18*** (0.276)	14.00*** (0.285)	14.85*** (0.275)	13.72*** (0.0462)	14.29*** (0.427)	14.72*** (0.240)	13.76*** (0.146)
Observations	19,182	19,182	19,182	19,182	19,182	19,182	19,182
Exporter FE	YES	YES	YES	YES	YES	YES	YES
Importer FE	YES	YES	YES	YES	YES	YES	YES

Cluster robust standard errors by exporter, importer and country pair in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

$lt_{iSj}^{1-\sigma}$ is the log of the inverse cost of fragmentation.

$lt_{ij}^{1-\sigma}$ is the log of bilateral costs to trade between countries “i” and “j” taken to the power $1 - \sigma$.

$AFlt_{ij}^{1-\sigma}$ is an interaction variable between the dummy for African exports and $lt_{ij}^{1-\sigma}$.

$AF2lt_{ij}^{1-\sigma}$ is an interaction variable between the dummy for African imports and $lt_{ij}^{1-\sigma}$.

2..2.4 Econometric results with a 60% threshold for the determination of the the aggregated regions trade costs variables

Table 2..15: Explanation of bilateral gross exports

VARIABLES	(1) OLS Log of gross exports	(2) OLS Log of gross exports	(3) PPML Gross exports	(4) PPML Gross exports
Exporter GDP	0.937*** (0.00434)		0.832*** (0.0138)	
Exporter total output		0.950*** (0.00413)		0.835*** (0.0128)
Distance	-0.720*** (0.0142)	-0.715*** (0.0138)	-0.722*** (0.0337)	-0.700*** (0.0329)
Common border	0.891*** (0.0817)	0.886*** (0.0802)	0.204*** (0.0790)	0.224*** (0.0814)
Common language	0.379*** (0.0313)	0.404*** (0.0305)	0.234*** (0.0764)	0.244*** (0.0753)
Colony	0.395*** (0.0732)	0.387*** (0.0716)	-0.0469 (0.0975)	-0.0110 (0.0959)
Common colonizer	0.423*** (0.0435)	0.434*** (0.0422)	0.455*** (0.117)	0.466*** (0.118)
RTA	0.342*** (0.0235)	0.309*** (0.0227)	0.0898 (0.0597)	0.0968* (0.0580)
aftrade	-0.534*** (0.0223)	-0.448*** (0.0218)	-0.167** (0.0836)	-0.0740 (0.0884)
Constant	-1.055*** (0.138)	-1.950*** (0.135)	3.504*** (0.334)	2.640*** (0.328)
Observations	19,182	19,182	19,182	19,182
R-squared	0.862	0.872		
Exporter FE	NO	NO	NO	NO
Importer FE	YES	YES	YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

aftrade is a dummy that is equal to 1 for African countries' exports and 0 otherwise.

RTA is a dummy that is equal to 1 when the countries are members of a regional trade agreement and zero otherwise.

Table 2.16: Explanation of bilateral final and intermediate goods exports (PPML estimator)

VARIABLES	Proportionality		UN BEC method	
	Intermediate goods exports	Final goods exports	Intermediate goods exports	Final goods exports
Distance	-0.679*** (0.0350)	-0.702*** (0.0298)	-0.650*** (0.0388)	-0.803*** (0.0445)
Common border	0.227** (0.0920)	0.278*** (0.0677)	0.233** (0.0958)	0.210** (0.0970)
Common language	0.260*** (0.0823)	0.193*** (0.0656)	0.304*** (0.0911)	0.0678 (0.0862)
Colony	0.0217 (0.0984)	-0.0134 (0.0996)	0.0458 (0.103)	-0.0340 (0.132)
Common colonizer	0.443*** (0.127)	0.500*** (0.119)	0.449*** (0.132)	0.437** (0.175)
RTA	0.105* (0.0622)	0.0914* (0.0513)	0.0635 (0.0652)	0.215*** (0.0794)
afrtrade	0.0245 (0.0946)	-0.219*** (0.0846)	0.0662 (0.106)	-0.726*** (0.106)
Exporter_supply1	0.830*** (0.0123)			
Exporter_supply2		0.829*** (0.0148)		
Exporter_supply3			0.771*** (0.0118)	
Exporter_supply4				0.991*** (0.0304)
Constant	2.710*** (0.342)	2.236*** (0.299)	3.306*** (0.357)	0.738 (0.486)
Observations	19,182	19,182	19,182	19,182
Exporter FE	NO	NO	NO	NO
Importer FE	YES	YES	YES	YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

afrtrade is a dummy that is equal to 1 for African countries' exports and 0 otherwise.

RTA is a dummy that is equal to 1 when the countries are members of a regional trade agreement and zero otherwise.

For each regression, the exporter mass variable (Exporter_supply) is the log of sum of exports regarding the relevant trade flows.

Table 2..17: Additional impact of distance on African trade flows (PPML estimator)

VARIABLES	Proportionality				UN BEC method		
	Gross exports	Final goods exports	Intermediate goods exports	Value-added exports	Final goods exports	Intermediate goods exports	Value-added exports
Distance	-0.691*** (0.0600)	-0.683*** (0.0605)	-0.695*** (0.0601)	-0.731*** (0.00739)	-0.695*** (0.0770)	-0.696*** (0.0634)	-0.713*** (0.0222)
Common border	0.261** (0.122)	0.278** (0.112)	0.255** (0.125)	0.292*** (0.0105)	0.296** (0.140)	0.225* (0.123)	0.304*** (0.0474)
Common language	0.119 (0.0810)	0.121 (0.0784)	0.119 (0.0828)	0.132*** (0.0157)	0.237** (0.108)	0.101 (0.0921)	0.266*** (0.0346)
Colony	0.0762 (0.148)	0.114 (0.150)	0.0553 (0.148)	0.0209 (0.0193)	0.0230 (0.173)	0.104 (0.145)	-0.00285 (0.0494)
Common colonizer	0.335** (0.159)	0.390*** (0.149)	0.306* (0.167)	0.367*** (0.0376)	0.557** (0.276)	0.254* (0.143)	0.544*** (0.0812)
RTA	0.172* (0.0888)	0.189** (0.0829)	0.169* (0.0925)	0.200*** (0.0109)	0.209* (0.110)	0.190** (0.0897)	0.217*** (0.0313)
$lt_{iSj}^{1-\sigma}$				1.497*** (0.0382)			1.142*** (0.0326)
afldist	-0.182 (0.175)	-0.150 (0.194)	-0.203 (0.170)	0.0414 (0.0342)	-0.628*** (0.181)	-0.136 (0.201)	-0.0906** (0.0424)
af2ldist	-0.122 (0.133)	-0.149 (0.152)	-0.108 (0.141)	-0.0303 (0.0332)	-0.0810 (0.170)	-0.138 (0.177)	-0.0346 (0.0565)
Constant	15.01*** (0.515)	13.82*** (0.523)	14.69*** (0.514)	13.73*** (0.0679)	14.27*** (0.659)	14.58*** (0.542)	13.76*** (0.191)
Observations	19,182	19,182	19,182	19,182	19,182	19,182	19,182
Exporter FE	YES	YES	YES	YES	YES	YES	YES
Importer FE	YES	YES	YES	YES	YES	YES	YES

Cluster robust standard errors by exporter, importer and country pairs in parentheses

*** p<0.01, ** p<0.05, * p<0.1

RTA is a dummy that is equal to 1 when the countries are members of a regional trade agreement and zero otherwise.

$lt_{iSj}^{1-\sigma}$ is the log of the inverse cost of fragmentation.

afldist is an interaction variable between the dummy equal to one for African exports or zero otherwise and the log of bilateral distance.

af2ldist is an interaction variable between a dummy equal to one for African imports or zero otherwise and the log of bilateral distance.

Table 2..18: Additional impact of trade costs on African trade flows (PPML estimator)

VARIABLES	Proportionality				UN BEC method		
	Gross exports	Final goods exports	Intermediate goods exports	Value-added exports	Final goods exports	Intermediate goods exports	Value-added exports
$lt_{ij}^{1-\sigma}$	1.017*** (0.0509)	1.016*** (0.0521)	1.017*** (0.0508)	1.000*** (0.00626)	0.991*** (0.0770)	1.016*** (0.0452)	0.997*** (0.0267)
$AFlt_{ij}^{1-\sigma}$	0.204 (0.211)	0.148 (0.237)	0.238 (0.201)	-0.0474 (0.0399)	0.674*** (0.197)	0.132 (0.241)	0.101** (0.0477)
$AF2lt_{ij}^{1-\sigma}$	0.173 (0.168)	0.208 (0.186)	0.153 (0.178)	0.0374 (0.0404)	0.165 (0.166)	0.188 (0.225)	0.0728 (0.0554)
$lt_{iSj}^{1-\sigma}$				1.498*** (0.0382)			1.142*** (0.0322)
Constant	15.18*** (0.277)	14.00*** (0.285)	14.86*** (0.275)	13.73*** (0.0464)	14.31*** (0.425)	14.74*** (0.241)	13.77*** (0.146)
Observations	19,182	19,182	19,182	19,182	19,182	19,182	19,182
Exporter FE	YES	YES	YES	YES	YES	YES	YES
Importer FE	YES	YES	YES	YES	YES	YES	YES

Cluster robust standard errors by exporter, importer and country pair in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

$lt_{iSj}^{1-\sigma}$ is the log of the inverse cost of fragmentation.

$lt_{ij}^{1-\sigma}$ is the log of bilateral costs to trade between countries “i” and “j” taken to the power $1 - \sigma$.

$AFlt_{ij}^{1-\sigma}$ is an interaction variable between the dummy for African exports and $lt_{ij}^{1-\sigma}$.

$AF2lt_{ij}^{1-\sigma}$ is an interaction variable between the dummy for African imports and $lt_{ij}^{1-\sigma}$.

2.3 Methodology used to obtain the value-added exports

In this appendix, we describe the methodology used to obtain the value-added exports data. We begin by presenting the [Koopman et al. \(2014\)](#) framework used to obtain these data and which is based on input-output analysis. We then describe the database on which this work is based. Finally, we present the two techniques used in order to disentangle gross exports into final goods and intermediate goods exports, a requirement for our analysis.

2.3.1 Breakdown of gross exports by value-added from different origins

Input-output analysis is a method of economic forecasting developed by Wassily Leontief, who received the Nobel Prize in economics in 1973. This method is based on input-output tables, which summarize the sale and purchase transactions in an economy by sector and by buyer or seller. Some strong assumptions are required to conduct the analysis:

- Constancy of intersectoral technical coefficients, which implies that an increase in production necessarily leads to a proportional increase in the inputs used throughout the production process (no economies of scale);
- Unrestricted availability of production factors;
- Absence of substitutability between production factors, which implies that irrespective of their price or quantity, the share of capital or labor or even intermediate inputs remains the same in a unit of production. The production technology is therefore the same within the period of analysis, at least for static models.

The input-output table is presented as follows: sales are listed in lines from left to right, and purchases in columns.¹¹ We therefore have in lines:

$$g_i = \sum_{j=1}^n a_{ij}g_j + x_i \quad (2.26)$$

where g_i represents the total production of sector "i" or the set of goods sold to satisfy sector "i"'s final demand (x_i) and demand for intermediate goods ($a_{ij}g_j$), and a_{ij} is the technical coefficient, which represents sector "i"'s units of intermediate goods used to produce sector "j"'s output. The constancy of technical coefficients assumption thus means that the intermediate consumption/production ratio does not vary for any sector "j" irrespective of the production volume. In this framework, final demand is assumed to be

¹¹See [Miller and Blair \(2009\)](#)

exogenous since it does not depend on total production, unlike intermediate consumption.

We have in columns:

$$g_j = \sum_{i=1}^n a_{ij}g_j + p_i \quad (2.27)$$

where g_j represents the total production of sector "j" or the purchases of intermediate consumption ($a_{ij}g_j$) and other production factors such as labour or capital (p_i) necessary to produce the goods. By writing equation (2.26) for all sectors, we obtain in matrix notation:

$$g = Ag + x \quad \text{Where } g = (I - A)^{-1}x = Lx \quad (2.28)$$

with A corresponding to a (n*n) matrix of technical coefficients, I the (n*n) identity matrix, $(I - A)^{-1} = L$ the Leontief inverse, g the production of each sector and x the corresponding final demand. As we are interested in relationships between a number of regions, a simple input-output framework is not suitable since it simply shows the interrelations between sectors of a single economy. We therefore need to use a different framework, which is called an inter-regional input-output table (IRIO) and which enables us to identify the interrelations between the different regions studied and their industries. Technically, the methodology used to build it is roughly the same as above. For example, in a simple two-region (i,j) and one-sector case, we would have for sales (in line):

$$g^i = a^{ii}g^i + a^{ij}g^j + x^{ii} + x^{ij} \quad (2.29)$$

with a^{ii} representing the units of intermediate goods used to produce one unit of output in country "i", a^{ij} country "i" units of intermediate goods used to produce one unit of output in country "j", x^{ii} country "i" production destined to satisfy its own final demand, and x^{ij} country "i" production destined to satisfy country "j" 's final demand.

In matrix form, we have the same expression as in equation (2.28) which gives an IRIO model as follows:¹²:

$$\begin{bmatrix} g^{11} & g^{12} \\ g^{21} & g^{22} \end{bmatrix} = \begin{bmatrix} I - a^{11} & -a^{12} \\ -a^{21} & I - a^{22} \end{bmatrix}^{-1} \begin{bmatrix} x^{11} & x^{12} \\ x^{21} & x^{22} \end{bmatrix} = \begin{bmatrix} b^{11} & b^{12} \\ b^{21} & b^{22} \end{bmatrix} \begin{bmatrix} x^{11} & x^{12} \\ x^{21} & x^{22} \end{bmatrix} \quad (2.30)$$

¹²This part is mainly inspired by [Koopman et al. \(2014\)](#)

In this matrix, the countries' output is broken down by place of absorption. For example, country 1's output ($g^1 = g^{11} + g^{12}$) is equal to the output produced and consumed at home (g^{11}) and the output produced at home and consumed abroad g^{12} . Similarly, final demand is broken down by place of absorption, with the total final demand of country 1 ($x^1 = x^{11} + x^{12}$) being equal to the final demand produced and consumed at home x^{11} and the final demand produced at home and consumed abroad x^{12} .

The matrix of b^{ij} is the matrix of "total requirement coefficients".¹³ For source country "i" and destination country "j", b^{ij} represents the total amount of country "i" gross output required to produce an extra unit of final good in country "j" that can be consumed either in "j" or in "i". By multiplying each coefficient in this matrix by the value-added share of gross output for corresponding source country v^i , we obtain a (2*2) matrix of coefficients $v^i b^{ij}$ representing the total amount of country "i" value-added or GDP required to produce an extra unit of final good in country "j" that can be consumed in "j" or "i". This formula enables us to disentangle a given country's production into value-added from different origins, either home or abroad.

Looking back at equation (2.30), we can, for example, easily break down a unit of production in destination country 1 (the first column) into its own value-added $v^1 b^{11}$ and the value-added from abroad $v^2 b^{21}$. Thus $v^2 b^{21}$ is the imported value-added share in country 1's production and, on the assumption generally made in the literature that exports and domestic sales use the same intensity of imported output, we can also interpret this expression as the value-added import content of one unit of export. With this framework set, we can easily break down a country's gross exports, and therefore explain the discrepancy between the latter and its exports of value-added.

As discussed by [Koopman et al. \(2014\)](#), this enables us to identify each country's place in the global and regional value chain.

We first rewrite country 1 and country 2's output as follows:

$$g^1 = [g^{11} + g^{12}] = [x^{11} + a^{11}g^1 + (x^{12} + a^{12}g^2)] = [((1 - a^{11})^{-1}x^{11}) + ((1 - a^{11})^{-1}e^{12})] \quad (2.31)$$

where $e^{12} = x^{12} + a^{12}g^2$ represents bilateral gross exports from country 1 to country 2.

$$g^2 = [g^{22} + g^{21}] = [x^{22} + a^{22}g^2 + (x^{21} + a^{21}g^1)] = [((1 - a^{22})^{-1}x^{22}) + ((1 - a^{22})^{-1}e^{21})] \quad (2.32)$$

where $e^{21} = x^{21} + a^{21}g^1$

¹³See [Koopman et al. \(2014\)](#)

With these expressions, we can further break down country 1's exports by source of origin. Using $v^1b^{11} + v^2b^{21} = 1$, we therefore obtain:

$$\begin{aligned}
e^{12} &= (v^1b^{11} + v^2b^{21})(x^{12} + a^{12}g^2) = v^1b^{11}x^{12} + v^1b^{11}a^{12}g^2 + v^2b^{21}x^{12} + v^2b^{21}a^{12}g^2 \quad (2.33) \\
&= v^1b^{11}x^{12} + v^1b^{12}x^{22} + v^1b^{12}x^{21} + v^1b^{12}a^{21}g^1 + v^2b^{21}x^{12} + v^2b^{21}a^{12}g^2
\end{aligned}$$

$$\text{where } v^1b^{11}a^{12}g^2 = v^1b^{12}x^{22} + v^1b^{12}x^{21} + v^1b^{12}a^{21}g^1$$

This equation simply means that country 1's total value of gross exports can be broken down in terms of value-added by place of origin. We therefore have four terms, with the first representing the value-added exported from country 1 to country 2 to satisfy the latter country's demand for final goods ($v^1b^{11}x^{12}$). The second term represents the value-added exported by country 1 and used as intermediate goods by country 2 to produce its final goods ($v^1b^{11}a^{12}g^2$). This term can be further broken down into intermediate exports absorbed in country 2 ($v^1b^{12}x^{22}$) and intermediate exports exported back to country 1 either within country 2's exports of final goods $v^1b^{12}x^{21}$ or within country 2's exports of intermediate goods $v^1b^{12}a^{21}g^1$.

The third term ($v^2b^{21}x^{12}$) represents the value-added imported by country 1 embedded in its exports of final goods to country 2. The last term represents the value-added imported by country 1 embedded in its exports of intermediate goods to country 2. On this basis, we can obtain a full breakdown of country 1's exports by highlighting the terms that are double counted, and which explain the gap between value-added exports and gross exports. We do this by combining the previous three equations, which results in the following expression:

$$\begin{aligned}
e^{12} &= [v^1b^{11}x^{12} + v^1b^{12}x^{22}] + [v^1b^{12}x^{21} + v^1b^{12}a^{21}(1 - a^{11})^{-1}x^{11}] \\
&+ v^1b^{12}a^{21}(1 - a^{11})^{-1}e^{12} + [v^2b^{21}x^{12} + v^2b^{21}a^{12}(1 - a^{22})^{-1}x^{22}] \\
&\quad + v^2b^{21}a^{12}(1 - a^{22})^{-1}e^{21} \quad (2.34)
\end{aligned}$$

The intuition behind this equation is very simple. The first two terms represent country 1's exports of value-added. These exports include country 1's value-added consumed abroad as final goods ($v^1b^{11}x^{12}$) and its value-added used as intermediate goods to produce final goods consumed in the destination country ($v^1b^{12}x^{22}$). These two terms also correspond to the [Johnson and Noguera \(2012a\)](#) measure of vertical specialization "Value-added exports". They obviously form a share of country 1's GDP. This is also the case for the following two terms in the second bracketed expression, which represent respectively country 1's intermediate exports of value-added embedded in country 2's exports of final goods to

country 1 ($v^2 b^{21} x^{12}$), and country 1's intermediate exports of value-added embedded in country 2's intermediate exports to country 1 and used to produce final goods consumed there $v^1 b^{12} a^{21} (1 - a^{11})^{-1} x^{11}$.

It is easily shown that country 1's GDP equals its value-added absorbed abroad (the first two terms), and its value-added absorbed at home, namely the following two terms that are first exported and finally return home as imports, plus a last term that represents the share of GDP that is never exported. Obviously, the terms in the second bracketed expression are double counted in the trade data because they are exported first by country 1 and then exported back by country 2. They therefore appear in the two countries' exports, and the double counting is clearly due to country 2 since they form a share of country 1's GDP. The fifth term is also a double counted term ($v^1 b^{12} a^{21} (1 - a^{11})^{-1} e^{12}$).

[Koopman et al. \(2014\)](#) report that this term is double counted twice, unlike the former terms. Intuitively, it represents country 1's value-added exports of intermediate goods to country 2 exported back by country 2 as intermediate goods used to produce country 1's exports (and therefore re-embedded in this country's exports). If we refer to the GDP breakdown presented above, this value does not appear in any of these countries' GDP. Since, intuitively, it appears in both countries' exports, it is double counted twice. However, as it initially originates in country 1, it necessarily forms a share of its domestic content of exports, i.e. all the value-added not initially produced abroad in its exports.

This is thus a different measure of vertical specialization from the "Value-added exports" discussed by [Johnson and Noguera \(2012a\)](#) and one that is made up of the first five terms of equation (2.34). Based on the same logic, we can label the last three terms "foreign content in country 1's exports". Respectively, the sixth term and seventh term represent the foreign value-added in country 1's exports of final goods and the foreign value-added in its exports of intermediate goods finally consumed abroad. They represent equation (2.34) third and fourth term in country 2's breakdown of gross exports. Finally, the eighth term shares similar characteristics with the fifth term. They are both double counted twice in export data. Precisely, the eighth term in country 1's breakdown of gross exports is the counterpart of the fifth term in country 2's breakdown of exports and vice versa.

Using this formula, we can accomplish a 100% breakdown of exports. Note, however, that the expression is slightly different when more than two countries are involved. In a

multi-country case with S countries and 1 sector, we write the following expression:

$$\begin{aligned}
E^{i*} = & [V^i \sum_{j \neq i}^S B^{ii} X^{ij} + V^i \sum_{j \neq i}^S B^{ij} X^{jj} + V^i \sum_{s \neq i, j}^S \sum_{j \neq i}^S B^{is} X^{sj}] + [V^i \sum_{j \neq i}^S B^{ij} X^{ji} + \\
& V^i \sum_{j \neq i}^S B^{ij} A^{ji} (I - A^{ii})^{-1} X^{ii}] + V^i \sum_{j \neq i}^S B^{ij} A^{ji} (I - A^{ii})^{-1} E^{i*} + \\
& [\sum_{s \neq i}^S \sum_{j \neq i}^S V^s B^{si} X^{ij} + \sum_{s \neq i}^S \sum_{j \neq i}^S V^s B^{si} A^{ij} (I - A^{jj})^{-1} X^{jj}] + \\
& \sum_{s \neq i}^S V^s B^{si} A^{ij} \sum_{j \neq i}^S (I - A^{jj})^{-1} E^{j*}]
\end{aligned} \tag{2.35}$$

where E^{i*} is an $S \times 1$ vector of exports, B is an $S \times S$ matrix that contains all the required coefficients mentioned above with B^{ij} as an element, X is an $S \times S$ matrix that contains the final goods produced in exporting countries and consumed in importing countries by sectors with X^{ij} as an element, A is an $S \times S$ matrix of technical coefficients with A^{ij} as an element, and V^i a $1 \times S$ row vector of value-added to gross output ratios. As can be seen from the above, the new expression contains nine terms rather than eight as before. This is because country “i”’s exported value-added is no longer made up solely of its value-added consumed abroad as final goods ($V^i \sum_{j \neq i}^S B^{ii} X^{ij}$) and its value-added used as intermediate goods to produce final goods consumed in the destination countries ($V^i \sum_{j \neq i}^S B^{ij} X^{jj}$), but also of its value-added exported to third countries and embedded in their exports of final goods to the rest of the world ($V^i \sum_{s \neq i, j}^S \sum_{j \neq i}^S B^{is} X^{sj}$).

The other terms have similar interpretations to equation (2.34). The fourth and fifth terms represent respectively the value-added exported by country “i” and exported back to “i” by all its trading partners, embedded either in final goods consumed in “i” ($V^i \sum_{j \neq i}^S B^{ij} X^{ji}$) or as intermediate goods used to produce goods ultimately consumed in country “i” $V^i \sum_{j \neq i}^S B^{ij} A^{ji} (I - A^{ii})^{-1} X^{ii}$. They therefore have similar characteristics to the third and fourth term in the previous equation. This is also true for the sixth term, which appears in many countries’ exports without being part of their GDP, as it is for the fifth term in the previous equation. The last three terms of this breakdown also represent the foreign content of country “i”’s exports, with the ninth term sharing the characteristics of the eighth term in equation (2.34), and the seventh and eighth terms respectively representing the value-added imported from abroad and exported back embedded either in final goods or as intermediate goods.

Bilateral value-added exports directly follow from the first bracketed expression in equa-

tion (2.35). We have:

$$V^{ij} = V^i B^{ii} X^{ij} + V^i B^{ij} X^{jj} + V^i \sum_{s \neq i, j}^S B^{is} X^{sj} \quad (2.36)$$

$$\implies V^{ij} = \sum_{s=i}^S V^i B^{is} X^{sj}$$

$$\implies V^{ij} = \sum_{s=i}^S \pi^{is} X^{sj}$$

With this framework set, we now turn to the presentation of the GTAP 9 database on which is based our analysis.

2..3.2 The GTAP database 9

The GTAP 9 Database is a multi-country input-output matrix covering 140 regions and 57 sectors, which we aggregate into one to perform our analysis. It has three reference years – 2004, 2007 and 2011 – from which we choose 2011 to conduct our calculations. The database has 40 data arrays representing different variables. The following are required for our analysis:

TVOM: Sales of domestic products at market prices;

VIMS: Imports at market prices;

VXMD: Non margin exports at market prices;

VST: margin exports;

VTWR: margins by margin commodity;

VIFM: import purchases by firms at market prices;

VIPM: import purchases by households at market prices;

VIGM: import purchases by governments at market prices;

VDFM: domestic purchases by firms at market prices;

VDPM: domestic purchases by households at market prices;

VDGM: domestic purchases by government at market prices;

MFAREV: export tax equivalent of MFA quota premia;

XTREV: ordinary export tax;

TARIFREV: ordinary import duty;

Note that VDFM and VIFM cover firms' purchases of intermediate goods, which we denote respectively by $VDFM^I$ and $VIFM^I$, and purchases of capital goods, which we denote respectively by $VDFM^{CGDS}$ and $VIFM^{CGDS}$. The following identities hold across the variables:

$$\sum_{i \neq j} VIMS_{ij} = VIFM_j^I + VIPM_j + VIGM_j + VIFM_j^{CGDS} \quad (2.37)$$

This means that a given country's total imports of goods are used either for final consumption $VIPM_j + VIGM_j$, investment $VIFM_j^{CGDS}$ or intermediate consumption $VIFM_j^I$.

The second identity is also related to total imports of goods at market prices.

$$\sum_{i \neq j} VIMS_{ij} = \sum_{i \neq j} VXMD_{ij} + XTREV_{ij} + MFAREV_{ij} + TARIFREV_{ij} + VTWR_{ij} \quad (2.38)$$

This means that imports at market prices embed transportation margins $VTWR_{ij}$ and trade duties, which are either export duties $XTREV_{ij} + MFAREV_{ij}$ or import duties $TARIFREV_{ij}$.

The third identity represents the column equilibrium condition of the input-output matrix.

$$TVOM_j = VDFM_j^I + VIFM_j^I + VDPM_j + VDGM_j + VIGM_j + VIPM_j + VDFM_j^{CGDS} + VIFM_j^{CGDS} + VST_j + \sum_{i \neq j} VXMD_{ji} - VIMS_{ij} \quad (2.39)$$

where country j's GDP at market prices is represented by $VDPM_j + VDGM_j + VIGM_j + VIPM_j + VDFM_j^{CGDS} + VIFM_j^{CGDS} + \sum_i VXMD_{ji} - VIMS_{ij} + VST_j$ and $VDFM_j^I + VIFM_j^I$ s country j's consumption of domestic and intermediate inputs, including custom duties and transportation margins. The row equilibrium is as follows:

$$TVOM_i = VDFM_i^I + VDPM_i + VDGM_i + VDFM_i^{CGDS} + VST_i + \sum_j VXMD_{ij} \quad (2.40)$$

The following table presents a simplified view of the GTAP database structure. It is clear that the database provides no information on the end use of exports $VXMD_{AM}$ or the different source countries for intermediate goods imports $VIFM_A^I$.

Table 2.19: A simplified view of the GTAP data base structure.

	Intermediate use		Final Demand		Rest of world (M)	Gross,output
	Country A	Rest of world (M)	Country A	Rest of world (M)		
Country A	$VDFM_A^I$		$VDPM_A$ $+VDGM_A$ $+VDFM_A^{CGDS}$		$VXMD_{AM}+VST_A$	$TVOM_A$
Rest of World (M)	$VIFM_A^I$					
Value-added	$VDFM_A^I$ $+VDPM_A + VDGM_A$ $+VIGM_A + VIPM_A$ $+VDFM_A^{CGDS}$ $+VIFM_A^{CGDS} + VST_A$ $+VXMD_{AM} - VIMS_{MA}$					
Gross output	$TVOM_A$					

As we saw earlier, we need a complete set of bilateral intermediate goods exports and final goods exports to obtain our data on value-added exports. To solve this problem, we use either a proportionality assumption or a reconciliation technique based on the UN BEC classification of goods by end-use categories and detailed trade data at the six-digit level from the UN COMTRADE database.

2..3.3 Disentangling of trade flows by end use

2..3.3.1 The proportionality assumption Applying the proportionality assumption is tantamount to assuming that a given country's imports of intermediate and final goods from a particular source are proportional to its total imports from that source. More specifically, we apply this assumption by first determining the share S_{intj} of intermediate goods in the total amount of goods imported by a given country using the following formula:

$$\frac{VIFM_j^I}{VIMS_j} = S_{intj} \quad (2.41)$$

We then apply this share to bilateral exports from other countries to the given country $VXMD_{ij}$ in order to obtain bilateral exports of intermediate goods, which we label $VXMD_{ij}^I$.

$$VXMD_{ij}^I = S_{intj} * VXMD_{ij} \quad (2.42)$$

Bilateral exports of final goods $VXMD_{ij}^F$. are then obtained by calculating the difference between bilateral exports of intermediate goods and total bilateral exports.

$$VXMD_{ij}^F = VXMD_{ij} - VXMD_{ij}^I \quad (2.43)$$

These bilateral exports of intermediate goods are net of custom duties and transportation margins. We apply the same share of intermediate goods as before S_{int} to the total amount of custom duties so as to determine the amount related to intermediate goods. With respect to transportation margins, we determine the bilateral supply of transport services by first calculating the share S_{VSTi} of each country in the world total supply of transport services (VST). We then apply these shares to the total demand for transport services for each country $VTWR_j$ in order to obtain our variable of interest. Finally, we use the share of intermediate goods S_{intj} to obtain the bilateral supply of transport services for intermediate goods. When properly done, the following identities should hold:

$$VIFM_j^I = \sum_i VXMD_{ij}^I + S_{intj} * [(XTREV_{ij} + MFAREV_{ij} + TARIFREV_{ij}) + S_{VSTi} * (VTWR_j)] \quad (2.44)$$

$$\begin{aligned} \sum_i VXMD_{ij}^F + (1 - S_{intj}) * [(XTREV_{ij} + MFAREV_{ij} + TARIFREV_{ij}) + S_{VSTi} * (VTWR_j)] \\ = VIPM_j + VIGM_j + VIFM_j^{CGDS} \end{aligned} \quad (2.45)$$

A simplified view of the resulting inter-country input-output matrix for a two-country case is presented in table 2.20. Although the proportionality assumption enables us to disentangle bilateral gross exports into intermediate and final goods exports, note that this assumption is too restrictive. Some countries are located downstream of the production process while others are upstream. Downstream countries export relatively more final goods than those upstream. The proportionality assumption does not capture this phenomenon. It could therefore be interesting to obtain the share of intermediate and final goods in each country's bilateral exports using existing classifications of goods by end use.

Table 2..20: A simplified view of the inter country input output matrix

	Intermediate use		Final Demand		Gross output
	Country A	Country B	Country A	Country B	
Country A	$VDFM^I_A$	$VXMD^I_{AB} + [S_{VST_A} * (VTWR_B) * S_{intB}]$	$VDFM^{CGDS}_A$	$VXMD^F_{AB} + [S_{VST_A} * (VTWR_B) * (1 - S_{intB})]$	$TVOM_A$
Country B	$VXMD^I_{BA} + [S_{VST_B} * (VTWR_A) * S_{intA}]$	$VDFM^I_B$	$VXMD^F_{BA} + [S_{VST_B} * (VTWR_A) * (1 - S_{intB})]$	$VDFM^{CGDS}_B$	$TVOM_B$
Custom duties and taxes	$S_{intA} * (XTREV_A + MFAREV_A + TARIFFREV_A)$	$S_{intB} * (XTREV_B + MFAREV_B + TARIFFREV_B)$			
Value-added	$VDPMA + VDCMA + VIGMA + VIPMA + VDFM^{CGDS}_A + VIFM^{CGDS}_A + VXMD_A - VIMS_A + VST_A$	$VDPMB + VDCMB + VIGMB + VIPMB + VDFM^{CGDS}_B + VIFM^{CGDS}_B + VXMD_B - VIMS_B + VST_B$			
Gross output	$TVOM_A$	$TVOM_B$			

2..3.3.2 The UN BEC method Rather than relying on ad-hoc assumptions, we use the UN BEC classification of products by end-use category with the UN COMTRADE database, which reports on bilateral exports and imports of goods between countries at the HS six-digit level, in order to obtain the share of intermediate and final goods in a given country's exports to a particular destination. Trade in services is captured by data from [Francois and Pindyuk \(2013\)](#), who use the EBOPS 2002 classification. In order to differentiate between goods and services by end-use category, we use UN BEC revision 4/HS 2002 tables of correspondence for goods and UN BEC revision 5/EBOPS tables of correspondence for services.

The HS/BEC tables of correspondence are available on the UN trade statistics website. The HS/EBOPS correspondence is based on a draft document from the same source that proposes a correlation table between the UN BEC revision 5 and the EBOPS classification.¹⁴ We use UN BEC revision 5 rather than revision 4 for trade in services because it identifies services better than revision 4. We also use HS 2002/EBOPS 2002/GTAP sector tables of correspondence to tie in these trade flows with the GTAP Database. The correspondence tables are taken respectively from the UN and European Commission websites¹⁵.

At the end of this process, we have goods and services identified by their GTAP sector and end-use category, whether final consumption, intermediate consumption or both. Some goods and services are therefore used for both final and intermediate consumption, and we need to assign a single end-use category to these goods to conduct our analysis. For this, we use the GTAP Database as a benchmark. To be more precise, we first determine the ratio of intermediate imports to total imports by sector in the GTAP Database and in our collected data. We then use an allocation method to converge the two ratios. Specifically, if the ratio we obtain from our collected data is higher than the ratio in the GTAP Database for a given sector, we consider that all remaining flows devoid of a single end use are final goods. If the ratio is lower, the dual-use items are used as a means of adjustment to converge to the GTAP Database ratio.

These dual-use items represent 10% of the database taken from COMTRADE and [Francois and Pindyuk \(2013\)](#) the year 2011, which is our year of analysis, and 7% for African countries. The African ratio of exported intermediate goods to final goods is equal to 6.35 before allocation, and becomes equal to 5.52 after allocation, which means that African final goods exports are relatively higher after allocation. Note that the reliability of the

¹⁴This correlation table is available in the online appendix.

¹⁵The GTAP sector/EBOPS table of correspondence is available in the online appendix.

trade flows reported in the UN COMTRADE database and in [Francois and Pindyuk \(2013\)](#) is not the same for every country. For instance, Ghana's reported imports from the USA might be significantly different to the USA's reported exports to Ghana. This needs to be taken into account to ensure the consistency of the resulting database. We do so by calculating a reliability index based on [Tsigas et al. \(2012\)](#). We use this index as a weight in the objective function of a quadratic optimization problem, which helps us to obtain a consistent database.¹⁶ The reliability index is obtained as follows:

$$RIX_i = \frac{XA_i}{\sum_j X_{ij}} \text{ where } XA_i = \sum_{j \in A_{ij} \leq 0.25} X_{ij} \text{ and } A_{ij} = \frac{|M_{ji} - X_{ij}|}{X_{ij}} \quad (2.46)$$

We then solve the following optimization problem:

$$VIFM_j^I = \sum_i \frac{VIMS_{ij}}{VXMD_{ij}^I} * VXMD_{ij}^I \quad (2.47)$$

$$VIPM_j + VIGM_j + VIFM_j^{CGDS} = \sum_i \frac{VIMS_{ij}}{VXMD_{ij}^F} * VXMD_{ij}^F \quad (2.48)$$

$$VIFM_j^I = \sum_i VXMD_{ij}^I + S_{intj} * [(XTREV_{ij} + MFAREV_{ij} + TARIFREV_{ij}) + S_{VSTi} * (VTWR_j)] \quad (2.49)$$

$$VXMD_{ij} = VXMD_{ij}^F + VXMD_{ij}^I \quad (2.50)$$

$$TVOM_j = VDFM_j^I + \sum_i \frac{VIMS_{ij}}{VXMD_{ij}^I} * VXMD_{ij}^I + VDPM_j + VDGM_j + VIGM_j + VIPM_j \\ + VDFM_j^{CGDS} + VIFM_j^{CGDS} + VST_j + \sum_{i \neq j} VXMD_{ji} - VIMS_{ij} \quad (2.51)$$

$$TVOM_i = VDFM_i^I + VDPM_i + VDGM_i + VDFM_i^{CGDS} + VST_i + \sum_j VXMD_{ij}^I + \sum_j VXMD_{ij}^F \quad (2.52)$$

$$MIN (OMEGA) = \frac{1}{2} \left\{ \sum_i \sum_j \left(\frac{(VXMD_{ij}^I - \overline{VXMD}_{ij}^I)^2}{RIX_i^{-1}} \right) + \sum_i \sum_j \left(\frac{(VXMD_{ij}^F - \overline{VXMD}_{ij}^F)^2}{RIX_i^{-1}} \right) \right\} \quad (2.53)$$

Where \overline{VXMD}_{ij}^I and \overline{VXMD}_{ij}^F are initial data obtained from the first breakdown of trade

¹⁶Some countries such as Taiwan and Puerto Rico are included in the GTAP database, but not in the COMTRADE database. In this case, a proportionality method is used to obtain the initial share of intermediate and final goods. A zero level of reliability is attributed to the flows obtained such that our objective function assigns less weight to these data in the optimization process.

flows into intermediate and final goods respectively and $\frac{VIMS_{ij}}{VXMD_{ij}}$ is the ratio of imports inclusive of import duties/transport services to imports at their FOB price. *OMEGA* is a quadratic objective penalty function that assigns more weight to data from reliable exporters, and therefore adjusts more data from unreliable exporters. To give an idea of the results, the correlation between initial and optimized intermediate goods flows is 0.87, while it is 0.92 for final goods. With respect to the African countries, this correlation is 0.87 for intermediate goods flows, and 0.69 for final goods. More detailed results are presented in table [2.21](#).

Table 2.21: Correlation between collected and optimized data (Author's calculations)

Exporter	Name	Correlation intermediate goods	Correlation final goods	Reliability index
ALB	Albania	0,80	0,50	0,57
ARE	United Arab Emirates	0,00	-0,01	0,00
ARG	Argentina	0,98	0,98	0,78
ARM	Armenia	0,70	0,77	0,47
AUS	Australia	0,99	0,87	0,72
AUT	Austria	0,99	0,99	0,72
AZE	Azerbaijan	0,88	0,74	0,69
BEL	Belgium	0,95	0,96	0,39
BEN	Benin	0,57	0,80	0,21
BFA	Burkina Faso	0,95	0,18	0,01
BGD	Bangladesh	0,35	0,97	0,77
BGR	Bulgaria	0,95	0,91	0,55
BHR	Bahrain	0,42	0,44	0,21
BLR	Belarus	0,56	0,61	0,26
BOL	Bolivia	0,72	0,21	0,55
BRA	Brazil	0,98	0,96	0,67
BRN	Brunei Darussalam	0,96	0,03	0,83
BWA	Botswana	0,99	0,02	0,75
CAN	Canada	1,00	1,00	0,81
CHE	Switzerland	0,94	0,79	0,60
CHL	Chile	0,98	0,86	0,63
CHN	China	0,80	0,88	0,45
CIV	Côte d'Ivoire	0,85	0,69	0,44
CMR	Cameroon	0,63	0,74	0,39
COL	Colombia	0,99	0,80	0,66
CRI	Costa Rica	0,95	0,97	0,59
CYP	Cyprus	0,87	0,89	0,44
CZE	Czech Republic	0,99	0,98	0,50
DEU	Germany	0,98	0,99	0,77
DNK	Denmark	0,95	0,97	0,61
DOM	Dominican Republic P	0,89	0,93	0,46
ECU	Ecuador	0,99	0,72	0,73
EGY	Egypt	0,85	0,85	0,46
ESP	Spain	0,95	0,96	0,69
EST	Estonia	0,93	0,93	0,34
ETH	Ethiopia	0,85	0,83	0,49
FIN	Finland	0,96	0,94	0,65

Table 2..21 – continued from previous page

Exporter	Name	Correlation intermediate goods	Correlation final goods	Reliability index
FRA	France	0,98	0,99	0,74
GBR	United Kingdom	0,96	0,97	0,63
GEO	Georgia	0,72	0,43	0,39
GHA	Ghana	0,34	0,50	0,14
GIN	Guinea	0,45	-0,02	0,00
GRC	Greece	0,72	0,80	0,64
GTM	Guatemala	0,97	0,90	0,50
HKG	Hong Kong	0,85	0,13	0,02
HND	Honduras	0,88	0,96	0,61
HRV	Croatia	0,88	0,82	0,61
HUN	Hungary	0,99	0,98	0,69
IDN	Indonesia	0,96	0,94	0,66
IND	India	0,88	0,91	0,51
IRL	Ireland	0,95	0,94	0,50
IRN	Iran	0,79	0,47	0,24
ISR	Israel	0,93	0,94	0,57
ITA	Italy	0,99	0,98	0,71
JAM	Jamaica	0,95	0,07	0,45
JOR	Jordan	0,54	0,57	0,33
JPN	Japan	0,95	0,98	0,73
KAZ	Kazakhstan	0,91	0,60	0,30
KEN	Kenya	0,09	0,34	0,00
KGZ	Kyrgyzstan	0,94	0,90	0,20
KHM	Cambodia	0,04	0,86	0,44
KOR	Korea, Republic of	0,97	0,98	0,62
KWT	Kuwait	0,66	0,09	0,28
LAO	Lao PDR	0,79	0,22	0,10
LKA	Sri Lanka	0,76	0,75	0,64
LTU	Lithuania	0,82	0,89	0,37
LUX	Luxembourg	0,88	0,75	0,47
LVA	Latvia	0,90	0,90	0,43
MAR	Morocco	0,88	0,78	0,52
MDG	Madagascar	0,71	0,18	0,37
MEX	Mexico	1,00	1,00	0,86
MLT	Malta	0,59	0,64	0,53
MNG	Mongolia	0,30	-0,01	0,00
MOZ	Mozambique	0,34	0,39	0,20
MUS	Mauritius	0,65	0,63	0,54
MWI	Malawi	0,82	0,22	0,17

Table 2..21 – continued from previous page

Exporter	Name	Correlation intermediate goods	Correlation final goods	Reliability index
MYS	Malaysia	0,94	0,92	0,56
NAM	Namibia	0,70	0,49	0,44
NGA	Nigeria	0,88	0,23	0,26
NIC	Nicaragua	0,87	0,49	0,75
NLD	Netherlands	0,99	0,99	0,54
NOR	Norway	0,85	0,90	0,40
NPL	Nepal	0,01	0,93	0,24
NZL	New Zealand	0,94	0,96	0,75
OMN	Oman	0,98	0,63	0,68
PAK	Pakistan	0,77	0,96	0,60
PAN	Panama	0,95	0,57	0,07
PER	Peru	0,96	0,23	0,50
PHL	Philippines	0,87	0,81	0,26
POL	Poland	0,99	0,98	0,64
PRI	Puerto Rico	0,03	0,00	0,00
PRT	Portugal	0,96	0,97	0,67
PRY	Paraguay	0,85	0,35	0,38
QAT	Qatar	0,95	0,54	0,25
ROU	Romania	0,98	0,97	0,66
RUS	Russia	0,79	0,77	0,35
RWA	Rwanda	0,37	-0,02	0,06
SAU	Saudi Arabia	0,54	0,78	0,41
SEN	Senegal	0,61	0,16	0,24
SGP	Singapore	0,91	0,87	0,26
SLV	El Salvador	0,78	0,98	0,73
SVK	Slovakia	0,97	0,96	0,54
SVN	Slovenia	0,97	0,89	0,59
SWE	Sweden	0,97	0,98	0,69
TGO	Togo	0,35	0,25	0,24
THA	Thailand	0,93	0,96	0,64
TTO	Trinidad and Tobago P	0,99	0,43	0,42
TUN	Tunisia	0,95	0,97	0,61
TUR	Turkey	0,93	0,98	0,59
TWN	Taiwan	0,11	0,34	0,00
TZA	Tanzania	0,75	0,72	0,10
UGA	Uganda	0,47	0,08	0,20
UKR	Ukraine	0,95	0,99	0,72
URY	Uruguay	0,83	0,91	0,71
USA	United States of America	0,96	0,96	0,65

Table 2..21 – continued from previous page

Exporter	Name	Correlation intermediate goods	Correlation final goods	Reliability index
VEN	Venezuela	0,54	0,31	0,31
VNM	Viet Nam	0,95	0,98	0,63
XAC	South Central Africa	0,99	-0,02	0,93
XCA	Rest of Central America	0,82	0,04	0,84
XCB	Rest of Caribbean	0,89	-0,01	0,14
XCF	Rest of Central Africa	0,78	0,00	0,02
XEA	Rest of East Asia	0,61	0,19	0,07
XEC	Rest of Eastern Africa	-0,01	0,03	0,28
XEE	Rest of Eastern Europe	0,72	0,93	0,38
XEF	Rest of European Free Trade Association	0,68	0,70	0,50
XER	Rest of Europe	0,73	0,66	0,63
XNA	Rest of North America	0,11	0,84	0,90
XNF	Rest of North Africa	0,87	0,05	0,73
XOC	Rest of Oceania	0,91	0,13	0,71
XSA	Rest of South Asia	0,01	0,63	0,10
XSC	Rest of South African Customs Union	0,06	-0,04	0,41
XSE	Rest of Southeast Asia	0,96	0,80	0,47
XSM	Rest of South America	0,78	0,29	0,28
XSU	Rest of Former Soviet Union	0,19	-0,02	0,00
XWF	Rest of Western Africa	0,31	0,17	0,05
XWS	Rest of Western Asia	0,61	0,30	0,24
ZAF	South Africa	0,93	0,79	0,60
ZMB	Zambia	0,94	0,04	0,03
ZWE	Zimbabwe	0,62	0,11	0,03

Table 2..21 – continued from previous page

Exporter	Name	Correlation intermediate goods	Correlation final goods	Reliability index
TOT	TOTAL	0,87	0,92	

Correlation BEC with CPC and EBOPS (UN statistics division)

EBOPS		CPC Code			BEC end-use category
Code	Description	Code	Description	BEC	Description
1	Manufacturing services on physical inputs owned by others	88	Manufacturing services on physical inputs owned by others	4.2.1.	Intermediate consumption
1	Manufacturing services on physical inputs owned by others	892	Moulding, pressing, stamping, extruding and similar plastic manufacturing services	2.2.1.	Intermediate consumption
1	Manufacturing services on physical inputs owned by others	893	Casting, forging, stamping and similar metal manufacturing services	2.2.1.	Intermediate consumption
1	Manufacturing services on physical inputs owned by others	854	Packaging services	5.2.1.	Intermediate consumption
2	Maintenance and repair services n.i.e.	8711	Maintenance and repair services of fabricated metal products, except machinery and equipment	2.2.2.	Capital Formation
2	Maintenance and repair services n.i.e.	8712	Maintenance and repair services of office and accounting machinery	6.2.2.	Capital Formation
2	Maintenance and repair services n.i.e.	8714	Maintenance and repair of transport machinery and equipment	5.2.2.	Capital Formation
2	Maintenance and repair services n.i.e.	8715	Maintenance and repair services of other machinery and equipment	3.2.2.	Capital Formation
2	Maintenance and repair services n.i.e.	872	Repair services of other goods	4.2.2.	Capital Formation
3.1.1	Sea Transport - Passenger	64231	Coastal and transoceanic water transport services of passengers by ferries	5.2.3.	Final Consumption
3.1.1	Sea Transport - Passenger	64239	Other coastal and transoceanic water transport services of passengers	5.2.3.	Final Consumption

EBOPS		CPC Code			BEC end-use category
3.1.1	Sea Transport - Passenger	66021	Rental services of passenger vessels for coastal and transoceanic water transport with operator	5.2.3.	Final Consumption
3.1.2	Sea Transport - Freight	6521	Coastal and transoceanic water transport services of freight	5.2.1.	Intermediate consumption
3.1.2	Sea Transport - Freight	66022	Rental services of freight vessels for coastal and transoceanic water transport with operator	5.2.1.	Intermediate consumption
3.1.3	Sea Transport - Other	67511	Port and waterway operation services (excl. cargo handling), on coastal and transoceanic waters	5.2.1.	Intermediate consumption
3.1.3	Sea Transport - Other	67521	Pilotage and berthing services on coastal and transoceanic waters	5.2.1.	Intermediate consumption
3.1.3	Sea Transport - Other	67531	Vessel salvage and refloating services on coastal and transoceanic waters	5.2.1.	Intermediate consumption
3.1.3	Sea Transport - Other	6759	Other supporting services for water transport	5.2.1.	Intermediate consumption
3.2.1	Air transport - Passenger	64134	Sightseeing services by air	5.2.3.	Final Consumption
3.2.1	Air transport - Passenger	6424	Air transport services of passengers	5.2.3.	Final Consumption
3.2.1	Air transport - Passenger	66031	Rental services of passenger aircraft with operator	5.2.1.	Intermediate consumption
3.2.2	Air transport - Freight	6531	Air transport services of freight	5.2.1.	Intermediate consumption
3.2.2	Air transport - Freight	66032	Rental services of freight aircraft with operator	5.2.1.	Intermediate consumption
3.2.3	Air transport - Other	6761	Airport operation services (excl. cargo handling)	5.2.1.	Intermediate consumption
3.2.3	Air transport - Other	6762	Air traffic control services	5.2.1.	Intermediate consumption
3.2.3	Air transport - Other	6763	Other supporting services for air transport	5.2.1.	Intermediate consumption
3.3	Other modes of Transport				
3.4	Post and courier services	68	Postal and courier services	5.2.1.	Intermediate consumption
3.5	Space transport	6425	Space transport services of passengers	5.2.3.	Final Consumption
3.5	Space transport	6532	Space transport services of freight	5.2.1.	Intermediate consumption
3.5	Space transport	6764	Supporting services for space transport	5.2.1.	Intermediate consumption
3.6.1	Rail transport - Passenger	64111	Urban and suburban railway transport services of passengers	5.2.1.	Intermediate consumption

EBOPS		CPC Code			BEC end-use category
3.6.1	Rail transport - Passenger	64131	Sightseeing services by rail	5.2.3.	Final Consumption
3.6.1	Rail transport - Passenger	6421	Interurban railway transport services of passengers	5.2.3.	Final Consumption
3.6.2	Rail transport - Freight	6512	Railway transport services of freight	5.2.1.	Intermediate consumption
3.6.3	Rail transport - Other	673	Supporting services for railway transport	5.2.1.	Intermediate consumption
3.7.1	Road transport - Passenger	64112	Urban and suburban scheduled road transport services of passengers	5.2.1.	Intermediate consumption
3.7.1	Road transport - Passenger	64113	Mixed mode urban and suburban transportation services of passengers	5.2.3.	Final Consumption
3.7.1	Road transport - Passenger	64114	Local special-purpose scheduled road transport services of passengers	5.2.3.	Final Consumption
3.7.1	Road transport - Passenger	64115	Taxi services	5.2.3.	Final Consumption
3.7.1	Road transport - Passenger	64116	Rental services of passenger cars with operator	5.2.3.	Final Consumption
3.7.1	Road transport - Passenger	64117	Road transport services of passengers by man- or animal-drawn vehicles	5.2.3.	Final Consumption
3.7.1	Road transport - Passenger	64118	Non-scheduled local bus and coach charter services	5.2.1.	Intermediate consumption
3.7.1	Road transport - Passenger	64119	Other land transportation services of passengers, n.e.c.	5.2.1.	Intermediate consumption
3.7.1	Road transport - Passenger	64132	Sightseeing services by land, except rail	5.2.3.	Final Consumption
3.7.1	Road transport - Passenger	6422	Interurban road transport services of passengers	5.2.3.	Final Consumption
3.7.1	Road transport - Passenger	66011	Rental services of buses and coaches with operator	5.2.1.	Intermediate consumption
3.7.2	Road transport - Freight	6511	Road transport services of freight	5.2.1.	Intermediate consumption
3.7.2	Road transport - Freight	66012	Rental services of trucks with operator	5.2.1.	Intermediate consumption
3.7.3	Road transport - Other	674	Supporting services for road transport	5.2.1.	Intermediate consumption
3.8.1	Inland waterway transport -Passenger	64121	Inland water transport services of passengers by ferries	5.2.3.	Final Consumption
3.8.1	Inland waterway transport -Passenger	64129	Other inland water transport services of passengers	5.2.3.	Final Consumption

EBOPS		CPC Code			BEC end-use category
3.8.1	Inland waterway transport -Passenger	64133	Sightseeing services by water	5.2.3.	Final Consumption
3.8.1	Inland waterway transport -Passenger	66023	Rental services of passenger vessels for inland water transport with operator	5.2.3.	Final Consumption
3.8.2	Inland waterway transport -Freight	6522	Inland water transport services of freight	5.2.1.	Intermediate consumption
3.8.2	Inland waterway transport -Freight	66024	Rental services of freight vessels for inland water transport with operator	5.2.1.	Intermediate consumption
3.8.3	Inland waterway transport -Other	67512	Inland waterway operation services (excl. cargo handling)	5.2.1.	Intermediate consumption
3.8.3	Inland waterway transport -Other	67522	Pilotage and berthing services in inland waters	5.2.1.	Intermediate consumption
3.8.3	Inland waterway transport -Other	67532	Vessel salvage and refloating services in inland waters	5.2.1.	Intermediate consumption
3.9	Pipeline transport	6513	Transport services via pipeline	2.2.1.	Intermediate consumption
3.10	Electricity transmission	69111	Electricity transmission (on own account)	2.2.1	Intermediate consumption
3.10	Electricity transmission	86311	Support services to electricity transmission	2.2.1.	Intermediate consumption
3.11	Other supporting and auxiliary services	63392	Contract food services for transportation operators	5.2.1.	Intermediate consumption
3.11	Other supporting and auxiliary services	671	Cargo handling services	5.2.1.	Intermediate consumption
3.11	Other supporting and auxiliary services	672	Storage and warehousing services	5.2.1.	Intermediate consumption
3.11	Other supporting and auxiliary services	679	Other supporting transport services	5.2.1.	Intermediate consumption
3.11	Other supporting and auxiliary services	8534*	Specialized cleaning services	5.2.1.	Intermediate consumption
Travel breakdown by purpose					
5.1.1	Acquisition of goods and services by border, seasonal and other short-term workers	N/A		5.2.3.	Final Consumption
5.1.2	Other	N/A		5.2.3.	Final Consumption

EBOPS		CPC Code			BEC end-use category
5.2.1	Health-related	N/A		5.2.3.	Final Consumption
5.2.2	Education-related	N/A		5.2.3.	Final Consumption
5.2.3	Other	N/A		5.2.3.	Final Consumption
Travel breakdown by product consumed					
4a.1	Goods	0	Agriculture, forestry and fishery products	5.2.3.	Final Consumption
4a.1	Goods	1	Ores and minerals; electricity, gas and water	5.2.3.	Final Consumption
4a.1	Goods	2	Food products, beverages and tobacco; textiles, apparel and leather products	5.2.3.	Final Consumption
4a.1	Goods	3	Other transportable goods, except metal products, machinery and equipment	5.2.3.	Final Consumption
4a.1	Goods	4	Metal products, machinery and equipment	5.2.3.	Final Consumption
4a.2	Local transport services	641	Local transport and sightseeing transportation services of passengers	5.2.3.	Final Consumption
4a.2	Local transport services	642	Long-distance transport services of passengers	5.2.3.	Final Consumption
4a.3	Accommodation services	631	Accommodation services for visitors	5.2.3.	Final Consumption
4a.3	Accommodation services	632	Other accommodation services for visitors and others	5.2.3.	Final Consumption
4a.4	Food-serving services	633	Food serving services	1.2.3.	Final Consumption
4a.4	Food-serving services	634	Beverage serving services	1.2.3.	Final Consumption
4a.4.1	Health services	931	Human health services	7.2.3.	Final Consumption
4a.4.1	Health services	9321	Residential health-care services other than by hospitals	7.2.3.	Final Consumption
4a.4.2	Education services	921	Pre-primary education services	7.2.3.	Final Consumption
4a.4.2	Education services	922	Primary education services	7.2.3.	Final Consumption
4a.4.2	Education services	923	Secondary education services	7.2.3.	Final Consumption
4a.4.2	Education services	924	Post-secondary non-tertiary education services	7.2.3.	Final Consumption
4a.4.2	Education services	925	Tertiary education services	7.2.3.	Final Consumption
4a.4.2	Education services	92911	Cultural education services	7.2.3.	Final Consumption
4a.4.2	Education services	92912	Sports and recreation education services	7.2.3.	Final Consumption

EBOPS		CPC Code			BEC end-use category
4a.4.2	Education services	92919	Other education and training services, n.e.c.	7.2.3.	Final Consumption
4a.4.2	Education services	9292	Educational support services	7.2.3.	Final Consumption
4.1	Construction abroad	53	Constructions	3.2.3.	Final Consumption
4.1	Construction abroad	54	Construction services	3.2.1.	Intermediate consumption
4.2	Construction in the reporting economy	53	Constructions	3.2.3.	Final Consumption
4.2	Construction in the reporting economy	54	Construction services	3.2.1.	Intermediate consumption
6.1.1	Direct insurance - Life insurance	71311	Life insurance services	7.2.3.	Final Consumption
6.1.2	Direct insurance - Freight insurance	71333	Freight insurance services	5.2.3.	Final Consumption
6.1.3	Direct insurance - Other direct insurance	7132	Accident and health insurance services	7.2.3.	Final Consumption
6.1.3	Direct insurance - Other direct insurance	71331	Motor vehicle insurance services	5.2.3.	Final Consumption
6.1.3	Direct insurance - Other direct insurance	71332	Marine, aviation, and other transport insurance services	5.2.3.	Final Consumption
6.1.3	Direct insurance - Other direct insurance	71334	Other property insurance services	3.2.3.	Final Consumption
6.1.3	Direct insurance - Other direct insurance	71335	General liability insurance services	6.2.3.	Final Consumption
6.1.3	Direct insurance - Other direct insurance	71336*	Credit and surety insurance services	6.2.3.	Final Consumption
6.1.3	Direct insurance - Other direct insurance	71337	Travel insurance services	5.2.3.	Final Consumption
6.1.3	Direct insurance - Other direct insurance	71339*	Other non-life insurance services	6.2.3.	Final Consumption
6.2	Reinsurance	714	Reinsurance services	6.2.1.	Intermediate consumption
6.3	Auxiliary insurance services	7161	Insurance brokerage and agency services	6.2.1.	Intermediate consumption
6.3	Auxiliary insurance services	7162	Insurance claims adjustment services	6.2.1.	Intermediate consumption
6.3	Auxiliary insurance services	7163	Actuarial services	6.2.1.	Intermediate consumption

EBOPS		CPC Code			BEC end-use category
6.3	Auxiliary insurance services	7169	Other services auxiliary to insurance and pensions	6.2.1.	Intermediate consumption
6.5.1	Pension services	71312	Individual pension services	7.2.3.	Final Consumption
6.5.1	Pension services	71313	Group pension services	7.2.3.	Final Consumption
6.5.1	Pension services	7164	Pension fund management services	7.2.3.	Final Consumption
6.5.2	Standardized guarantee services	71336*	Credit and surety insurance services	6.2.3.	Final Consumption
6.5.2	Standardized guarantee services	71339*	Other non-life insurance services	6.2.3.	Final Consumption
7.1	Explicitly charged and other financial services	7111*	Central Banking services	6.2.3.	Final Consumption
7.1	Explicitly charged and other financial services	7112*	Deposit services	6.2.3.	Final Consumption
7.1	Explicitly charged and other financial services	7113*	Credit-granting services	6.2.3.	Final Consumption
7.1	Explicitly charged and other financial services	7114*	Financial leasing services	6.2.3.	Final Consumption
7.1	Explicitly charged and other financial services	7119	Other financial services, except investment banking, insurance services and pension services	6.2.3.	Final Consumption
7.1	Explicitly charged and other financial services	712	Investment banking services	6.2.1.	Intermediate consumption
7.1	Explicitly charged and other financial services	715	Services auxiliary to financial services other than to insurance and pensions	6.2.1.	Intermediate consumption
7.1	Explicitly charged and other financial services	717	Services of holding financial assets	6.2.1.	Intermediate consumption
7.2	Financial Intermediation Services Indirectly Measured (FISIM)	7111*	Central Banking services	6.2.1.	Intermediate consumption
7.2	Financial Intermediation Services Indirectly Measured (FISIM)	7112*	Deposit services	6.2.1.	Intermediate consumption

EBOPS		CPC Code		BEC end-use category	
7.2	Financial Intermediation Services Indirectly Measured (FISIM)	7113*	Credit-granting services	6.2.1.	Intermediate consumption
7.2	Financial Intermediation Services Indirectly Measured (FISIM)	7114*	Financial leasing services	6.2.1.	Intermediate consumption
8.1	Franchises and trademarks licensing fees	8396	Trademarks and franchises	6.2.1.	Intermediate consumption
8.2	Licenses for the use of outcomes of research and development	7333	Licensing services for the right to use R&D products	6.2.1.	Intermediate consumption
8.3	Licenses to reproduce and/or distribute computer software	7331*	Licensing services for the right to use computer software and databases	6.2.1.	Intermediate consumption
8.5.1	Licenses to reproduce and/or distribute audiovisual products	7332	Licensing services for the right to use entertainment, literary or artistic originals	6.2.1.	Intermediate consumption
8.5.1	Licenses to reproduce and/or distribute audio-visual products	7332*	Licensing services for the right to use entertainment, literary or artistic originals	6.2.1.	Intermediate consumption
8.5.2	Licenses to reproduce and/or distribute other products	7331*	Licensing services for the right to use computer software and databases	6.2.1.	Intermediate consumption
8.5.2	Licenses to reproduce and/or distribute other products	7332*	Licensing services for the right to use entertainment, literary or artistic originals	6.2.1.	Intermediate consumption
8.5.2	Licenses to reproduce and/or distribute other products	7335	Licensing services for the right to use mineral exploration and evaluation	2.2.1.	Intermediate consumption
8.5.2	Licenses to reproduce and/or distribute other products	7339	Licensing services for the right to use other intellectual property products	7.2.1	Intermediate consumption
4.1	Telecommunications services	841	Telephony and other telecommunications services	6.2.3.	Final Consumption
4.1	Telecommunications services	842	Internet telecommunications services	6.2.3.	Final Consumption
4.1	Telecommunications services	84631	Broadcasting services	6.2.3.	Final Consumption
4.2.1	Computer services - Computer software	83143	Software originals	6.2.1	Intermediate consumption

EBOPS		CPC Code			BEC end-use category
4.2.1	Computer services - Computer software	8434	Software downloads	6.2.3.	Final Consumption
4.2.1	Computer services - Computer software	84391	On-line games	6.2.3.	Final Consumption
4.2.1	Computer services - Computer software	84392	On-line software	6.2.3.	Final Consumption
4.2.2	Computer services - Other computer services	8313	IT consulting and support services	6.2.1.	Intermediate consumption
4.2.2	Computer services - Other computer services	83141	IT design and development services for applications	6.2.1.	Intermediate consumption
4.2.2	Computer services - Other computer services	83142	IT design and development services for networks and systems	6.2.1.	Intermediate consumption
4.2.2	Computer services - Other computer services	8315	Hosting and information technology (IT) infrastructure provisioning services	6.2.1.	Intermediate consumption
4.2.2	Computer services - Other computer services	8316	IT infrastructure and network management services	6.2.1.	Intermediate consumption
4.2.2	Computer services - Other computer services	8713	Maintenance and repair services of computers and peripheral equipment	6.2.2.	Capital Formation
4.2.2	Computer services - Other computer services	92919*	Other education and training services, n.e.c.	7.2.1	Intermediate consumption
4.3.1	Information services - News agency services	844	News agency services	6.2.3.	Final Consumption
4.3.2	Information services - Other information services	8394	Original compilations of facts/information	6.2.1.	Intermediate consumption
4.3.2	Information services - Other information services	8399*	All other professional, technical and business services, n.e.c.	6.2.1.	Intermediate consumption
4.3.2	Information services - Other information services	84312	On-line newspapers and periodicals	6.2.3.	Final Consumption
4.3.2	Information services - Other information services	84313	On-line directories and mailing lists	6.2.3.	Final Consumption
4.3.2	Information services - Other information services	84393	On-line adult content	6.2.3.	Final Consumption

EBOPS		CPC Code			BEC end-use category
4.3.2	Information services - Other information services	84394	Web search portal content	6.2.3.	Final Consumption
4.3.2	Information services - Other information services	84399	Other on-line content n.e.c.	6.2.3.	Final Consumption
4.3.2	Information services - Other information services	845	Library and archive services	6.2.3.	Final Consumption
10.1.1.1	Provision of customized and non-customized research and development services	811	Research and experimental development services in natural sciences and engineering	7.2.1.	Intermediate consumption
10.1.1.1	Provision of customized and non-customized research and development services	812	Research and experimental development services in social sciences and humanities	7.2.1.	Intermediate consumption
10.1.1.1	Provision of customized and non-customized research and development services	813	Interdisciplinary research and experimental development services	7.2.1.	Intermediate consumption
10.1.1.1	Provision of customized and non-customized research and development services	83912	Industrial design services	7.2.1.	Intermediate consumption
10.1.1.2	Sale of proprietary rights arising from research and development	814	Research and development originals	7.2.1.	Intermediate consumption
10.1.1.2	Sale of proprietary rights arising from research and development	8392	Design originals	7.2.1.	Intermediate consumption
10.1.2	Other research and development services	8344*	Technical testing and analysis services	7.2.1.	Intermediate consumption
10.2.1.1	Legal services	821	Legal services	6.2.1.	Intermediate consumption
10.2.1.2	Accounting; auditing; bookkeeping; and tax consulting services	822	Accounting, auditing and bookkeeping services	6.2.1.	Intermediate consumption
10.2.1.2	Accounting; auditing; bookkeeping; and tax consulting services	823	Tax consultancy and preparation services	6.2.1.	Intermediate consumption

EBOPS		CPC Code		BEC end-use category	
10.2.1.2	Accounting; auditing; bookkeeping; and tax consulting	824	Insolvency and receivership services	6.2.1.	Intermediate consumption
10.2.1.3	Business and management consulting and public relations services	8311	Management consulting and management services	6.2.1.	Intermediate consumption
10.2.1.3	Business and management consulting and public relations services	8312	Business consulting services	6.2.1.	Intermediate consumption
10.2.1.3	Business and management consulting and public relations services	8319	Other management services, except construction project management services	6.2.1.	Intermediate consumption
10.2.2	Advertising; market research; and public opinion polling	836	Advertising services and provision of advertising space or time	6.2.1.	Intermediate consumption
10.2.2	Advertising; market research; and public opinion polling	837	Market research and public opinion polling services	6.2.1.	Intermediate consumption
10.2.2	Advertising; market research; and public opinion polling	83812	Advertising and related photography services	6.2.1.	Intermediate consumption
10.2.2.1	Advertising; market research; and public opinion polling	8596	Convention and trade show assistance and organization services	6.2.1.	Intermediate consumption
10.3.1.1	Architectural services	832	Architectural services, urban and land planning and landscape architectural services	3.2.1.	Intermediate consumption
10.3.1.2	Engineering services	833	Engineering services	3.2.1.	Intermediate consumption
10.3.1.3	Scientific and other technical services	8342	Surface surveying and map-making services	3.2.1.	Intermediate consumption
10.3.1.3	Scientific and other technical services	8343	Weather forecasting and meteorological services	6.2.1.	Intermediate consumption
10.3.1.3	Scientific and other technical services	8393	Scientific and technical consulting services n.e.c.	7.2.1.	Intermediate consumption
10.3.1.3	Scientific and other technical services	8344*	Technical testing and analysis services	7.2.1.	Intermediate consumption

EBOPS		CPC Code			BEC end-use category
10.3.2.1	Waste treatment and de-pollution	894	Materials recovery (recycling) services, on a fee or contract basis	2.2.3.	Final Consumption
10.3.2.1	Waste treatment and de-pollution	941	Sewerage, sewage treatment and septic tank cleaning services	3.2.3.	Final Consumption
10.3.2.1	Waste treatment and de-pollution	942	Waste collection services	3.2.3.	Final Consumption
10.3.2.1	Waste treatment and de-pollution	943	Waste treatment and disposal services	2.2.1.	Intermediate consumption
10.3.2.1	Waste treatment and de-pollution	944	Remediation services	2.2.3.	Final Consumption
10.3.2.1	Waste treatment and de-pollution	945	Sanitation and similar services	3,2,3,	Final Consumption
10.3.2.1	Waste treatment and de-pollution	949	Other environmental protection services n.e.c.	1.2.1.	Intermediate consumption
10.3.2.2	Services incidental to agriculture, forestry and fishing	835	Veterinary services	1.2.1.	Intermediate consumption
10.3.2.2	Services incidental to agriculture, forestry and fishing	861	Support services to agriculture, hunting, forestry and fishing	1.2.1.	Intermediate consumption
10.3.2.3	Services incidental to mining, and oil and gas extraction	862	Support services to mining	2.2.1.	Intermediate consumption
10.3.2.3	Services incidental to mining, and oil and gas extraction	8341	Geological, geophysical and other prospecting services	2.2.1.	Intermediate consumption
10.3.3	Operating leasing services	7211	Rental or leasing services involving own or leased property	3.2.1.	Intermediate consumption
10.3.3	Operating leasing services	731	Leasing or rental services concerning machinery and equipment without operator	5.2.1.	Intermediate consumption
10.3.3	Operating leasing services	7321	Leasing or rental services concerning televisions, radios, video cassette recorders and related equipment and accessories	6.2.1.	Intermediate consumption
10.3.3	Operating leasing services	7323	Leasing or rental services concerning furniture and other household appliances	3.2.1.	Intermediate consumption
10.3.3	Operating leasing services	7324	Leasing or rental services concerning pleasure and leisure equipment	7.2.1.	Intermediate consumption

EBOPS		CPC Code			BEC end-use category
10.3.3	Operating leasing services	7325	Leasing or rental services concerning household linen	3.2.1.	Intermediate consumption
10.3.3	Operating leasing services	7326	Leasing or rental services concerning textiles, clothing and footwear	4.2.1.	Intermediate consumption
10.3.3	Operating leasing services	7327	Leasing or rental services concerning do-it-yourself machinery and equipment	3.2.1.	Intermediate consumption
10.3.3	Operating leasing services	7329	Leasing or rental services concerning other goods n.e.c.	3.2.1.	Intermediate consumption
10.3.4	Trade-related services	612	Wholesale trade services on a fee or contract basis	6.2.1.	Intermediate consumption
10.3.4	Trade-related services	625	Retail trade services on a fee or contract basis	6.2.1.	Intermediate consumption
10.3.4	Trade-related services	7222	Building sales on a fee or contract basis	3.2.1.	Intermediate consumption
10.3.4	Trade-related services	7223	Land sales on a fee or contract basis	1.2.1.	Intermediate consumption
10.3.5	Other business services n.i.e.	6912	Gas distribution through mains (on own account)	2.2.1.	Intermediate consumption
10.3.5	Other business services n.i.e.	692	Water distribution (on own account)	2.2.1.	Intermediate consumption
10.3.5	Other business services n.i.e.	7221	Property management services on a fee or contract basis	3.2.1.	Intermediate consumption
10.3.5	Other business services n.i.e.	7224	Real estate appraisal services on a fee or contract basis	3.2.1.	Intermediate consumption
10.3.5	Other business services n.i.e.	83811	Portrait photography services	6.2.1.	Intermediate consumption
10.3.5	Other business services n.i.e.	83813	Event photography and event videography services	7.2.1.	Intermediate consumption
10.3.5	Other business services n.i.e.	83814	Specialty photography services	4.2.1.	Intermediate consumption
10.3.5	Other business services n.i.e.	83815	Restoration and retouching services of photography	4.2.1.	Intermediate consumption
10.3.5	Other business services n.i.e.	83819	Other photography services	6.2.1.	Intermediate consumption
10.3.5	Other business services n.i.e.	8382	Photographic processing services	6.2.1.	Intermediate consumption
10.3.5	Other business services n.i.e.	83911	Interior design services	3.2.1.	Intermediate consumption
10.3.5	Other business services n.i.e.	83919	Other specialty design services	3.2.1.	Intermediate consumption
10.3.5	Other business services n.i.e.	8395	Translation and interpretation services	6.2.1.	Intermediate consumption

EBOPS		CPC Code			BEC end-use category
10.3.5	Other business services n.i.e.	873	Installation services (other than construction)	2.2.1.	Intermediate consumption
10.3.5	Other business services n.i.e.	891	Publishing, printing and reproduction services	6.2.1.	Intermediate consumption
11.1.1	Audiovisual services	73220	Leasing or rental services concerning video tapes and disks	6.2.3.	Final Consumption
11.1.1	Audiovisual services	8461	Radio and television broadcast originals	6.2.3.	Final Consumption
11.1.1	Audiovisual services	8462*	Radio and television channel programmes	6.2.3.	Final Consumption
11.1.1	Audiovisual services	84632	Home programme distribution services, basic programming package	6.2.3.	Final Consumption
11.1.1	Audiovisual services	84633	Home programme distribution services, discretionary programming package	6.2.3.	Final Consumption
11.1.1	Audiovisual services	84634	Home programme distribution services, pay-per-view	6.2.3.	Final Consumption
11.1.1	Audiovisual services	961	Audiovisual and related services	6.2.3.	Final Consumption
11.1.1	Audiovisual services	8432	On-line audio content	6.2.3.	Final Consumption
11.1.1	Audiovisual services	8433	On-line video content	6.2.3.	Final Consumption
11.1.2	Artistic related services	962	Performing arts and other live entertainment event presentation and promotion services	7.2.3.	Final Consumption
11.1.2	Artistic related services	963	Services of performing and other artists	7.2.3.	Final Consumption
11.1.2	Artistic related services	84311	On-line books	7.2.3.	Final Consumption
11.2.1	Health services	931	Human health services	7.2.3.	Final Consumption
11.2.1	Health services	9321	Residential health-care services other than by hospitals	7.2.3.	Final Consumption
11.2.2	Education services	921	Pre-primary education services	7.2.3.	Final Consumption
11.2.2	Education services	922	Primary education services	7.2.3.	Final Consumption
11.2.2	Education services	923	Secondary education services	7.2.3.	Final Consumption
11.2.2	Education services	924	Post-secondary non-tertiary education services	7.2.3.	Final Consumption
11.2.2	Education services	925	Tertiary education services	7.2.3.	Final Consumption
11.2.2	Education services	92911	Cultural education services	7.2.3.	Final Consumption
11.2.2	Education services	92912	Sports and recreation education services	7.2.3.	Final Consumption

EBOPS		CPC Code			BEC end-use category
11.2.2	Education services	92919*	Other education and training services, n.e.c.	7.2.3.	Final Consumption
11.2.2	Education services	9292	Educational support services	7.2.3.	Final Consumption
11.2.3	Heritage and recreational services	964	Museum and preservation services	7.2.3.	Final Consumption
11.2.3	Heritage and recreational services	965	Sports and recreational sports services	7.2.3.	Final Consumption
11.2.3	Heritage and recreational services	966	Services of athletes and related support services	7.2.3.	Final Consumption
11.2.3	Heritage and recreational services	969	Other amusement and recreational services	7.2.3.	Final Consumption
11.2.4	Other personal services	631	Accommodation services for visitors	7.2.3.	Final Consumption
11.2.4	Other personal services	632	Other accommodation services for visitors and others	7.2.3.	Final Consumption
11.2.4	Other personal services	633	Food serving services	7.2.3.	Final Consumption
11.2.4	Other personal services	634	Beverage serving services	7.2.3.	Final Consumption
11.2.4	Other personal services	9322	Residential care services for the elderly and persons with disabilities	7.2.3.	Final Consumption
11.2.4	Other personal services	933	Other social services with accommodation	7.2.3.	Final Consumption
11.2.4	Other personal services	934	Social services without accommodation for the elderly and disabled	7.2.3.	Final Consumption
11.2.4	Other personal services	935	Other social services without accommodation	7.2.3.	Final Consumption
11.2.4	Other personal services	95	Services of membership organizations	7.2.3.	Final Consumption
11.2.4	Other personal services	971	Washing, cleaning and dyeing services	7.2.3.	Final Consumption
11.2.4	Other personal services	972	Beauty and physical well-being services	7.2.3.	Final Consumption
11.2.4	Other personal services	973	Funeral, cremation and undertaking services	7.2.3.	Final Consumption
11.2.4	Other personal services	979	Other miscellaneous services	7.2.3.	Final Consumption
11.2.4	Other personal services	98	Domestic services	7.2.3.	Final Consumption
12.1	Embassies and consulates	99	Services provided by extraterritorial organizations and bodies	7.2.3.	Final Consumption
12.2	Military units and agencies	99	Services provided by extraterritorial organizations and bodies	7.2.3.	Final Consumption

EBOPS		CPC Code			BEC end-use category
12.3	Other government services	911	Administrative services of the government	7.2.3.	Final Consumption
12.3	Other government services	912	Public administrative services provided to the community as a whole	7.2.3.	Final Consumption
12.3	Other government services	913	Administrative services related to compulsory social security schemes	7.2.3.	Final Consumption

GTAP service sector mapping to EBOPS (Ecorys)

GTAP N°	Abbr	GTAP Sector	EBOPS	Sector description
49	wtp	Water transport		Sea transport
			206	1.1 Sea transport
			207	1.1.1 Passenger
			208	1.1.2 Freight
			209	1.1.3 Other
50	atp	Air transport		Air transport
			210	1.2 Air transport
			211	1.2.1 Passenger
			212	1.2.2 Freight
			213	1.2.3 Other
48	otp	Transport nec		Other transport
			214	1.3 Other transport
			215	1.3.1 Passenger
			216	1.3.2 Freight
			217	1.3.3 Other
			218	1.4 Other transport of which: Space transport
			219	1.5 Other transport of which: Rail transport
			220	1.5.1 Passenger
			221	1.5.2 Freight
			222	1.5.3 Other
			223	1.6 Other transport of which: Road transport
			224	1.6.1 Passenger
			225	1.6.2 Freight
			226	1.6.3 Other
			227	1.7 Other transport of which: Inland waterway transport
			228	1.7.1 Passenger

GTAP N°	Abbr	GTAP Sector	EBOPS	Sector description
			229	1.7.2 Freight
			230	1.7.3 Other
			231	1.8 Other transport of which: Pipeline transport and electricity transmission
			232	1.9 Other transport of which: Other supporting and auxiliary transport services
51	cmn	Communication		Communication
			245	3 Communications services
			246	3.1 Postal and courier services
			247	3.2 Telecommunications services
47	trd	Trade		Distribution
			957	2.2 Travel - Expenditure on accommodation and food and beverage serving services
			271	9.1.2 Other trade-related services
52	ofi	Financial services nec		Financial services
			260	6 Financial services
53	isr	Insurance		Insurance
			253	5 Insurance services
			254	5.1 Life insurance and pension funding
			255	5.2 Freight insurance
			256	5.3 Other direct insurance
			257	5.4 Reinsurance
			258	5.5 Auxiliary services
54	obs	Business services nec		Business and professional services
			272	9.2 Operational leasing services
			266	8 Royalties and license fees
			891	8.1 Franchises and similar rights

GTAP N°	Abbr	GTAP Sector	EBOPS	Sector description
			892	8.2 Other royalties and license fees
			274	9.3.1 Legal, accounting, management consulting, and public relations
			275	9.3.1.1 Legal services
			276	9.3.1.2 Accounting, auditing, bookkeeping, and tax consulting services
			277	9.3.1.3 Business and management consulting and public relations services
			278	9.3.2 Advertising, market research, and public opinion polling
			279	9.3.3 Research and development
			280	9.3.4 Architectural, engineering, and other technical services
			281	9.3.5 Agricultural, mining, and on-site processing services
			282	9.3.5.1 Waste treatment and depollution
			283	9.3.5.2 Agricultural, mining, and other on-site processing services
			284	9.3.6 Other business services
			285	9.3.7 Services between related enterprises, n.i.e.
54	obs	Business services nec		ICT
			262	7 Computer and information services
			263	7.1 Computer services
			264	7.2 Information services
			889	7.2.1 News agency services
			890	7.2.2 Other information provision services

GTAP N°	Abbr	GTAP Sector	EBOPS	Sector description
46	cns	Construction		Construction
			249	4 Construction services
			250	4.1 Construction abroad
			251	4.2 Construction in the compiling economy
55	ros	Personal and recreational services		Personal and recreational services
			287	10 Personal, cultural, and recreational services, less 895, 896)
			288	10.1 Audio-visual and related services
			897	10.2.3 Other personal, cultural, and recreational services, excl education, health
43	ely	Electricity		Electricity
44	gdt	Gas manufacture, distribution		Gas manufacture, distribution
45	wtr	Water		Water
56	osg	Public administration, defence, health, and education		Public administration, defence, health, and education
			291	11 Government services, n.i.e.
			292	11.1 Embassies and consulates
			293	11.2 Military units and agencies
			294	11.3 Other government services
			241	2.2.1 Health-related expenditure
			242	2.2.2 Education-related expenditure
			895	10.2.1 Education services
			896	10.2.2 Health services
57	dwe	Dwellings		Dwellings

Chapter 3

Trade in value-added and the welfare gains of international fragmentation

Abstract: To take profit from the differences in factor endowments and technology that exist between countries, firms delocalize or externalize a share of their goods' production process to other countries. This phenomenon is so widespread today that very few manufactured goods are produced entirely within the borders of a single country. We examine in this paper the macroeconomic gains related to this phenomenon by determining the net contribution of international fragmentation in the welfare gains of trade. To do so, we propose a model that allows us to identify all the elements related to international fragmentation in these welfare gains, something that most of the classical trade models fail to do. We show that international fragmentation represents on average approximately 24% of the welfare gains of trade, a way lower figure than what suggest standard trade models. The shutdown of international fragmentation would, therefore, reduce the average real wage by approximately 3.5%.

Global supply chains, Welfare effects of trade, Trade in value-added, Computable general equilibrium

JEL classification code : F110

3.1 Introduction

In 2018, the WTO reported that trade in manufactured goods represented 68 % of world trade, far ahead primary goods like agricultural and fuel and mining products. In the current era of global supply chains, few countries carry out the production process of these goods from the upstream to the downstream. Rather, the process is fragmented between a lot of countries so that each one is specialized on particular tasks that are realized with the highest degree of efficacy, provided that the gains from fragmentation exceed the costs. It means that before a good reaches its final destination, it could cross the border of a country as many times as required for the completion of the production process.

As international fragmentation is a widespread phenomenon today, there is no doubt that its gains exceed its costs whenever it occurs because otherwise, companies would be losing money. These gains, however, could be under threat in the current context marked by the global pandemic caused by COVID-19. This pandemic has highlighted the vulnerabilities that the fragmented organisation of the world production process implies despite its obvious interests, which fueled the public debate onto whether companies should relocalize the externalized part of their production process or favour local inputs for their production. Meanwhile, the ongoing trade war launched by President Donald Trump with China could lead to the same detrimental consequences on vertical specialization between the two countries, as a small variation in tariffs can have magnified and non-linear effects on the growth of trade and especially on vertically specialized goods. See [Yi \(2003\)](#). It is therefore interesting to determine the welfare reduction that would imply such a situation.

From a microeconomic standpoint, it is straightforward to determine the net gains related to international fragmentation because companies are able to identify what they earn by delocalizing or externalizing a share of their production process to other countries. From a macroeconomic standpoint however, the answer to this question is a bit more complicated. A solution to provide an answer to this question is to calculate the welfare gains of trade with a model that takes into account the fragmented organization of the world production process and make the difference with the gains predicted by a model that does not. This difference would represent the contribution of international fragmentation in the welfare gains of trade. It should be understood that the model that assumes no production linkages between countries should be a model where each unit of final good is produced using only value-added of the producing country and should therefore be calibrated on data that reflect this reality for the calculation to be reliable.

In principle, any trade model that allows for tradable intermediate inputs takes into account in a certain way the fragmented organization of the world production process. Among these models, we can cite for instance the seminal works of [Eaton and Kortum \(2002\)](#) or [Caliendo and Parro \(2015\)](#) which are models based upon roundabout production structure. [Costinot and Rodríguez-Clare \(2014\)](#) present a review of this kind of models with different market structures. Using trade models featuring notably perfect and monopolistic competition, these authors calculate the welfare gains of trade in two cases where trade in intermediate goods is allowed and not. They find that the welfare gains of trade are almost twice as high when trade in intermediate goods is allowed than without, suggesting that the contribution of international fragmentation in the welfare gains of trade is 50% of the total gains.

However, as explained earlier, for this result to be reliable, the models without trade in intermediate goods should have been calibrated on final goods trade data where each unit of final good is obtained using only value-added of the producing country. Instead, [Costinot and Rodríguez-Clare \(2014\)](#) calibrate their models using actual trade data that do not satisfy this requirement. We label the result obtained by these authors the gross contribution of international fragmentation in the welfare gains of trade, which is the gross contribution of trade in intermediate goods in these gains. We use the term gross because it is obvious that the model which is supposed to be without intermediate goods, in fact, hides a component of the impact of international fragmentation in the welfare gains of trade. To provide a reliable estimation of the net contribution of international fragmentation in the welfare gains of trade, we propose a model that allows us to identify in these gains all the components related to international fragmentation such that this net contribution can be identified. It is a model that is based upon value-added trade flows rather than gross trade flows.

Gross trade flows are trade statistics that are obtained by recording the value of goods crossing a country's borders. This strategy renders difficult the identification of the true country of origin and the destination of final consumption of a good, especially in the presence of international fragmentation. Value-added trade flows however, which are obtained through a specific statistical transformation (see [Daudin et al. \(2011\)](#), [Johnson and Noguera \(2012\)](#), or [Koopman et al. \(2014\)](#)) identify the value-added of each country incorporated in the goods and services that are produced and exported worldwide. Unlike bilateral gross exports that depend only on direct bilateral trade costs, a given country value-added exports to a particular destination depend on intermediate countries final goods exports to this destination, and therefore, on intermediate countries trade costs with it [Koopman et al. \(2014\)](#).

Standard trade models¹ do not take into account this more complex structure of value-added exports and thus, are not suitable to explain this kind of trade flows. Authors such as [Noguera \(2012\)](#) or [Aichele and Heiland \(2018\)](#) have already proposed a structural model for value-added exports, but none of them derive the welfare formula for the gains of trade with their models. To our knowledge, no other papers rely explicitly upon value-added exports to do so. Theoretically, it should be noted that the welfare gains of trade are not supposed to be different with a value-added exports model in comparison to a gross exports model, as the economy's total expenditures remain the same in the two approaches. In fact as value-added trade flows are obtained by a statistical transformation of gross trade flows, we need to specify a full gross trade flows model to get our value-added trade flows model. The gross trade flows model that we specify is close to [Eaton and Kortum \(2002\)](#) and [Caliendo and Parro \(2015\)](#).

However, these two models assume implicitly that the share of a given origin country in the total demand of inputs by firms in a destination country is also the share of this origin country in the destination country total demand of final goods. This assumption is not confirmed by the data. To solve this problem, we specify a different model for the two kinds of trade as [Alexander \(2017\)](#), [Antràs and Chor \(2018\)](#) or [Wicht \(2020\)](#). Unlike the latter though who assume that the market structure for both trades in intermediate and final goods is perfect competition, we assume that only trade in intermediate goods is based upon perfect competition while for trade in final goods, we assume that consumers have a "love of variety-like" utility function and consume all the varieties produced and exported by each country in the world.

Using a value-added exports model rather than a gross exports model to infer the welfare gains of trade allows us to identify what we labelled earlier the gross contribution of international fragmentation in the welfare gains, but also allows us to identify what we label the macroeconomic cost of fragmentation. This cost is the accumulated cost that appears when intermediate goods go back and forth between countries before reaching the country of final transformation. It is the hidden component of the impact of international fragmentation in the welfare gains of trade that we mentioned earlier, which is critical to calculate the net contribution of fragmentation in these gains.

Besides, this model also allows us to determine the real implications of a trade costs reduction on a given country's participation in the global supply chain. This is also worthy of interest because, as many countries anticipate that participating more in the

¹By standard trade models we refer to models with Armington utility functions such as the one of [Anderson and Van Wincoop \(2003\)](#) or models with perfect and monopolistic competition as market structures such as the one of [Eaton and Kortum \(2002\)](#) or [Chaney \(2008\)](#) respectively.

global value chain will foster their exports and GDP growth, a lot of them are devising policies in order to stimulate their integration into the world production process. Among these policies, reducing the level of trade costs is one of the top priorities.

Our results show that a reduction in the bilateral trade costs of a given country with each of its trading partners unambiguously increase in absolute terms its participation in the global supply chain whether backward or forward but, could imply relatively less forward participation. In fact, the origin country could become more efficient at exporting final goods to the country of final consumption than exporting intermediate goods to intermediate countries which are then transformed before being exported to the destination of final consumption. It results in more final goods directly exported to a particular destination of final consumption by the origin country than intermediate goods indirectly exported to this destination embedded in intermediate countries final goods exports, which means a relatively lower forward participation.

Moreover, we show that the change in welfare that would imply a move to autarky is different when estimated using our model rather than a model that does not distinguish trade in intermediate and final goods. Specifically, it appears similarly to the findings of [Fally and Hillberry \(2018\)](#) or [Alexander \(2017\)](#) that downstream countries feature higher welfare gains than upstream countries compared to what predicts a classical model.

We finally show that the net contribution of international fragmentation in the welfare gains from trade represents approximately 24% of these gains, a way lower figure than the gross contribution that we inferred from [Costinot and Rodríguez-Clare \(2014\)](#). It is due to the impact of what we labelled earlier the macroeconomic cost of fragmentation, the new variable that appears in our welfare formula, and which is also a function of the relative price of a given origin country indirectly exported flows through third countries to a given destination country in term of directly exported flows.

In the context of the welfare gains formula, it captures the share of intermediate goods exported by the origin country to third countries and reexported by the latter to the origin country embedded in their final goods exports (in term of the share of the origin country domestic trade in final goods). It amounts to an indirect domestic trade in intermediate goods, hidden in the share of domestic trade in final goods and which increases the share of internal trade in intermediate goods. As the gains from trade are inversely proportional to the shares of internal trade in intermediate goods and final goods, this variable lowers the contribution of trade in intermediate inputs in the welfare gains. The structure of the paper is as follows. The second section describes the model, the third and fourth sections present respectively the data with their different sources and the results of our estimations, and the last section concludes.

3.2 The model

The presentation of the model is organized in three sub-sections. In the first, we describe how goods and value-added are produced and traded between countries. In the following, we derive the welfare formula that is used to infer the gains from trade against autarky and in the third we present the method used to infer the change in the welfare gains related to any trade costs shock other than a move to autarky.

While trade in goods implies a bilateral relationship between the origin country of the goods and the country of destination, trade in value-added involves a set of other actors that we label intermediate countries which is the set of countries through which the value-added of the origin country passes to reach its final destination. Let “i”, “s” and “j” be any three countries in the set of countries N. Throughout this model, we use indices “i” and “j” alternatively for the origin country and the destination country of the trade flows. When it comes to trade in value-added, we use index $s \in S$ for the intermediate countries. It is worth to note that the set of origin countries, the set of destination countries and the set of intermediate countries are composed of the same countries which means that a country can be simultaneously origin, destination and intermediate.

3.2.1 Production and trade in intermediate goods

To produce a unit of good either intermediate or final, a given country combines labor with intermediate inputs coming from itself and other countries. Specifically for intermediate goods, we assume that the production technology takes the form of the following Cobb-Douglas function:

$$q_j(\omega) = z_j(\omega) l_j(\omega)^{\alpha_j} m_j(\omega)^{1-\alpha_j} \quad (3.1)$$

Where $z_j(\omega)$ represents country “j” efficiency at producing intermediate good ω , $l_j(\omega)$ is labor, $m_j(\omega)$ represents the composite intermediate inputs used in order to produce intermediate good ω and where α_j is the share of labor required to produce a unit of good in country “j”. We assume that countries do not have the same access to technology but also that producing a given intermediate good implies a specific technology requirement. $z_j(\omega)$, therefore, vary by country and by good.

In order to get the composite intermediate inputs, producers purchase intermediate goods from suppliers across all countries at the lowest price possible and aggregate them accord-

ing to the following production technology:

$$I_j = \left[\int_0^1 k_j(\omega)^{\frac{\varepsilon-1}{\varepsilon}} d\omega \right]^{\frac{\varepsilon}{\varepsilon-1}} \quad (3.2)$$

Where I_j is the total quantity of composite intermediate inputs produced in country “j” and used to produce either intermediate or final goods², $k_j(\omega)$ is country “j” demand of input ω and ε the elasticity of substitution across inputs. As in [Caliendo and Parro \(2015\)](#), the solution to the intermediate input producer problem is thus given by:

$$k_j(\omega) = \left(\frac{p_j(\omega)}{P_j} \right)^{-\varepsilon} I_j \quad (3.3)$$

$$\text{With } P_j = \left[\int_0^1 p_j(\omega)^{1-\varepsilon} d\omega \right]^{\frac{1}{1-\varepsilon}} \quad (3.4)$$

P_j is the unit price of the composite intermediate input in country “j” and $p_j(\omega)$ the price at which is bought intermediate input ω by country “j”.

Let $p_{ij}(\omega)$ be the price of producing and exporting input ω from country “i” to country “j”. Following [Eaton and Kortum \(2002\)](#), this price is given by:

$$p_{ij}(\omega) = \left(\frac{c_i}{z_i(\omega)} \right) t_{ij} \quad (3.5)$$

Where $\frac{c_i}{z_i(\omega)}$ represents the unitary cost for producing input ω in country “i” with c_i the cost of a bundle of production factors which is the same for each input as we assume the production factors to be mobile across activities within a country and $z_i(\omega)$ country “i” efficiency at producing input ω as in equation (3.1). t_{ij} represents the bilateral trade cost factor between country “i” and country “j”. This trade cost factor is composed of iceberg costs and ad-valorem flat rate tariffs³. It is such that the internal trade cost of a country be equal to unity ($t_{ii} = 1$). Assuming that bilateral barriers obey the triangle inequality because of cross-border arbitrage, we have for any three countries “i”, “j”, “s”, $t_{ij} \leq t_{is}t_{sj}$.

The price of a given input is therefore:

²We have $I_j = \int_0^1 m_j(\omega) d\omega = \frac{\int_0^1 p_j(\omega) k_j(\omega) d\omega}{P_j}$ with $\int_0^1 p_j(\omega) k_j(\omega) d\omega = I_j P_j$ the budget constraint of the intermediate good producer.

³It is worth to mention that our dataset does not provide data on ad-valorem tariffs. To perform our counterfactual analysis, we will calibrate them using actual data on tariff revenues and trade flows.

$$p_j(\omega) = \min \{p_{ij}(\omega); i = 1, \dots, N\}$$

With N being the number of countries. We use the same probabilistic representation of technologies as proposed by Eaton and Kortum (2002). More precisely, we assume that country “ i ” efficiency in producing input ω , $z_i(\omega)$ is the realization of a random variable Z_i drawn for each input independently from its country-specific probability distribution. This probability distribution is $F_i(z) = Pr[Z_i \leq z]$ which is also by the law of large numbers the fraction of inputs for which country i ’s efficiency is below z . Assuming a Fréchet distribution, we have:

$$F_i(z) = e^{-\Upsilon_i z^{-\theta}} \quad (3.6)$$

Where $\Upsilon_i > 0$ is a country-specific state of technology parameter whose value indicates the likeliness of a good efficiency draw. The bigger its value, the higher the likeliness of a good efficiency draw for any input ω . $\theta > 1$, the shape parameter of the Fréchet distribution is not country specific. As explained by Eaton and Kortum (2002), the higher its value the lesser is the variability of efficiency draws within the countries. This parameter therefore regulates the heterogeneity of efficiencies across inputs in the countries. It follows that the probability π_{ij} that country “ i ” provides an input at the lowest price in country “ j ” is⁴:

$$\pi_{ij} = \frac{\Upsilon_i (c_i t_{ij})^{-\theta}}{\Phi_j} \quad (3.7)$$

This probability is the same regardless of the type input. It also represents the share of country “ i ” in the total demand of inputs by firms in country “ j ”. Let $H_j + R_j^I = K_j$ be this demand inclusive of intermediate goods imports tariff revenues, with R_j^I representing tariff revenues on intermediate goods. Also, let $1 + \tau_{ij}^I$ be the bilateral ad-valorem flat rate tariff for intermediate goods imports.

The value of country “ j ” bilateral demand of inputs or intermediate goods from country “ i ” exclusive of intermediate goods imports tariff revenues⁵ is therefore:

$$h_{ij} = \frac{\Upsilon_i (c_i t_{ij})^{-\theta}}{\Phi_j} K_j \quad (3.8)$$

⁴For more details, see Eaton and Kortum (2002)

⁵We need intermediate goods imports exclusive of tariff revenues because it is what is required to obtain the input requirements matrix necessary for the calculation of value-added exports.

$$\text{With } \Phi_j = \sum_{i=1}^n \Upsilon_i (c_i t_{ij})^{-\theta} \quad (3.9)$$

$$\text{And where } \ddot{t}_{ij} = \frac{t_{ij}}{(1+\tau_{ij}^t)^{\frac{1}{1-\theta}}}$$

Φ_j is a parameter of the composite intermediate input price in country “j”. Assuming as [Eaton and Kortum \(2002\)](#) that $\varepsilon < 1 + \theta$ for the price index to be well defined, we get the exact price index from equation (3.4) and the distribution of $p_j(\omega)$ implied by the assumptions made earlier, which gives⁶:

$$P_j = \gamma \left(\sum_{i=j}^N \Upsilon_i (c_i t_{ij})^{-\theta} \right)^{\frac{-1}{\theta}} \quad (3.10)$$

Where $\gamma = [\Gamma(\frac{1-\varepsilon+\theta}{\theta})]^{\frac{1}{1-\varepsilon}}$ with Γ the gamma function.

The cost of a bundle of production factors c_i net of export trade costs is then given by:

$$c_i = \zeta_i w_i^{\alpha_i} P_i^{1-\alpha_i} \quad (3.11)$$

Where w_i is the nominal wage in country “i” and $\zeta_i = \alpha_i^{-\alpha_i} 1 - \alpha_i^{\alpha_i - 1}$ a constant.

[Eaton and Kortum \(2002\)](#) or [Caliendo and Parro \(2015\)](#) assume implicitly that π_{ij} , the share of country “i” in the total demand of inputs by firms in country “j” (3.7) is also the share of country “i” in country “j” total demand of final goods. This is because π_{ij} in their framework is the share of goods (not only intermediate goods as in our model but also final goods) imported from country “i” by country “j” in its total demand but also the probability that country “i” provides a good at the lowest price in country “j”. Once again, this probability is the same regardless of the type of good.

As [Antràs and De Gortari \(2017\)](#) suggested, the implicit assumption of these authors is not confirmed by the data. To solve this problem, [Alexander \(2017\)](#) assumed that for a given country, the average technology parameter Υ_i for producing intermediate and final goods is different. It allows him to stay in this Ricardian framework for modelling trade in final goods. We do not follow this approach.

Instead, we assume that consumers have a “love of variety-like” utility function which has different implications in terms of final goods price indexes, trade shares and the trade

⁶See Appendix A in [Caliendo and Parro \(2015\)](#) for more details

elasticity. More precisely, consumers do not necessarily search for the lowest cost supplier but want to consume all the varieties of goods supplied by each country. This assumption leads to a different model as regards trade in final goods, a model that is similar to the standard [Anderson and Van Wincoop \(2003\)](#) gravity equation.

3.2.2 Production and trade in final goods

Let us define v as the variety of final good produced by the representative producer in country “i”. Country “i” supply of final goods follows from the following production function :

$$q_i(v) = z_i l_i(v)^{\alpha_i} m_i(v)^{1-\alpha_i} \quad (3.12)$$

Where $q_i(v)$ is the quantity of final goods produced by country “i”, z_i represents country “i” efficiency at producing the final good, $l_i(v)$ is labor and $m_i(v)$ the composite intermediate inputs used in order to produce the final good. The cost of producing a unit of good v is such that :

$$\frac{c_i}{z_i} = \frac{\zeta_i w_i^{\alpha_i} P_i^{1-\alpha_i}}{z_i} \quad (3.13)$$

Where c_i is the cost of a bundle of production factors defined in equation (3.11). Country “i” nominal total supply of final goods is thus given by :

$$F_i = c_i \frac{z_i l_i(v)^{\alpha_i} m_i(v)^{1-\alpha_i}}{z_i} \quad (3.14)$$

Country “j” consumers maximize the following utility function:

$$\left(\sum_i \beta_i^{\frac{1-\sigma}{\sigma}} f_{ij}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \quad (3.15)$$

Subject to the budget constraint:

$$\sum_i p_{ij} f_{ij} = X_j \quad (3.16)$$

Where β_i is a positive distribution parameter, f_{ij} the consumption of country “i” final good by country “j” consumers, p_{ij} the price of country “i” final good for country “j”

consumers and X_j represents country “j” total demand of final goods inclusive of final goods tariff revenues (the economy’s total expenditures). We have $p_{ij} = \frac{c_i}{z_i} t_{ij}$ where the exporter’s supply price net of trade costs is $\frac{c_i}{z_i}$ as in equation (3.13) and t_{ij} the trade cost factor between “i” and “j”. The nominal value of country “i” final goods imports from “j” inclusive of tariff revenues is therefore $p_{ij} f_{ij}$. A simple maximization of the utility function under the budget constraint yields:

$$p_{ij} f_{ij} = \frac{(\ddot{\beta}_i c_i t_{ij})^{1-\sigma}}{\sum_i (\ddot{\beta}_i c_i t_{ij})^{1-\sigma}} \sum_i p_{ij} f_{ij} \text{ with } \ddot{\beta}_i = \frac{\beta_i}{z_i}$$

In order to determine value-added exports flows as we do in the following section, we need final goods imports exclusive of tariff revenues. Let us define country “i” bilateral imports of final goods from “j” exclusive of tariff revenues as $x_{ij} = \frac{p_{ij} f_{ij}}{1+\tau_{ij}^F}$ with τ_{ij}^F representing the bilateral ad-valorem flat rate tariff for final goods imports. We will get:

$$x_{ij} = \frac{(\ddot{\beta}_i c_i t_{ij})^{1-\sigma} X_j}{P_j^F{}^{1-\sigma}} \quad (3.17)$$

With $\ddot{t}_{ij} = \frac{t_{ij}}{(1+\tau_{ij}^F)^{\frac{1}{1-\sigma}}}$ and where :

$$P_j^F = \left(\sum_i (\ddot{\beta}_i c_i \ddot{t}_{ij})^{1-\sigma} \right)^{\frac{1}{1-\sigma}} \quad (3.18)$$

P_j^F is, therefore, the price index of final goods in country “j”. The market clearing condition implies that country “i” total supply of final goods is also equal to equation (3.14) and is given by $F_i = \sum_j x_{ij}$. As it should be clear now, this supply of final goods is as total output composed of value-added from different origins, be it local or foreign, so as bilateral exports of final goods. If we are interested in bilateral value-added exports which are exports that embed only value-added from local origin, a derivation of what the above model implies in terms of value-added trade flows should be made.

3.2.3 Trade in value-added

We can determine the amount of value-added that a given country exports to its trading partners including itself as a function of the total supply of final goods. This amount is equivalent to its GDP. Let us define α_{is} as the fraction of country “i” GDP required by country “s” in order to produce a unit of final good. The GDP of country “i” is equal to

the sum of the value-added that it provides to each country “s” including itself. We have:

$$w_i L_i = \left(\sum_{s=i}^S \alpha_{is} F_s \right) \quad (3.19)$$

As each country “s” exports its final goods to the countries of final consumption including itself, we can also determine the value-added exported by a given origin country “i” to a given destination of final consumption “j”. As shown in equation (3.20), it is the sum of the value-added originated in “i” that is firstly sent to intermediate countries “s ∈ S” for transformation into final goods before being sent to the country of final consumption “j”.

$$v_{ij} = \left(\sum_{s=i}^S \alpha_{is} X_{sj} \right) \quad (3.20)$$

Where v_{ij} represents bilateral value-added exports from country “i” to country “j”⁷, X_{sj} defined as in equation (3.17) represents final goods exports from country “s” to country “j” and α_{is} as said earlier is the fraction of country “i” GDP required by country “s” in order to produce a unit of final good.

Note that the set S includes the origin country “i” and the destination country “j”. Hence, when $i = s$ country “i” exports directly its value-added to country “j”. When $i \neq s$, country “i” exports indirectly its value-added to country “j” via the other intermediate countries’ final goods exports to “j”. When $s = j$, country “i” exports its value added to the destination of final consumption “j”, but this value-added is transformed in final good in “j” before consumption.

By combining equation (3.17) and equation (3.20), it follows that:

$$\begin{aligned} v_{ij} &= \sum_{s=i}^S \frac{\left(\ddot{\beta}_s c_s t_{sj} \right)^{1-\sigma} X_j}{P_j^{F^{1-\sigma}}} \alpha_{is} \\ &= \left(\frac{\left(\ddot{\beta}_i c_i t_{ij} \right)^{1-\sigma} X_j}{P_j^{F^{1-\sigma}}} \alpha_{ii} \right) + \left(\sum_{s \neq i}^S \frac{\left(\ddot{\beta}_s c_s t_{sj} \right)^{1-\sigma} X_j}{P_j^{F^{1-\sigma}}} \alpha_{is} \right) \\ \Rightarrow v_{ij} &= \left(\frac{\left(\ddot{\beta}_i c_i t_{ij} \right)^{1-\sigma} X_j}{P_j^{F^{1-\sigma}}} \alpha_{ii} \right) \left(\frac{\left(\ddot{\beta}_i c_i t_{ij} \right)^{1-\sigma} X_j \alpha_{ii} + \sum_{s \neq i}^S \frac{\left(\ddot{\beta}_s c_s t_{sj} \right)^{1-\sigma} X_j}{P_j^{F^{1-\sigma}}} \alpha_{is}}{\frac{\left(\ddot{\beta}_i c_i t_{ij} \right)^{1-\sigma} X_j}{P_j^{F^{1-\sigma}}} \alpha_{ii}} \right) \end{aligned}$$

⁷It is straightforward to see that $w_i L_i = \sum_{s=i}^S \sum_j \alpha_{is} X_{sj}$

$$\begin{aligned}
&= \left(\frac{(\ddot{\beta}_i c_i t_{ij})^{1-\sigma} X_j}{P_j^{F1-\sigma}} \right) \left(\frac{\sum_{s=i}^S \alpha_{is} (\ddot{\beta}_s c_s t_{sj})^{1-\sigma}}{(\ddot{\beta}_i c_i t_{ij})^{1-\sigma}} \right) \\
\Rightarrow v_{ij} &= \left(\frac{(\ddot{\beta}_i c_i t_{ij} t_{iSj})^{1-\sigma} X_j}{P_j^{F1-\sigma}} \right) \tag{3.21}
\end{aligned}$$

$$\text{Where } t_{iSj} = \left(\frac{\sum_{s=i}^S \alpha_{is} (\ddot{\beta}_s c_s t_{sj})^{1-\sigma}}{(\ddot{\beta}_i c_i t_{ij})^{1-\sigma}} \right)^{\frac{1}{1-\sigma}} \tag{3.22}$$

This term t_{iSj} is a function of the weighted relative price of the indirectly exported flows by the origin country “i” to the destination country “j” through intermediate countries “ $s \in S$ ” in term of the directly exported flows by the origin country “i” to the destination country “j”. Besides, we can see that equation (3.21) is nothing more than the Anderson and Van Wincoop’s gravity equation scaled by this term t_{iSj} that we label “the cost of fragmentation”.

As bilateral trade costs, this term exerts a negative effect on bilateral value-added exports. However, it decreases with the amount of value added exported as input by the origin country to intermediate countries, that is to say $\frac{\partial t_{iSj}}{\partial \alpha_{is}} < 0$. It means that the more a country exports its intermediate inputs to a given destination’s main providers of final goods, the lesser its cost of fragmentation will be and the higher will be its indirectly exported flows to this destination, comparatively to a country that exports less intermediate inputs to the said providers of final goods. Consequently, upstream countries, that are countries with a high forward participation in a given chain of production undergo a low cost of fragmentation, whereas the most downstream countries that have a low forward participation in comparison to the previous but a higher backward participation undergo a higher cost of fragmentation and, therefore, export more directly their goods to final consumers⁸.

t_{iSj} therefore, measures the proximity of country “i” to the final consumers in country “j”.⁹ The lower it is, the further away is the origin country from the final consumer. It implies higher indirectly exported flows to the country of final consumption. On the contrary, the higher it is, the closer is the origin country from the final consumer. The indirectly

⁸Direct exports of goods to final consumers refer to final goods exports.

⁹Fally (2012) and Antràs et al. (2012) also proposed indexes to measure the distance of industries to final demand or the average position of countries in global supply chains.

exported flows are, therefore, lesser and exports of final goods are higher. As equation (3.22) shows, t_{isj} depends critically on α_{is} which is the fraction of country “i” value-added required by country “s” in order to produce a unit of final good. The latter is obtained using input-output analysis. More precisely, we have:

$$\alpha_{is} = \alpha_i * B_{is} \quad (3.23)$$

Where $\alpha_i = \frac{w_i L_i}{G_i}$ is the share of GDP (total value-added) in total output, and where B_{is} is the quantity of output sourced by country “s” from country “i” in order to produce a unit of final good. It is thus an element of the input requirements matrix also known as the Leontief inverse matrix. Let A be the input-coefficient matrix obtained from an input-output table with $\frac{h_{ij}}{G_j}$ as elements; h_{ij} being the value of country “i” bilateral supply of intermediate goods to country “j” and G_j the nominal output of country “j”(the sum of the intermediate and final goods supply) such that :

$$\begin{aligned} G_j &= \int_0^1 \frac{c_j}{z_j(\psi)} q_j(\psi) d\psi \\ &= \int_0^1 \zeta_j (w_j l_j(\psi))^{\alpha_j} (P_j m_j(\psi))^{1-\alpha_j} d\psi \end{aligned} \quad (3.24)$$

With ψ representing either a variety of intermediate or final good.

The Leontief inverse is given by $B = (ID - A)^{-1}$ with ID being an identity matrix. From matrix algebra, we know that $ID = (ID - A)^{-1} (ID - A)$. If we define ID_{ij} as an element of the identity matrix, it follows that the Leontief inverse can be obtained by solving:

$$ID_{ij} = \sum_{s=1}^S B_{is} \left(ID_{sj} - \frac{h_{sj}}{G_j} \right) \quad (3.25)$$

3.2.4 Total expenditures and trade balance

Let us set country “j” for the sake of presentation as the benchmark country in this section. The economy’s total expenditures X_j are given by the following equation:

$$X_j = w_j L_j + R_j + D_j \quad (3.26)$$

X_j also represents the final absorption of country “j” which is the sum of labor income $w_j L_j$, tariff revenues R_j and the trade deficit D_j ; where $R_j = R_j^I + R_j^F$ is the sum of tariff

revenues on intermediate goods R_j^I and final goods R_j^F and labor income is also the sum of value-added exports such that $w_j L_j = \sum_i v_{ji} = \sum_{s=j}^S \sum_i \alpha_{js} X_{si}$. We have:

$$R_j^I = \sum_i \tau_{ij}^I h_{ij} \quad (3.27)$$

$$R_j^F = \sum_i \tau_{ij}^F x_{ij} \quad (3.28)$$

With τ_{ij}^I and τ_{ij}^F representing the bilateral ad-valorem flat-rate tariffs respectively for intermediate and final goods imports.

$D_j = \sum_i (h_{ij} + x_{ij}) - \sum_i (h_{ji} + x_{ji})$ is the difference between total imports of intermediate and final goods and total exports. As [Caliendo and Parro \(2015\)](#) we assume the country's trade deficit to be exogenous in this model and the sum of trade deficits across countries to be equal to zero.

The economy's total expenditures X_j are also given by $X_j = E_j + R_j^F$ where E_j is country "j" total demand of final goods exclusive of final goods tariff revenues. It follows that:

$$E_j = w_j L_j + R_j^I + D_j \quad (3.29)$$

In equilibrium, the country total supply of goods G_j which is defined in equation (3.24) should be equal to the total expenditures excluding tariff revenues of the economy, final goods and intermediate goods included, minus the trade deficit. We thus have:

$$G_j = H_j + E_j - D_j \quad (3.30)$$

where H_j is the total demand of intermediate goods exclusive of intermediate goods tariff revenues. Writing equation (3.30) differently, we would get:

$$G_j = H_j + R_j^I + E_j + R_j^F - R_j - D_j \quad (3.31)$$

We can directly see from equation (3.29) that $E_j + R_j^F - R_j - D_j = w_j L_j$ is by definition the GDP of country "j". We thus get:

$$G_j = H_j + R_j^I + w_j L_j \quad (3.32)$$

Moreover, in equilibrium, a given country's total supply of goods should be equal to the total expenditures (excluding tariff payments) of all the countries in the world on goods from this given country. Using equation (3.32) as the definition of country "j" total supply of goods which is equivalent to equation (3.24), it follows that:

$$\sum_i h_{ij} (1 + \tau_{ij}^I) + w_j L_j = \sum_i (h_{ji} + x_{ji}) \quad (3.33)$$

In appendix 3.A.3, I represent these equations in an inter-country input-output table.

3.2.5 Welfare predictions

In trade theory, welfare is generally defined as the real expenditures of the economy. It is represented in this work by $\frac{X_j}{P_j^F}$ where X_j , given by equation (3.26) is the nominal value of the economy's total expenditures and P_j^F given by equation (3.18) is the price index of final goods. This variable, thus, depends on tariff revenues and trade imbalances. A lot of static models¹⁰, however, generally assume that there are no trade imbalances and abstract from tariff revenues, which implies that the welfare variable depends only on the real wage. In this model, we assume that trade imbalances are lump-sum transfers which remain unchanged between the initial and the counterfactual equilibrium as suggested by Costinot and Rodríguez-Clare (2014) and following Caliendo and Parro (2015), but allow for tariff revenues to change between the initial and counterfactual equilibrium. Nevertheless, to ensure comparability with the above-mentioned static models and for simplicity, we will focus on analyzing the real wage and especially the change in real wage following a trade shock as our measure of welfare, given that real wage should be the same regardless of trade imbalances or tariff revenues.

To determine this real wage, we firstly combine the trade equation for a given country's intermediate goods internal flows (equation (3.7)), with equations (3.10) and (3.11) representing respectively the price index for intermediate goods and the unit cost of production. This allows us to obtain the nominal wage. Then, the relevant price index which is the price of final goods is obtained by rearranging equation (3.17), the final goods trade equation, in order to express it in terms of trade data. We have with $t_{jj}^{\ddot{}} = 1$:

$$\left(\frac{\pi_{jj} \Phi_j}{\Upsilon_j} \right)^{\frac{-1}{\theta}} = c_j = \zeta_j w_j^{\alpha_j} p_j^{1-\alpha_j}$$

¹⁰See for instance Fally and Hillberry (2018), Alexander (2017), Arkolakis et al. (2012), Eaton and Kortum (2002)

$$\begin{aligned}
\implies w_j^{\alpha_j} &= \frac{1}{\zeta_j} \left(\gamma \Phi_j^{\frac{-1}{\theta}} \right)^{\alpha_j - 1} \left(\frac{\pi_{jj} \Phi_j}{\Upsilon_j} \right)^{\frac{-1}{\theta}} \\
\implies w_j &= \left(\frac{1}{\zeta_j} \right)^{\frac{1}{\alpha_j}} (\gamma)^{\frac{\alpha_j - 1}{\alpha_j}} \left(\frac{\pi_{jj} \Phi_j^{\alpha_j}}{\Upsilon_j} \right)^{\frac{-1}{\theta \alpha_j}}
\end{aligned} \tag{3.34}$$

We also have from equation (3.17):

$$\implies P_j^F = \frac{\ddot{\beta}_j c_j}{\lambda_{jj}^{\frac{1}{1-\sigma}}} = \frac{\ddot{\beta}_j}{\lambda_{jj}^{\frac{1}{1-\sigma}}} \left(\frac{\pi_{jj} \Phi_j}{\Upsilon_j} \right)^{\frac{-1}{\theta}} \tag{3.35}$$

Where $\lambda_{jj} = \frac{x_{jj}}{X_j}$

Combining equation (3.34) and (3.35), we get the following real wage equation:

$$\frac{w_j}{P_j^F} = \left(\frac{1}{\zeta_j} \right)^{\frac{1}{\alpha_j}} (\gamma)^{\frac{\alpha_j - 1}{\alpha_j}} \left(\frac{\pi_{jj}}{\Upsilon_j} \right)^{\frac{-1}{\theta} \left(\frac{1 - \alpha_j}{\alpha_j} \right)} \left(\frac{\lambda_{jj}}{\ddot{\beta}_j^{1-\sigma}} \right)^{\frac{1}{1-\sigma}} \tag{3.36}$$

This equation is in many regards similar to the real wage formula that we would get from a standard one sector [Eaton and Kortum \(2002\)](#) or Armington model with tradable intermediate goods. Precisely, it must be assumed for the formulas to be equivalent that the share of intermediate goods sourced locally in the total demand of intermediate goods is the same as the share of final goods sourced locally in the total demand of final goods but also that trade elasticities are the same regardless of the type of trade flows (intermediate or final goods). If it is the case, there would be no need to model trade in final goods differently than trade in intermediate goods, and we could get the real wage by dividing the nominal wage in equation (3.36) with the price index of intermediate goods in equation (3.10). This would give:

$$\frac{w_j}{P_j} = (\gamma \zeta_j)^{\frac{-1}{\alpha_j}} \left(\frac{\pi_{jj}}{\Upsilon_j} \right)^{\frac{-1}{\theta \alpha_j}} \tag{3.37}$$

$$\implies \frac{w_j}{P_j} = (\gamma \zeta_j)^{\frac{-1}{\alpha_j}} \left(\frac{\pi_{jj}}{\Upsilon_j} \right)^{\frac{-1}{\theta} \left(\frac{1 - \alpha_j}{\alpha_j} \right)} \left(\frac{\pi_{jj}}{\Upsilon_j} \right)^{\frac{-1}{\theta}} \tag{3.38}$$

It is the same real wage equation determined by [Eaton and Kortum \(2002\)](#) ¹¹

¹¹See equation 15 in [Eaton and Kortum \(2002\)](#)

Thus, assuming that the share of intermediate goods sourced locally in the total demand of intermediate goods is equivalent to the share of final goods sourced locally in the total demand of final goods, an assumption non consistent with trade data, have implications as Alexander (2017) already showed on the welfare gains of trade. The results section will make it clear.

We could also derive equation (3.36) using value-added trade flows instead of final goods trade flows. Theoretically, this should not modify the real wage value as the price index of final goods is not supposed to change between the two models. Using equation (3.21), we can express the price of final goods in terms of value-added trade data as following:

$$P_j^F = \frac{\ddot{\beta}_j c_j t_{jSj}}{\lambda_{jjva}^{1-\sigma}} = \frac{\ddot{\beta}_j t_{jSj}}{\lambda_{jjva}^{1-\sigma}} \left(\frac{\pi_{jj} \Phi_j}{\Upsilon_j} \right)^{\frac{-1}{\theta}} \quad (3.39)$$

Where $\lambda_{jjva} = \frac{v_{jj}}{X_j}$

$$\implies \frac{w_j}{P_j^F} = \left(\frac{1}{\zeta_j} \right)^{\frac{1}{\alpha_j}} (\gamma)^{\frac{\alpha_j-1}{\alpha_j}} \left(\frac{\pi_{jj}}{\Upsilon_j} \right)^{\frac{-1}{\theta} \left(\frac{1-\alpha_j}{\alpha_j} \right)} \left(\frac{\lambda_{jjva}}{\ddot{\beta}_j^{1-\sigma} t_{jSj}^{1-\sigma}} \right)^{\frac{1}{1-\sigma}} \quad (3.40)$$

The condition required for equation (3.36) and equation (3.40) to be equal is that $\lambda_{jj} = \frac{\lambda_{jjva}}{t_{jSj}^{1-\sigma}}$ i.e. that the ratio of the share of internal trade in value-added over the internal cost of fragmentation be equal to the share of final goods internal trade. As we will see in the data section, this condition is met.

It appears as (3.36) and (3.40) show that real wage decreases with internal trade be it internal trade in intermediate goods π_{jj} , internal trade in final goods λ_{jj} or internal trade in value-added λ_{jjva} , but increases with technology Υ_j . We can also see that it decreases with the trade cost of fragmentation t_{jSj} . As said earlier t_{jSj} summarizes the production linkages of the origin country with all the indirect exporters “ $s \in S$ ” of its value-added. In this case, the value-added is exported as intermediate inputs in the first step by the origin country to intermediate countries and exported back to the origin country embedded in these intermediate countries’ final goods. From this formula, we see which factors can drive a given country’s welfare gains from a change in trade costs for example. Expressing (3.40) in relative change assuming ζ_j , Υ_j and $\ddot{\beta}_j$ to be constant across equilibria gives:

$$\ln \frac{\widehat{w}_j}{\widehat{P}_j^F} = \frac{-1}{\theta} \left(\frac{1-\alpha_j}{\alpha_j} \right) \ln \widehat{\pi}_{jj} - \frac{1}{\sigma-1} \ln \widehat{\lambda}_{jjva} - \ln \widehat{t}_{jSj} \quad (3.41)$$

Where a variable with a hat, for instance \widehat{X} represents the relative change of the variable

between an initial and a counterfactual equilibrium such that $\widehat{X} = \frac{X'}{X}$, with X the variable in the initial equilibrium and X' the variable in the counterfactual equilibrium.

Consider for example a reduction in the level of a given country's bilateral trade costs on imports and exports with its trading partners. This shock would reduce the import price of its intermediate inputs, which is the source of the first gain. In this case, the share of internal trade in intermediate goods π_{jj} decreases between the initial and the counterfactual equilibrium because more intermediate inputs are imported from other countries as a result of the decrease in bilateral trade costs. $\frac{-1}{\theta} \left(\frac{1-\alpha_j}{\alpha_j} \right) \ln \widehat{\pi}_{jj}$ which represents the first source of gains is thus positive. The second source of change in the gains, $\frac{1}{1-\sigma} \ln \widehat{\lambda}_{jjva}$, is also affected positively by the decrease in the level of bilateral trade costs. In fact, the share of value-added exported to itself by the given country decreases between the initial and the counterfactual equilibrium, because more value-added is imported from other countries. This implies a positive value of $\frac{1}{\sigma-1} \ln \widehat{\lambda}_{jjva}$ and, therefore, a positive change of the given country real wage.

The last source of change in the gains, $\ln \widehat{t}_{jSj}$, depends on the change in the relative price of the inputs exported by origin country “j” to its partners or intermediate countries ($s \in S$), and that are exported back by the latter to “j” embedded in their final goods. In autarky, this term is equal to one by construction. It means that decreasing the level of bilateral trade costs should have a positive impact on this variable and therefore, exert a negative impact on the welfare gains change. This last source of gains as explained earlier appears in the welfare formula because of the use of the value-added trade equation to determine the price index. Had we used the final goods trade equation that it would have been captured by the gains related to trade in final goods since : $\frac{1}{\sigma-1} \ln \widehat{\lambda}_{jjva} - \ln \widehat{t}_{jSj} = \frac{1}{\sigma-1} \ln \widehat{\lambda}_{jj}$.

It follows that this approach based on value-added exports allows us to determine the net contribution of international fragmentation in the welfare gains of trade. This is because we can identify the direct impact of being able to import cheap intermediate inputs on the change in real wage thanks to the change in the share of direct domestic trade in intermediate goods $\frac{-1}{\theta} \left(\frac{1-\alpha_j}{\alpha_j} \right) \ln \widehat{\pi}_{jj}$, but also the hidden indirect impact of trade in intermediate goods thanks to the change in the share of indirect domestic trade in intermediate goods in term of the share of domestic trade in final goods captured by $-\ln \widehat{t}_{jSj}$. With a standard trade model à la [Eaton and Kortum \(2002\)](#) or [Anderson and Van Wincoop \(2003\)](#) with tradable intermediate goods, we would not be able to do so because we could only identify $\frac{1}{\sigma-1} \ln \widehat{\lambda}_{jj}$ which embeds $-\ln \widehat{t}_{jSj}$ as explained earlier. We define the net contribution of international fragmentation in the welfare gains of trade as

following:

$$\ln \frac{\widehat{w}_j^F}{\widehat{P}_j} = \frac{\frac{-1}{\theta} \left(\frac{1-\alpha_j}{\alpha_j} \right) \ln \widehat{\pi}_{jj} - \ln \widehat{t}_{jSj}}{\ln \frac{\widehat{w}_j}{\widehat{P}_j}} \quad (3.42)$$

Consider for example the hypothetical situation of a move to autarky for country “j”. $\frac{-1}{\theta} \left(\frac{1-\alpha_j}{\alpha_j} \right) \ln \widehat{\pi}_{jj}$ on one hand that would be negative, represents the log change in real wage related to the fact that country “j” could not anymore source cheap inputs from other countries in order to produce its final goods. On the other hand, $-\ln \widehat{t}_{jSj}$ which would be positive represents the log change in real wage related to the fact that country “j” would not be able to send its inputs to intermediate countries before re-importing them embedded in final goods or intermediate inputs used in the production of its final goods. With a one stage production process the log change in real wage would simply be $-\frac{1}{\sigma-1} \ln \widehat{\lambda}_{jjva}$ where λ_{jjva} , the share of domestic expenditures related to value-added trade flows would be equal to the share of domestic expenditures related to final goods flows.

In this regard, our results share similarities with the model of [Fally and Hillberry \(2018\)](#) who proposed a sequential model of global supply chains. More precisely, they proposed a welfare formula for a two-country case with one country upstream, the other one downstream, and they showed that the welfare gains in presence of fragmentation are lower than without for the upstream country and higher for the downstream country. This is due to the fact that the upstream country re-imports its previously exported inputs to the downstream one embedded in the latter final goods exports. As this amounts to an indirect export to oneself and that welfare decreases with internal trade, this result is totally sensical. The downstream country however does not export inputs whatsoever in their framework, but sources some of its inputs from the upstream one, everything that increases its welfare.

Their welfare formula is, therefore, suitable to analyze the net welfare gains of international fragmentation, but ours is more general because it works also for a “more than two country-case” where both upstream and downstream countries import and export intermediate inputs.

3.2.6 Counterfactual analysis

Different kind of trade costs shocks are often envisaged to determine the welfare gains of trade. The most commonly used in the literature is a move to autarky.

3.2.6.1 Autarky

It is straightforward to see that one does not need to solve the full general equilibrium model to get the change in real wage as in autarky, the internal trade shares and the internal cost of fragmentation would be equal to 1.

From equation (3.41), It follows that the welfare formula (the log change in real wage) after a move to autarky is given by:

$$W = \frac{1}{\theta} \left(\frac{1 - \alpha_j}{\alpha_j} \right) \ln \pi_{jj} + \frac{1}{\sigma - 1} \ln \lambda_{jjva} + \ln t_{jSj} \quad (3.43)$$

Something interesting to mention is that we don't need to calculate the internal cost of fragmentation t_{jSj} as it could be straightforwardly approximated through the data. We can see this from equation (3.22) which defines the cost of fragmentation.

$$\begin{aligned} t_{jSj} &= \left(\frac{\sum_{s=j}^S \alpha_{js} (\beta_s c_s t_{sj})^{1-\sigma}}{(\beta_j c_j t_{jj})^{1-\sigma}} \right)^{\frac{1}{1-\sigma}} \\ \implies t_{jSj} &= \left(\frac{\alpha_{jj} (\beta_j c_j t_{jj})^{1-\sigma} + \sum_{s \neq j}^S \alpha_{js} (\beta_s c_s t_{sj})^{1-\sigma}}{(\beta_j c_j t_{jj})^{1-\sigma}} \right)^{\frac{1}{1-\sigma}} \\ \implies t_{jSj} &= \left(\alpha_{jj} + \frac{\sum_{s \neq j}^S \alpha_{js} (\beta_s c_s t_{sj})^{1-\sigma}}{(\beta_j c_j t_{jj})^{1-\sigma}} \right)^{\frac{1}{1-\sigma}} \end{aligned}$$

Where $\frac{\sum_{s \neq j}^S \alpha_{js} (\beta_s c_s t_{sj})^{1-\sigma}}{(\beta_j c_j t_{jj})^{1-\sigma}}$ represents the ratio of the value-added exported as intermediate good by “j” to intermediate countries $S \neq j$ and that comes back to “j” embedded in its final goods imports from the intermediate countries, over the internal trade in final goods of country “j”. To see this, we can rewrite the ratio as following:

$$\frac{\sum_{s \neq j}^S \alpha_{js} (\beta_s c_s t_{sj})^{1-\sigma}}{(\beta_j c_j t_{jj})^{1-\sigma}} = \frac{\sum_{s \neq j}^S \frac{\alpha_{js} (\beta_s c_s t_{sj})^{1-\sigma} X_j}{P_j^{F1-\sigma}}}{\frac{(\beta_j c_j t_{jj})^{1-\sigma} X_j}{P_j^{F1-\sigma}}}$$

It is straightforward to see that this ratio is negligible as countries tend to trade more with themselves than with others. Besides, the numerator of the ratio is low by definition as it is only a tiny fraction (α_{js}) of the final goods imports from intermediate countries. We show that in the data section. Thus, the internal cost of fragmentation can be approximated by:

$$t_{jSj} \approx (\alpha_{jj})^{\frac{1}{1-\sigma}} \quad (3.44)$$

Where $\alpha_{jj} = \alpha_j * B_{jj}$ as shown in equation (3.23) is the fraction of local value-added

required to produce a unit of final good in country “j”, with α_j the share of GDP in total output and B_{jj} the fraction of local output required to produce a unit of final good in country “j”. As shows equation (3.25), B_{jj} is obtained through the Leontief inverse. These data are generally observable or could be obtained with minimal transformations.

When the shock is not a move to autarky but an infinitesimal change in trade costs for example, one needs to solve the full general equilibrium model to get the counterfactual shares of internal trade and the counterfactual cost of fragmentation. To do so, we follow the approach of Dekle et al. (2008) which is to solve the model in change and, therefore, apart from the trade elasticities, avoid having to calibrate unobservable parameters such as preferences or technology.

3.2.6.2 Other trade costs shocks

We assume as Caliendo and Parro (2015) that the share of value-added in total output $\alpha_j = \frac{w_j L_j}{G_j}$ is fixed across equilibria as well as technology and preference parameters. It implies that:

$$\ln \widehat{w}_j = \ln \widehat{G}_j \quad (3.45)$$

This change in the nominal wage $\ln \widehat{w}_j$ affects the change in the unit cost of a bundle of inputs associated to a trade costs shock $\ln \widehat{c}_j$. Equation (3.11) states that this cost is $c_j = \zeta_j w_j^{\alpha_j} P_j^{1-\alpha_j}$. The log change is thus equal to:

$$\ln \widehat{c}_j = \alpha_j \ln \widehat{w}_j + (1 - \alpha_j) \ln \widehat{P}_j \quad (3.46)$$

With $\ln \widehat{P}_j$ the change in the intermediate inputs price index given by:

$$\ln \left(\widehat{P}_j \right) = \frac{-1}{\theta} \ln \left(\widehat{\Phi}_j \right) \quad (3.47)$$

The log change in Φ_j , the intermediate goods price index parameter follows from equation (3.9) which states that $\Phi_j = \sum_{i=1}^N \Upsilon_i (c_i t_{ij})^{-\theta}$. It follows that:

$$\ln \left(\widehat{\Phi}_j \right) = \sum_{i=1}^N \frac{h_{ij} (1 + \tau_{ij}^I)}{K_j} \ln \left(\widehat{c}_i t_{ij} \right)^{-\theta} \quad (3.48)$$

Where bilateral imports in intermediate goods, $h_{ij} = \frac{\Upsilon_i (c_i t_{ij})^{-\theta} K_j}{\Phi_j}$ come from equation

(3.8). Expressed in log change, it gives:

$$\ln \widehat{h}_{ij} = \ln (\widehat{c}_i)^{-\theta} + \ln (\widehat{t}_{ij})^{-\theta} + \ln \widehat{K}_j - \ln \widehat{\Phi}_j \quad (3.49)$$

The change in $K_j = H_j + R_j^I$, country “j” total demand of intermediate inputs inclusive of tariff revenues follows from equation (3.32), which states that $G_j = H_j + R_j^I + w_j L_j$. This implies that:

$$\ln \widehat{G}_j = \frac{H_j}{G_j} \ln \widehat{H}_j + \frac{R_j^I}{G_j} \ln \widehat{R}_j^I + \frac{w_j L_j}{G_j} \ln \widehat{w}_j \quad (3.50)$$

Where $\ln \widehat{R}_j^I$, the log change of tariff revenues on intermediate goods follows from equation (3.27) with $R_j^I = \sum_{i=1}^N \tau_{ij}^I h_{ij}$. In log change, we would have:

$$\ln \widehat{R}_j^I = \sum_{i=1}^N \frac{\tau_{ij}^I h_{ij}}{R_j^I} \ln \widehat{h}_{ij} \quad (3.51)$$

As regards bilateral exports of final goods, equation (3.17) states that $x_{sj} = \frac{(\ddot{\beta}_s c_s t_{sj})^{1-\sigma} X_j}{P_j^{F1-\sigma}}$, which implies in relative change :

$$\ln \widehat{x}_{sj} = \ln (\widehat{c}_s)^{1-\sigma} + \ln (\widehat{t}_{sj})^{1-\sigma} + \ln \widehat{X}_j - \ln (\widehat{P}_j^F)^{1-\sigma} \quad (3.52)$$

And where the log change of the final goods price index P_j^F is given by:

$$\ln (\widehat{P}_j^F)^{1-\sigma} = \sum_{s=1}^n \frac{x_{sj} (1 + \tau_{sj}^F)}{X_j} \ln (\widehat{c}_s t_{sj})^{1-\sigma} \quad (3.53)$$

The log change of the economy’s total expenditures $\ln \widehat{X}_j$ follows from equation (3.26) where $X_j = w_j L_j + R_j + D_j$. We thus get:

$$\ln \widehat{X}_j = \frac{w_j L_j}{X_j} \ln \widehat{w}_j + \frac{R_j^I}{X_j} \ln \widehat{R}_j^I + \frac{R_j^F}{X_j} \ln \widehat{R}_j^F + \frac{D_j}{X_j} \ln \widehat{D}_j \quad (3.54)$$

As mentioned earlier, we assume trade deficits (the difference between imports and exports) to be exogeneous in this model. It follows that:

$$\ln \widehat{D}_j = 0 \quad (3.55)$$

We now turn to the determination of the log change in bilateral value-added exports. From equation (3.21), we know that $\lambda_{ijva} = \left(\frac{\beta_i c_i t_{ij} t_{isj}}{P_j^F} \right)^{1-\sigma}$ with $\lambda_{ijva} = \frac{v_{ij}}{X_j}$. It implies in log change:

$$\ln \widehat{\lambda_{ijva}} = (1 - \sigma) \left[\ln \widehat{c_i} + \ln \widehat{t_{ij}} + \ln \widehat{t_{isj}} - \ln \widehat{P_j^F} \right] \quad (3.56)$$

The change in the cost of fragmentation $\ln \widehat{t_{isj}}$ comes from equation (3.21), (3.22) and (3.23). Specifically:

$$t_{isj} = \left(\frac{\sum_{s=i}^S \alpha_{is} (\beta_s c_s t_{sj})^{1-\sigma}}{(\beta_i c_i t_{ij})^{1-\sigma}} \right)^{\frac{1}{1-\sigma}} \quad \text{and} \quad \alpha_{is} = \alpha_i * B_{is}$$

$$\implies d \ln t_{isj} = \frac{1}{1-\sigma} \frac{\sum_{s=i}^S (1-\sigma) \alpha_i B_{is} \left[\frac{(\beta_s c_s t_{sj})^{-\sigma} d(\beta_s c_s t_{sj})}{(\beta_i c_i t_{ij})^{1-\sigma}} - \frac{(\beta_s c_s t_{sj})^{1-\sigma} d(\beta_i c_i t_{ij})}{(\beta_i c_i t_{ij})^{2-\sigma}} + \frac{(\beta_s c_s t_{sj})^{1-\sigma} d(\alpha_i B_{is})}{(\beta_i c_i t_{ij})^{1-\sigma} (1-\sigma) \alpha_i B_{is}} \right]}{t_{isj}^{1-\sigma}}$$

We know from equation (3.21) that $\frac{1}{t_{isj}^{1-\sigma}} = \frac{X_j}{v_{ij}} \left(\frac{\beta_i c_i t_{ij}}{P_j^F} \right)^{1-\sigma}$

$$\implies \frac{1}{t_{isj}^{1-\sigma}} = \frac{x_{sj}}{v_{ij}} \left(\frac{\beta_i c_i t_{ij}}{\beta_s c_s t_{sj}} \right)^{1-\sigma}$$

where $P_j^{F1-\sigma}$ is given by : $P_j^{F1-\sigma} = \frac{X_j (\beta_s c_s t_{sj})^{1-\sigma}}{x_{sj}}$

$$\implies \ln \widehat{t_{isj}} = \sum_{s=i}^S \frac{\alpha_i B_{is} x_{sj}}{v_{ij}} \left[\ln \widehat{c_s t_{sj}} - \ln \widehat{c_i t_{ij}} + \ln \widehat{B_{is}}^{\frac{1}{1-\sigma}} \right] \quad (3.57)$$

As we can see, the change in the cost of fragmentation $\ln \widehat{t_{isj}}$ depends critically on the change in the input requirements $\ln \widehat{B_{is}}$. From equation (3.25), we have $ID_{ij} = \sum_{s=1}^S B_{is} (ID_{sj} - \frac{h_{sj}}{G_j})$ where ID_{ij} is an element of the identity matrix.

Expressing this equation in change gives:

$$d ID_{ij} = \sum_{s=1}^S \left[\left(ID_{sj} - \frac{h_{sj}}{G_j} \right) d B_{is} + B_{is} d ID_{sj} - \frac{B_{is}}{G_j} d h_{sj} + \frac{B_{is} h_{sj}}{G_j^2} d G_j \right]$$

$$\implies 0 = \sum_{s=1}^S \left[\left(ID_{sj} - \frac{h_{sj}}{G_j} \right) d B_{is} - \frac{B_{is}}{G_j} d h_{sj} + \frac{B_{is} h_{sj}}{G_j^2} d G_j \right]$$

$$= \sum_{s=1}^S \left[\left(B_{is} ID_{sj} - \frac{B_{is} h_{sj}}{G_j} \right) d \ln B_{is} - \frac{B_{is} h_{sj}}{G_j} (d \ln h_{sj} - d \ln G_j) \right]$$

$$\implies 0 = \sum_{s=1}^S \left[\left(B_{is} ID_{sj} \right) \ln \widehat{B_{is}} - \frac{B_{is} h_{sj}}{G_j} \left(\ln \widehat{h_{sj}} - \ln \widehat{G_j} + \ln \widehat{B_{is}} \right) \right] \quad (3.58)$$

To close the model, we use the equilibrium condition defined in equation (3.33) which

states that $\sum_{i=1}^N h_{ij} (1 + \tau_{ij}^I) + w_j L_j = \sum_{i=1}^N (h_{ji} + x_{ji})$. Writing this condition in change gives the following expression:

$$\sum_{i=1}^N \left((1 + \tau_{ij}^I) \frac{h_{ij}}{G_j} \ln \widehat{h}_{ij} + \frac{w_j L_j}{G_j} \ln \widehat{w}_j \right) = \sum_{i=1}^N \left(\frac{h_{ji}}{G_j} \ln \widehat{h}_{ji} + \frac{x_{ji}}{G_j} \ln \widehat{x}_{ji} \right) \quad (3.59)$$

Equations (3.45) to (3.59) represent the set of 15 equations and 15 unknowns that describe our model in relative change between an initial and a counterfactual equilibrium. As we can see, solving it requires mostly data that are readily observables with the exception of the trade elasticities $(1 - \sigma)$ and $-\theta$. As they play a critical role in determining the results, we provide a discussion on their calibration in the next section.

Before that, it is interesting to analyze the conditions required for a decrease in the bilateral cost of fragmentation following a decrease in the level of trade costs; which would mean for the exporting country a higher forward participation in the production network of the goods bought by the importing country. At constant nominal wage, it is necessary for this to occur, that the impact of a decrease in the level of trade costs regarding the indirect relationship from the origin country “i” to the destination of final consumption “j” through intermediate countries $s \neq i \in S$ which is represented by “ $\sum_{s \neq i}^S \frac{\alpha_i B_{is} x_{sj}}{v_{ij}} \left[\ln \widehat{(c_s t_{sj})} + \ln \widehat{B_{is}}^{\frac{1}{(1-\sigma)}} \right] < 0$ ”, be higher than the impact of trade costs on the direct relationship from the origin country “i” to the destination country “j” represented by “ $\frac{\alpha_j B_{ij}}{t_{ij}^{1-\sigma}} \ln \widehat{B_{ij}}^{\frac{1}{(1-\sigma)}} + \sum_{s \neq i}^S \frac{\alpha_i B_{is} x_{sj}}{v_{ij}} \left[-\ln \widehat{(c_i t_{ij})} \right] > 0$ ”.

As the change in the elements of the Leontief inverse $\ln \widehat{B_{is}}$ depends as shown in equation (3.58) on the change in intermediate goods trade flows, it follows that the change in the cost of fragmentation depends critically on the intermediate goods flows trade elasticity $-\theta$. Ceteris paribus, the higher the absolute value of this elasticity, the more $\ln \widehat{B_{is}}^{\frac{1}{(1-\sigma)}}$ would change up to the point where the cost of fragmentation would decrease. However, the higher $(\sigma - 1)$, the less $\ln \widehat{B_{is}}^{\frac{1}{(1-\sigma)}}$ would change such that the cost of fragmentation would increase. Hence, if the trade costs of intermediate countries remain constant, we can conjecture that a necessary condition for the cost of fragmentation to decrease is that the trade elasticity for intermediate goods be sufficiently high in comparison to the trade elasticity for final goods.

It is also straightforward to see that the change in country “j” internal cost of fragmentation, $\ln \widehat{t_{jsj}}$ would be equal to $\ln \widehat{B_{jj}}^{\frac{1}{(1-\sigma)}}$ because as shown in equation (3.44), $\frac{\alpha_j B_{jj}}{t_{jsj}^{1-\sigma}} \approx 1$ with $\sum_{s \neq j}^S \frac{\alpha_j B_{js} x_{sj}}{v_{jj}} \left[-\ln \widehat{(c_j t_{jj})} \right]$ as well as $\sum_{s \neq j}^S \frac{\alpha_j B_{js} x_{sj}}{v_{jj}} \left[\ln \widehat{(c_s t_{sj})} + \ln \widehat{B_{js}}^{\frac{1}{(1-\sigma)}}$ being negligible.

We summarize the results of this model as following:

- Classical models implicitly assume that the share of intermediate goods sourced locally in the total demand of intermediate goods is equivalent to the share of final goods sourced locally in the total demand of final goods for a given country. As we relax this assumption, the welfare gains of trade in this model are different.
- Deriving the welfare gains of trade using the value-added exports equation rather than the gross trade flows equation allows the identification of the net contribution of international fragmentation in these welfare gains.
- Calculating the welfare gains of trade against autarky from the value-added trade equation only requires a supplementary parameter obtained after minimal transformations from observable data on top of the internal trade shares and the trade elasticities. This parameter is the fraction of local value-added required to produce a unit of final good in a given country.
- A decrease of a country direct bilateral trade costs, those of intermediate countries remaining constant implies a move towards downstream stages of the production process, provided that the trade elasticity for intermediate goods be sufficiently low.

3.2.7 Calibration of the trade elasticities

The elasticity of import with respect to variable trade costs generally referred in the literature as the trade elasticity is a key parameter required to infer the gains from trade. [Hillberry and Hummels \(2013\)](#) even go so far as to say that it is the most important parameter in modern trade theory. Estimating it does not come without difficulties regarding notably the identification assumptions, as well explained by the previous authors. This is why a lot of trade theory practitioners have relied upon off-the-shelf elasticities provided by the literature. We follow the same path; however, the particularity of our model imposes us some restrictions.

First of all, as we distinguish between intermediate and final goods trade flows and assume a specific market structure for the trade in intermediate goods, notably perfect competition, the trade elasticities have different interpretations for these two kinds of trade. In a model with perfect competition, the trade elasticity is the shape parameter of the distribution of productivity. It determines the extensive and the intensive margins of the change in trade flows following a change in trade costs and is a sufficient parameter along with the internal trade shares to derive the welfare gains of trade provided that certain conditions are met. We should therefore use a trade elasticity obtained from a method

that allows the identification of this parameter specifically. [Simonovska and Waugh \(2014\)](#) or [Caliendo and Parro \(2015\)](#) provide these estimates with a preferred value for the former equal to 4.14, and an aggregate value for the latter equal to 4.45.

Secondly, as regards trade in final goods, we did not assume perfect competition as the market structure and derived our model using an Armington utility function. In this environment, the trade elasticity depends on the elasticity of substitution across varieties. As explained by [Simonovska and Waugh \(2014\)](#), estimations that are based upon the method of [Feenstra \(1994\)](#) allows the identification of this parameter. [Imbs and Mejean \(2015\)](#) use this method and find estimates between 2.2 and 54 with an average of 5.4. [Ossa \(2015\)](#) also provides estimates of this parameter for 251 industries.

Thirdly, it is important to note that we use one sector models for the two kinds of trade, and as [Imbs and Mejean \(2015\)](#) suggests, for a one sector model to mimic the welfare gains of trade that a multi sector-model could predict, the trade elasticity should be a weighted average of sector level elasticities instead of being obtained using aggregated trade data. Unfortunately, we are not able to perform such a calculation without proper weights and trade elasticities matching our disaggregated data.

Another point worth to mention is that, it is common in the theoretical literature as mentioned after equation (3.9) to assume that the shape parameter of the distribution of productivity is higher than the elasticity of substitution across goods minus one “ $\varepsilon - 1 < \theta$ ”. [Crozet and Koenig \(2010\)](#) verify empirically this assumption for a set of firms’ data calibrated upon a model of monopolistic competition. This assumption is critical in our perfect competition model for the price index to be well defined (See [Eaton and Kortum \(2002\)](#)).

Lastly, as [Antràs and De Gortari \(2017\)](#) suggest, the trade elasticity seems to be lower on average for intermediate inputs than for final goods. The findings of [Fally and Hillberry \(2018\)](#) could help understanding this point. They explain that with international fragmentation, the final goods trade elasticity is higher than without fragmentation. To illustrate that, they take a two-country case with an upstream and a downstream country, and explain that a 1% increase in trade costs increases the price of the final goods imported by the upstream country by more than 1% since these goods embeds intermediate goods previously exported as inputs to the downstream country.

This point seems to be confirmed by the data. To show it, using the work of [Ossa \(2015\)](#) who provides a set of substitution elasticities for 251 SITC-Rev3 sectors at the 3 digits level, we calculate the average elasticity for intermediate goods and final goods sectors. To do so, using a table of concordance between SITC-Rev3 and the UN classification of

goods by end-use (UN-BEC), we select sectors corresponding exclusively to intermediate goods and final goods taken separately according to the UN BEC-Rev4 classification and compute the average. We are left with 129 industries for intermediate goods and 32 industries for final goods, with averages that are respectively 3.08 and 4.75.

In sum, the trade elasticity that we should set for intermediate goods trade flows should be higher than the elasticity of substitution for intermediate goods minus one, but lower than the elasticity of substitution for final goods minus one such that $\varepsilon - 1 < \theta < \sigma - 1$. We select the aggregate estimate of [Caliendo and Parro \(2015\)](#) which is obtained using gross trade flows (final and intermediate goods included) as our benchmark. We do so because their gravity-based estimation of the trade elasticity can fit with models using different market structures provided that they can generate a gravity equation. As this value is equal to 4.45 for all the trade flows combined, we set $\theta = 4.25$ for the intermediate goods model and $\sigma - 1 = 4.85$ for the final goods model.

3.3 Data

To calculate the net contribution of fragmentation in the welfare gains of trade, we need a dataset of value-added trade flows. To obtain these data, we use the GTAP 9 database which is a multi-country input-output table. The table comprises 140 entities which are countries or aggregations of countries and 57 sectors that we aggregate into one to simplify the analysis. Released in 2015, it has 3 base years among which we choose 2011 to carry out our analysis. We obtained our value-added trade flows data using the methodology developed by [Koopman et al. \(2014\)](#). As the table is a multi-country table, imports of intermediate inputs are not broken down by countries of origin just as final demand imports. This poses a problem because we need the complete set of bilateral intermediate and final demand imports in order to calculate each country bilateral value-added exports.

To solve this problem, two solutions are generally used in the literature. Applying a proportionality assumption which amounts to assume that the imports of intermediate and final goods of a given country from a particular source are proportional to its total imports from this source. The second solution is to use the UN BEC classification of products by end-use category along with the UN COMTRADE database which reports bilateral exports and imports between countries at the HS 6 digits level, in order to obtain the share of intermediate and final goods in the exports of a given country to a particular destination. These shares are then applied to the export data from the GTAP database to disentangle bilateral exports between intermediate and final goods and calculate the value-added exports. By disentangling bilateral exports by type, we get a new table which

is an inter-country input output table and that should be consistent with the initial multi-country input output table.

We decided to choose the second option as it is done in the seminal work of [Koopman et al. \(2014\)](#). To ensure the consistency between the inter-country and the multi-country input-output tables, we used the quadratic mathematical programming model formulated by [Tsigas et al. \(2012\)](#).¹²

It is worth to note that our value-added exports include both goods and services. We therefore use the comprehensive database on trade in services of [Francois and Pindyuk \(2013\)](#) along with a preliminary draft of the UN BEC revision 5 classification of goods by broad economic categories to perform our calculations. This revision, unlike previous ones, does a better job at distinguishing goods and services and classifying them by end-use categories.

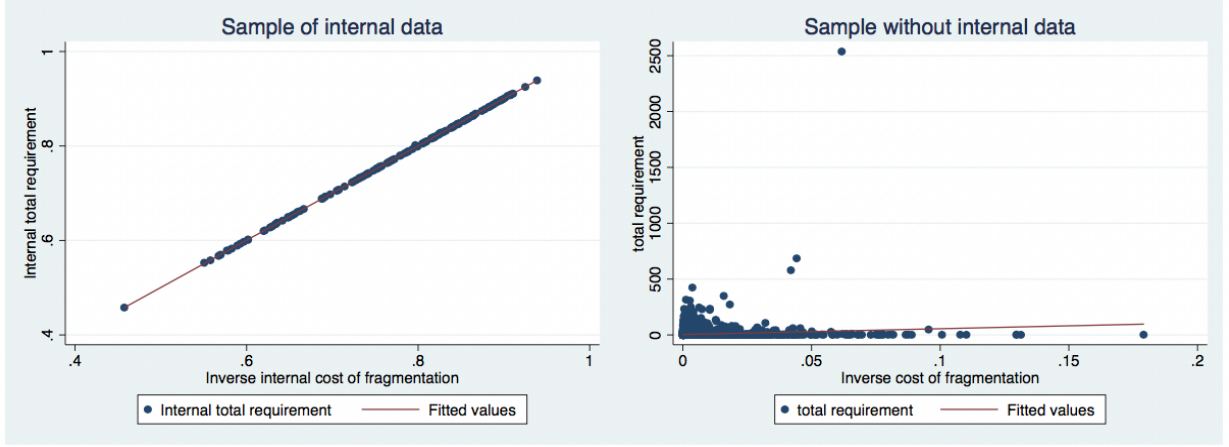
Using our reconstructed inter-country input-output table, we calculate the cost of fragmentation with the method presented in chapter 2. Precisely, to calculate the cost of fragmentation $t_{iSj} = \left(\frac{\sum_{s=i}^S \alpha_{is} (\beta_s c_s t_{sj}^{\ddot{}})^{1-\sigma}}{(\beta_i c_i t_{ij}^{\ddot{}})^{1-\sigma}} \right)^{\frac{1}{1-\sigma}}$ we need proxies for the bilateral trade costs indexes $(t_{sj}^{\ddot{}})^{1-\sigma}$ and the unobservable variables $\beta_s c_s$. To obtain them, an econometric estimation with importer and exporter fixed effects is performed on final goods trade flows. We then predict $(t_{sj}^{\ddot{}})^{1-\sigma}$ using the specified trade costs function and approximate the unobservable variables $\beta_s c_s$ using the fixed-effects estimates as in [Fally \(2015\)](#). In what follows, we present:

- The relationship between the obtained inverse internal cost of fragmentation $t_{jSj}^{1-\sigma}$ and the fraction of local value-added “ α_{jj} ” required to produce a unit of final good in a given country.
- The relationship between internal trade in final goods x_{jj} and the ratio of internal value-added trade flows over the inverse internal cost of fragmentation $\frac{v_{jj}}{t_{jSj}^{1-\sigma}}$.

Chart 3.1 suggests that there is a perfect correlation as mentioned earlier in equation (3.44) between the inverse internal cost of fragmentation $t_{jSj}^{1-\sigma}$ and the fraction of local value-added required to produce a unit of final good in a given country “ α_{jj} ”. We label this variable internal total requirement in the left panel of the chart.

It appears as the right panel of the chart shows, that there is no correlation when it comes to non-symmetric relationships i.e. when the exporter is not also the importer.

¹²The GAMS code is available upon request



Source: Author's calculations

Figure 3.1: Correlation between total requirements and the cost of fragmentation

This is perfectly sensical. To see why, let us analyze again the formula of the cost of fragmentation:

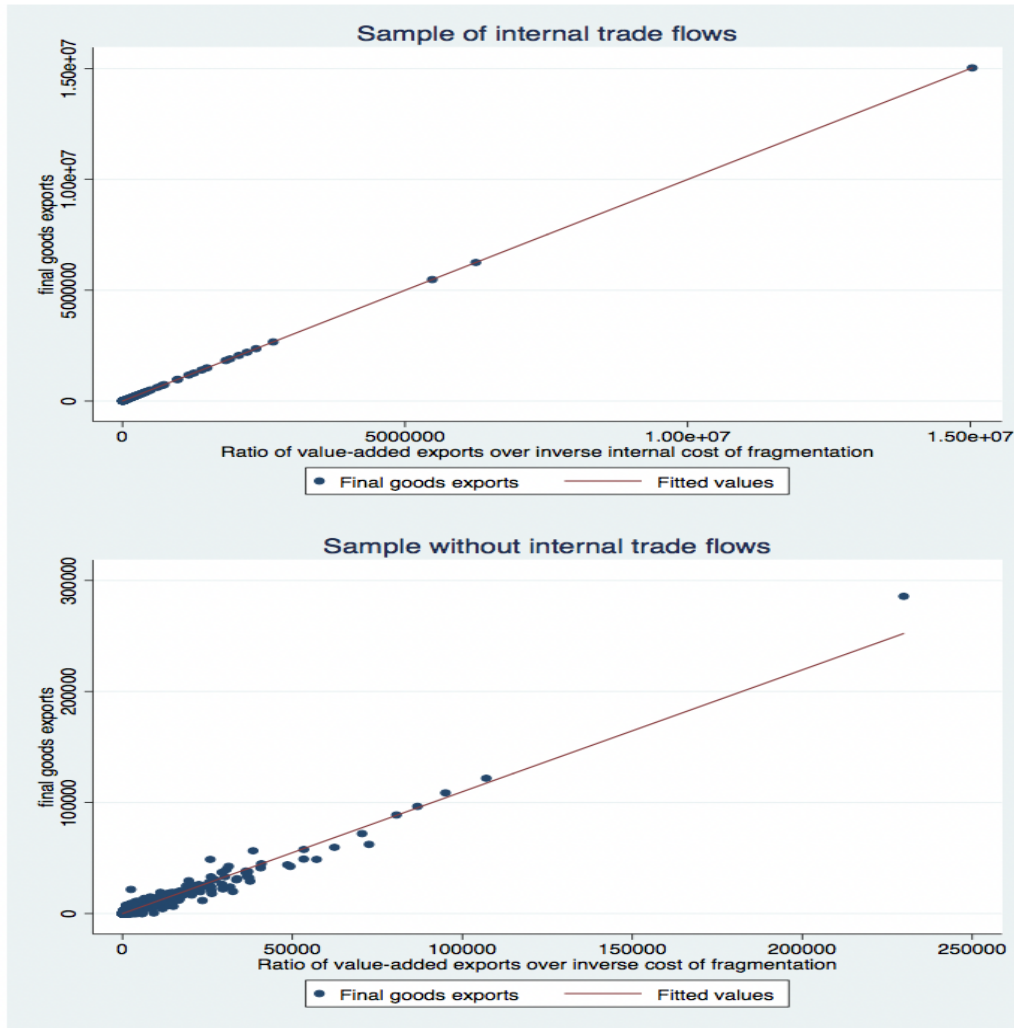
$$t_{isj} = \left(\frac{\sum_{s=i}^S \alpha_{is} (\beta_s c_s t_{sj})^{1-\sigma}}{(\beta_i c_i t_{ij})^{1-\sigma}} \right)^{\frac{1}{1-\sigma}}$$

When the exporter is also the importer, we have $t_{jsj} = \left(\alpha_{jj} + \frac{\sum_{s \neq j}^S \alpha_{js} (\beta_s c_s t_{sj})^{1-\sigma}}{(\beta_j c_j t_{jj})^{1-\sigma}} \right)^{\frac{1}{1-\sigma}}$

and we explained in page 157 that the term $\frac{\sum_{s \neq j}^S \alpha_{js} (\beta_s c_s t_{sj})^{1-\sigma}}{(\beta_j c_j t_{jj})^{1-\sigma}}$ is negligible because the denominator, internal trade in final goods is very high for all the countries. When the exporter is not the importer, this denominator is not that high anymore which explains why the term is no longer negligible.

Chart 3.2 shows the correlation between bilateral final goods exports “ x_{ij} ” and the ratio of value-added trade flows over the inverse cost of fragmentation “ $\frac{v_{ij}}{t_{isj}^{1-\sigma}}$ ”. This ratio can be interpreted as the value-added that is directly exported by country “i” to country “j”. We can see in the upper panel of the chart dedicated to internal trade flows that the correlation is perfect. In the lower panel of the chart related to non-internal trade flows, the correlation is also very high, but not as perfect as for internal trade flows. This is normal since the inverse cost of fragmentation is estimated with error. As shown in chapter 2 it is obtained via gravity-based estimates of bilateral trade costs.

However, given that $(t_{jsj})^{1-\sigma} \approx \alpha_{jj}$ and that internal value-added trade flows by definition are given by $v_{jj} = X_{jj} \left(\alpha_{jj} + \frac{\sum_{s \neq j}^S \alpha_{js} X_{sj}}{X_{jj}} \right)$, with $\frac{\sum_{s \neq j}^S \alpha_{js} X_{sj}}{X_{jj}}$ being negligible, the approximation of trade costs that affects only $\frac{\sum_{s \neq j}^S \alpha_{js} X_{sj}}{X_{jj}}$ has a little impact on $t_{jsj}^{1-\sigma}$ such that $\frac{v_{jj}}{t_{jsj}^{1-\sigma}} \approx X_{jj}$. Hence, equations (3.36) and (3.38) that represent respectively



Source: Author's calculations

Figure 3.2: Correlation between final goods and value-added trade flows

the real wages obtained with the final goods exports model and the value-added exports model are equivalent as suggested theoretically, so as the welfare gains from trade derived with the two methods. The counterfactual analysis results will render this more explicit.

3.4 Counterfactual analysis results

In this section we perform two counterfactual exercises featuring two different trade costs shocks. The first trade costs shock is a move from 2011 levels of trade openness to autarky for all the countries in the world, and the second a 20% reduction of the trade costs indexes regarding African trade flows.¹³ We first analyse the differences in predictions between

¹³Unlike the shock related to autarky, the second shock requires to solve the system of equations presented in section (3.2.6.2). We do so by using GAMS. The code is available upon request.

our extended model that distinguishes the trade shares regarding intermediate and final goods trade flows and a classical model with gross exports allowing tradable intermediate goods but not sectoral linkages. The welfare formula¹⁴ regarding the latter is a special case of equation 29 in Costinot and Rodríguez-Clare (2014) or equation 7 in Ossa (2015) and is equal to:

$$\ln \frac{\widehat{w}_i}{\widehat{P}_i} = \frac{-1}{\sigma - 1} \left(\frac{1 - \alpha_i}{\alpha_i} \right) \ln \widehat{\lambda}_{ii} - \frac{1}{\sigma - 1} \ln \widehat{\lambda}_{ig} \quad (3.60)$$

Where λ_{ii} represents the share of domestic expenditures related to gross trade flows and α_i the value-added to gross output ratio.

3.4.1 Autarky

Table 3.1 presents summary statistics on the results regarding the move to autarky. The detailed results are available in appendix 3.A.1. This table is composed of five parts, the first presenting the results for the entire set and the two following respectively for the countries the less open of the sample and for the most open ones. We define the less open countries as those who present a ratio of internal trade in value-added over GDP $> 77\%$ and the more open ones as those who present a ratio of internal trade in value-added over GDP $< 60\%$.

The last two parts of table 3.1 present respectively the results for the most downstream countries i.e. with an upstreamness level of less than 1.7, and for the most upstream countries in the production process with an upstreamness level of more than 2.4 where the upstreamness level is calculated following Fally and Hillberry (2018). We discuss how to obtain it in equation (3.61).

The first two rows in each part of table 3.1 represent respectively the welfare gains obtained using the standard model with gross exports as in equation (3.60) (W_standard model) and the welfare gains using our approach as in equation (3.40) (W_extended model).

The last three rows in each part of table 3.1 represent the gross and net contributions of international fragmentation in the welfare gains. For the standard model (G), the contribution is obtained using $1 - \frac{-\frac{1}{\sigma-1} \ln \widehat{\lambda}_{ii}}{\ln \frac{\widehat{w}_i}{\widehat{P}_i}}$. For the extended model (VA), the net contribution is obtained using $\frac{-\frac{1}{\theta} \left(\frac{1-\alpha_i}{\alpha_i} \right) \ln \widehat{\pi}_{ii} - \ln \widehat{nt}_{isi}}{\ln \frac{\widehat{w}_i}{\widehat{P}_i}}$, and the gross contribution just $\frac{-\frac{1}{\theta} \left(\frac{1-\alpha_i}{\alpha_i} \right) \ln \widehat{\pi}_{ii}}{\ln \frac{\widehat{w}_i}{\widehat{P}_i}}$.

¹⁴Our welfare formula is as said earlier the change in real wage instead of the change in the economy's real expenditures to ensure the comparability with previous studies.

Table 3.1: The welfare gains of trade (Autarky)

Entire set (Part 1)				
Variable	Obs	Mean	Min	Max
W_standard model	139	-12.08%	-46.07%	-01.91%
W_extended model	139	-14.28%	-56.73%	-2.97%
Gross share of fragmentation (G)	139	50.80%	21.06%	66.71%
Gross share of fragmentation (VA)	139	65.59%	30.64%	95.94%
Net share of fragmentation (VA)	139	23.86%	07.90%	55.71%
Ratio of internal trade in value-added over GDP >0.77 (Part 2)				
Variable	Obs	Mean	Min	Max
W_standard model	38	-05.45%	-07.48%	-01.91%
W_extended model	38	-08.96%	-31.68%	-02.97%
Gross share of fragmentation (G)	38	47.20%	21.06%	66.59%
Gross share of fragmentation (VA)	38	65.70%	34.88%	95.94%
Net share of fragmentation (VA)	38	20.11%	09.26%	39.49%
Ratio of internal trade in value-added over GDP <0.6 (Part 3)				
Variable	Obs	Mean	Min	Max
W_standard model	39	-21.08%	-46.07%	-13.50%
W_extended model	39	-20.37%	-56.73%	-05.15%
Gross share of fragmentation (G)	39	53.22%	29.07%	66.71%
Gross share of fragmentation (VA)	39	67.40%	30.64%	86.79%
Net share of fragmentation (VA)	39	29.27%	07.90%	55.71%
Upstreamness <1.7 (Part 4)				
Variable	Obs	Mean	Min	Max
W_standard model	20	-08.73%	-21.75%	-01.91%
W_extended model	20	-18.39%	-39.95%	-05.10%
Gross share of fragmentation (G)	20	47.05%	21.06%	58.56%
Gross share of fragmentation (VA)	20	61.18%	34.88%	95.94%
Net share of fragmentation (VA)	20	24.75%	09.26%	39.49%
Upstreamness >2.4 (Part 5)				
Variable	Obs	Mean	Min	Max
W_standard model	20	-18.72%	-36.92%	-06.58%
W_extended model	20	-13.36%	-31.74%	-05.15%
Gross share of fragmentation (G)	20	50.43%	29.07%	66.71%
Gross share of fragmentation (VA)	20	60.50%	30.64%	86.79%
Net share of fragmentation (VA)	20	21.38%	07.90%	44.26%

As regards the “upstreamness” indexes we follow [Fally and Hillberry \(2018\)](#). They calculate upstreamness indexes for each sector in a country and then obtain the aggregate country index by computing an export-weighted average of sectoral indexes. To follow their words, these sectoral indexes measure the distance of each industry from final demand where distance is “the number of stages of production an industry’s output passes through before reaching final consumers”. As said in the data section, we use an inter-regional input-output matrix that does not feature sectoral linkages within and between countries but only aggregate trade linkages, since we aggregated the 57 original sectors of the GTAP database into a unique sector. Our index is therefore not sectoral, and we

don't need to apply a weighting scheme to get the aggregate index. More precisely, we have:

$$U_i = 1 + \varphi_{ii}U_i + \sum_{i \neq j} \varphi_{ij}U_j \quad (3.61)$$

Where U_i is the upstreamness index of country "i" and φ_{ij} denotes the share of output from country "i" that is needed to produce one unit of output in country "j".

As the table shows, on average, a move to autarky would reduce real wage by 12.08 % if we follow the standard model, and by 14.28 % if we follow our extended model (See the first part of table 3.1 named "entire set"). These results seem quite close, however, the correlation between the two models' results is only 75 %, which means that there are differences. Among these differences, it appears that the welfare loss for the countries that are less open is higher by $(-5.45 - (-8.96)) = 3.51$ percentage points on average with the extended model than with the standard model, whereas it is just slightly lower, 0.71 percentage points on average for the more open countries (See respectively the second and the third part of table 3.1). It means that the gains from trade are understated for the less open countries when we use the standard gross exports model.

A result that is also worth mentioning is that the welfare gains of trade are higher, $(-8.73 - (-18.39)) = 9.66$ percentage points on average for the most downstream countries with the extended model in comparison to the standard model (See the fourth part of table 3.1). On the contrary, the gains for the most upstream countries are $(-13.36 - (-18.72)) = 5.36$ percentage points lower (See the fifth part of table 3.1). This result relates as said earlier to the work of [Fally and Hillberry \(2018\)](#) who built a sequential model of international fragmentation and also found that downstream countries feature higher welfare gains compared to the prediction of a standard model of trade. The difference is that the model that they use as a benchmark for comparison is a model of trade without intermediate goods flows. Unlike them, we compare our model predictions to a standard trade model featuring intermediate goods flows. This benchmark is the relevant one because our model allows back and forth trade in intermediate goods unlike theirs.

[Alexander \(2017\)](#) using a model that distinguishes intermediate and final goods trade flows, also find similar results regarding the difference between the gains on average in comparison to the standard trade model, but also as regards the difference between upstream and downstream countries. This suggests that the difference between the gains comes from the assumption regarding intermediate and final goods trade shares.

As regards the net contribution of fragmentation in the welfare gains of trade, it appears that it is not as high as one could expect. To see this, we multiply the net contribution of

fragmentation in the welfare gains from trade (the fifth row of each part of table 3.1) with the estimated total gains by the extended model for each category of countries be it the entire set or the most upstream countries for example. More precisely, the net contribution of fragmentation in the total welfare gains from trade represents 23.86 % on average of the welfare reduction for the entire set as it is shown in the fifth row of the first part of the table. On this basis, our model predicts that turning off trade in intermediate goods would reduce the average real wage by less than $(23.86 * (14.28)) \approx 3.5$ percentage points, with $(29.27 * (20.37)) \approx 6$ percentage points on average for the more open countries (See the third part of the table) and $(20.11 * (8.96)) \approx 1.8$ percentage point for the less open countries (See the second part of the table).

Interestingly, the gross contribution of fragmentation in the welfare gains is higher with our approach (14.79 percentage points more on average) compared to the standard approach as it is shown in the rows 3 and 4 of the first part of the table. It represents 65% of the total gains with our model compared to 50.80% with the standard model. This is due to the difference between the domestic trade shares related to intermediate goods and final goods that is allowed in our model contrarily to the standard model. There is anyway a striking difference between the gross and net contributions of fragmentation in the welfare gains of trade. This substantiates the necessity to take into account the share of indirect domestic trade in intermediate goods in the calculation of the net contribution of international fragmentation in the welfare gains from trade, as our model allows us to do.

More precisely, because of autarky, the situation that appears when a given country exports its intermediate goods to intermediate countries and imports them back embedded in the latter final goods exports would not be possible anymore. This amounts to an indirect domestic trade in intermediate goods which increases the share of internal trade in intermediate goods. As the gains from trade are inversely proportional to the shares of internal trade in intermediate goods and final goods, this variable lowers the contribution of trade in intermediate inputs in the welfare gains of trade. The evidence that the gross welfare gains from international fragmentation are high but largely compensated by what we labeled the cost of fragmentation has a trivial implication: reducing significantly this cost *ceteris paribus* could drastically improve the gains from trade. As shown in section 3.2.6.2, this seems to be impossible as the change in the cost of fragmentation depends on the change in the cost of a bundle of inputs, the change in the total requirements (the elements of the Leontief inverse) and the change in bilateral trade costs. All these variables also affect trade flows. As amongst them only bilateral trade costs are exogeneous, we will analyse what is the impact of a reduction in trade costs on the cost of fragmentation and on the gains from trade.

3.4.2 Decrease of African bilateral trade costs

In this section, we simulate the impact of a 20 % decrease on the level of African countries' direct bilateral trade costs¹⁵ which are among the countries with the highest level of trade costs in the world. We analyse the consequences of this shock in term of welfare, and also in term of participation in the global supply chain. We both take into consideration the change in real wage and the change in the economy's real expenditures.

Table 3.2: The welfare gains of trade (20% decrease of African trade costs)

Countries	Real wages	Real expenditures	Cost of fragmentation	Inverse internal cost of fragmentation	Internal total requirement
TGO	21,53%	21,97%	4,90%	-14,33%	-14,34%
TUN	14,16%	16,16%	5,65%	-17,47%	-17,49%
GIN	13,40%	16,34%	3,64%	-11,89%	-11,89%
MUS	13,25%	13,36%	4,65%	-13,09%	-13,10%
ZMB	12,86%	18,23%	5,33%	-23,73%	-23,74%
MOZ	12,52%	14,27%	2,73%	-14,21%	-14,27%
BEN	10,92%	16,77%	4,54%	-7,39%	-7,39%
MAR	10,62%	11,33%	6,04%	-16,66%	-16,69%
ZWE	10,45%	14,73%	4,15%	-12,05%	-12,07%
CIV	9,85%	13,29%	4,15%	-14,55%	-14,57%
SEN	9,60%	11,62%	4,81%	-12,27%	-12,28%
KEN	9,47%	11,30%	5,48%	-14,78%	-14,79%
MWI	9,46%	12,07%	4,83%	-15,00%	-15,00%
NAM	9,35%	12,42%	3,90%	-16,08%	-16,09%
GHA	8,94%	11,36%	4,31%	-10,74%	-10,76%
TZA	8,83%	11,78%	4,46%	-9,29%	-9,31%
MDG	8,22%	9,99%	4,44%	-15,00%	-15,01%
BFA	7,78%	11,07%	2,87%	-10,67%	-10,67%
UGA	7,70%	9,65%	3,61%	-11,55%	-11,55%
BWA	7,57%	10,64%	2,60%	-11,06%	-11,06%
ZAF	7,33%	8,69%	5,17%	-14,13%	-14,17%
CMR	6,87%	9,30%	4,19%	-11,43%	-11,44%
RWA	5,99%	7,38%	3,09%	-8,52%	-8,52%
NGA	5,46%	7,57%	1,44%	-4,99%	-5,03%
ETH	4,93%	6,88%	4,19%	-7,70%	-7,71%

Table 3.2 presents the results, with the second column representing the change in real wage, the third column the change in real expenditures, the fourth column the average change in the cost of fragmentation, and the last two columns the changes in the inverse internal cost of fragmentation " $\ln \widehat{t_{jsj}}^{1-\sigma}$," and the internal total requirement $\ln \widehat{B_{ii}}$ ¹⁶ respectively.

As we can expect, a 20 % reduction in the level of African countries' direct bilateral trade costs would increase real wage by as much as 21.53% for small open economies like Togo

¹⁵The trade costs that are borne when they export or import directly a good from a given country.

¹⁶The fraction of local output required by a given country to produce a unit of final good.

or as much as 5.46 % for relatively closed and large economies like Nigeria. The results are qualitatively the same when it comes to real expenditures. In term of magnitude, the change in real expenditures is systematically higher than the change in real wage for all the countries. This is due to the fact that the economy's total expenditures is the sum of labor revenues and tariff revenues as shown in equation (3.26). These revenues increase as the countries imports more goods following the decrease in trade costs.¹⁷

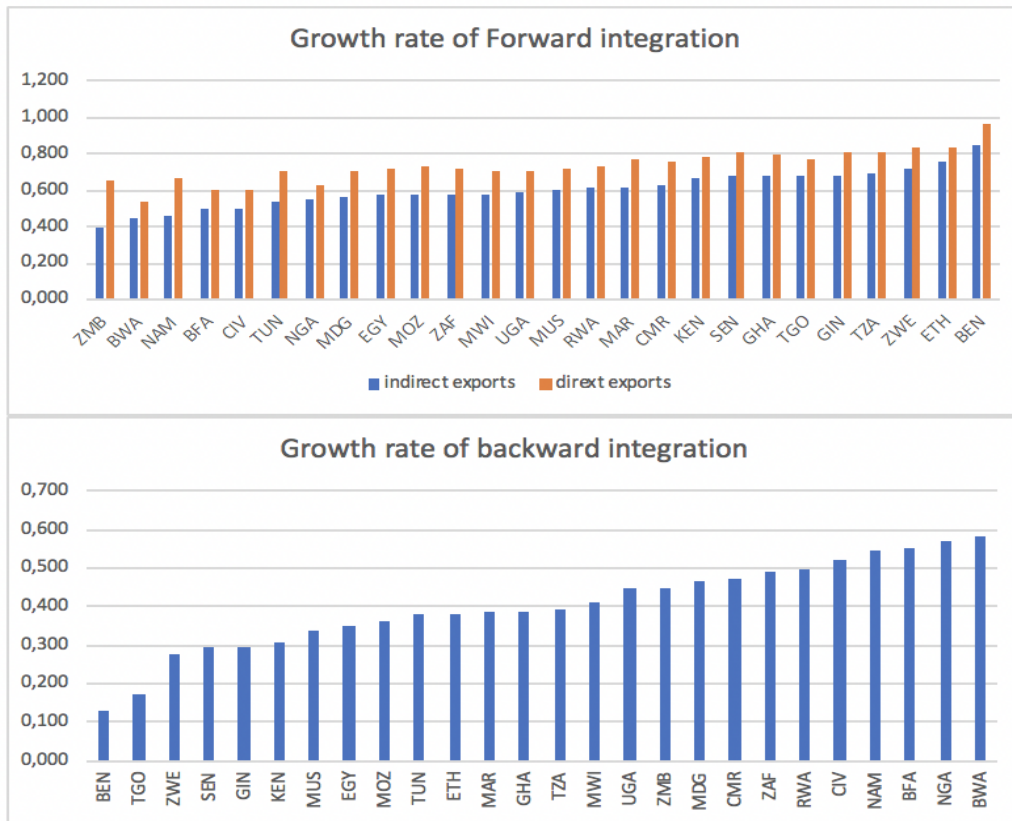
It is interesting to note that the cost of fragmentation would increase on average. This result is consistent with what we could expect theoretically. The intermediate goods trade elasticity is sufficiently lower than the final goods trade elasticity, a critical condition for this result to occur. Besides, we have only 32 African countries and aggregated regions for which trade costs decrease.

The remaining others are countries for which bilateral trade costs remain constant except with their African partners. As they are considered as intermediate countries for African value-added exports, the increase in the average cost of fragmentation makes even more sense. There are however instances where the bilateral cost of fragmentation decreases, especially for intra-African trade. This is natural since the trade costs of intermediate countries with African ones do decrease. Appendix 3.A.2 presents detailed results for the change in the bilateral cost of fragmentation regarding Cameroon. We also include a case where the trade elasticity for intermediate goods is higher (7.25) than the trade elasticity for final goods (4.85). In this case, the cost of fragmentation would decrease on average, which confirms our theoretical results.

We presented this cost of fragmentation in section 3.2.3 as a function of the relative price of a given origin country indirectly exported flows through intermediate countries to a given destination country in term of its directly exported ones. If this cost increases, it becomes relatively more expensive for the origin country to indirectly export goods through intermediate countries than directly exporting final goods to end consumers.

The chart below suggests that this is the case for our set of African countries. This chart presents different measures of integration in the global supply chain. We can for instance see in the upper panel of the chart that indirectly exported flows grow, which means that the countries' forward participation in the global supply chain increase in absolute terms, but these flows grow less than the directly exported ones (final goods exports), which is consistent with our previous result. It means that the countries moved to downstream stages of the production process, at least in relative terms. Another way to see it is to analyze the growth of backward participation that is shown in the lower panel of the

¹⁷It should be recalled that we imposed that trade imbalances remain constant between equilibria as well as bilateral tariffs.



Source: Author's calculations

Figure 3.3: Participation of selected countries in the global supply chain

chart. As it becomes cheaper to import intermediate inputs, the countries import more of them, everything that increases their backward participation¹⁸ in the global supply chain.

The last result that highlights table 3.2 is the exact similarity between the variation of the internal cost of fragmentation and the fraction of local output required to produce a unit of final good in country “i” (internal total requirement). This result confirms our previous finding that the internal cost of fragmentation could be approximated by the latter, which makes possible the calculation of the share of international fragmentation in the gains from trade against autarky using only observable data.

3.5 Concluding remarks

The goal of this paper was to propose a trade model to determine more accurately the contribution of international fragmentation in the welfare gains of trade. To do so, we relied upon value-added exports as the variable of interest instead of gross exports. It allowed us to highlight what we labeled the macroeconomic cost of fragmentation, a

¹⁸In this chart backward integration is represented by the share of foreign output required to produce a unit of final good.

critical variable for the determination of this contribution.

Our model predicts that the net contribution of international fragmentation in the welfare gains of trade is not as high as one could expect, at least in comparison to the gross contribution that could be inferred from a classical model. It represents approximately 24% on average of the gains of trade. As the welfare gains are inversely proportional to the shares of internal trade in intermediate goods and final goods and that the model allows us to identify the share of indirect domestic trade in intermediate goods unlike classical trade models, the net contribution of international fragmentation is lowered.

We also show that using our framework to derive the welfare gains of trade in comparison to a standard trade model give different results. This is due as explained [Alexander \(2017\)](#) to the implicit assumption made by standard trade models that the share of intermediate goods sourced from a given origin country in the total demand of intermediate goods of a given destination country is equivalent to the share of final goods sourced from this origin country in the total demand of final goods of the destination country. Specifically, we show that the reduction in real wage that a move to autarky would provoke is lower using our approach than the traditional one for upstream countries, and higher for downstream countries and countries that are less open in terms of the imports in value-added penetration ratio. The gains from trade are thus understated by the classical model for this last category even if they remain way lower than the gains associated to the more open countries with our model.

Finally, we show that reducing the level of a country's bilateral trade costs with its trading partners does not necessarily imply more forward participation in the global supply chain. In fact, unless the reduction in trade costs affects more the indirectly exported flows than the directly exported ones, the increase in exports would be biased towards the latter, which implies a weaker forward participation in relative terms to the global production network. Backward integration, however, undoubtedly increase, and the countries are closer to the final consumers than before. This result has interesting implications in term of trade policies since increasing the participation in the global supply chain is a key concern for many countries.

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Appendices

3.A Appendices

3.A.1 Detailed results, trade and welfare

Country	Autarky		20 % decrease African trade costs		
	Real wage benchmark	Real wage value-added exports	Real wage (VA)	(VA) Real expenditures	Cost of fragmentation
TGO	-17,44%	-39,94%	21,53%	21,97%	4,90%
TUN	-13,77%	-16,55%	14,16%	16,16%	5,65%
GIN	-10,30%	-20,11%	13,40%	16,34%	3,64%
MUS	-12,19%	-16,86%	13,25%	13,36%	4,65%
ZMB	-16,38%	-13,17%	12,86%	18,23%	5,33%
MOZ	-11,99%	-15,63%	12,52%	14,27%	2,73%
BEN	-5,66%	-31,68%	10,92%	16,77%	4,54%
MAR	-9,33%	-13,63%	10,62%	11,33%	6,04%
ZWE	-7,05%	-17,27%	10,45%	14,73%	4,15%
CIV	-11,42%	-9,69%	9,85%	13,29%	4,15%
SEN	-7,22%	-15,48%	9,60%	11,62%	4,81%
KEN	-6,66%	-14,43%	9,47%	11,30%	5,48%
MWI	-8,66%	-11,50%	9,46%	12,07%	4,83%
NAM	-11,43%	-8,79%	9,35%	12,42%	3,90%
GHA	-7,21%	-12,04%	8,94%	11,36%	4,31%
TZA	-6,98%	-12,13%	8,83%	11,78%	4,46%
MDG	-7,85%	-9,15%	8,22%	9,99%	4,44%
BFA	-9,28%	-7,24%	7,78%	11,07%	2,87%
UGA	-7,06%	-8,71%	7,70%	9,65%	3,61%
BWA	-10,44%	-6,61%	7,57%	10,64%	2,60%
ZAF	-7,17%	-8,16%	7,33%	8,69%	5,17%
CMR	-6,06%	-8,04%	6,87%	9,30%	4,19%
RWA	-5,64%	-6,51%	5,99%	7,38%	3,09%
NGA	-6,32%	-5,10%	5,46%	7,57%	1,44%
ETH	-3,39%	-7,56%	4,93%	6,88%	4,19%
XWF	-16,77%	-36,06%	21,13%	21,38%	5,32%
XCF	-15,41%	-10,33%	11,91%	20,67%	3,66%
XAC	-13,50%	-9,18%	10,29%	15,89%	2,58%
XSC	-3,86%	-5,90%	9,52%	12,86%	4,40%

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Country	Autarky		20 % decrease African trade costs		
	Real wage benchmark	Real wage value-added exports	Real wage (VA)	(VA) Real expenditures	Cost of fragmentation
EGY	-6,24%	-11,50%	8,71%	9,86%	5,27%
XNF	-8,38%	-7,43%	7,52%	9,84%	2,77%
XEC	-6,35%	-7,65%	6,92%	9,56%	3,50%
XCA	-26,75%	-25,45%	4,71%	8,95%	1,51%
TTO	-23,44%	-13,39%	1,03%	1,02%	0,84%
XCB	-8,09%	-11,69%	0,93%	0,90%	1,20%
BHR	-16,87%	-14,67%	0,81%	1,24%	0,22%
PRT	-9,51%	-11,21%	0,71%	0,67%	1,17%
JOR	-11,95%	-24,37%	0,64%	0,43%	1,23%
BEL	-24,83%	-28,95%	0,64%	0,58%	1,35%
XNA	-13,77%	-25,95%	0,60%	0,38%	1,44%
MLT	-32,39%	-51,42%	0,46%	0,17%	1,23%
CYP	-16,74%	-23,12%	0,43%	0,32%	1,18%
ESP	-7,43%	-8,57%	0,40%	0,39%	1,20%
TUR	-5,70%	-8,74%	0,39%	0,34%	1,38%
EST	-24,37%	-27,83%	0,39%	0,33%	1,50%
CHE	-14,09%	-12,73%	0,39%	0,46%	1,22%
IND	-4,74%	-7,91%	0,39%	0,41%	1,19%
LUX	-46,07%	-56,73%	0,38%	0,30%	1,31%
THA	-21,26%	-22,66%	0,37%	0,41%	0,93%
XEF	-14,79%	-17,02%	0,37%	0,35%	1,25%
NIC	-15,39%	-17,37%	0,36%	0,35%	1,27%
MYS	-23,84%	-22,40%	0,36%	0,48%	1,36%
SAU	-16,57%	-9,20%	0,35%	0,66%	0,75%
FRA	-7,05%	-8,05%	0,34%	0,33%	1,02%
NLD	-13,97%	-12,29%	0,34%	0,39%	1,20%
ARE	-13,42%	-15,73%	0,32%	0,32%	1,09%
SGP	-36,92%	-31,74%	0,31%	0,50%	1,40%
LTU	-18,49%	-23,47%	0,31%	0,23%	1,38%
IRL	-35,47%	-25,38%	0,31%	0,64%	1,42%
BGR	-18,43%	-22,36%	0,30%	0,28%	1,25%
VNM	-22,26%	-31,23%	0,30%	0,23%	0,96%
ITA	-7,19%	-8,18%	0,29%	0,27%	1,11%
UKR	-14,39%	-17,39%	0,29%	0,29%	1,42%

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Country	Autarky		20 % decrease African trade costs		
	Real wage benchmark	Real wage value-added exports	Real wage (VA)	(VA) Real expenditures	Cost of fragmentation
XSM	-10,83%	-12,42%	0,28%	0,30%	1,40%
KWT	-22,26%	-8,61%	0,28%	0,87%	1,06%
KOR	-14,21%	-15,25%	0,28%	0,41%	1,32%
XWS	-10,84%	-9,67%	0,27%	0,30%	1,19%
HKG	-20,53%	-19,65%	0,27%	0,29%	1,43%
SVN	-19,29%	-21,75%	0,23%	0,21%	1,36%
CHN	-6,58%	-6,24%	0,23%	0,27%	1,02%
DEU	-12,07%	-11,14%	0,23%	0,25%	1,08%
GRC	-7,48%	-12,51%	0,23%	0,18%	1,34%
GBR	-7,58%	-9,22%	0,22%	0,21%	1,07%
TWN	-22,13%	-18,84%	0,22%	0,29%	1,19%
BLR	-13,41%	-22,01%	0,22%	0,12%	1,49%
XER	-6,31%	-9,64%	0,21%	0,18%	1,21%
XEE	-12,19%	-26,44%	0,21%	0,06%	1,46%
HUN	-26,09%	-25,87%	0,20%	0,25%	1,05%
OMN	-18,66%	-11,32%	0,20%	0,34%	0,98%
GEO	-6,60%	-14,74%	0,19%	0,11%	1,57%
URY	-6,41%	-7,52%	0,19%	0,20%	1,17%
SWE	-12,38%	-11,17%	0,19%	0,23%	1,06%
DNK	-14,87%	-13,84%	0,18%	0,22%	1,27%
HRV	-11,27%	-12,09%	0,18%	0,19%	1,08%
LVA	-14,35%	-19,47%	0,18%	0,11%	1,45%
PAK	-3,44%	-6,94%	0,17%	0,17%	0,69%
ALB	-9,45%	-16,09%	0,17%	0,14%	1,39%
PRY	-8,52%	-10,72%	0,17%	0,16%	1,03%
NZL	-7,74%	-7,18%	0,16%	0,19%	1,00%
ROU	-10,12%	-12,35%	0,16%	0,14%	1,06%
XEA	-11,38%	-9,19%	0,15%	0,22%	1,30%
AUT	-15,10%	-15,10%	0,15%	0,16%	1,25%
FIN	-10,14%	-11,26%	0,15%	0,15%	1,10%
PRI	-3,06%	-4,49%	0,15%	0,15%	1,33%
ISR	-9,46%	-10,47%	0,15%	0,15%	1,36%
JAM	-9,38%	-16,63%	0,15%	0,09%	1,25%
CZE	-21,26%	-20,86%	0,14%	0,17%	1,25%

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Country	Autarky		20 % decrease African trade costs		
	Real wage benchmark	Real wage value-added exports	Real wage (VA)	(VA) Real expenditures	Cost of fragmentation
ARG	-4,36%	-3,98%	0,14%	0,19%	0,75%
IRN	-8,53%	-5,84%	0,13%	0,27%	0,93%
XSA	-4,47%	-13,77%	0,13%	0,15%	1,30%
PAN	-14,70%	-32,56%	0,12%	0,01%	1,21%
USA	-2,85%	-4,15%	0,12%	0,12%	1,21%
BRA	-2,75%	-2,97%	0,11%	0,12%	0,86%
XOC	-12,07%	-19,54%	0,11%	0,03%	1,36%
POL	-10,76%	-12,67%	0,11%	0,10%	1,34%
NOR	-11,10%	-7,60%	0,11%	0,22%	1,34%
SVK	-23,78%	-25,31%	0,10%	0,09%	1,34%
PER	-7,04%	-5,77%	0,10%	0,11%	1,13%
DOM	-6,41%	-9,52%	0,09%	0,09%	1,19%
BGD	-6,41%	-8,82%	0,09%	0,10%	1,09%
IDN	-6,05%	-6,12%	0,09%	0,10%	1,11%
QAT	-16,83%	-5,15%	0,08%	0,39%	1,16%
CAN	-7,00%	-7,16%	0,08%	0,09%	1,37%
BOL	-7,37%	-8,29%	0,07%	0,07%	1,30%
CHL	-10,07%	-8,91%	0,07%	0,10%	1,23%
RUS	-6,17%	-5,57%	0,07%	0,10%	1,30%
AUS	-5,12%	-4,84%	0,07%	0,09%	1,21%
LKA	-5,17%	-10,01%	0,07%	0,09%	1,07%
MNG	-21,75%	-24,90%	0,06%	0,03%	1,45%
XSU	-10,13%	-8,61%	0,06%	0,09%	1,30%
KGZ	-13,04%	-34,63%	0,06%	-0,05%	1,36%
CRI	-15,90%	-14,15%	0,06%	0,08%	1,30%
AZE	-15,50%	-7,87%	0,06%	0,19%	1,33%
JPN	-3,84%	-4,10%	0,06%	0,06%	1,02%
BRN	-16,53%	-9,70%	0,06%	0,12%	1,32%
KAZ	-10,98%	-6,78%	0,06%	0,09%	1,43%
ARM	-5,06%	-10,51%	0,05%	0,01%	1,41%
NPL	-1,91%	-8,04%	0,04%	0,07%	1,29%
SLV	-7,59%	-11,88%	0,04%	0,04%	1,22%
XSE	-11,88%	-8,72%	0,04%	0,02%	1,13%
GTM	-7,08%	-9,15%	0,04%	0,03%	1,25%

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Country	Autarky		20 % decrease African trade costs		
	Real wage benchmark	Real wage value-added exports	Real wage (VA)	(VA) Real expenditures	Cost of fragmentation
PHL	-7,78%	-10,91%	0,03%	0,02%	1,20%
LAO	-10,08%	-14,06%	0,03%	0,00%	1,22%
MEX	-7,80%	-7,50%	0,03%	0,04%	1,23%
COL	-4,12%	-4,51%	0,03%	0,03%	1,19%
ECU	-7,28%	-8,25%	0,02%	0,03%	1,28%
HND	-13,73%	-15,93%	0,01%	0,00%	1,33%
VEN	-6,45%	-4,74%	0,00%	0,00%	1,36%
KHM	-23,38%	-29,57%	0,00%	-0,05%	1,18%

3.A.2 Change in the bilateral cost of fragmentation (Cameroon)

Countries	$\theta = 4.25$ and	$\theta = 7.25$ and
	$\sigma - 1 = 4.85$	$\sigma - 1 = 4.85$
ALB	5,45%	-5,87%
ARE	4,34%	-2,00%
ARG	3,56%	0,23%
ARM	5,40%	-6,03%
AUS	3,36%	-0,86%
AUT	5,54%	-5,88%
AZE	5,43%	-6,01%
BEL	5,76%	-5,49%
BEN	-0,95%	-1,55%
BFA	4,29%	2,99%
BGD	2,70%	3,15%
BGR	5,60%	-5,81%
BHR	6,00%	-5,66%
BLR	3,51%	0,33%
BOL	5,39%	-6,12%
BRA	5,25%	-6,24%
BRN	3,36%	0,97%
BWA	4,37%	-8,19%

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Countries	$\theta = 4.25$ and	$\theta = 7.25$ and
	$\sigma - 1 = 4.85$	$\sigma - 1 = 4.85$
CAN	3,19%	0,57%
CHE	4,06%	-1,63%
CHL	3,45%	0,53%
CHN	5,11%	-6,46%
CIV	1,11%	-2,03%
CMR	2,37%	4,37%
COL	5,35%	-6,08%
CRI	5,34%	-6,07%
CYP	5,70%	-5,64%
CZE	3,96%	-0,77%
DEU	5,16%	-4,88%
DNK	3,40%	1,05%
DOM	2,90%	2,43%
ECU	5,26%	-6,16%
EGY	9,53%	1,44%
ESP	5,74%	-5,45%
EST	5,58%	-5,78%
ETH	-0,55%	-9,25%
FIN	5,48%	-6,01%
FRA	5,65%	-5,69%
GBR	5,51%	-5,88%
GEO	5,36%	-6,07%
GHA	0,59%	0,84%
GIN	-1,38%	-9,14%
GRC	5,42%	-5,91%
GTM	5,30%	-6,12%
HKG	5,37%	-5,93%
HND	5,33%	-6,08%
HRV	5,54%	-5,95%
HUN	5,53%	-5,92%
IDN	5,28%	-6,17%
IND	5,45%	-5,73%
IRL	5,59%	-5,76%
IRN	4,34%	-2,77%
ISR	5,47%	-5,89%

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Countries	$\theta = 4.25$ and $\sigma - 1 = 4.85$	$\theta = 7.25$ and $\sigma - 1 = 4.85$
ITA	5,56%	-5,77%
JAM	5,41%	-6,02%
JOR	5,54%	-5,70%
JPN	5,32%	-6,19%
KAZ	3,42%	0,56%
KEN	4,26%	-3,21%
KGZ	3,57%	-0,15%
KHM	3,90%	-0,79%
KOR	5,48%	-6,01%
KWT	5,42%	-6,07%
LAO	3,98%	-0,96%
LKA	5,35%	-6,06%
LTU	5,47%	-5,92%
LUX	3,18%	1,89%
LVA	5,52%	-5,92%
MAR	-0,56%	-2,31%
MDG	-1,51%	-5,06%
MEX	5,30%	-6,09%
MLT	5,62%	-5,77%
MNG	3,49%	0,24%
MOZ	1,79%	-6,82%
MUS	-0,26%	-1,16%
MWI	5,16%	-3,62%
MYS	5,47%	-5,97%
NAM	-2,06%	-7,21%
NGA	-2,18%	-5,97%
NIC	5,47%	-6,06%
NLD	5,66%	-5,68%
NOR	5,45%	-6,02%
NPL	5,34%	-5,99%
NZL	3,36%	0,82%
OMN	3,29%	1,01%
PAK	5,34%	-6,13%
PAN	3,72%	-0,38%
PER	4,57%	-7,07%

Continued from previous page

Countries	$\theta = 4.25$ and	$\theta = 7.25$ and
	$\sigma - 1 = 4.85$	$\sigma - 1 = 4.85$
PHL	5,36%	-6,11%
POL	5,45%	-5,99%
PRI	5,02%	-6,39%
PRT	6,00%	-5,31%
PRY	3,41%	0,76%
QAT	5,43%	-6,06%
ROU	5,53%	-5,91%
RUS	5,39%	-6,10%
RWA	1,65%	-8,79%
SAU	5,52%	-5,96%
SEN	1,56%	1,22%
SGP	5,47%	-5,95%
SLV	5,30%	-6,11%
SVK	5,46%	-5,98%
SVN	5,55%	-5,83%
SWE	5,55%	-5,92%
TGO	-1,26%	-2,60%
THA	5,55%	-5,91%
TTO	-1,16%	-12,51%
TUN	0,18%	-0,82%
TUR	5,60%	-5,64%
TWN	4,17%	-4,96%
TZA	-1,45%	-10,27%
UGA	5,44%	-3,39%
UKR	5,46%	-6,02%
URY	2,85%	-1,25%
USA	5,16%	-6,32%
VEN	3,46%	0,49%
VNM	5,50%	-5,91%
XAC	12,61%	2,86%
XCA	7,36%	-4,95%
XCB	5,97%	-5,98%
XCF	4,96%	4,08%
XEA	5,45%	-6,05%
XEC	-3,83%	-8,86%

Continued from previous page

Countries	$\theta = 4.25$ and	$\theta = 7.25$ and
	$\sigma - 1 = 4.85$	$\sigma - 1 = 4.85$
XEE	3,61%	0,21%
XEF	5,62%	-5,74%
XER	5,50%	-5,97%
XNA	3,36%	0,82%
XNF	1,83%	-3,35%
XOC	3,65%	-0,04%
XSA	5,14%	-6,22%
XSE	5,38%	-6,15%
XSC	-2,10%	-5,31%
XSM	5,37%	-5,99%
XSU	5,36%	-6,13%
XWF	8,65%	5,04%
XWS	5,36%	-5,99%
ZAF	-3,65%	-10,21%
ZMB	9,51%	-1,54%
ZWE	2,13%	-4,06%

3.A.3 A two-country inter-country input output table

	Intermediate use		Final Demand		Gross output	Trade Balance
	Country j	Country i	Country j	Country i		
Country j	h_{jj}	h_{ji}	x_{jj}	x_{ji}	$G_j = \sum_{i=j} (h_{ji} + x_{ji})$	$D_j = \sum_i (h_{ij} + x_{ij}) - \sum_i (h_{ji} + x_{ji})$
Country i	h_{ij}	h_{ii}	x_{ij}	x_{ii}	$G_i = \sum_{j=i} (h_{ij} + x_{ij})$	$D_i = \sum_j (h_{ji} + x_{ji}) - \sum_j (h_{ij} + x_{ij})$
Total	$H_j = \sum_{i=j} h_{ij}$	$H_i = \sum_{j=i} h_{ji}$	$E_j = \sum_{i=j} x_{ij}$ $= X_j - R_j^F$ $= w_j L_j + R_j^L + D_j$	$E_i = \sum_{j=i} x_{ji}$ $= X_i - R_i^F$ $= w_i L_i + R_i^L + D_i$		
Custom duties and tax	$R_j^L = \sum_{i=j} \tau_{ij}^L h_{ij}$	$R_i^L = \sum_{j=i} \tau_{ji}^L h_{ji}$	$R_j^F = \sum_{i=j} \tau_{ij}^F x_{ij}$	$R_i^F = \sum_{j=i} \tau_{ji}^F x_{ji}$		
Value-added	$w_j L_j = \sum_{s=j} \alpha_{js} X_{js}$	$w_i L_i = \sum_{s=i} \alpha_{is} X_{is}$	$w_j L_j = X_j - R_j^F - R_j^L - D_j$	$w_i L_i = X_i - R_i^F - R_i^L - D_i$		
Gross output	$G_j = H_j + R_j^L + w_j L_j$ $= \sum_{i=j} h_{ij} (1 + \tau_{ij}^L) + w_j L_j$	$G_i = H_i + R_i^L + w_i L_i$ $= \sum_{j=i} h_{ji} (1 + \tau_{ji}^L) + w_i L_i$	$G_j = H_j + E_j - D_j$	$G_i = H_i + E_i - D_i$		

With $\{i, j\} = S$

General Conclusion

Main results

This thesis was organised around two main research questions. Firstly, as many regions and countries in the world face high transport costs in part due to geographical constraints or the lack of qualitative transport infrastructures and considering the importance of trade for economic growth and the reduction of poverty, we examined whether high trade costs and export performance were antinomic. Secondly, given the place of international fragmentation in the production process of goods today and the will of many countries to participate more in the global value chain, we proposed a method to assess reliably the net impact of this way of organising the production process on the welfare gains of trade.

To provide answers to these questions, we organised our research in three chapters. The first studied the intra-national export performance of the state of Amazonas in Brazil, and specifically the city of Manaus where a Free trade zone is implanted. The goal was to assess the level of integration of Manaus and the rest of Amazonas into the Brazilian economy and to examine the eventual role of the Import Processing zone of Manaus to explain their situation. We found that despite the high level of trade costs faced by these two entities, their intra-national export performance was among the highest of the set of Brazilian states. We also found that a high share of manufactured goods in the total value-added created by a region plays a role in explaining its export efficiency. As Manaus is the top performer as regards this share among the set of Brazilian states, a performance explained by the presence of many foreign and local firms in the sector of manufactured goods that take advantage of the incentives provided by the import processing zone, we concluded that the intra-national export performance of the state of Amazonas was at least in part due to this Free trade zone.

The second chapter studied the export performance of African countries in light of the recent methods used to estimate trade flows between countries. Considering the quasi-consensus in the literature that African exports be it intra-regional or international are weaker than they should and that it is related mostly to the lack of qualitative transport infrastructures, we examined whether this conclusion still hold when the most recent techniques regarding the estimation of trade flows between countries are applied. We found

that African countries do not export less than the average country in the world when the Poisson pseudo maximum likelihood estimator is used to estimate bilateral gross trade flows instead of ordinary least squares. Nevertheless, when we distinguished final goods from intermediate goods, we found a clear under-performance regarding African final goods exports contrarily to their intermediate goods exports. This result was substantiated by the finding that trade costs, especially distance, exert a higher impact on African final goods exports in comparison to other countries unlike on their intermediate goods exports. However, contrarily to our expectation trade costs did not seem to have the same impact on African final goods exports and imports. This led us to the conclusion that weak preferences from foreign countries towards African final goods could also be a credible explanation for the weakness of their exports. Either way, when we used value-added exports which is the variable that matters the most for policymakers as the dependent variable in our estimations, we found that the supplementary impact of trade costs mentioned earlier for African final goods exports was at least 6 times lower. It means that value-added exports are less sensitive to direct bilateral trade costs for African countries.

In the third chapter, we proposed a general equilibrium model of trade based upon value-added trade flows instead of gross trade flows to assess more reliably the impact of international fragmentation on the welfare gains of trade. Using this framework, we found that the net contribution of fragmentation in the welfare gains of trade is lower than what could suggest a classical trade model. More precisely, we showed that it represents on average 24 % of the total gains of trade, less than the 51 % that we could infer from a standard trade model based upon gross trade flows. We also find a similar result to [Alexander \(2017\)](#) and [Fally and Hillberry \(2018\)](#), namely that using our model, the gains from trade are different in comparison to a standard trade model based upon gross trade flows, especially for the most upstream countries that would lose less real wage from a move to autarky with our model, and for the most downstream countries that would lose more. Finally, we showed that a reduction in the direct bilateral trade costs of a country with its partners does not necessarily imply more forward participation in the global value chain, as the relative trade cost of the indirectly exported flows becomes higher than the one of the directly exported flows. It however undoubtedly implies more backward participation in the global value chain, as the country would source more inputs from its bilateral partners to produce its final goods.

These findings have interesting implications in term of policies. We examine in the following section enlightened by these results which policies could effectively foster African exports.

How to stimulate African countries exports?

As mentioned in the previous developments, notably in the second chapter, African countries are under-efficient as regards their final goods exports. It means that there is a clear potential for an increase in these exports if relevant policies are implemented. Similarly, intra-regional trade between African countries is very low in comparison to other continents. In 2018, according to data from UNCTAD, intra-African trade represented 18 % of the total exports of these countries. Meanwhile, 69 % of European exports were sent to fellow European countries, while the share is 56 % for America and 61 % for Asia. Stimulating African exports could, therefore, also pass through an improvement in intra-regional trade; which on top of its effects on export flows, is essential to attenuate the strong dependence of these countries on foreign extra-African markets. A lot of initiatives are implemented to achieve this goal. Among these, the creation of a continental free trade area (AFCFTA) which currently involves 54 African states and upon which a lot of hope is put to foster African trade. What can we really expect from this initiative? Are there any other possibilities to achieve this goal or stimulate African exports in general ? To answer these questions, it is important to understand why intra-regional trade is low in Africa, and to identify the source of African-countries under-performance as regards final goods exports.

Firstly, the production process in Africa is not regionally fragmented, or said otherwise, there is not a regional value chain. In fact, most of African countries are specialized in intermediate goods exports or primary goods such as mining and unprocessed agricultural products to developed markets. As a matter of facts, in 2014, only 25% of the total trade in intermediate goods in Africa (Imports+exports) was intraregional ([Dollar et al., 2017](#)). It is not the case for other regions in the world such as Asia, or Europe where regional value chains exist. For this phenomenon to occur, it is necessary that the countries in a regional block have significantly different levels of technology or labor costs so that the gains of regional fragmentation exceed the costs. More precisely, the production process is composed of tasks that are broken down between the countries of the region according to their complexity, the countries the most advanced technologically realizing the most complex tasks and inversely. These regional value chains imply a lot of back and forth trade between countries, everything that increases the volume of gross trade flows in the region. They, therefore, represent good candidates to explain the low share of intra-African trade. Consequently, it appears unlikely that as a result of the AFCFTA, an African value chain emerges because it requires that the differences in technology and labor costs be sufficient enough to ensure that there are gains in fragmenting the production process regionally, something that is not necessarily true yet for African countries.

Secondly, the similarity in the goods produced and exported by our countries of interest has another impact on intra-regional trade. As mentioned earlier, as these goods are mostly unprocessed agricultural goods or mining products such as oil, it is not relevant to trade this kind of goods between each other as they are not really differentiated. Bananas, which are among the main export products in Cameroon and Ivory-coast taste quite the same whether produced in one or the other country. Trading this kind of goods between each other won't be profitable because of transport costs notably, everything that partly explains the weakness of intra-regional trade and why these goods are mostly exported to markets such as Europe where they are not or barely produced. This does not however explain the under-performance of African countries as regards their final goods exports in general.

We identified two possible reasons in the second chapter that could explain this phenomenon. First, the higher impact of trade costs, distance especially in comparison to other countries. As transport infrastructures are often of low quality when they exist, travelling 1 km of distance is more costly and takes more time in Africa than in other regions in the world. This affects the time required for the transit of the goods from the factory to the port of expedition, not to mention the time required to meet the customs procedures. Nevertheless, as we did not identify the same additional impact of trade costs as regards African final goods imports, or as regards their intermediate goods flows with the rest of the world, we also envisaged that the preferences of other countries towards African final goods were low as an explanation which is our second point. This would suggest that many of the goods produced by these countries and that are not enough exported, do not meet the standards of quality required to compete in the international market, something that would not be surprising, or simply that they are not of the taste of the potential importing countries. In this context, the AFCFTA would probably not be enough to significantly foster intra-regional trade because African final goods would still be competing with the more qualitative goods produced elsewhere; given the numerous trade agreements signed by our countries of interest with their more advanced partners in Europe or America. In the same vein, an improvement in African transport infrastructures would probably increase African final goods exports in general, but probably not significantly enough if not followed by an increase in the quality of the goods.

The AFCFTA, therefore, offer interesting perspectives for African trade, but alone could have an impact not substantial enough to involve a structural change in African exports. To avoid this situation, it is critical that the continental free trade area be accompanied by policies that could improve the quality of African final goods so that they become qualitative enough to compete in international markets, beyond the essential policies that are required to improve the quality of transport infrastructures and customs procedures

in Africa. This can be done in many ways, and we propose at least two that could serve this goal.

On one hand, the experience of the free trade zone of Manaus could be instructive. As we have shown in chapter 1, this import processing zone stimulates intermediate goods imports from other countries in the world including Brazilian states, inputs that are assembled and then exported as final goods to the other Brazilian states mostly. We notably showed that a high share of manufactured value-added in GDP is positively related to export performance, knowing that Manaus, where this Free trade zone is implanted, has the highest share in Brazil and is among the most efficient intranational exporter in the country. This policy of providing incentives to firms, foreign and local in order to encourage their settling in a place where the conditions in term of customs procedures, fiscal policy or financial constraints are better than in the rest of the economy, notably to carry out assembling or other productive activities has a lot of advantages. It stimulates the imports of competitive and qualitative inputs from more advanced countries technologically. This allows the importing firms to indirectly benefit from the technology of the exporting countries and also improves the quality of the final goods then produced. Another interest is that it increases the backward participation in the global value chain of the importing country which allows it to move in the downstream of the production process. We showed in chapter 3 that the gains of trade are higher for downstream countries than for upstream countries. It finally could imply technology transfers to local firms if the incentives are able to attract enough companies from more advanced economies. The AFCFTA if supplemented by this kind of policies could probably stimulate more intra-regional trade in final goods and also trade in value-added.

On the other hand, International institutions can play a role. Most of them insist rightly in the necessity to improve the quality of infrastructures, especially transport infrastructures to foster African exports in general and intra-African trade particularly. They, therefore, provide funds to finance infrastructures projects. However, as we suggested earlier, this policy of reducing trade costs if not supplemented by policies dedicated to improve the quality of the goods proposed by African firms, could fall short of generating a structural change in African trade. It is therefore necessary to implement strategies with this goal in sight. Specifically, African firms are for example confronted to financial constraints that impede their entering into local and international markets, but also that prevent them from investing in qualitative and generally expensive capital goods that could improve the quality of their products and enhance their technology of production. To alleviate these constraints, international institutions such as the World Bank could play a role by implementing for example a mechanism of guarantees that could encourage local financial institutions to lend to local firms and entrepreneurs so that even fairly small projects could

qualify. A program like that has in our point of view the potential to increase exports at the extensive margin, because more firms would be able to enter in international markets, but also at the intensive margin because a less stringent financial constraint would allow firms to acquire more capital goods, and thus increase their production and exports. As a future avenue of research, it could be interesting to quantify more accurately the impact of a reduction in these financial constraints on African exports.

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RÉSUMÉ

La littérature économique attribue aux coûts commerciaux une importance fondamentale dans l'explication des flux commerciaux internationaux. L'explosion des échanges commerciaux sur les dernières décennies est d'ailleurs régulièrement associée à la forte baisse des barrières commerciales entre les pays du monde sur cette période. Cette thèse a pour but de réexaminer l'importance véritable de ces coûts sur les échanges à travers différentes méthodologies. Nous étudions notamment dans le premier chapitre la performance économique de Manaus située dans l'État d'Amazonas au Brésil, dans l'idée de déterminer si les coûts commerciaux importants auxquels cette région fait face altèrent substantiellement sa performance à l'exportation, notamment vers les autres états Brésiliens. Le deuxième chapitre quant à lui étudie la performance à l'exportation des pays africains, pays faisant également face à des coûts à l'échange très élevés; ceci à l'aune des avancées les plus récentes dans la littérature sur le commerce international, mais aussi en utilisant les valeurs ajoutées exportées au lieu des exportations brutes comme éléments d'analyse. Le troisième chapitre quant à lui étudie l'importance de la fragmentation internationale dans les gains à l'échange, mais aussi le rôle que jouent les coûts commerciaux dans l'intégration à la chaîne de valeur mondiale. Ces trois chapitres laissent apparaître l'idée que des coûts commerciaux élevés ne sont pas nécessairement opposés à des flux commerciaux importants ou au moins dans la moyenne, mais que de faibles coûts commerciaux sont nécessaires pour se positionner plus en aval du processus de production, et ainsi bénéficier de gains au commerce plus élevés.

MOTS CLÉS

Performance à l'exportation, Fragmentation internationale, Gains au commerce

ABSTRACT

The economic literature attributes a critical role to trade costs in explaining international trade flows. The expansion of trade over the last few decades is regularly associated with the sharp drop in trade barriers between countries around the world over this period. The purpose of this thesis is to re-examine the real importance of these costs on international trade through different methodologies. In the first chapter, we examine the economic performance of Manaus in the Brazilian state of Amazonas, to determine whether the significant trade costs it faces substantially affect its export performance notably towards other Brazilian states. The second chapter examines the export performance of African countries, which also face high levels of trade costs, in the light of the most recent advances in the literature on international trade, but also by using value-added exports instead of gross exports as the variable of interest. The third chapter examines the impact of international fragmentation in the welfare gains of trade, but also the role played by trade costs in the participation in global value chains. These three chapters suggest that a high level of trade costs is not necessarily opposed to export performance, but that low trade costs are necessary to locate in the downstream of the production process, and thus benefit from higher welfare gains of trade.

KEYWORDS

Export performance, International Fragmentation, Welfare gains of trade