JOÃO PEDRO MONTENEGRO CARVALHAES

EFFECTS FROM PREFERENTIAL TRADE AGREEMENTS ON GLOBAL VALUE CHAINS: ANALYSIS OF THE EUROPEAN UNION – MERCOSUR SCENARIO

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FICHA CATALOGRÁFICA

Montenegro Carvalhaes, João Pedro
Effects from preferential trade agreements on global value chains: Analysis of the European Union – Mercosur scenario / J. P. M. Carvalhaes. -- São Paulo, 2021.
177 p.

Trabalho de Formatura - Escola Politécnica da Universidade de São Paulo. Departamento de Engenharia de Produção.

1. Cadeias de valor global 2. Acordos comerciais preferenciais 3. União Europeia 4. Mercosul I. Universidade de São Paulo. Escola Politécnica. Departamento de Engenharia de Produção II. t.

Para meus pais.

ACKNOWLEDGEMENTS

This study represents the outcome of a decades-long academic and personal development project and is, therefore, the aggregated product of many fields of study and interests I both encountered individually through my own experiences or had the pleasure of being presented. It represents the output of an associative network of interests in essentially human-born topics, either purely abstract or purely social, created and presented to me (directly or not) by many other humans, to whom I dedicate this project.

Nonetheless, some more specific acknowledgements should be given to some particularly relevant relationships:

To my father and my mother, for their unextinguishable love and support through all steps of my journey. Many paths I have taken, and I was extremely fortunate to have had them always as friends and guides wherever I decided to go. Thank you for teaching me to love people and ideas alike, while being good, stoic, and cheerful.

To my sister and my brothers, with whom I have the pleasure of engaging in the most varied and interesting discussions and conversations, encompassing our strikingly heterogeneous specializations in philosophy and sociology and art, biological and physical nature, and computational hardware and software. To my aunt Manja and all my family for their love, support, and care.

To the many friends I have the pleasure of sharing a common exploration of reality as my peers, defining and redefining through endless conversations and diverse experiences our identities and, in the process, learning a lot about each other. Particularly, to Alejandro, Cláudio and Marcos, for their enduring and endearing friendship through all these long years together.

To Professors Celma Ribeiro and Lucia Tajoli, for their caring support in this endeavor with attention, patience, and knowledge, providing insightful suggestions and guidance up to its very end.

RESUMO

A partir da década de 1980, a estrutura suportando a globalização tornou-se fundamentalmente baseada nas emergentes tecnologias de informação e comunicação. Esta mudança levou a cadeias produtivas dispersas, com a realização de etapas de produção espacialmente separadas, e realizadas independentemente das fronteiras dos países, conhecidas como cadeias de valor global (CVGs). Este paradigma tem sido estruturalmente apoiado por uma harmonização de políticas desenvolvidas regionalmente ou bilateralmente, através do estabelecimento de acordos comerciais preferenciais (ACPs) que, atualmente, cobrem muito mais do que simples termos de comércio entre os parceiros. Neste cenário, na metade de 2019, uma discussão de décadas sobre o estabelecimento de um ACP entre a União Europeia (UE) e o Mercado Comum do Sul (MERCOSUL) foi concluída com um acordo alcançado para o estabelecimento de uma zona de livre comércio. Esta pesquisa foi desenvolvida com o objetivo de compreender o impacto que tal acordo poderá ter sobre o desenvolvimento futuro de ambos os blocos, e como ele pode promover ou dificultar a integração entre eles, aqui entendida como suas interconectividades através de cadeias de valor. Essa avalição é realizada através de uma análise em duas etapas: primeiro, com uma análise qualitativa das tendências recentes de ambos os blocos em termos de níveis de comércio e de comércio de valor agregado (CVA), globalmente e entre si, e, segundo, através de uma análise quantitativa medindo o impacto que ACPs tiveram sobre CVGs, através de uma regressão econométrica de um modelo Gravitacional de CVA, cujo desempenho foi posteriormente comparado com o de uma rede neural artificial. Foi detectado que os blocos têm características significativamente assimétricas em várias dimensões de comércio, além de níveis ainda baixos de integração entre si, enquanto o efeito de acordos sobre cadeias de valor foi encontrado como sendo significativo e positivo, e o uso de redes neurais na substituição de soluções empíricas e tradicionais obteve resultados promissores. O acordo atingido entre os dois blocos ainda está sujeito a diversos debates e alterações em seu conteúdo, e vários fatores e choques exógenos estão fadados a afetar seu resultado. De qualquer forma, alavancar tais assimetrias identificadas através do uso do acordo como uma plataforma para a harmonização de políticas entre os blocos ainda pode ser de extremo valor econômico e social.

Palavras-chave: Cadeias de valor global, acordos comerciais preferenciais, União Europeia, MERCOSUL.

ABSTRACT

From the 1980's onwards, the framework supporting globalization became fundamentally based on the arising information and communication technologies. This shift led to dispersed production chains, through spatially unbundled production steps performed irrespective of countries boundaries, known as global value chains (GVCs). This paradigm has been structurally supported by a harmonization of policymaking developed regionally or bilaterally, through the setting of preferential trade agreements (PTAs) that, nowadays, cover much more than simply terms of trade between partners. In this scenario, in mid-2019, a decades-long discussion concerning the setting of a PTA between the European Union (EU) and the Southern Common Market (MERCOSUR) was finished with an agreement reached for the setting of a free trade area. This thesis was developed with the aim of understanding the impact that such an agreement could have on the future developments of both blocs, and how it can foster or hinder their integration, here understood as their interconnectedness via value chains. This is performed through a two-step analysis: firstly, with a qualitative analysis of the recent trends of both blocs in standard trade and value added trade (VAT) terms, globally and with one another, and, secondly, with a quantitative analysis measuring the impact that PTAs have had on GVCs, through an econometric regression of a Gravitational model of VAT, whose performance was later compared to those of an artificial neural network. The blocs were found to have largely asymmetric characteristics on several dimensions of trade and still low levels of integration among themselves, while the effect of agreements on value chains was found significative and positive, while the usage of neural network was found to be very promising on substituting traditional statistical solutions. Moreover, the agreement itself is still probably subject to much change and debate, and several exogenous factors and shocks are bound to affect its outcome. Nonetheless, leveraging on such asymmetries and using the agreement as a facility for harmonization of policies could still be extremely valuable economically and socially.

Keywords: Global value chain, preferential trade agreement, European Union, MERCOSUR.

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LIST OF ABBREVIATIONS AND ACRONYMS

ANN – Artificial Neural Network

ASEAN – Association of Southeast Asian Nations (Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, Vietnam)

AVW – Anderson and Van Wincoop

BIT – Bilateral Investment Treaty

BRICS – Brazil, Russia, India, China, and South Africa

CAGR – Compound Annual Growth Rate

CEPII – *Centre d'Etudes Prospectives et d'Informations Internationales*

CU – Customs Union

CM – Common Market

DVA – Domestic Value Added

DVX – Indirect Value Added

EAEU – Eurasian Economic Union (Armenia, Belarus, Kazakhstan, Kyrgyzstan, Russia)

EC – European Commission

EIA – Economic Integration Agreement

EU – European Union (*see below*)

EU27 – Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden

FCM – Fundación Círculo de Montevideo

FE – Fixed Effect

FDI – Foreign Direct Investment

FTA – Free Trade Area

FVA – Foreign Value Added

G7 – Group of Seven (Canada, France, Germany, Italy, Japan, United Kingdom, United States)

G20 – Group of Twenty (Argentina, Australia, Brazil, Canada, China, EU, France, Germany, India, Indonesia, Italy, Japan, Mexico, Russia, Saudi Arabia, South Africa, South Korea, Turkey, United Kingdom, United States)

GDP – Gross Domestic Product

GVC – Global Value Chain

HDI – Human Development Index

HS92 – Harmonized System (1992)

I2E – Import to Export

I2P – Import to Produce

ICT – Information and Communication Technology

ICSID – International Centre for Settlement of Investment Disputes

IMF – International Monetary Fund

IO – Input-Output

LVC – Local Value Chain

MERCOSUR – Southern Common Market (Argentina, Brazil, Paraguay, Uruguay)

MFN – Most Favored Nation

MRIO – Multi-Regional Input-Output

MRT – Multilateral Resistance Term

MSE – Mean Square Error

OEC – Observatory of Economic Complexity

OECD – Organization for Economic Co-operation and Development

OLS – Ordinary Least Squares

PPP – Purchasing Power Parity

PPML – Poisson Pseudo-Maximum Likelihood

PTA – Preferential Trade Agreement

RHS – Right Hand Side

RMSE – Root Mean Square Error

RTA – Regional Trade Agreement

SGD – Stochastic Gradient Descent

TiVA – Trade in Value Added

UK – United Kingdom

UN – United Nations

UNCTAD – United Nations Conference on Trade and Development

UNSD – United Nations Statistics Division

USMCA – United States-Mexico-Canada Agreement

VC – Value Chain

VA – Value-Added

VAT – Value-Added Trade

USA – United States of America

WB – World Bank

WEO – World Economic Outlook

WIOD – World Input-Output Database

WTO – World Trade Organization

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1 INTRODUCTION

On June 28th, 2019, the Southern Common Market and the European Union reached a positive agreement on a decades-long bilateral discussion concerning the blocs intensifying associative and synergetic pursuits with each other. The aim of these discussions, in this sense, was of setting up a free trade area agreement between the blocs, completely encompassing the four South American member states of the former; Argentina, Brazil, Paraguay and Uruguay, and the twenty-seven European member states of the latter; Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and Sweden. This result was celebrated by many state heads, political and economic observers, and found a positive description in the ensuing praise by the then European Union's Commission President, Jean-Claude Juncker:

> "I measure my words carefully when I say that this is a historical moment. In the midst of international trade tensions, we are sending today a strong signal with our Mercosur partners that we stand for rules-based trade. Through this trade pact, Mercosur countries have decided to open up their markets to the EU. This is obviously great news for companies, workers and the economy on both sides of the Atlantic, saving over €4 billion worth of duties per year. This makes it the largest trade agreement the EU has ever concluded. Thanks to the hard and patient work of our negotiators, this is matched with positive outcomes for the environment and consumers. And that's what makes this agreement a win-win deal." [1]

Nonetheless the praise given, also much negative criticism was directed at the agreement, concerning not only topics already well discussed, that also played a role in delaying the agreement's conclusion, but also new issues that came to be after this deal. The goal of this study, thus, is to understand the impacts that developing and putting in place such an agreement may have on both economic blocs in economic terms and, with the achieved results, put into perspective these expectations voiced by the previous European Commission's (EC) head, whilst understanding the criticisms to the current form of the agreement. In that way, the objective is to understand the role that a free trade area agreement can play on the economies and integration of both blocs, as can be measured from the past.

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[1] EUROPEAN COMMISSION. (2019, June 28). *EU and Mercosur reach agreement on trade*. Retrieved from European Commission: trade.ec.europa.eu/doclib/press/index.cfm?id=2039.

This is done following a two-sided approach: first in practical terms, assessing from a broad standpoint and moving progressively inwards to the specific case of the two highlighted blocs, by discussing and elucidating wherein the modern global economic scenario and its recent trends of development and integration such an agreement arises, followed by an in depth study of the positioning in such landscape occupied by the European Union and the Southern Common Market; and second in theoretical terms, by studying what are the observable effects that trade agreements tend to generate in the integrating partners.

1.1 RELEVANCE

As argued by the EC's previous head, the deal would represent the largest of its kind for the European Union, and this would also be the case for the Southern Common Market (BALTENSPERGER & DADUSH, 2019). As will be seen later, it represents significant tariff-based policy reductions for the blocs, but perhaps most importantly, it creates incentives and a new depth of integration that could further foster important harmonization on domestic policies and through this, advances in the regulatory framework of relevant environmental, agricultural and industrial dimensions.

Moreover, besides the direct gains in trade due to its liberalization (even though spaced out in a long implementation period), the rise of globalized production on recent decades has been the bulwark of international trade, and trade agreements have been seen to be key drivers of these unbundled supranational productive chains. Thus, the agreement can also play a role in integrating and generating value creation between the blocs in a non-directly trade-specific manner, by incentivizing the development of cross-bloc value chains.

Combining the commercial and policymaking harmonization incentives that arise from this new economic proximity, through the setting up of a trade agreement that develops trade and value-added trade, the net outcome could be of self-reinforcing positive effects, where additional policy integration and compliance allows and incentivizes more economic integration, which leads to more interest in further integration and so on in a feedback manner. Thus, the overall benefits on the long run could be progressively accrued through this dynamic, and the new found relevance that each bloc achieves in virtue of one another should facilitate in the tackling of major socioeconomical and environmental problems that will mark the future decades, such as the post-Covid-19 economic reignition and climate change, while at the same time reinforcing the role that each bloc and its member states can play at the global arena.

Thus, this research was pursued due to the very pertinent multidimensional effects that this trade agreement, if eventually put in place, may engender in the future of both blocs, and the author’s particular interest in such impacts, having lived in both blocs through his double-degree studies in Brazil and Italy, a Southern Common Market country and an European Union country.

1.2 OBJECTIVES

As already stated, the overall goal of the study is to understand the impact that such agreement may have on each bloc. The objectives thus pursued expand on this notion, through developing a deeper understanding on cross-bloc effects, and is so done following the two-sided approach previously mentioned, broken down into three main objectives:

- Firstly, to place the agreement into its context. This is done with an analysis of the economic paradigms currently in place and their overall trends in the past decades. The starting point is from a global perspective and focuses on the rise of global value chains in the so-called “second unbundling” of production and its association with preferential trade agreements, such as the free trade area agreement studied. It then shifts inward, focusing instead on the European Union and Southern Common Market themselves, and how they have fared in this global panorama. The ultimate objective of this initial step is to understand the global and local (i.e., at the level of the blocs) scenario where this agreement arises and exists.
- Secondly, as an offshoot of the analysis of the current global paradigm, to understand the interplay that unbundled production, which has been ever so the more predominant factor in trade terms, has with trade agreements, and thus the impact that the agreement may have on developing economic integration between the blocs via intertwined value chains.
- Finally, and from a practitioners’ point of view, to assess the validity of substituting tried-and-through empirical methodologies commonly used on the analysis of trade data with more modern and robust models for dealing with lots of data. This final objective is tackled by comparing the efficiency achieved in accurately mapping value-added trade data given a set of quantitative and qualitative variables through the usage of the Gravitational model of trade and artificial neural networks. This tertiary objective follows directly and most relevantly from the research of both Laget et al. (2018) and Wohl and Kennedy (2018).

It is relevant to note that this study does not promote an in-depth breakdown of the agreement itself, mainly due to the fact that the probability of actual adoption of the agreement studied has been declining as political and social controversies between the two blocs have arisen, and new diplomatic issues have marred the talks and progress on the setting of the new agreement, and the final document of a possible future agreement would probably be still subject to much change from the current format. Moreover, this study also does not attempt to quantitatively or qualitatively forecast on the specific impacts that the agreement may have on the blocs' economies, and is thus not comprehensive in taking into consideration, for example, the impact of the current global pandemic Covid-19 that undoubtedly will affect not only aggregated economic growth worldwide, but also the fast-paced modern growth of globalization and unbundling of value chains.

1.3 STRUCTURE

This research is divided into 6 different chapters, in which are built the methodological and social framework for understanding the trade agreement, its scenario and the role its impacts may have, in order to address the questioning around its relevance.

Thus, the first chapter, concluded by this section, presents the topic at hand, its overall relevance and the objectives pursued, and the structure of the study for tackling the objectives proposed.

The second chapter is a review of the relevant literature that encompasses the themes addressed in this study, and it serves as the depository for all the framework and methodological tools and definitions used throughout the rest of the study.

The third chapter focuses on tackling the first objective, through an analysis of trade patterns of each bloc in gross terms, in sectoral flows, and finally in global value chain terms. It finishes with an exposition of the placement of the agreement within the current global and local scenario of the possible partners to be.

The fourth and fifth chapter combinedly tackle the second objective. The fourth chapter presents the quantitative models adopted to better understand the impact of trade agreements on value chains worldwide in the past decades, being the first of them an econometric and the second a neural network, and the database built for both analyses.

The fifth chapter, conversely, presents and discusses the results of the statistical regression and the outputs achieved through the neural network, and, with those, the discernible role that different types of agreements are observed to have in driving the global internationalization of production. The chapter closes with an overview of its results, that are focused on the second objective, but also reconciling them with the earlier results in chapter three about the first objective.

The sixth chapter, finally, concludes the study by discussing the context in which the agreement has arose, with the answers found to the two objectives initially set forward for this purpose. As a perspective for future studies, it also presents new venues through which further research can be done surrounding both the exogenous factors not considered in the study, but also in key endogenous factors that were not its focus.

2 MEASURING GLOBAL VALUE CHAINS AND VALUE-ADDED TRADE

This chapter establishes the global historical and theoretical framework that underpins the methodological approach utilized in this research, by reviewing the available literature covering the relevant topics. Section 2.1 focuses on the phenomenon of Global Value Chains (GVCs), developing initially, in subsection 2.1.1, the social and economic background that helps in explaining their quick rise and their synergetic effect on the upsurge of preferential trade agreements (PTAs), and later, in subsection 2.1.2, the quantitative approach used for their measurement. Section 2.2 describes the two quantitative methodologies used in this study to measure the impact of different trade-related variables, that will be presented in chapter 4, on value-added trade. In that manner, in subsection 2.2.1, the Gravitational model of trade is elaborated, whilst in subsection 2.2.2, the framework for data analysis via artificial neural networks is presented. Finally, section 2.3 reviews the recent literature studying these topics combinedly.

2.1 GLOBAL VALUE CHAINS

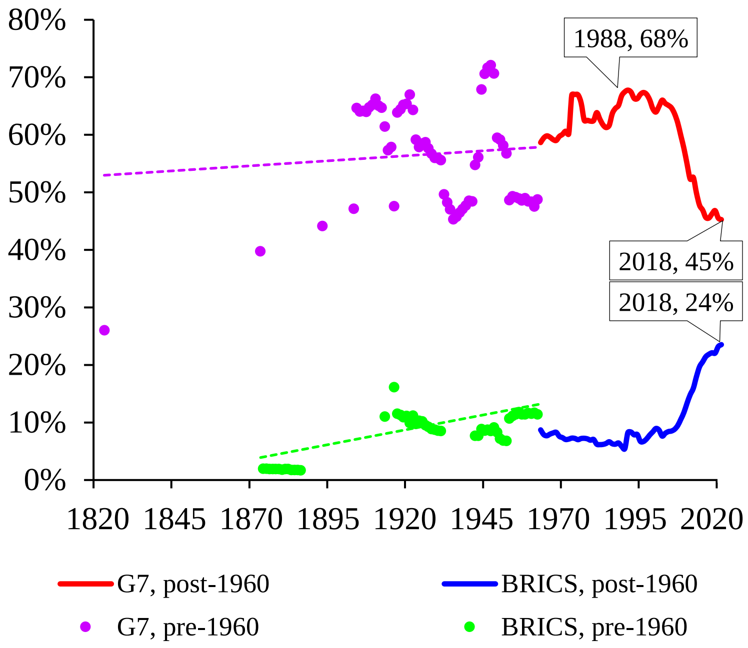
2.1.1 The second unbundling of production and rise of preferential trade agreements

From the late 1980’s onwards, the developmental framework that supported globalization shifted away from declining costs of trade brought by, among other factors, new transportation technologies, to integration via the technological revolution brought in new information and communication technologies (ICT; BALDWIN, 2011b).

This new paradigm marked, therefore, a shift from the previous global economic mainstream framework. As noted by Baldwin (2006; 2011b), global income shifted away from the hegemonic developed countries to developing (Figure 1), followed by a decline in their share of global exports (Figure 2), as global value addition went to the periphery (Figure 3). All the while, the role of trade costs in facilitating trade during the post-World War II period subsided, as their fluctuations (and decline) became more muted (JACKS, MEISSNER, & NOVY, 2011).

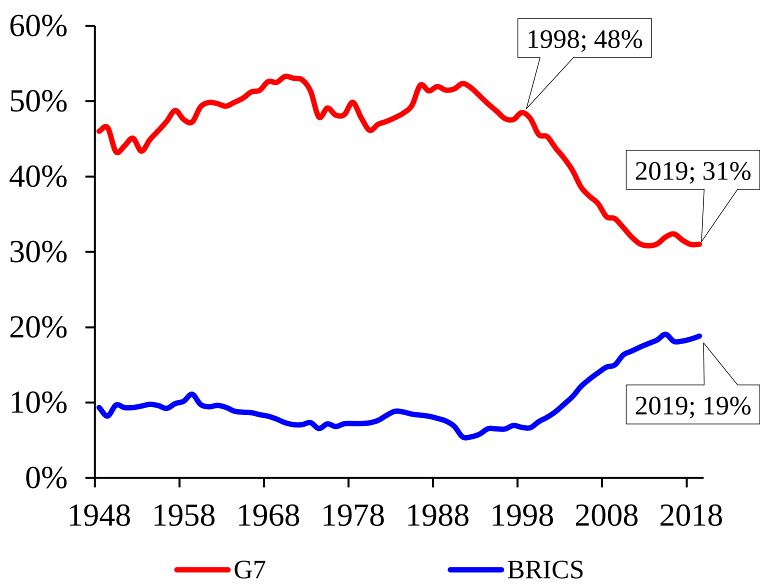
Thus, while the first wave of globalization was driven by technologies that supplanted the need for producing close to consumption through the facilitation of transportation and cross-border access – i.e. spatially unbundling the industry and the consumers –, the second wave is being driven mainly by an easiness of coordination brought by instant communication and access to information worldwide – i.e. spatially unbundling the factory from the office, and, at a deeper level, spatially unbundling also the different processes of the factory (BALDWIN, 2006).

Figure 1 – Percentage of world GDP held by the G7 and the BRICS



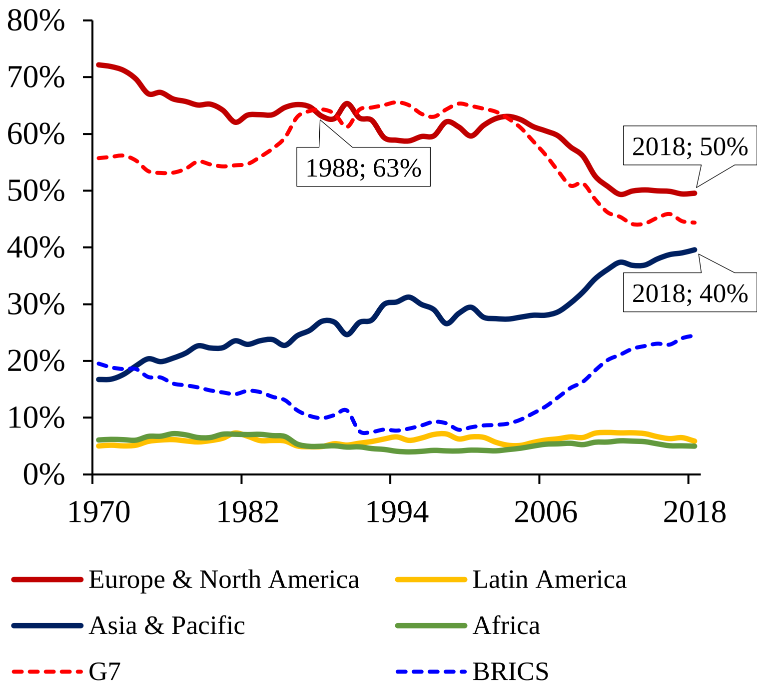
Source: Bolt, Inklaar, Jong and Zanden (2018), World Bank (2020) and author calculations. Note: Data availability of the selected countries before 1960 vary greatly, and only a sample of observation of each group is here displayed due to scarcity; the dashed lines represent the linearly regressed trend in the selected samples pre-1960.

Figure 2 – Percentage of world exports done by the G7 and the BRICS



Source: World Trade Organization (2020a) and author calculations.

Figure 3 – Breakdown of global value added by geographic region



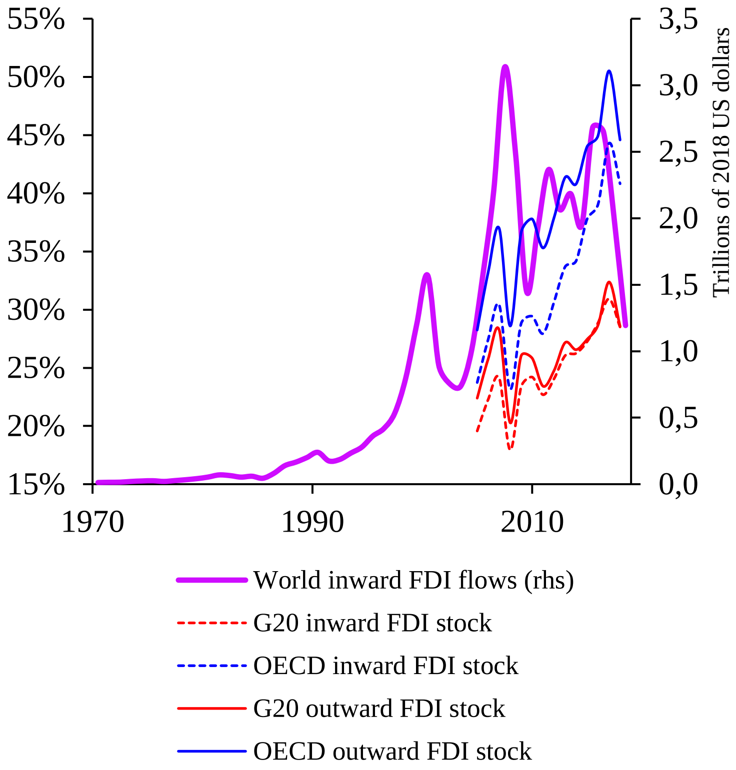
Source: United Nations Statistics Division (2020) and author calculations.

This second unbundling, therefore, has been the linchpin for the rise of GVCs. Moreover, the fragmentation of production means that the comparative advantages of countries and geographical regions now needs to be understood as in their capabilities of adding value to intermediate steps of the supply chains, rather than simply in terms of creating final goods (AMADOR & CABRAL, 2016).

In that way, as noted by Antràs (2015), more and more firms today strategize and operationalize their production globally by considering local advantages, and offshoring production of different parts and components to where it is cheaper and easier to build and later integrate in the final assembly. Thus, the "Made in" categorization of production lost most of its value, as goods by and large become "Made in the World" (WTO, 2019a). Krugman et al. (2018) exemplifies this paradigm with the analysis of the smartphone "iPhone 7" that, launched in 2016, had an unsubsidized price of $649 (in its launch year), while costing only $225 to be assembled in China. However, only $5 represented actual costs of testing and assembling in that country, while the remaining $220 representing the costs of all other components involved in producing the smartphone, in turn largely done outside China in other Asian, European and American countries.

The fragmentation of production has had a strong effect of intertwining developed ("north") with developing ("south") countries, in a "North-South" pattern. This production sharing, as argued by Baldwin and Gonzalez (2015), fueled the rapid rise of some "south" markets, particularly in south and southeast Asia, through the advances in mobility of managerial and technical (manufacturing) know-how brought by the new ICT in place. This shift helps in partially explaining the trends observed in Figures 1-3, and can also be seen with the growth of foreign direct investments (FDIs), consistently pushed by developed countries, in Figure 4, that are essential for financially establishing GVCs (AMADOR & CABRAL, 2016). This process is particularly interesting for developing countries, since it provides a way for becoming more integrated in the global productive system and overall economy with lower entry costs since they are responsible only for some components or parts (WTO, 2014).

Figure 4 – World flow of FDI, OECD and G20 stocks of FDI as percentages of GDP



Source: World Bank (2020b), Organization for Economic Co-operation and Development (2020), and author calculations.

The new productive organization also impacted policymaking (WTO, 2011). Amador and Cabral (2016) argue that this higher economic integration of countries severely influence modern policymakers, particularly regarding trade policy but not only, since the complex GVC networks demand functioning and integrated systems of logistics, transportation, and manufacturing, irrespective of country or continent.

In this sense, ease of investing through inwards and outwards flows of capital, clear competition policies and guarantees of intellectual property, among other factors, also become more relevant, as to ensure firms that production can be safely internationalized without major concerns (ANTRÀS, 2005; BALDWIN & GONZALEZ, 2015). As noted by the World Trade Organization (WTO), deeper agreements with harmonized and mutually compatible policy-setting are structural for promoting cross-border integration of production (WTO, 2011).

The need for this type of international standardization of policies and controls, however, has been developed mostly outside the WTO forums, since the institution has been stalled in multilateral talks for the last decades, with the Doha Development Round still unresolved (MELTZER, 2011).

Thus, bilateral investment treaties (BITs) and preferential trade agreements (PTAs) ballooned, as countries bilaterally (or regionally) searched for both improving access to other markets, liberalizing trade by reducing barriers, but also structuring agreements on policies currently outside the multilateral scope of the WTO, guaranteeing their place in GVCs, with thus "pro-GVC" policies (AMADOR & CABRAL, 2016; ANTRÀS & STAIGER, 2012; BALDWIN, 2011a; BALDWIN & GONZALEZ, 2015; FERRAZ & RIBEIRO, 2018; BOFFA, JANSEN, & SOLLEDER, 2018; MELTZER, 2011)[2]. The growth of these agreements is represented on Figure 5.

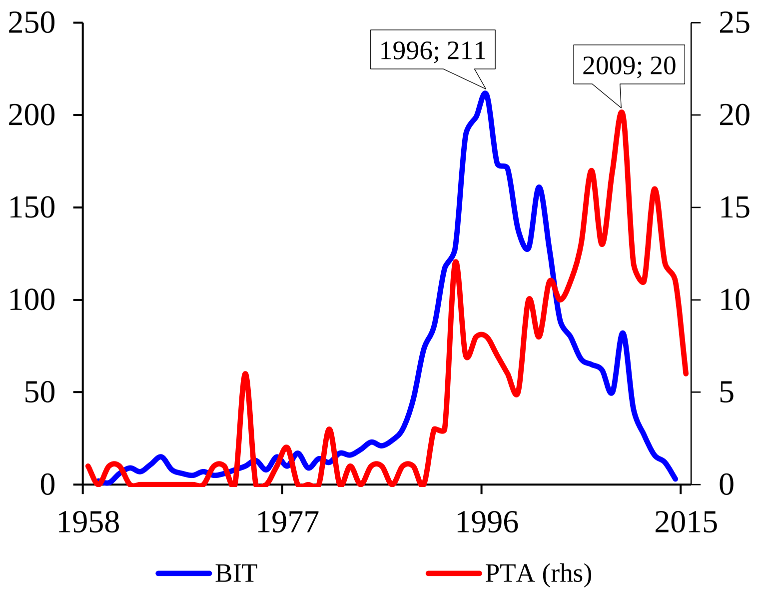
The growth of these pro-GVC policies is reflected as new provisions on trade agreements. Hofmann et al. (2017) categorized provisions on PTAs as either falling into the current scope of the WTO, dubbed as "WTO+" provisions, or outside the current scope of the WTO, dubbed as "WTO-X". The rise of WTO-X provisions, leading to deeper integration, is represented in Figure 6.

This growth of provisions can also be analyzed by whether it represents "extensive" margin expansions, referring to the simple increase of policy areas through additional provisions included in the agreements, and "intensive" margin expansions, referring to the increase of the institutional depth of the agreement, for example by setting provisions with assurances on legally enforceability (WTO, 2011). Overall, in this scenario, the deal between the two blocs

[2] There are many factors that contributed for the modern rise of PTAs other than simply seeking the establishment via harmonization of rules of GVCs that, however, are out of the scope of this study. Some relevant relationships are presented, for example, by Bergstrand et al. (2015), that studies how close geographical proximity of parties, large countries (in terms of GDP) or simply countries with similar sizes (also in terms of GDP) are factors that help in explaining a large part of the recent agreements.

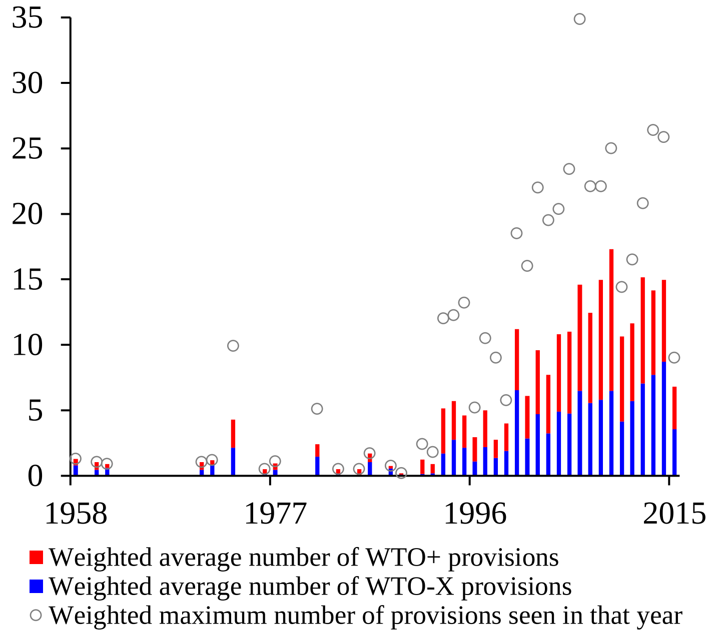
here studied fits well with the rise of “North-South” agreements, and could mean deeper integration in economic and policy terms.

Figure 5 – New BITs and PTAs yearly



Source: International Centre for Settlement of Investment Disputes (2019) and Hofmann, Osnago and Ruta (2017).

Figure 6 – Appearance of different types of provisions on PTAs yearly



Source: Hofmann, Osnago and Ruta (2017) and author calculations. Note: Individual observations are weighed by the number of PTAs signed each year.

2.1.2 Measuring global value chains with value-added trade

In 2008, intra-PTA trade represented approximately 35% of total merchandise trade worldwide, approximately double the share of 18%, in 1990 (excluding intra-European; WTO, 2011). Discerning from this value or, more generally, from any merchandise trade in and outside trade agreements, the presence and impact of GVCs, however, requires additional considerations.

An initial possible method for such measurement is to consider customs classifications. Thus, in order to disaggregate exports and measure the intensity of value chain trade, the WTO, for example, in its "World Trade Report 2011", measures trade in "Parts and Components", defined as those exports falling into codes 42 and 53 of the Broad Economic Categories, supplemented by "unfinished textile products" of code 65, all from the 3rd Revision of the Standard International Trade Classification, an harmonized standard classification of goods developed by the United Nations (UN; WTO, 2011). This method follows the approach by Ng and Yeats (1999) and is used empirically, for example, by Orefice and Rocha (2013) and Laget et al. (2018), among others.

However, this approach may not be satisfactory for well characterizing the presence of cross-border value chains. As noted by Baldwin and Gonzalez (2015), a "part" can be both an intermediary good, used in the assembly of some final good, or a traded good absorbed by the receiving (importing) country as is (e.g., a "car tire" can be both an intermediary in the assembly of a car, or a final good on its own as a spare tire). While the former case could indicate a higher involvement in GVCs, the latter would be better ascribed as simple trade in goods. Thus, the use of goods needs to be taken into consideration, and not only their classification.

Moreover, as countries become increasingly more traversed by international flows of production and GVCs networks become complex, it is expected that intermediary products will also increasingly more cross their borders, and not only in direct intermediaries, but also in higher degrees of reexports and reimports, as the same goods pass through different steps of production in different countries. This process further compromises the capability of traditional trade values of capturing these effects, as they are not designed to take into consideration where value has been added (JOHNSON & NOGUERA, 2017; KOOPMAN, WANG, & WEI, 2014).

A different approach that considers this idiosyncrasy of value chain trade is by considering the actual uses of imported goods, given by countries' input-output (IO) tables (and in larger scales with multi-regional input-output, or MRIO, tables). This is done by disaggregating gross trade into where and how it is used and developed (by local value addition) into value-added trade (VAT) measurements.

This problematization and subsequent development of measuring value chain trade is more thoroughly expanded in Table 1 with supply-chain concepts, and the untangling of value addition is represented with a generic model of trade in Figure 7.

Table 1 – I2P, I2E and VAT: definitions of value chain trade

Type	Import to Produce (*I2P*)	Import to Export (*I2E*)	Value-added Trade (*VAT*)
Description	The broadest breakdown of imports, I2P, considers all productive factors that enter a country and are there used in some manner of production. Thus, it implies some broad sense of internationalization of production even though not necessarily through explicitly developed or formally set production networks. Nonetheless, the goods there produced may be internally absorbed or exported elsewhere.	The next categorization of imports, I2E, subdivides I2P by considering only those goods imported that are not locally absorbed, but rather take part in local production but later are exported to another party internationally. This measurement is, in turn, a more appropriate proxy for GVC participation, as it measures the role effective participation that the country has in globalized production.	VAT changes the disaggregation focus by considering that the total value of any export can be broken down into whether it comes from (1) intermediary products used in assembly, sourced internationally or domestically; and (2) the assembly itself of the export good. That is, it considers both how products are combined in different sectors and how international and domestic value addition contribute individually.

Source: Adapted from Baldwin and Gonzalez (2015).

Table 1 – I2P, I2E and VAT: uses and notions of value chain trade (*cont.*)

Type	Import to Produce (I2P)	Import to Export (I2E)	Value-added Trade (VAT)
Downsides to GVC measurement	I2P makes no distinction between final goods which, once imported, stay at the country (i.e., are absorbed there), and intermediaries, which not necessarily do. This separation is relevant to more clearly understand the role the importing country has on production in the international scenario.	I2E fails to accommodate the implication of reimports and reexports. Thus, a country that imports some component for production, may be also reimporting partially some value it has already previously embedded in that good, and the figure tends to be, therefore, overestimated by double-counting (and higher order moments).	VAT is much more synthetic when compared to real flows of exports worldwide, and thus requires a deeper comprehension on what is actually being represented numerically. Moreover, it depends on harmonized values that allow for similar calculations to take place with statistics from different countries, which may not always be the case.

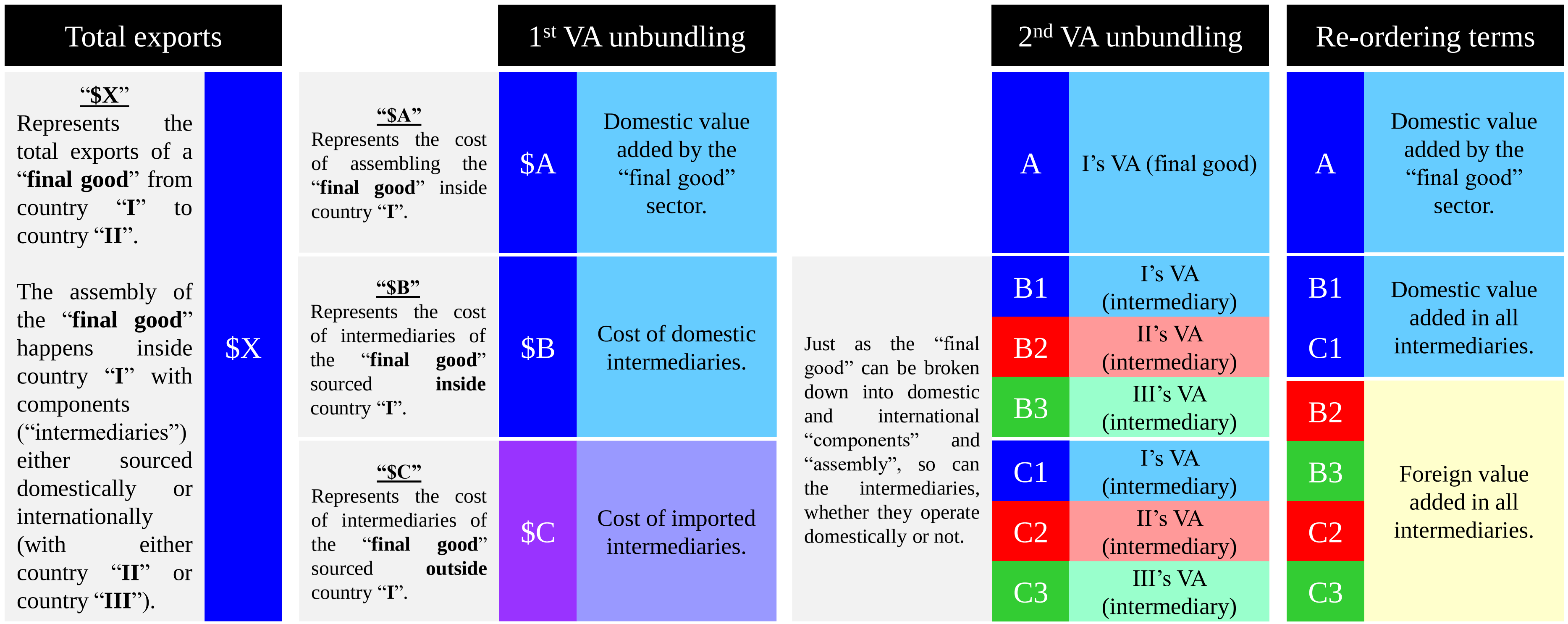
Source: Adapted from Baldwin and Gonzalez (2015).

This last approach was mainly developed in the seminal works from Koopman et al. (2010; 2014), Hummels et al. (2001) and Johnson and Noguera (2012). Hereafter will be presented the methodological framework developed by Koopman et al. (2010; 2014), resumed from Equation 1 throughout Equation 26, developing the relevant VAT measurements used in this study (such as “Domestic Value Added”, or DVA, and “Foreign Value Added”, or FVA):

Assuming a two-country world trading in N different sectors, the output x_{in} of each country $i = 1{,}2$ in each of its sectors $n = 1, \dots, N$ can be written vectorially as:

$$X_i = \begin{bmatrix} x_{i1} \\ \cdots \\ x_{iN} \end{bmatrix}, \qquad i = 1{,}2 \qquad (1)$$

Figure 7 – Unbundling exports into value addition



Source: Adapted from Baldwin and Gonzalez (2015). Note: This example considers a three countries world ("I", "II" and "III"), focusing only on the exports from one of them (country "I") to another (country "II") in one specific industry (of the "final good"). Also note that $X = A + B + C$, $B = B1 + B2 + B3$ and $C = C1 + C2 + C3$. The latter two represent the breakdown of value addition of domestic intermediaries (B's) and foreign intermediaries (C's), summarized by the "second unbundling", onto their own inputs and assemble by each of the three countries (country "I" being responsible for "B1"/"C1" and so on), unbundled recursively upstream in the production chain.

The goods produced by each sector can either be used as intermediary products (in other sectors) or consumed as final goods themselves. This consumption can happen due to domestic demand or international demand. That is:

$$X_i = A_{ii}X_i + Y_{ii} + A_{ij}X_j + Y_{ij}, \qquad i,j = 1,2 \qquad (2)$$

Where

- A_{ij} is a NxN matrix ascribing the unitary use of intermediary goods produced by i required for producing unitary final goods in j in any combination of sectors (it is the IO matrix), and
- Y_{ij} is a $Nx1$ matrix describing the final good demand of each good produced by i in j.

Thus, the first two terms represent domestic demand (in intermediary or final good form), and the second two terms represent international demand. The equation can be rearranged as:

$$\begin{bmatrix} X_1 \\ X_2 \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} + \begin{bmatrix} Y_{11} + Y_{12} \\ Y_{21} + Y_{22} \end{bmatrix} \qquad (3)$$

By defining global demand of goods by any country as:

$$Y_i = Y_{ii} + Y_{ij}, \qquad i,j = 1,2 \qquad (4)$$

Equation 3 can be algebraically rewritten as:

$$\begin{bmatrix} X_1 \\ X_2 \end{bmatrix} = \begin{bmatrix} I - A_{11} & -A_{12} \\ -A_{21} & I - A_{22} \end{bmatrix}^{-1} \begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix} = \begin{bmatrix} B_{11} & B_{12} \\ B_{21} & B_{22} \end{bmatrix} \begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix} \qquad (5)$$

Where B_{ij} is a NxN matrix condensing the information both on domestic and international demand of both intermediary and final goods known as the “total requirement matrix”. Each entry in each total requirement matrix represents how much of an increase in output of country i is needed to drive up production (output) of one extra unit of final good in country j. The aggregated matrix B is defined as the “Leontief inverse” matrix:

$$B = \begin{bmatrix} B_{11} & B_{12} \\ B_{21} & B_{22} \end{bmatrix} \qquad (6)$$

Similarly to Equation 4, total output of each country can also be defined as consumption in the domestic market (X_{ii}) or internationally (X_{ij}):

$$X_i = X_{ii} + X_{ij}, \qquad i,j = 1,2 \qquad (7)$$

Equation 7 can be used together with Equation 4 to expand Equation 5 as:

$$\begin{bmatrix} X_{11} & X_{12} \\ X_{21} & X_{22} \end{bmatrix} = \begin{bmatrix} B_{11} & B_{12} \\ B_{21} & B_{22} \end{bmatrix} \begin{bmatrix} Y_{11} & Y_{12} \\ Y_{21} & Y_{22} \end{bmatrix} \quad (8)$$

Which assigns a formal structure for each disaggregated term presented by Equation 6:

$$\begin{bmatrix} X_{11} \\ X_{12} \\ X_{21} \\ X_{22} \end{bmatrix} = \begin{bmatrix} B_{11}Y_{11} + B_{12}Y_{21} \\ B_{11}Y_{12} + B_{12}Y_{22} \\ B_{21}Y_{11} + B_{22}Y_{21} \\ B_{21}Y_{12} + B_{22}Y_{22} \end{bmatrix} \quad (9)$$

For country 1, for example, whose output is represented by the first two equations (as $X_1 = X_{11} + X_{12}$ follows from Equation 6), is disaggregated as:

- X_{11}, that represents output used for domestic consumption, given by:
  - $B_{11}Y_{11}$, that represents the share used in producing final goods absorbed domestically, and
  - $B_{12}Y_{21}$, that represents the share used in producing intermediary products exported internationally, re-imported, and absorbed domestically.
- X_{12}, that represents output used for international consumption, given by:
  - $B_{11}Y_{12}$, that represents the share used in producing final goods absorbed internationally, and
  - $B_{12}Y_{21}$, that represents the share used in producing intermediary products exported internationally and absorbed internationally.

Where "domestic", in this case, refers to country 1, and "international" to country 2. The same analysis is valid for the second set of equations in Equation 8, when analyzing country 2.

Given that the IO matrix A_{ij} represents the required amount of intermediaries from j used in producing a marginal increase on total output in i, meaning, therefore, that for the unitary production of country 1's goods, that country requires A_{11} units of intermediary goods sourced domestically and A_{12} units of intermediary goods sourced internationally (similarly for country 2). Therefore, the share of domestic output that uses only domestic value addition done by each country, V_i, is given by the marginal increase net of the intermediaries used:

$$V_i = I - A_{ii} - A_{ij}, \qquad i,j = 1,2 \quad (10)$$

That can be represented in aggregated matricial form by the direct value-added coefficient matrix V in Equation 11.

$$V = \begin{bmatrix} V_1 & 0 \\ 0 & V_2 \end{bmatrix} \tag{11}$$

When combined with the Leontief inverse, it produces the value-added share matrix:

$$VB = \begin{bmatrix} V_1 B_{11} & V_1 B_{12} \\ V_2 B_{21} & V_2 B_{22} \end{bmatrix} \tag{12}$$

Where the main diagonal terms represent the domestic value-added share of all products domestically produced ($V_1 B_{11}$ for country 1, $V_2 B_{22}$ for country 2), while the off-diagonal terms represent the international value-added share of the same domestic production ($V_2 B_{21}$ for country 1, $V_1 B_{12}$ for country 2).

Note that the sum of each column is equal to 1, given that they represent the disaggregation on whether value is added domestically or internationally on each country. Thus,

$$V_1 B_{11} + V_2 B_{21} = V_1 B_{12} + V_2 B_{22} = 1 \tag{13}$$

The exports from one country (i) to another (j) is given by the last two terms of Equation 2:

$$E_{ij} = Y_{ij} + A_{ij} X_j, \qquad i, j = 1,2 \tag{14}$$

The total exports worldwide of country i is:

$$E_i = \sum_{j \neq i} Y_{ij} + A_{ij} X_j, \qquad i, j = 1,2 \tag{15}$$

Which is trivial for the two-country model, but useful for the subsequent generalization to any number of countries. The global exports aggregated matrix can be constructed as:

$$E = \begin{bmatrix} E_1 & 0 \\ 0 & E_2 \end{bmatrix} \tag{16}$$

Which can be combined with Equation 12:

$$VBE = \begin{bmatrix} V_1 B_{11} E_1 & V_1 B_{12} E_2 \\ V_2 B_{21} E_1 & V_2 B_{22} E_2 \end{bmatrix} \tag{17}$$

The diagonal elements embody the domestic value added in a country exports, the DVA measure of VAT, whilst off-diagonal elements embody the foreign value added in a country exports, the FVA measure of VAT.

A more thorough breakdown of exports into VA measurements comes from combining Equation 14 with the result from Equation 13, leading to the expanded form in Equation 18.

$$E_{ij} = \left(V_i B_{ii} + V_j B_{ji}\right)\left(Y_{ij} + A_{ij} X_j\right), \qquad i,j = 1,2 \qquad (18)$$

Which can be finally reorganized and expanded as: [3]

$$\begin{aligned} E_{ij} = {} & V_i B_{ii} Y_{ij} + V_i B_{ij} Y_{jj} + V_i B_{ij} Y_{ji} + V_i B_{ij} A_{ji} (I - A_{ii})^{-1} Y_{ii} \\ & + V_i B_{ij} A_{ji} (I - A_{ii})^{-1} E_{ij} + V_j B_{ji} Y_{ij} \\ & + V_j B_{ji} A_{ij} \left(I - A_{jj}\right)^{-1} Y_{jj} + V_j B_{ji} A_{ij} \left(I - A_{jj}\right)^{-1} E_{ji}, \end{aligned} \qquad i,j = 1,2 \qquad (19)$$

Before characterizing the terms in Equation 19, the model can be generalized to contain G countries, by expanding[4] the results found in Equations 17 and 19:

$$VBE = \begin{bmatrix} V_1 B_{11} E_1 & V_1 B_{12} E_2 & \cdots & V_1 B_{1G} E_G \\ V_2 B_{21} E_1 & V_2 B_{22} E_2 & \cdots & V_2 B_{2G} E_G \\ \vdots & \vdots & \ddots & \vdots \\ V_G B_{G1} E_1 & V_G B_{G2} E_2 & \cdots & V_G B_{GG} E_G \end{bmatrix} \qquad (17')$$

Thus, for any country i, DVA can be defined as the value-addition done by itself embedded on its own exports:

$$DVA_i = V_i B_{ii} E_i, \qquad i = 1, \dots, G \qquad (20)$$

The bilateral FVA can be defined as the value-addition done by any other country j embedded in i's exports:

$$FVA_{ij} = V_j B_{ji} E_i, \qquad i,j = 1, \dots, G; \; i \neq j \qquad (21)$$

And total FVA can be defined as the sum of all foreign value-addition embedded in i's exports:

$$FVA_i = \sum_{j=1, j\neq i}^{G} V_j B_{ji} E_i = \sum_{j=1, j\neq i}^{G} FVA_{ij}, \qquad i = 1, \dots, G \qquad (22)$$

Finally, the VAT measurements can be concluded by defining bilateral indirect value added, or DVX, as the value-addition done by i embedded in any other country j's exports:

$$DVX_{ij} = V_i B_{ij} E_j, \qquad i,j = 1, \dots, G; \; i \neq j \qquad (23)$$

[3] The step-by-step algebraic development can be seen in Koopman et al. (2010) and Koopman et al. (2014).
[4] Ibid.

While total DVX can be defined as the sum of all value-addition done by i embedded in global exports (other than its own):

$$DVX_i = \sum_{j=1, j\neq i}^{G} V_i B_{ij} E_j = \sum_{j=1, j\neq i}^{G} DVX_{ij}, \qquad i = 1, \dots, G \qquad (24)$$

The expansion of Equation 19 follows the same principle, but with some additional complexity due to its higher preciseness in breaking down exports:

$$\begin{aligned} E_i = \quad & V_i B_{ii} \sum_{j=1, j\neq i}^{G} Y_{ij} \\ & + V_i \sum_{j=1, j\neq i}^{G} B_{ij} Y_{jj} \\ & + V_i \sum_{j=1, j\neq i}^{G} \sum_{k=1, k\neq i,j}^{G} B_{ij} Y_{jk} \\ & + V_i \sum_{j=1, j\neq i}^{G} B_{ij} Y_{ji} \\ & + V_i \sum_{j=1, j\neq i}^{G} B_{ij} A_{ji} (I - A_{ii})^{-1} Y_{ii} \qquad i,j,k = 1, \dots, G \qquad (19') \\ & + V_i \sum_{j=1, j\neq i}^{G} B_{ij} A_{ji} (I - A_{ii})^{-1} E_i \\ & + \sum_{j=1, j\neq i}^{G} \sum_{k=1, k\neq i}^{G} V_k B_{ki} Y_{ij} \\ & + \sum_{j=1, j\neq i}^{G} \sum_{k=1, k\neq i}^{G} V_k B_{ki} A_{ij} \left(I - A_{jj}\right)^{-1} Y_{jj} \\ & + \sum_{k=1, k\neq i}^{G} V_k B_{ki} \sum_{j=1, j\neq i}^{G} A_{ij} \left(I - A_{jj}\right)^{-1} E_j, \end{aligned}$$

The expanded form no longer focuses only on exports from one country to another, by considering exports from one country globally (i.e., explicitly changing from E_{ij} to the more broad E_i, hitherto irrelevant since these were mathematically identical). The characterization of the terms is analogous, albeit generalized, to those in Equation 19:

The first six terms deal with the domestic content of exports, or what country i adds in value for its own exports. Of those, the first three represent domestic value absorbed by other countries:

- The first term is the domestic value in exports of final goods,
- the second term is the domestic value in exports of intermediaries absorbed by direct importers of them, and
- the third term (new, with regards to Equation 19) is the domestic value in exports of intermediaries absorbed by indirect importers of them (i.e., third parties, that previously did not exist).

The next three in this first set of terms represent the domestic value ultimately absorbed by the original country:

- The fourth term is the domestic value in exports of intermediaries absorbed domestically by reimporting final goods,
- the fifth term is the domestic value in exports of intermediaries absorbed domestically by reimporting intermediaries (i.e., to produce final goods absorbed domestically), and
- the sixth term is a double counting factor that arises from the trade of intermediaries.

The final three terms deal with the foreign content of exports, or what other countries add in value to i's exports:

- The seventh term is the foreign value in exports of final goods,
- the eight term is the foreign value in exports of intermediary goods, and
- the ninth term is a second double counting factor that arises symmetrically from the trade of intermediaries.

These breakdowns of exports presented in Equations 17 and 19 (and their generalizations) are, nevertheless, connected. In the broad definition previously established, DVA is equal to the sum of the first six terms, while FVA is equal to the sum of the last three.

Lastly, these measurements can be combined into indicators that provide in a broad sense the role that each country plays in GVCs. By considering the VAT measurements disaggregated by sectors, the position of country i's sector n in GVC can be estimated with:

$$Position_{in} = \ln\left(1 + \frac{DVX_{in}}{E_{in}}\right) - \ln\left(1 + \frac{FVA_{in}}{E_{in}}\right) \qquad \begin{matrix} i = 1, \dots, G \\ n = 1, \dots, N \end{matrix} \qquad (25)$$

A country that is upstream in any sector should be more active in adding value to other countries exports, thus making the first term bigger, and the index positive. Conversely, a country downstream in any sector should have a larger participation of other countries adding value on its exports, thus making the second term bigger, and the index negative. A complementary indicator measures the participation of country i's sector n in its GVC, estimated by:

$$Participation_{in} = \frac{DVX_{in} + FVA_{in}}{E_{in}} \qquad \begin{matrix} i = 1, \dots, G \\ n = 1, \dots, N \end{matrix} \qquad (26)$$

More active countries should either add value to or have value added to their exports, making the numerator larger, whilst inactive countries generate most of the value exported internally, thus making the numerator smaller (relative to exports).

2.2 QUANTITATIVE MODELS FOR EVALUATING VALUE-ADDED TRADE

There are different quantitative models commonly used in empirical literature to evaluate the relationship between different quantitative and qualitative variables and their impact on trade in general. In this section, two different approaches are presented: in subsection 2.2.1, the more usual Gravitational model of trade is presented, whilst in subsection 2.2.2, artificial neural networks are described as a more modern way of dealing with lots of data, such as typically is the case for trade datasets.

2.2.1 Gravitational model of trade

In 1687, the English mathematician and physicist Sir Isaac Newton published "*Philosophiæ Naturalis Principia Mathematica*", in which he hypothesized a structural form for a law of universal gravitation, where the relative force that two bodies exert on one another is proportional to their masses and inversely proportional to the square of their distances (NEWTON, 1846):

$$F_{ij} = G m_i m_j r_{ij}^{-2} \qquad (27)$$

Where

- F_{ij} is the gravitational force acting between objects i and j,
- m_i is the mass of object i,

- r_{ij} is the distance between the center of mass of objects i and j, and
- G is a fixing, “gravitational”, constant.

Almost three centuries later, in 1962, the Dutch economist Jan Tinbergen adapted the Newtonian framework whilst in the process of trying to model how countries trade, in his book “*Shaping the World Economy: Suggestions for an International Economic Policy*”. He proposed that, just as bodies are attracted based on their relative masses and distance, so should countries trade be attracted, thus developing ties through bilateral trade flows, in a manner proportional to their economic size, generally measured through gross domestic product (GDPs), and geographical distance (TINBERGEN, 1962).

These empirical observations lead to the translation of Newtonian gravity into the “Gravitational model of trade”, which can be expressed in a generalized form as:

$$T_{ij} = AY_i^{\beta_1}Y_j^{\beta_2}d_{ij}^{\beta_3} \tag{28}$$

Where

- T_{ij} is the trade flow between countries i and j,
- Y_i is the GDP of country i,
- d_{ij} is the distance between countries i and j, and
- A, β_1, β_2 and β_3 are the model’s parameters.

Naturally, when $\beta_1 = \beta_2 = 1$ and $\beta_3 = -2$ the model is in the Newtonian form presented in Equation 27. As noted by Krugman et al. (2018), the Gravitational model produces good estimations since, in loose terms, larger countries have larger incomes, and thus the capacity to spend more on imports, while exporting more since they also possess a larger base of products available (in both quantity and types). Moreover, trade also seems to be broadly inverse to distance (i.e., β_3 tends to be negative, approximating the model to that of Newton), since trade costs negatively affect the viability of longer distance flows, and closer partners should more easily be capable to establish trade connections between themselves.

The theoretical groundwork for the Gravitational model originated with the seminal works of Anderson (1979) and Bergstrand (1985; 1989). Nowadays, many theoretical structures exist for the modern Gravitational equation (HEAD & MAYER, 2014). Hereafter will be presented one of those, as developed by Anderson and Van Wincoop (2003), from Equation 29 throughout Equation 42, henceforth called the “AVW” Gravitational model form:

Assuming a N countries world, each specialized in producing only one good with fixed supply. All goods are, therefore, differentiated by origin. If preferences are identical and homothetical, consumers from country j maximize the constant elasticity of substitution (CES) utility function:

$$U_j = \left(\sum_{i}^{N} \beta_i^{\frac{1}{\sigma}} c_{ij}^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}} \qquad i,j \in N \tag{29}$$

Where

- U_j is the utility of consumers from country j,
- c_{ij} is the consumption of country i's goods by consumers from country j,
- β_i is the distribution parameter of the CES, and
- σ is the elasticity of substitution between all N goods.

The consumers are subject to the budget constraint: [5]

$$y_j = \sum_{i}^{N} p_{ij} c_{ij} \tag{30}$$

Where

- p_{ij} is the price of country i's goods to consumers from country j, and
- y_j is the income of country j's residents.

The international price, p_{ij}, can be explicitly expressed as:

$$p_{ij} = p_i \tau_{ij} \tag{31}$$

Where

- p_i is the price of country i's goods net of trade costs, and
- τ_{ij} is a factor summarizing the trade costs implied in a transaction between i and j.

The trade costs, τ_{ij}, are incurred by the sellers (exporters) in country i, but are shifted onwards to the buyers (importers) in country j. They are recursively defined as the excess cost incurred

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[5] For simplicity, the set membership of i and j is not represented hereafter, but the same set is ubiquitous in all equations throughout this subsection.

by the exporters for each unit of good sent to the importers, measured as equal to $\tau_{ij} - 1$ of exporter goods (e.g., if $\tau_{ij} = 1.5$, then an unit sent from i to j costs, just due to this transaction, an additional 0.5 i good).

Thus, the nominal value of trade, or the total payment from residents of j to residents of i, is:

$$x_{ij} = p_{ij}c_{ij} \tag{32}$$

Equations 30 and 32 can be combined with market clearance condition:

$$y_i = \sum_{j}^{N} x_{ij} \tag{33}$$

The maximization of Equation 29 with the budget constraint in Equation 30 yields the relation of trade from country i to j: [6]

$$x_{ij} = \left(\frac{\beta_i p_i \tau_{ij}}{P_j}\right)^{1-\sigma} y_j \tag{34}$$

Where P_j is defined as the "multilateral resistance term" (MRT) to trade of country j, given by:

$$P_j = \left[\sum_{i}^{N} \left(\beta_i p_i \tau_{ij}\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}} \tag{35}$$

Combining Equations 33 and 34:

$$y_i = \sum_{j}^{N} \left(\frac{\beta_i p_i \tau_{ij}}{P_j}\right)^{1-\sigma} y_j \tag{36}$$

If exporters face the same costs to import bilaterally, that is, if costs are symmetric:

$$\tau_{ij} = \tau_{ji} \tag{37}$$

Then, the trade costs function can be generalized: [7]

$$\beta_i p_i P_i = \theta_i^{\frac{1}{1-\sigma}} \tag{38}$$

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[6] The step-by-step development can be seen in Anderson and Van Wincoop (2003).
[7] Ibid.

Where θ_i represents the percentage of country's i income on total world income:

$$\theta_i = \frac{y_i}{\sum_i^N y_i} \tag{39}$$

Finally, Equation 38 can be substituted into Equation 34, deriving the Gravitational equation in the AVW form:

$$x_{ij} = \frac{y_i y_j}{\sum_i^N y_i}\left(\frac{\tau_{ij}}{P_i P_j}\right)^{1-\sigma} \tag{40}$$

That can be log-transformed into the linear form (BACCHETTA, et al., 2012):

$$\ln(x_{ij}) = k + \ln(y_i) + \ln(y_j) + (1-\sigma)\ln(\tau_{ij}) - (1-\sigma)\ln(P_i) - (1-\sigma)\ln(P_j) \tag{41}$$

Where k is the opposite of the natural log of world income. The MRTs are given by:

$$P_j^{1-\sigma} = \sum_i^N P_i^{\sigma-1}\theta_i \tau_{ij}^{1-\sigma} \tag{42}$$

The AVW framework, therefore, establishes using CES utility the Gravitational relation between trade flows due to the sizes of the economies trading and a composite term of bilateral barriers and incentives to trade. Moreover, it complements the structural form with a specific term for measuring each country openness to trade with the rest of the word, the MRTs P_i and P_j. By adjusting trade elasticity, setting the MRTs to one, and if τ_{ij} is proxied with the distance d_{ij}, Equation 40 can be reduced to the original Gravitational form of Tinbergen (1962) in Equation 28.

However, as noted by the Bacchetta et al. (2012), the inclusion of MRTs is structural in reducing bias in the model, mainly due to correlation of the error with trade costs in their absence. A new general form for the trade equation, therefore, is usually so constructed by including these unilateral terms, and in general is known as "Structural Gravity" (HEAD & MAYER, 2014):

$$x_{ij} = S_i M_j \phi_{ij} \tag{43}$$

Where

- S_i characterizes the exporter market (in AVW given by y_i and P_i),
- M_j characterizes the importer market (in AVW given by y_j and P_j), and

- ϕ_{ij} characterizes bilateral openness to consumption in j by producers in i (in AVW given by τ_{ij}).

Several approaches have been developed arriving at functional forms that can be reduced to the Structural Gravitational model, most of which are presented in Head and Mayer (2014), besides the previously presented AVW. A general approach is to consider the gross expenses of the importer:

$$x_j = \frac{x_{ij}}{\pi_{ij}} \tag{44}$$

Where π_{ij} is the share of expense allocated to country i (such that $\sum_i^N \pi_{ij} = 1$), so that Equation 43 can be expanded as:

$$x_{ij} = \frac{y_i}{\Omega_i}\frac{x_j}{\Phi_j}\phi_{ij} \tag{45}$$

Where

- Ω_i is generally defined as the market potential or accessibility of country i, and
- Φ_j is generally defined as the market competitiveness or set of opportunities of country j.

Equations 43 and 45 can naturally be reduced to the AVW form following Anderson and Van Wincoop's (2003) assumptions of balanced trade, leading to $x_j = y_j$, symmetric trade costs that replace the bilateral openness factor, leading to $\phi_{ij} = \tau_{ij} = \tau_{ji} = \phi_{ji}$, which implies $\Omega_i = \Phi_i$[8] and, thus, $S_i = M_i$. This symmetry in the assumptions of the AVW form is why it is also known as the "symmetric Gravity equation" (HEAD & MAYER, 2014).

For estimations, Equation 41 can be rewritten in general parameters in the stochastic form:

$$\ln(x_{ij}) = \beta_0 + \beta_1 \ln(y_i) + \beta_2 \ln(y_j) + \beta_3 \ln(\tau_{ij}) + \beta_4 \ln(P_i) + \beta_5 \ln(P_j) + \ln(\varepsilon_{ij}) \tag{46}$$

Empirical uses of the Gravitational model in the stochastic form adopt different strategies for measuring τ_{ij} and the MRTs[9]. Bacchetta et al. (2012) provides a review of empirical research

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[8] The step-by-step development can be seen in Head and Mayer (2014).
[9] Some examples of empirical strategies used in proxying these parameters are presented in section 2.3.

done and notes that trade costs typically are proxied with a multidimensional measurement of distance, both in physical terms, with d_{ij}, but also in cultural terms, with dummies on whether countries i and j are contiguous, share a common language, have or had a common colonizer, are or ever where in a colony-colonizer relationship, are landlocked, and if they are part of a PTA. Head (2003) discusses the logic behind these choices of parameters by arguing how "distance" (either literally in spatial terms or socially in cultural terms) drives higher costs, so that "closer" countries should be more likely to trade with one another. This is succinctly described in Table 2. More specifically, a typical form used for trade costs is (BACCHETTA, et al., 2012):

$$\tau_{ij} = d_{ij}^{\delta_1} e^{\delta_2 cont_{ij} + \delta_3 lang_{ij} + \delta_4 ccol_{ij} + \delta_5 col_{ij} + \delta_6 landlock_{ij} + \delta_7 PTA_{ij}} \qquad (47)$$

Where

- $cont_{ij}$ is a dummy variable equal to one whenever countries i and j are contiguous,
- $lang_{ij}$ is a dummy variable equal to one whenever countries i and j share a common language,
- $ccol_{ij}$ is a dummy variable equal to one whenever countries i and j share or ever shared a common colonizer,
- col_{ij} is a dummy variable equal to one whenever countries i and j are or were in a colony-colonizer relationship,
- $landlock_{ij}$ is a dummy variable equal to one whenever one or both countries i and j are landlocked,
- PTA_{ij} is a dummy variable equal to one whenever countries i and j are in a PTA, and
- δ_i, for $i = 1, \ldots, 7$, are stochastic parameters.

When considering MRTs, a simple strategy widely used for controlling them is with the use of fixed-effects (FE) estimators for each country in each role (i.e., when each is an importer or exporter), or in a combined manner, with FE for country-pairs (BACCHETTA, et al., 2012). The latter case has the advantage of controlling for the heterogeneity of pairs but is usually discarded (or replaced with random effects estimators) when using the trade costs form given by Equation 47 as to avoid perfect multicollinearity.

Table 2 – Distance costs and trade proxies

Distance costs	Description
Transport cost	Consuming from farther away imply higher transportation costs, such as shipping costs and higher trade insurance, thus negatively impacting trade.
Time cost	Trade in perishable goods and services is evidently negatively affected by distance if their travel is not sufficiently timely by spoiling/decomposing/non-storability; lengthy transportations also increase the exposure to risks not connected to neither production nor consumption, which can drive up costs (such as trade insurance) and the risk of loss of demand at arrival, as consumers are no longer interested or able to purchase the imported goods.
Synchronization cost	With the rise of unbundled production, in order for assembly to occur without bottlenecks due to, for example, a lack of parts, there is a higher cost of either being sure that everything arrives when required (e.g., with higher shipping fees) or to have local intermediary stockpiles (thus incurring in renting costs, supervision costs etc.).
Communication cost	Distance between consumer and producer introduces difficulties in transmitting informal communication that may be essential, for example, to guarantee the correct specification of the traded content, which may not be easily transmitted digitally.
Transaction cost	Distance also makes it more difficult for buyers to be knowledgeable of possible suppliers, thus reducing opportunities for trade to occur, and increases the asymmetry on the content of trade, thus, for example, decreasing the development of trust between partners.
Cultural cost	Finally, cultural "distance" can severely impact trade by hampering the ability of possible partners to communicate effectively due to different languages, increasing difficulties with divergent trade styles and legal/political structures and incentives, among other complicating factors.

Source: Adapted from Head (2003).

However, as shown by Silva and Tenreyro (2006), the linearization of the model with the log-transformation used in estimations, usually through ordinary least squares (OLS), has two main issues: zero trade flows become unanalyzable in this functional form, and it has the potential of introducing correlation of the error with the covariates in the presence of heteroskedasticity on the sample.

The first issue is simple to assess; logarithmic functions are not defined at zero. The second issue arises from the work of Danish mathematician Johan Jensen, that in 1906 proved “Jensen’s inequality” (JENSEN, 1906), which, when applied to probability theory, implies that:

$$\mathbb{E}[\ln(x)] \neq \ln(\mathbb{E}[x]) \tag{48}$$

That is, the expected value of the logarithm of a random variable is different from the logarithm of the expected value of the same random variable. The stochastic form in Equation 44 can be rewritten in the original multiplicative form as:

$$x_{ij} = \left(e^{\beta_0} y_i^{\beta_1} y_j^{\beta_2} t_{ij}^{\beta_3} P_i^{\beta_4} P_j^{\beta_5}\right) \varepsilon_{ij} \tag{49}$$

Estimating through OLS implies expecting that the error ε_{ij} is statistically independent to the regressors. However, the expected value of the logarithm of the error term depends not only on its mean, as shown in Equation 48, but also on higher-order moments of the distribution (SILVA & TENREYRO, 2006).

Thus, in the presence of heteroskedasticity in the sample, the logarithm of the error may be correlated to the regressors, which removes consistency from the results of the OLS regression, resulting in biased estimations of the estimated elasticities.

An alternative, therefore, presented by Silva and Tenreyro (2006), is to estimate the parameters with the dependent variable in levels, using a Poisson pseudo-maximum likelihood (PPML) estimator, by solving the set of first-order conditions for the estimated parameters $\widehat{\beta_\iota}$, as represented by Equation 50.

$$\begin{aligned}\sum_{i}^{N}\sum_{j}^{N}\{x_{ij} - \exp[\widehat{\beta_0} + \widehat{\beta_1}\, ln(y_i) + \widehat{\beta_2}\, ln(y_j) + \widehat{\beta_3}\, ln(\tau_{ij}) \\ + \widehat{\beta_4}\, ln(P_i) + \widehat{\beta_5}\, ln(P_j)]\}(y_i y_j \tau_{ij} P_i P_j) = 0\end{aligned} \tag{50}$$

This structure solves the previously detected issues, but depends on the assumption that the conditional variance of the dependent variable is proportional to the conditional mean, that is:

$$V\left[x_{ij} \middle| y_i, y_j, \tau_{ij}, P_i, P_j\right] \propto \mathbb{E}\left[x_{ij} \middle| y_i, y_j, \tau_{ij}, P_i, P_j\right] \tag{51}$$

Which may not necessarily be the case. This can be controlled for, however, by using Eicker-White robust covariance matrix estimators (SILVA & TENREYRO, 2006) while performing the estimation.

Finally, the model can also be fitted for observations spanning a time horizon rather than only cross-sectional data. This expansion for time data on the original stochastic form presented in Equation 46, considering the trade costs form given by Equation 47 and the presentation in levels of Equations 49 and 50, leads to the expanded Gravitational model:

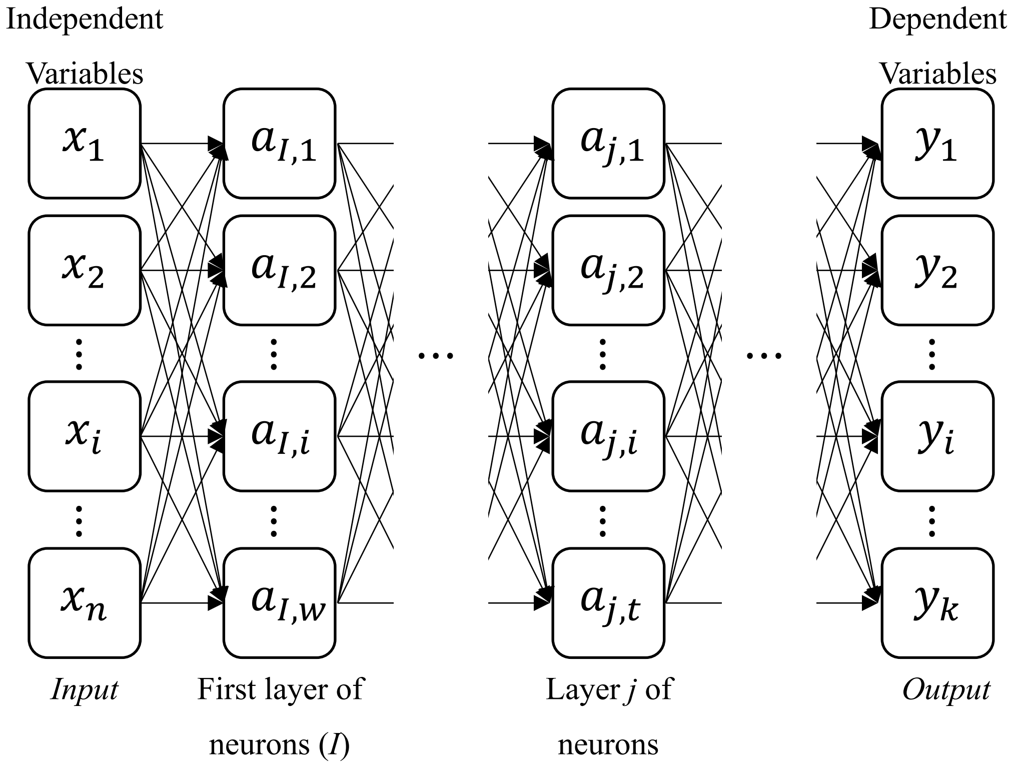
$$\begin{aligned} x_{ijt} = \exp\big[&\beta_0 + \beta_1\, ln(y_{it}) + \beta_2\, ln\big(y_{jt}\big) + \beta_3\, ln\big(d_{ij}\big) + \beta_4\, ln(P_{it}) \\ &+ \beta_5\, ln\big(P_{jt}\big) + \beta_6 cont_{ij} + \beta_7 lang_{ij} + \beta_8 ccol_{ij} \\ &+ \beta_9 col_{ij} + \beta_{10} landlock_{ij} + \beta_{11} PTA_{ij}\big]\, \varepsilon_{ijt} \end{aligned} \tag{52}$$

2.2.2 Artificial neural networks

Artificial neural networks (ANN) are non-parametric, statistical models that are useful in modeling complex problems in which the relationships between the dependent variables may be hard, or impossible, to come up with in a straightforward functional form (HO, CHAN, YIP, & TSANG, 2020). In that sense, ANNs are useful as being fast in testing and eventually finding general relationships within datasets.

As illustrated by Wohl and Kennedy (2018), the input dataset, that is, the entry or independent variables, can be seen as “neurons”, or nodes, that “feed” a secondary layer of nodes through a function of any sort, that combines the entry nodes with different weights, or coefficients, into a new value. Additional layers can be “stacked” on top of this secondary layer, and new connections can be drawn between the intermediary layers (or “hidden layers”), until a final node (or set of nodes) is reached. The dimensionality of each layer, measured as the number its nodes, defines its width, and the overall number of layers its depth (GOODFELLOW, BENGIO, & COURVILLE, 2016). An illustration of the architecture of a generic neural network can be seen on Figure 8 - General architecture of an ANN.

Figure 8 - General architecture of an ANN



Source: Adapted from Wohl and Kennedy (2018).

In this architecture, each node from each layer is a generic function that takes in all previous nodes, each weighted by a unique coefficient:

$$a_{j,i} = f\left(\sum_{k=1}^{n} \theta_{j,k}^{(i)} a_{j-1,k}\right) \qquad \begin{matrix} i = 1, \dots, n \\ j = I, \dots, N \end{matrix} \tag{53}$$

Where

- $a_{j,i}$ is the node i at layer j,
- $f(\cdot)$ is the function that describes the relationship between each layer, often known as the "activation function", and
- $\theta_{j,k}^{(i)}$ is the coefficient that weights the node k of layer $j-1$ to the node i of layer j.

Most ANNs use a logistic activation function, that is,

$$f(x) = \frac{1}{1+e^{-x}} \tag{54}$$

Since it linearly and smoothly maps the entire domain of the independent variable into an output between 0 and 1, which can be later fed easily into any number of subsequent layers of additional logistical (or sigmoidal) functions. Thus, without any intermediary layers the model reduces to a simple logistic regression (WOHL & KENNEDY, 2018).

These models are also known as feedforward networks, due to their unidirectional flow of data from input layer, through the hidden layers, and into the output variables. The most defining feature of an ANN is in arriving at solutions to problems, such as the efficient modelling and forecasting of trade and international productivity integration, by substituting the standard approach of developing precise functional forms to, as previously mentioned, benefitting from highly sophisticated modern computing in order to optimize highly generic activation functions through pre-determined optimization algorithms and underlying cost functions and trying to best fit the largest amount of data possible (GOODFELLOW, BENGIO, & COURVILLE, 2016).

However, the complexity and hidden connections between different layers and nodes typically causes the most standard measurements of model error and minimization procedures to become nonconvex, and no convergence guarantees are easily available (GOODFELLOW, BENGIO, & COURVILLE, 2016). Thus, specific approaches are used to assess the current level of fit to the data of the model, given the entry parameters, and to enhance it.

Mean squared error (MSE) loss is the standard approach in many computing packages (BROWNLEE, 2019), and is evaluated as:

$$MSE = \frac{\sum_{i=1}^{N}(y_i^* - \hat{y}_i)^2}{N} \tag{55}$$

Where

- y_i^* is the actual value of variable y observed at i,
- $\hat{y}_i$ is the predicted value of variable y estimated at i, and
- N is the size of the observed population.

This preference is due to the cost function being usually derived from training via maximum likelihood, such as is the basis for standard OLS and econometric estimations. In this case, assuming a normal distribution of the dependent variables given the independent variables, the negative log-likelihood reduces to a scaled down MSE cost function (GOODFELLOW, BENGIO, & COURVILLE, 2016).

The optimization of the input parameters, given the underlying current cost level of the model, is most typically done through gradient-based optimization algorithms (BROWNLEE, 2017). This strategy is based on the general notion that, given a continuous function

$$f(x): \mathbb{R} \to \mathbb{R} \tag{56}$$

and its derivative $f'(x)$, since

$$f(x+\varepsilon) \approx f(x) + \varepsilon f'(x) \tag{57}$$

an initial point $y^{(1)} = f(a)$ can be minimized by marginally reducing the input quantity a to find a smaller output:

$$y^{(2)} = f\left(a - \varepsilon^{(2)} f'(a)\right) \tag{58}$$

which leads to a monotonic decreasing sequence of $y^{(i)}$, given the selected set of steps $\varepsilon^{(i)}$. In more general terms, given any function:

$$f(x): \mathbb{R}^n \to \mathbb{R} \tag{59}$$

the same logic can be applied through its gradient $\nabla_x f(x)$, in a method known as gradient descent (GOODFELLOW, BENGIO, & COURVILLE, 2016):

$$\vec{y}^{(2)} = \vec{y}^{(1)} - \varepsilon \nabla_x f(\vec{a}) \tag{60}$$

The application of gradient descent in machine learning models comes via several different approaches, the most straightforward being known as the “batch gradient descent”, which uses the notion presented in Equation 66 to update the model’s parameters given the topology of the its surface, that is, by moving against the gradient, or “downhill” (RUDER, 2016):

$$\theta^{(i+1)} = \theta^{(i)} - \varepsilon \nabla_\theta J\left(\theta^{(i)}\right) \tag{61}$$

Where

- $\theta^{(i)}$ are the model’s parameters at step i,
- ε is the step size, or learning rate, chosen, and
- $J(\cdot)$ is the cost function minimized

Batch gradient descent is based on updating the parameters given the entire dataset and does converge to the global minimum on convex error surfaces. A more typical strategy, however, is through stochastic gradient descent (SGD), which performs parameters updates on each training data point $x^{(j)}$ and $y^{(j)}$ (RUDER, 2016):

$$\theta^{(i+1)} = \theta^{(i)} - \varepsilon \nabla_{\theta} J\left(\theta^{(i)}, x^{(j)}, y^{(j)}\right) \quad (62)$$

Which typically accelerates the algorithm at the expense of being more volatile as different data points drive the parameters in stochastic directions. This fluctuation can be useful, however, as it can drive the parameter curve outside of local minima on the error surface to more optimal configurations when such volatility-induced overshooting happens. A combined approached, also known as “mini-batch gradient descent”, combines the overall effectiveness of smooth parameter optimization of the batch gradient descent model with the overall speed and capability to find new minimal points of SGD by performing updates on sets of n data points (RUDER, 2016):

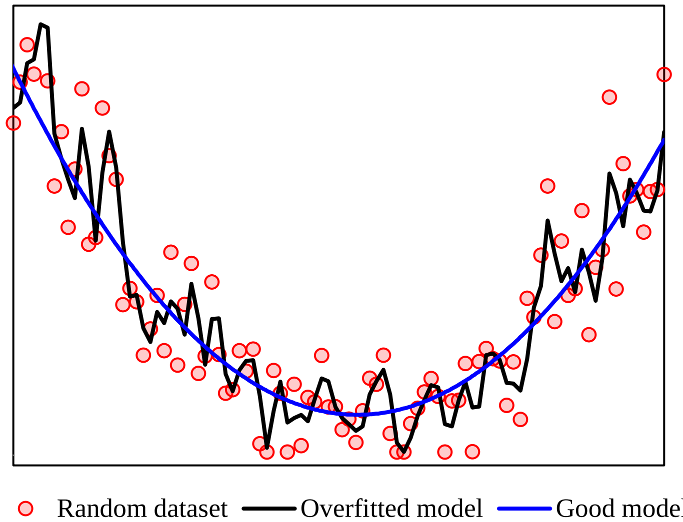
$$\theta^{(i+1)} = \theta^{(i)} - \varepsilon \nabla_{\theta} J\left(\theta^{(i)}, x^{(j:j+n)}, y^{(j:j+n)}\right) \quad (63)$$

However, more complex and optimized algorithms have been shown to be more efficient in taking into consideration (1) the overall features of the error surface, (2) the effects of variations on the parameters and (3) the effects of variations on the learning rate on the performance of minimization of the error (RUDER, 2016). Among such models, Adam, or Adaptive Moment Estimation, is generally the most used in regressions due to its overall efficiency when compared to other algorithms (BROWNLEE, 2017), and differs from others by including in its updating formula for parameters a record of past gradients through an exponential decay average measurement of past squared and non-squared gradients (RUDER, 2016).

Regardless of the cost function and optimization algorithm, a parallel issue that must be dealt with is the general applicability of the results found given the possible high degree of dependency of the parameters with the underlying test data (CAWLEY & TALBOT, 2010). A general representation of this issue is represented in Figure 9.

This problem deals, therefore, with the capability of the generated model in being applicable to analyze unseen data after its development, and is a direct measure of its generalization towards being able to express more general relationships between input and output variables, and not in only mapping the given entry data into the given output data. In the “overfitted model” illustrated in Figure 9, for example, while it should be expected to possess a much lower “error” when compared to the “good model”, its usage in accurately predicting new data may be questioned, when considering its volatility and dependency on the dataset used in estimation.

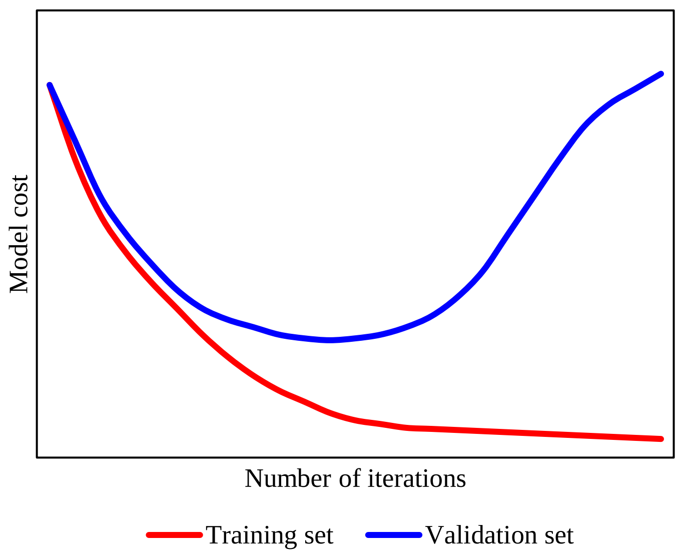
Figure 9 – Overfitted versus good model



Source: Author elaboration.

Thus, when considering the overall performance of the model as it progresses during development, by optimizing and minimizing its cost, it “fits” increasingly more the given data, and becomes increasingly more able to react to patterns of the dependent variables. However, this generalization capability decreases as the model becomes too fitted to the data being used in training. A general representation of the curvature of the cost of the model while being successively trained on a “training set”, and the expected performance on an independent “validation set” of data are represented on Figure 10.

Figure 10 – Model cost on increasing iterations on training and validation sets



Source: Author elaboration.

A strategy for dealing with and measuring overfitting of the model is k-fold cross validation, which randomly divides the data into k subsets, or “folds”, of approximately equal size, and iteratively holds each fold out of the remaining dataset as a validation set while the remaining $k - 1$ folds are used as a training set for the model (CAWLEY & TALBOT, 2010). Thus, as each data point is always assigned to a single fold, the entirety of the entry data is used $k - 1$ times for training and once for validation (BROWNLEE, 2018).

2.3 LITERATURE ON THE IMPACTS OF PREFERENTIAL TRADE AGREEMENTS ON GLOBAL VALUE CHAINS

Surveying recent empirical literature, a great volume of research has been done in measuring the impacts on GVCs from PTAs, with many studies using the Gravitational framework as the basis for the econometric evaluation, and only one having attempted to use a neural network in the same scenario. A preliminary scan of the literature shows this increasing mass of research on the past few years, as summarized in Table 3.

A seminal work on this intersection comes from Antràs and Staiger (2012), that developed a theoretical model aimed at understanding the role played by trade agreements in unbundled production. Key conclusions found by the authors are that the demands of such production networks are not met uniquely by the hitherto standard multilateral approach of “reciprocity” and “non-discrimination”, and deeper harmonization of policies are required to increase overall effectiveness. This served as a framework for many empirical studies on how PTAs impact gross trade and VAT, and particularly the role played on this impact by their depth (usually measured as the number of policy areas included on the agreement, and their possible enforceability).

Conversely, in empirical work, a complementary seminal study is that developed by Baier and Bergstrand (2007), in which the authors study bilateral trade flows gravitationally regressed on GDPs, distance, language in common, contiguity and the presence of a PTA, in the period between 1960 and 2000, with a sample of 96 potential trading partners. They find a positive pressure from PTAs on the volume of trade between partners, confirming previous observations on literature. Additionally, however, the authors discuss the bias-inducing impact of endogeneity in the standard Gravitational trade equation, particularly when considering the PTA dummy on cross-sectional data. In this regard, panel analyzes should help in controlling for such factors, when considering solutions such as fixed and random effects estimators.

Table 3 – Articles published on PTAs and GVCs on the last decades

Years	PTA	GVC
2004-07	37	30
2008-11	116	100
2012-15	174	129
2016-19	237	461

Source: Web of Science. Note: search terms for each category included both abbreviated and unabbreviated terms, search categories included "economics, business, management, international relations, political science, business finance and law".

An analysis of the main findings of empirical studies will be presented hereafter, with most studies building on the conclusions drawn by Antràs and Staiger (2012) and Baier and Bergstrand (2007). In a not exhaustive coverage of the literature, the works here covered are those by Hayakawa and Yamashita (2011), Orefice and Rocha (2013), Johnson and Noguera (2017), Rubínová (2017), Boffa et al. (2018), Laget et al. (2018), and Osnago et al. (2020).

In empirical terms, on the sample of researches previously mentioned, the development set forward by Johnson and Noguera (2017) marks a pivotal moment on later studies by, through the establishment of a theoretical framework and subsequent empirical analysis, driving the shift of Gravitational analyzes when trying to understand GVCs to VA variables, claiming (and demonstrating empirically) that increasingly more standard trade measurements are losing its capacity to properly explain VAT.

Thus, after this work, most of subsequent research follows in its footsteps, with similar strategies of using VA measurements as dependent variables on Rubínová (2017), Boffa et al. (2018) and Laget et al. (2018). Earlier research uses varied approaches, with some, such as Hayakawa and Yamashita (2011) and Orefice and Rocha (2013) employing the same approach initially set forth by Ng and Yeats (1999), of using "trade in parts and components" as a subset of gross trade disaggregated on the relevant categories in the SITC 3rd revision system, as mentioned in section 2.1. Baier and Bergstrand (2007) employs gross trade (more closely resembling the traditional Gravitational model), while Osnago et al. (2020) tries to capture the verticalization of value chains internationally by studying revenues from international subsidiaries of German, Japanese and American firms sent home.

There is a wider variability when concerning independent variables. All studies in this sample recognize the endogeneity problem discussed by Baier and Bergstrand (2007), and thus use FEs to control for this issue. Orefice and Rocha (2013), Johnson and Noguera (2017), Rubínová (2017), Boffa et al. (2018) and Laget et al. (2018) all omit most of the Gravitational variables presented in Equation 47 for proxying trade costs, while the remaining studies use heterogeneous combinations of GDPs, distance, and the dummies for contiguity, language in common and colonial relationship. The most unique variables are in Hayakawa and Yamashita (2011), that includes the volatility of exchange rates between partners, and Osnago et al. (2020), that includes the level of rule of law in the bilateral pair.

Nevertheless, all studies contain some measurement for the presence of PTAs, as to gauge its impact on VC trade, among the independent variable set. There is also heterogeneity on the approaches used for measuring this presence: a simple dummy signaling its presence; separate dummies for different types of agreements; or count variables for the depth of the agreement (measured as some combination of the number of policies included). In general, regardless of the approach followed, all studies find a positive coefficient connecting the presence of an agreement to VAT or trade in parts and components.

Hayakawa and Yamashita (2011) finds that PTA increases gross trade on the short run, but in parts and components only on the long run. Orefice and Rocha (2013) introduce the measurement of different depths of agreements and finds that deeper PTAs significantly increase trade in parts and components (even in the short run). Additionally, they also find that deeper agreements are even more relevant in industries (by them identified as) beneficiated by deeper levels of policy harmonization (e.g., automotive). Conversely, they also find that increasing levels of production sharing, as measured with trade in parts, also appears to increase the probability of partners to sign deeper agreements.

Osnago et al. (2020) finds that deep PTAs increases FDIs (by them measured as financial flows between firms international subsidiaries and headquarters in Germany, Japan and the USA), but that the types of policies included in the agreements may be a more relevant factor in vertical integration expansion, rather than simply signing an agreement. Johnson and Noguera (2017) find that PTAs negatively impact the rate of VA to gross trade in bilateral partners. The decline of the ratio, albeit heterogeneous in different sectors (impacting mainly in manufacturing industries) and countries (predominant in emerging markets), imply a rising unreliability on gross trade measurements for understanding the integration of countries, since these become enlarged due to rising double-counting figures (and higher order moments) generated by the rise of border-crossings by production. Deep agreements (measured by type, i.e., Customs Unions – CUs – and Common Markets – CMs) tend to result in even faster declines of the ratio, as do bilaterally closer partners (generally in Regional Trade Agreements – RTAs).

Rubínová (2017) uses a disaggregation of flows into “North” and “South” countries (i.e., developed and developing/emerging), and among all flows, finds a positive pressure from deeper PTAs on increasing VAT in general. On its North-South disaggregation, the research notes that while deeper agreements do enhance trade in all directions, shallow PTAs still are capable to provide a boost in some directional flows. Moreover, provisions regarding services are seen to have a large impact on the increasing the participation of South countries on GVCs, and investment provisions seem to be crucial for increasing the participation of the partners in upstream production stages.

Boffa et al. (2018) finds that deeper agreements have a relatively greater effect on GVCs than shallow PTAs and BITs on their own. They also find that even when “average” depth deals (i.e., a PTA and a BIT) are combined, they still have a smaller effect that a single “deep” agreement could have. As found by Rubínová (2017), they also note the apparent particular importance of investment provisions as enablers of integration via higher levels of VAT. BITs are found to impact more backwardly (i.e., using foreign components on exports) while deep PTAs impact both directions (i.e., also providing components for others’ exports).

Laget et al. (2018) also finds that deeper agreements impact backward and forward, or “bidirectional”, links, while also noting the important role of such agreements for higher VA industries (such as the automotive). On the content of agreements, they find that WTO-X policies appear to be particularly beneficial for incentivizing North-South VAT, and, among those specially the competition and investment provisions, while WTO+ policies appear to stimulate South-South VAT.

Concerning the usage of ANNs to model and interpret international trade data, the studies by Wohl and Kennedy (2018), Ho et al. (2020) and Dumor and Li (2019) are among the few already dedicated in trying to harness the advances in modern computing into tackling this international economic and production organization problem of understanding the effective drivers of growth in such an extremely complex environment of deeply intertwined variables.

Thus, and despite the small amount of work already developed, the findings by the previously mentioned authors showed promising results when considering the gains of efficiency in accurately modeling and predicting the levels of trade between partners. Dumor and Yao (2019) argument that, due to the capabilities of the neural networks in capturing first and higher-order complex relationships between the dependent variables through the information on the underlying training data, its outputs end up being more efficient, even though not easily broken apart, and in general a more efficient tool for policymakers and researches to use, given the availability of more computing power and platforms for testing relationships between datasets.

Finally, Ferraz and Ribeiro (2018) also provided some key insights for this research, particularly on their characterization of the Southern Common Market's recent developments on GVCs, even though their study focused on modelling through a computable general equilibrium (though through Gravitational estimation of some parameters) the possible impacts that a trade agreement between that bloc and China could have on all countries involved. Nevertheless the different methodology used, the study still finds a positive impact, in terms of GVC bidirectional integration arising from the formation of PTAs among the relevant partners.

3 EUROPEAN UNION – MERCOSUR INTEGRATION ANALYSIS

To understand the scenario where the new trade agreement between European Union and Southern Common Market arises, this chapter analyzes both blocs and describes some of their modern trends on global trade terms. With this objective, section 3.1 briefly overviews both the establishment and current geopolitical and international economical organization of both blocs, focusing on their role in international trade. Section 3.2 analyzes their role on GVCs in different industries and between each other. Lastly, section 3.3 summarizes the current trade deal as it stands, and what a trade deal in general could imply within the scenario described.

3.1 EUROPEAN UNION AND MERCOSUR ON INTERNATIONAL TRADE

The European Union, or EU, is a political and economic union of 27 European states: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and Sweden (EU27), covering approximately 3% of Earth's total land area (UNSD, 2019), that generated circa 14% of the global PPP GDP in 2019 (IMF, 2020). The bloc had circa 447 million inhabitants in 2019, or approximately 7% of the global population (UNSD, 2019), with a very high Human Developed Index (HDI), as averaged by each state's population, at approximately 0.895 in 2018 (KOVACECIC & JAHIC, 2020; UNSD, 2019). The EU has eleven different currencies, but the Euro serves as the currency for 19 of the member states of the bloc. The brief historical review of the creation of the EU that is presented hereafter comes mainly from Baldwin and Wyplosz (2020):

The Union originates in the Treaty of Paris, signed in 1951, which established the European Coal and Steel Community (ECSC) between Belgium, France, Italy, Luxembourg, the Netherlands and West Germany on the aftermath of the Second World War, the first step on a federalist integration of the European states under a supranational body. The treaty created a common market for coal and steel, with the objective of helping in the economic reconstruction of the continent, but also to economically entangle the European countries as to disincentivize and impede further conflicts in Europe by interweaving those structural industrial resources. In 1957, the Treaty of Rome established the European Economic Community (EEC), with the objective of further integrating the member states by establishing a customs union. Simultaneously, the European Atomic Energy Community (EAEC) treaty was signed to promote cooperation in atomic research and nuclear power.

These three communities (ECSC, EEC and EAEC) where merged by the Treaty of Brussels signed in 1965, establishing a common vehicle and institutions among the members, in what became known as the European Communities. The Communities first enlargement came in 1973, when Denmark, Ireland and the United Kingdom became members, followed in the next decade by the ascension of Greece in 1981, and Portugal and Spain in 1985. In 1986 the Single Market Act deepened integration via the establishment of a single market between the now 12 members, reinforcing the “four freedoms” (free movement of goods, services, people and capital) initially established in the Treaty of Rome. By 1990, East Germany reunified with the west and entered the Communities.

The next major integration step came with the signature of the Maastricht Treaty in 1992, that created the European Union by structurally reforming the EEC and the European Community, through the establishment of common external and internal intergovernmental policy-making institutions. This, among other agreements, further established the single market, developed the legal and political arms and roles of the bloc and its institutions, and paved the way for the creation of the monetary union through the transfer of monetary authority from most of the member countries to a central body. By 1995, Austria, Finland and Sweden joined the bloc.

By the end of the 1990s, the single currency, Euro, started circulating, first in digital flows, and, in 2002, as a physical currency. This expansion into deeper integration was not followed by all members of the then-EU, and was adopted only by Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain, a group of countries that became known as the Eurozone; Greece joined in 2001 before the first issuance of physical notes and coins. In 2004 the EU was further enlarged by the entry of Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia and Slovenia.

In 2007, Slovenia joined the Eurozone by adopting the Euro, while Bulgaria and Romania joined the EU. In the end of the decade, the monetary union further enlarged when Cyprus and Malta joined (2008), followed by Slovakia (2009). In 2009 the Lisbon Treaty was signed, reforming the legal structure and bureaucracy of the EU, further unifying various agreements into a single body. Estonia joined the Eurozone in 2011, Croatia ascended into the EU in 2013. The latest enlargements of the monetary union where with the entry of Latvia, in 2014, and Lithuania, in 2015. By early 2021, the bloc thus had 27 member states due to the exit of the United Kingdom on January 2020, being the first country to do so.

The most relevant characteristics of the EU that, by and large, directly correlates to the study at hand are, firstly, its large size, in terms of number of member states, that in bureaucratic terms means that the entity must deal with a lot of heterogeneous preferences and asymmetric economies and sociopolitical desires and needs, thus characterizing the process of reaching and enforcing any agreement with an external entity, such as the MERCOSUR, intrinsically difficult due to the need for a single agreement to be reached satisfying all parties involved, and, secondly, the overall harmony of the bloc with regards of trade and external policymaking that arises from the interconnectedness of the common market that, as will be seen later, generates a very relevant role for the intra-EU trade and of value chains for all member states, thus reinforcing the need for a common external approach that allows for the internal well-behaving economic progress of the bloc.

The Southern Common Market, or MERCOSUR (in Spanish; MERCOSUL in Portuguese; *Ñemby Ñemuha* in Guarani), is an economic union of 4 South American states: Argentina, Brazil, Paraguay and Uruguay, covering approximately 9% of Earth's total land area (UNSD, 2019), that generated circa 3% of the global PPP GDP in 2019 (IMF, 2020). The bloc had circa 263 million inhabitants in 2019, or approximately 4% of the global population (UNSD, 2019), with a high HDI, as averaged by each state's population, at approximately 0.772 in 2018 (KOVACECIC & JAHIC, 2020; UNSD, 2019). Each member state has its own currency.

The MERCOSUR originates in the Iguaçu Declaration, signed in 1985, where Brazil and Argentina commenced pushing for greater integration in the continent by developing stronger ties between themselves (MATHIAS, 2010). This was followed in 1986 by the creation of the Argentina-Brazil Integration and Economics Cooperation Program, with the objective of gradually introducing bilateral preferential treatment on their trade flows (ALMEIDA, 2011). In the same year, Uruguay joins the bilateral talks, interested in being included in the integration of its two most relevant trade partners (FCM, 2000).

In 1990, the Buenos Aires Act progressed the now trilateral integration by establishing a timeline for the creation of a full customs union. This draw the interest of Paraguay, another neighboring country whose trade with the two major South American countries was essential for its economy (ALMEIDA, 2011). The Treaty of Asunción, signed in 1991 by the now four countries, formally established the bloc as a free trade zone, but with the aim of creating a common market with a unified customs system later (MATHIAS, 2010).

The establishment of the legal instruments and institutions that would enable the customs union occurred in 1994 with the Treaty of Ouro Preto, and in 1995 the bloc effectively became one. The first enlargement of the bloc was in 2005, when Venezuela became a member (MERCOSUR, 2005). Other South American countries have also demonstrated interest, namely Chile and Bolivia, with the latter in accession talks since 2012 (MFA, 2012). All countries in the continent are at least associated members to the bloc[10]. However, in 2017, Venezuela was suspended by the bloc due to a “rupture in its democratic order”, the first to do so (MERCOSUR, 2018).

The most relevant characteristics for the MERCOSUR that directly correlates with this study, conversely, are the overall sociopolitical fluctuations that create somewhat inconsistent long-term prospects for the countries and difficulties in establishing durable and reliable external agreements, such as the EU-MERCOSUR FTA, and, as will be discussed hereafter, the highly asymmetric composition of the economies, in both internal markets and exports.

In aggregate terms, when analyzing the flows of trade from both blocs since the 1990s, some patterns can be noted. First, there was a steady growth for both blocs during the nineties in their volume of international trade, with an increase of approximately 54% and 88% in gross exports done by the EU and the MERCOSUR respectively, and of approximately 62% and 157% of imports done by the same blocs. This development is represented in Figure 11 and Figure 12.

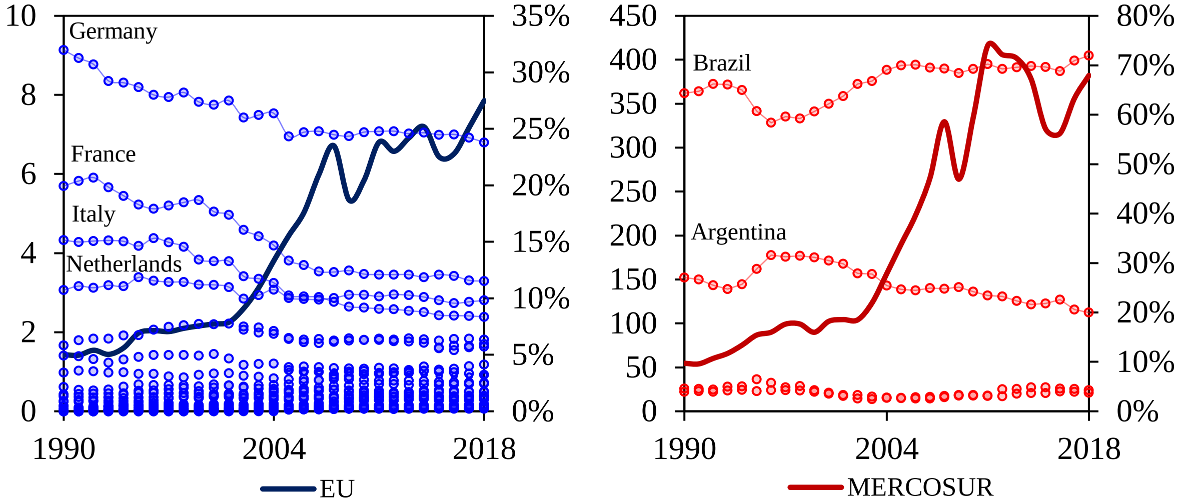
On the following decade, however, the growth rate of trade until the Global Financial crisis in 2009 was much more accelerated. Even after an initial slump in trade by MERCOSUR countries, possibly due to the combined effects of the Brazilian financial crisis and Argentine depression that followed the Russian and Asian crises on the eve of the new millennium (CIBILS, WEISBROT, & KAR, 2002), in the 2001-09 period exports grew by circa 137% for the EU and circa 153% for the MERCOSUR, with imports also increasing by approximately 149% and 108% for both blocs, in the same order.

From the Global Financial crisis onwards, however, the trends have been somewhat varied for each bloc, but trade overall slumped. MERCOSUR countries responded rather quickly in the years that followed, but the blocs’ gross figure was badly affected from 2016 onwards, most

[10] MERCOSUR. (2020). *MERCOSUR Countries*. Retrieved from www.mercosur.int/en/about-mercosur/mercosur-countries/.

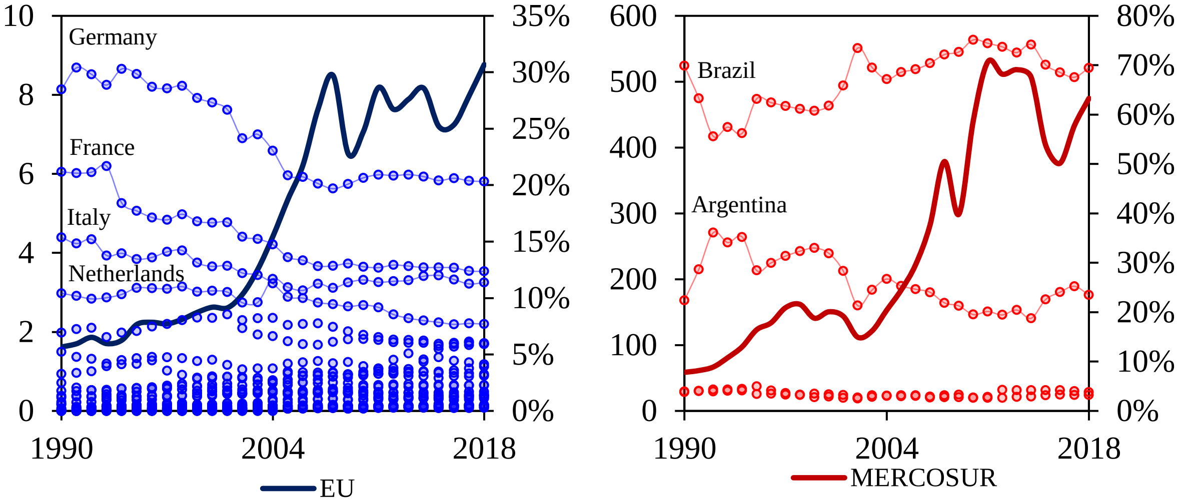
relevantly due to succeeding crisis faced by the Brazilian economy that were felt across the continent (FILHO, 2017).

Figure 11 – Annual gross exports of the EU in trillions of dollars and MERCOSUR in billions of dollars



Source: World Bank (2020c) and author calculations. Note: The scattered observations represent the captured percentage of each country on its bloc's total export volume, with the blocs' lines representing the total exports. Countries percentages use the right-hand side axis, and the most relevant for each bloc are highlighted. For the calculation of the gross exports, all current members were considered (EU27 for the EU; Argentina, Brazil, Paraguay, and Uruguay for MERCOSUR) in all periods. These values include intra-EU and intra-MERCOSUR trade.

Figure 12 – Annual gross imports of the EU in trillions of dollars and MERCOSUR in billions of dollars



Source: World Bank (2020d) and author calculations. Note: The scattered observations represent the captured percentage of each country on its bloc's total import volume, with the blocs' lines representing the total imports. Countries percentages use the right-hand side axis, and the most relevant for each bloc are highlighted. For the calculation of the gross imports, all current members were considered (EU27 for the EU; Argentina, Brazil, Paraguay, and Uruguay for MERCOSUR) in all periods. These values include intra-EU and intra-MERCOSUR trade.

From the previous high in 2008, exports grew only by approximately 16% (or circa 45% when compared to 2009) in the decade to 2018, and imports by approximately 25% (or circa 59%

from 2009) in the same period. The EU countries, conversely, had a more muted return to pre-crisis levels, with an approximated 17% growth in exports from 2008 (or circa 47% from the minimum in 2009) to 2018, and approximated 3% in imports (or circa 35% from 2009) in the same period.

When disaggregating each bloc in its constituent countries, however, it must be noted that some member states have much more weight on the composition of the aggregated figures, most notably due to the internal variability of the sizes (in terms of GDP) of the countries of each bloc. Thus, Germany, France and the Netherlands are responsible for roughly half of EU's gross exports and imports, while Brazil accounts for circa 70% of MERCOSUR's gross exports and imports. These profiles of highly concentrated trade in some countries have been somewhat stable for both blocs, at least in the past decade.

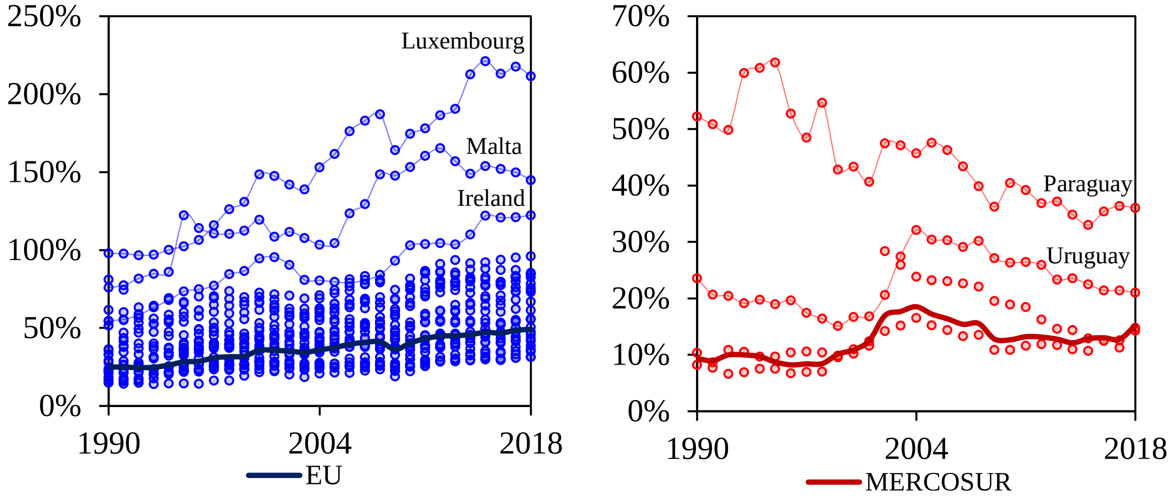
Moreover, when compared relatively to each other, the EU total size in international trade remained roughly 21 times bigger than that of the MERCOSUR's size, both in exports and imports, in the 1990-2018 period. The relative size of imports had a wider variability in the past decades, but remained smaller than the relative size of exports only from the mid-90s to the early 2000s, and then again from the Financial Crisis until 2018. These relative fluctuations of the sizes of the blocs is represented on Figure 13.

Figure 13 – Relative size of EU trade to MERCOSUR trade

Source: Author calculations on data from the World Bank (2020c; 2020d). Note: traced lines represent the average of each type on the period. These values include intra-EU and intra-MERCOSUR trade.

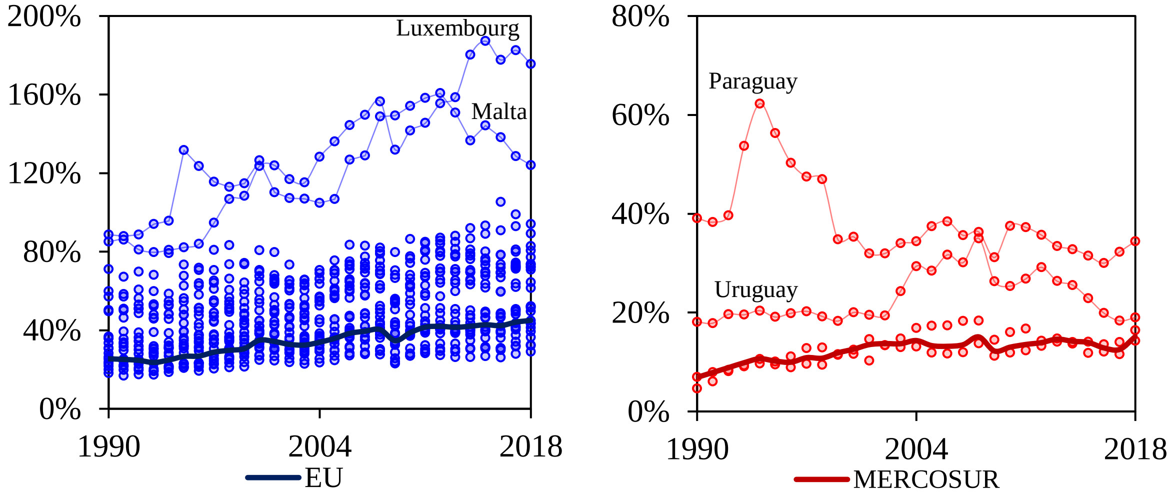
The heterogeneity of sizes of the member states of both blocs can be controlled by offsetting their trade figures by countries GDPs, and measuring imports and exports as percentages of each countries incomes, as represented in Figure 14 and Figure 15, the relative importance of trade for each bloc's economy becomes clearer.

Figure 14 – Exports share of GDP of EU and MERCOSUR



Source: World Bank (2020e) and author calculations. Note: Scattered observations represent each individual country of each bloc, with the blocs' lines representing their weighted exports by GDP. The countries with the highest levels of exports relative to GDPs are highlighted. For the calculation of the weighted average, all current members were considered (EU27 for the EU; Argentina, Brazil, Paraguay, and Uruguay for MERCOSUR) in all periods. These values include intra-EU and intra-MERCOSUR trade.

Figure 15 – Imports share of GDP of EU and MERCOSUR



Source: World Bank (2020f) and author calculations. Note: Scattered observations represent each individual country of each bloc, with the blocs' lines representing their weighted imports by GDP. The countries with the highest levels of imports relative to GDPs are highlighted. For the calculation of the weighted average, all current members were considered (EU27 for the EU; Argentina, Brazil, Paraguay, and Uruguay for MERCOSUR) in all periods. These values include intra-EU and intra-MERCOSUR trade.

Whilst the EU has had a more significant stable long-term growth in the relative importance of trade to its GDP, starting also from a higher percentage than the weighted average of MERCOSUR countries, the latter bloc has had also a much slower pace of growth during the same period, although both rates of change are comparable in an yearly growth approximation. The absolute change in the period, as well as the compounded annual growth rate (CAGR) are represented in Table 4.

Table 4 – Total growth (Δ) and CAGR of trade for the EU and MERCOSUR weighted averages from 1990 to 2018

	Exports		Imports	
	Δ	CAGR	Δ	CAGR
EU	24%	2.4%	20%	2.0%
MERCOSUR	6%	1.7%	8%	2.8%

Source: Author calculations on data from the World Bank (2020e; 2020f). These values include intra-EU and intra-MERCOSUR trade.

In this GDP weighted analysis, different countries, when compared to the gross volume participation in trade, gain more prominence. Even if their overall impact on the weighted average is slim due to their smaller sizes, lower GDP countries in both blocs are also the ones with a greater percentage of participation in international trade (as a percentage of their national income). For the EU this is represented most relevantly by Luxembourg, Malta, and Ireland, whilst for the MERCOSUR this is also true for the smaller Paraguay and Uruguay.

This asymmetry on gross and relative trade between the blocs is also represented on their tariff levels on imports, and average levels are presented in Table 5. When comparing the average tariffs for all products, the EU levels are several times lower than the same measurements for the MERCOSUR average. This difference is much more apparent on bound tariff levels, i.e., the tariff upper limit agreed by countries, than on Most Favored Nation (MFN) tariff levels, i.e. the tariff levels used in trade with other nations in the WTO.

The difference between bound and MFN tariffs, or the “binding overhang”, is much higher, on average, for the MERCOSUR countries, which allows them more leeway for changing their levels when desired, but implies less predictability on trade policy, which in turn can negatively affect trade. Moreover, whilst EU tariffs are lower, at least relative to their MERCOSUR counterparts, they are asymmetrically divided on imports, being much higher on agricultural (approximately two times bigger than the total average) than non-agricultural products.

Table 5 – Average tariff levels on EU and MERCOSUR in 2018

	All products		Agricultural		Non-agricultural	
	Bound	MFN	Bound	MFN	Bound	MFN
EU	5.1	5.2	12.8	12.0	3.9	4.2
MERCOSUR	31.8	13.3	33.2	10.2	31.5	13.8

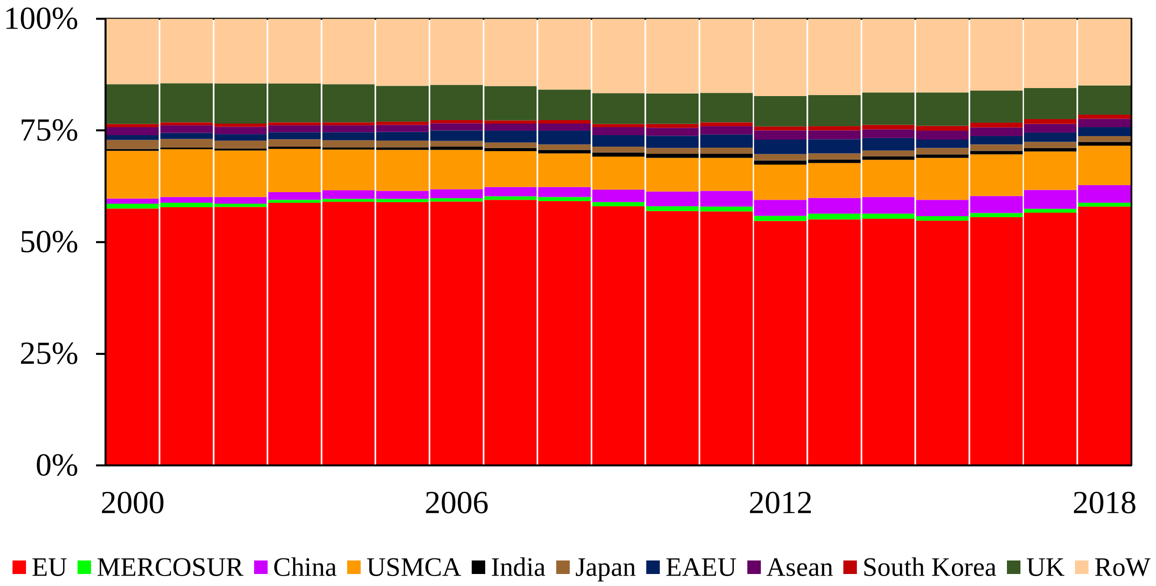
Source: World Trade Organization (2019b) and author calculations. Note: MERCOSUR tariffs were calculated as individual countries tariffs weighted by imports, using data from the World Bank (2020d); EU tariffs were already available at the original source.

Trade partners of each bloc, both in exports and imports, also are very heterogeneous. Focusing on a more recent time span, from 2000 to 2018, and disaggregating flows into 11 possible destinations of exports or origins of imports, it is evident that most of the trade done by EU countries is within the bloc itself. On the other hand, MERCOSUR countries in 2018 had as main trade partner China. The selected countries or economically integrated blocs besides the EU and the MERCOSUR are: China; the United States-Mexico-Canada Agreement (USMCA) between the USA, Mexico and Canada; India; Japan; the Eurasian Economic Union (EAEU) between Armenia, Belarus, Kazakhstan, Kyrgyzstan and Russia; the Association of Southern Asian Nations (ASEAN) between Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand and Vietnam; South Korea; United Kingdom (UK); and a "Rest of the World" (RoW) category for all remaining countries. The disaggregation for EU exports is represented in Figure 16, and imports in Figure 17. The disaggregation for MERCOSUR exports is represented in Figure 18, and imports in Figure 19.

Among all partners, China is evidently the fastest grower, in both blocs and directions. The gross change of percentage between 2000 and 2018 for trade partners is represented in Figure 20, while the average annual pace (measured as the CAGR) is represented in Figure 21. That country, in these variation measurements, boasted a gross increase of upwards of 16% in both trade measurements with the MERCOSUR, and had also the most vigorous increase in trade with the EU, with a rate higher than 3% in also both directional flows of trade.

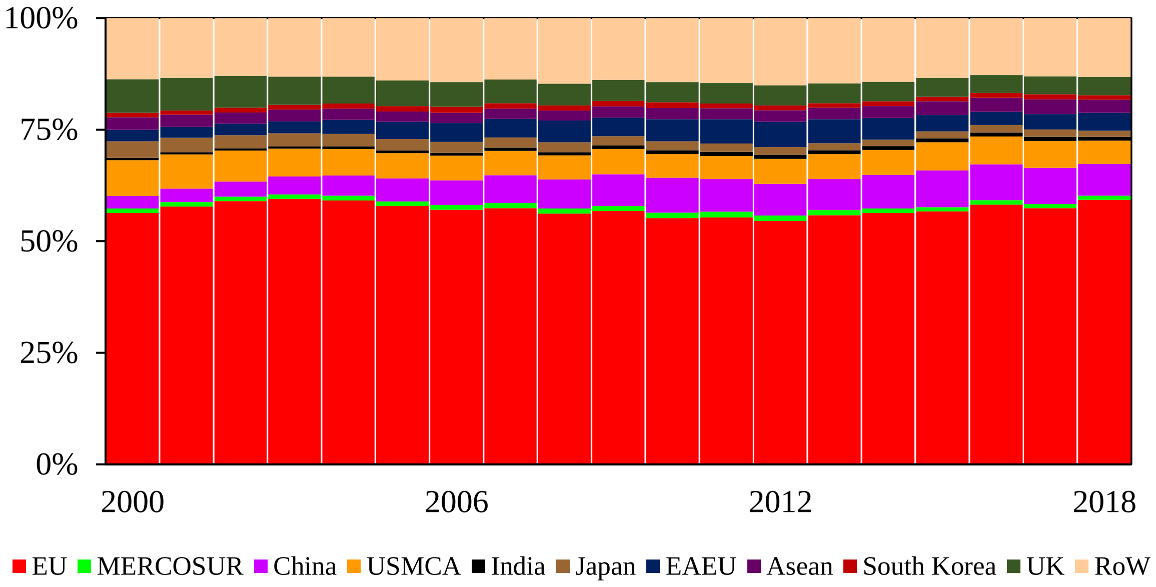
All factors considered, economic integration through internal trade is very evident in the EU, with both internal exports and imports representing historically more than half the total volume traded. Besides the bloc itself, the next most relevant trade partners are the UK, even though at a decreasing rate, the USMCA (also decreasing), and more recently China, but at the previously stated increasing rate.

Figure 16 – Exports by destination of the EU



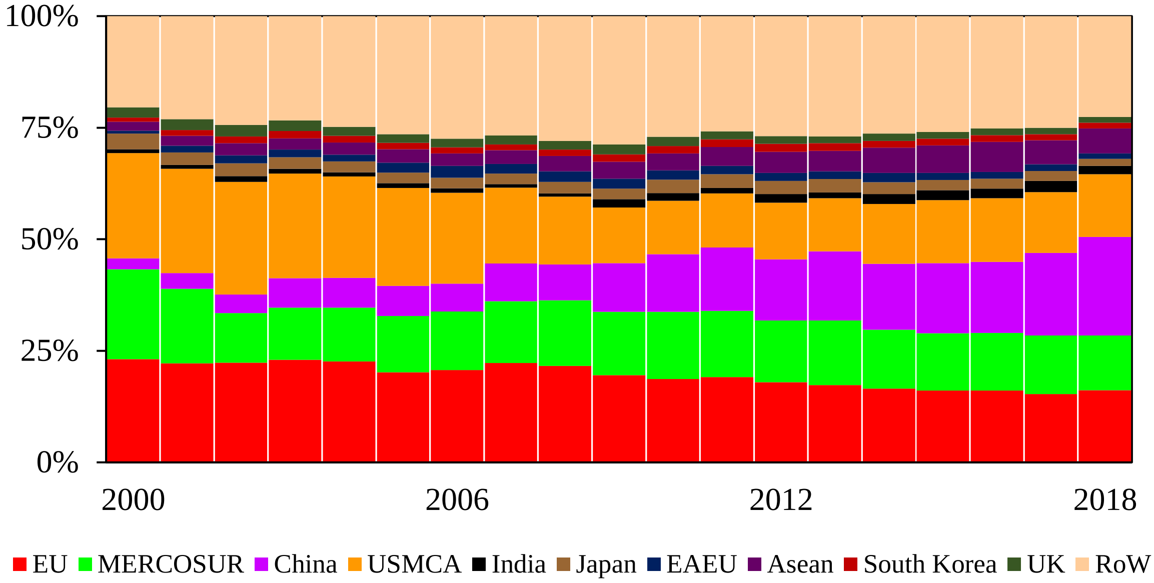
Source: Author calculations on data from Gaulier and Zignago (2010) and Simoes and Hidalgo (2011).

Figure 17 – Imports by origin of the EU



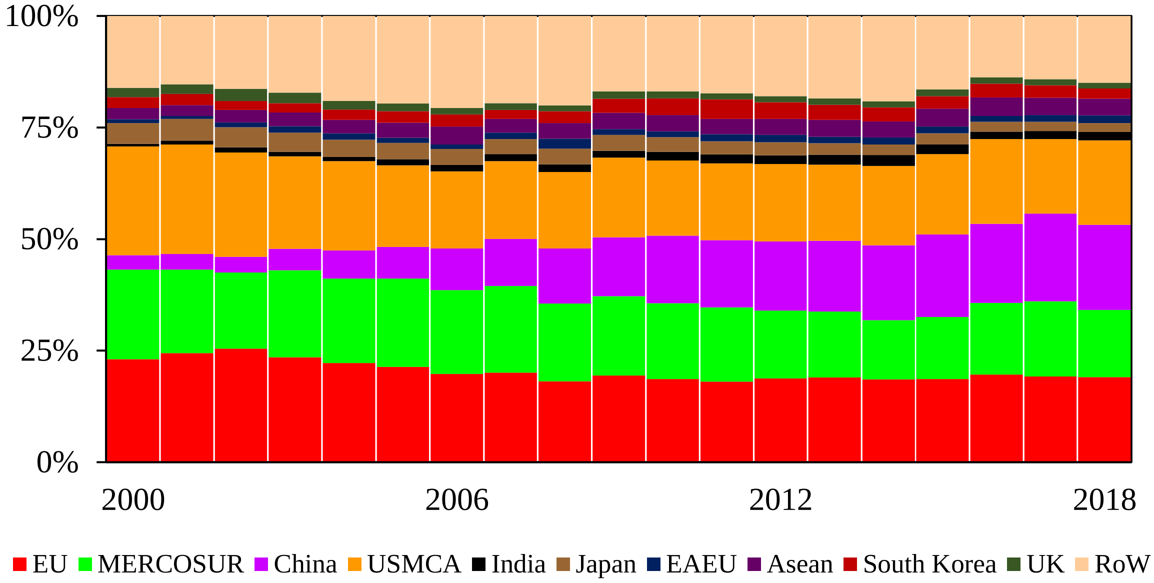
Source: Author calculations on data from Gaulier and Zignago (2010) and Simoes and Hidalgo (2011).

Figure 18 – Exports by destination of the MERCOSUR



Source: Author calculations on data from Gaulier and Zignago (2010) and Simoes and Hidalgo (2011).

Figure 19 – Imports by origin of the MERCOSUR

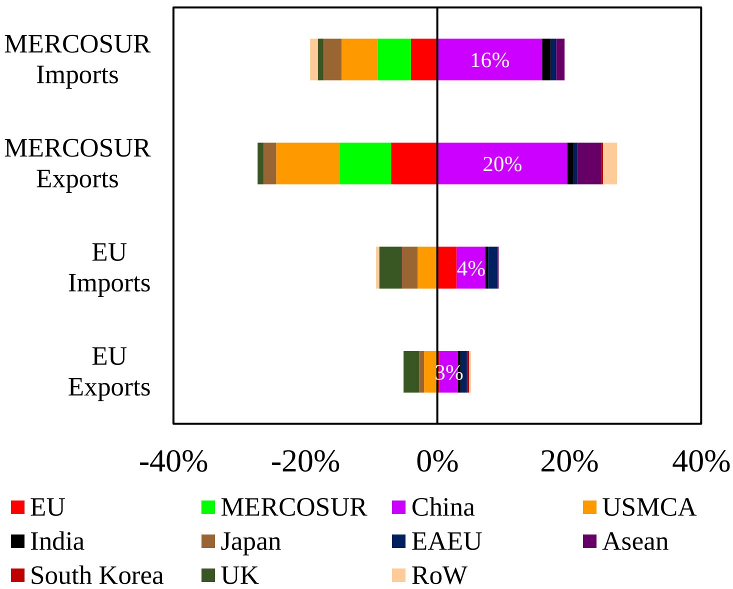


Source: Author calculations on data from Gaulier and Zignago (2010) and Simoes and Hidalgo (2011).

Focusing instead on the MERCOSUR, whilst internal trade is relevant to the total figure, it has been progressively less so, a trend marked also by the growth of China, that has become a very relevant player in both exports and imports. The EU and USMCA represent the third and fourth most relevant trade partners for the bloc, but both also at a decreasing pace. This shift on its trade profile meant a loss of the gross internal share of trade, declining 4% in imports and 7% in exports, and also with its other two major partners, the EU (-5% gross change of imports,

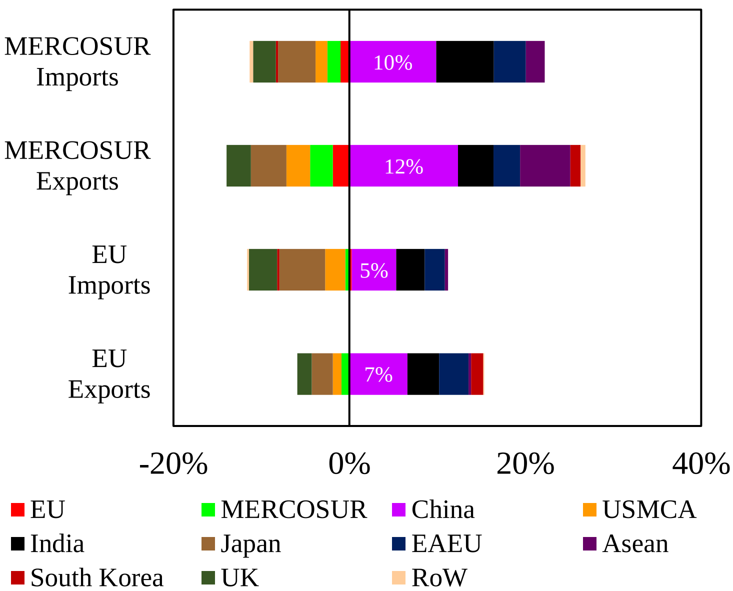
-8% gross change of exports) and the USMCA (-6% imports, -10% exports). The most relevant increase for the bloc besides China was of trade with ASEAN countries. The gross variation for the EU trade profile in this period was much more subdued, at least when reviewed relatively to the MERCOSUR variability. Besides the already noted growth on trade with China, the bloc also increased imports internally (+3%), most relevantly at the expense of trade with the USMCA (-3% imports, -2% exports), the UK (-3% imports, -2% exports) and Japan (-2% imports, -1% exports).

Figure 20 – Absolute change of trade by destination/origin from 2000 to 2018



Source: Author calculations on data from Gaulier and Zignago (2010) and Simoes and Hidalgo (2011).

Figure 21 – CAGR of trade by destination/origin from 2000 to 2018



Source: Author calculations on data from Gaulier and Zignago (2010) and Simoes and Hidalgo (2011).

Focusing instead on the compounded rate in the period, the variation of previously less relevant partners becomes more evident, but still China plays the biggest role of capturing shares of trade with both blocs in both directions. Nevertheless, a relevant continuous loss of share of trade with Japan in all directions of both blocs becomes very relevant, followed by a similar pattern (although at a smaller rate) with the UK. On the growth side, India and the EAEU now display a clear continuous, albeit smaller than China's, growth in all directions of both blocs in the period.

Finally, the content itself of trade of the two blocs is also very varied. The sectoral disaggregation of flows for 2000 and 2018, alongside with the gross variation and the CAGR for the EU is presented in Table 6, and for the MERCOSUR in Table 7[11]. This data uses the Harmonized System of 1992 (HS92) categorization of trade, as it provides the longest continuous-running set of trade statistics available, while the sectoral breakdown of trade comes from the division used by the Observatory of Economic Complexity (OEC) into 20 different categories of goods (SIMOES & HIDALGO, 2011). These categories are defined, in a non-exhaustive manner, as: animal products, such as meats, milk and derived goods; vegetable products, such as soybean, coffee, wheat and corn; animal and vegetable bi-products, such as oils, acids and waxes; foodstuffs, such as sugars, juices, chocolate and alcoholic drinks; mineral products, such as crude and refined petroleum, natural gas and ores; chemical products, such as pharmaceuticals, laboratory and industrial reagents, pesticides and cleaning products; plastics and rubbers, such as rubber tires and polymers; animal hides, such as tanned hides and other items made with hides; wood products, such as sawn wood, plywood, carpentry and fiberboards; paper goods, such as wood pulps, coated and uncoated papers, and objects made with paper; textiles, such as raw cotton, non-knitted and knitted apparel; footwear and headwear, such as leather, textile or rubber footwear and headwear; stone and glass, such as building stones, ceramics and glass panes and articles; precious metals, such as gold, platinum and jewelry; metals, such as alloys, ingots and objects made with metallic materials; machines, such as engines, circuits and industrial machinery; transportation, such as cars, planes, ships and their respective parts; instruments, such as medical equipment and instruments, thermostats and compasses; weapons, such as guns, ammunition and gun parts; miscellaneous, such as furniture, seats, mattresses and video games; and arts and antiques, such as paintings and sculptures.

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[11] The sectoral disaggregation is available for all years in the 2000-2018 period in Appendix A.

Table 6 – Trade in sectors by the EU

	Exports				Imports			
	2000	2018	Δ	CAGR	2000	2018	Δ	CAGR
Animal Products	3%	3%	0%	0%	2%	2%	0%	0%
Vegetable Products	2%	2%	0%	0%	2%	3%	0%	1%
Animal/Vegetable Biproducts	0%	1%	0%	1%	0%	1%	0%	3%
Foodstuffs	4%	5%	1%	1%	3%	4%	1%	1%
Mineral Products	4%	5%	1%	2%	10%	12%	2%	1%
Chemical Products	12%	14%	3%	1%	9%	12%	2%	1%
Plastics and Rubbers	5%	6%	0%	0%	5%	5%	1%	1%
Animal Hides	1%	1%	0%	0%	1%	1%	0%	-1%
Wood Products	1%	1%	0%	-1%	1%	1%	0%	-1%
Paper Goods	3%	2%	-1%	-2%	3%	2%	-1%	-2%
Textiles	5%	3%	-2%	-2%	6%	5%	-1%	-1%
Footwear and Headwear	1%	1%	0%	0%	1%	1%	0%	2%
Stone and Glass	2%	1%	0%	-1%	1%	1%	0%	-1%
Precious Metals	1%	1%	0%	-1%	2%	1%	0%	-1%
Metals	8%	8%	1%	0%	8%	9%	1%	1%
Machines	27%	23%	-4%	-1%	27%	22%	-4%	-1%

Source: Author calculations on data from Gaulier and Zignago (2010) and Simoes and Hidalgo (2011). Note: These values include intra-EU trade.

Table 6 – Trade in sectors by the EU (*cont.*)

	Exports				Imports			
	2000	2018	Δ	CAGR	2000	2018	Δ	CAGR
Transportation	16%	16%	0%	0%	13%	12%	0%	0%
Transportation	16%	16%	0%	0%	13%	12%	0%	0%
Instrument	3%	4%	1%	2%	3%	3%	0%	0%
Weapons	0%	0%	0%	0%	0%	0%	0%	-1%
Miscellaneous	2%	2%	0%	0%	2%	3%	0%	1%
Arts and Antiques	0%	0%	0%	-5%	0%	0%	0%	1%

Source: Author calculations on data from Gaulier and Zignago (2010) and Simoes and Hidalgo (2011). Note: These values include intra-EU trade.

Since most of the trade done by the EU is internal, i.e. EU exports flowing to EU importers, the breakdown of exports and imports ends up being quite similar, as the existence of one is likely to generate a similar presence of the other. Moreover, there has not been much change in the content of trade done by the bloc on the last decades – at least from this sectorial approximation of goods traded –, with the greatest variation being a decline in trade of the most representative category, machines, of 3% in exports and 4% in imports, as some other sectors grew, such as mineral and chemical products.

Nevertheless, trade in machines (both exports and imports) was and still is the main traded category by the bloc. It is a very pulverized sector, but is mostly composed of, at least in 2018, trade in broadcast equipment, computers, circuits, and turbines. It is followed in importance by transportation, composed mainly of trade in cars and vehicle parts, chemical products, composed mainly of pharmaceuticals, mineral products, that will be discussed subsequently, and finally metals, composed mainly of aluminum and iron products.

The only sector with a more pronounced variation between exports and imports is the aforementioned "mineral products", where imports were larger than exports by a difference of 6% in 2000 (i.e., the share of mineral products for total imports was 6 percentage points higher than the share of these products for total exports), and more recently by a difference of 7% in

2018. This variation is noteworthy due to a fundamental difference in the content of trade in this sector, with exports containing at a substantive amount refined petroleum, while imports are mainly composed of crude petroleum (followed by a also relevant percentage of refined petroleum).

Table 7 – Trade in sectors by the MERCOSUR

	Exports				Imports			
	2000	2018	Δ	CAGR	2000	2018	Δ	CAGR
Animal Products	5%	8%	2%	2%	1%	1%	0%	-1%
Vegetable Products	11%	19%	8%	3%	3%	3%	0%	0%
Animal/Vegetable Biproducts	3%	2%	-1%	-2%	0%	1%	0%	1%
Foodstuffs	12%	12%	-1%	0%	2%	2%	0%	0%
Mineral Products	12%	18%	7%	2%	12%	14%	2%	1%
Chemical Products	6%	5%	-1%	-1%	15%	19%	4%	1%
Plastics and Rubbers	3%	2%	-1%	-2%	5%	6%	0%	0%
Animal Hides	2%	1%	-2%	-5%	0%	0%	0%	-2%
Wood Products	2%	1%	-1%	-3%	0%	0%	0%	-4%
Paper Goods	4%	4%	1%	1%	3%	1%	-2%	-5%
Textiles	2%	1%	-1%	-4%	3%	3%	0%	0%
Footwear and Headwear	2%	0%	-2%	-8%	0%	1%	0%	1%
Stone and Glass	1%	1%	0%	-2%	1%	1%	0%	0%
Precious Metals	2%	2%	0%	1%	0%	0%	0%	1%

Source: Author calculations on data from Gaulier and Zignago (2010) and Simoes and Hidalgo (2011). Note: These values include intra-MERCOSUR trade.

Table 7 – Trade in sectors by the MERCOSUR (*cont.*)

	Exports				Imports			
	2000	2018	Δ	CAGR	2000	2018	Δ	CAGR
Metals	9%	6%	-3%	-2%	5%	6%	1%	1%
Machines	10%	6%	-4%	-2%	32%	24%	-8%	-2%
Transportation	12%	10%	-2%	-1%	10%	13%	3%	1%
Instrument	1%	0%	0%	-3%	3%	3%	0%	0%
Weapons	0%	0%	0%	1%	0%	0%	0%	-5%
Miscellaneous	1%	0%	-1%	-6%	1%	2%	0%	1%
Arts and Antiques	0%	0%	0%	9%	0%	0%	0%	10%

Source: Author calculations on data from Gaulier and Zignago (2010) and Simoes and Hidalgo (2011). Note: These values include intra-MERCOSUR trade.

Differently from the EU, trade done by the MERCOSUR is not mostly internal, and, more importantly, is relatively more pulverized worldwide, thus reducing the tendency of exports to reflect in imports with any trade partner. Moreover, the bloc tends to be mostly an exporter of commodity goods, and mostly an importer of higher value-added goods.

This is reflected by the predominance of vegetable and mineral products, followed by foodstuffs and animal products, as the main exporting categories for the bloc. These four categories were responsible for 57% of total exports in 2018, up from 40% in 2000, also representing the fastest growers, in terms of capturing gross share of exports, in the period, with “vegetables” increasing by 8% and “minerals” 7%.

These sectors are mostly represented by exports in soybeans, a “vegetable product”, that alone accounted for circa 12% of all exports done by the bloc in 2018, followed by crude petroleum (circa 8% of all exports) and iron ore (6%), both “mineral products”, different types of meats (6%), which are an “animal product”, and soybean meals (5%), a “foodstuff”. A non-commodity sector that is very relevant nevertheless is “transportation”, that was the second most relevant exporting sector in 2000, with 12% of total exports, but fell to the fourth position in 2018, with 10% of exports. It is mainly driven by the export of cars and trucks. Other sectors that saw a decline in participation of exports were, most relevantly, machines, that had their participation reduced by 4% in the same period, and metals with 3% less.

When switching to the import side, a clear change from the export profile is evident: the main sectors now are machines, chemical and mineral products, and transportation, accounting for 70% of imports in 2018, up from 69% in 2000. This variation is most well represented by comparing the share captured by each sector in the bloc's exports and imports, and if focusing on 2018, there are relevant changes of, for example, 18% from machines (i.e., this sector represented only 6% of exports but 24% of imports), followed by a variation of 16% in vegetable products, 13% in chemical products, 9% in foodstuffs and 7% in animal products. That is, the most relevant categories exported differ structurally from the most relevant categories imported by the bloc. When compared to the EU for instance, most of the sectors have relatively the same share of exports and imports, with only one big fluctuation, of mineral products, that have a much higher share of imports (12% in 2018 and 10% in 2000) than exports (5% in 2018 and 4% in 2000). These changes of the composition of trade are represented in Table 8.

Table 8 – Difference between the share of exports and imports of sectors in trade done by the EU and MERCOSUR in 2000 and 2018

	MERCOSUR		EU	
	2000	2018	2000	2018
Animal Products	4%	7%	0%	0%
Vegetable Products	8%	16%	0%	0%
Animal/Vegetable Biproducts	2%	1%	0%	0%
Foodstuffs	10%	9%	0%	1%
Mineral Products	-1%	4%	-6%	-7%
Chemical Products	-9%	-13%	2%	3%

Source: Author calculations on data from Gaulier and Zignago (2010) and Simoes and Hidalgo (2011). Note: These values include intra-EU and intra-MERCOSUR trade.

Table 8 – Difference between the share of exports and imports of sectors in trade done by the EU and MERCOSUR in 2000 and 2018 (*cont.*)

	MERCOSUR		EU	
	2000	2018	2000	2018
Plastics and Rubbers	-3%	-3%	1%	0%
Animal Hides	2%	1%	0%	0%
Wood Products	2%	1%	0%	0%
Paper Goods	1%	3%	1%	0%
Textiles	-1%	-2%	-1%	-2%
Footwear and Headwear	1%	0%	0%	0%
Stone and Glass	0%	0%	0%	0%
Precious Metals	1%	2%	0%	0%
Metals	4%	0%	0%	0%
Machines	-22%	-18%	0%	1%
Transportation	2%	-3%	3%	3%
Instrument	-3%	-3%	0%	1%
Weapons	0%	0%	0%	0%
Miscellaneous	0%	-1%	0%	0%
Arts and Antiques	0%	0%	0%	0%

Source: Author calculations on data from Gaulier and Zignago (2010) and Simoes and Hidalgo (2011). Note: These values include intra-EU and intra-MERCOSUR trade.

In any case, returning to the analysis of the MERCOSUR disaggregated flows, there is a more muted variation of mineral products, which play a significant role on both sides of trade.

However, if breaking down the content of trade of this sector, the inverse of what was noted on the EU is seen, that is, while the MERCOSUR mainly exports crude petroleum, it imports refined petroleum and natural gas. On the other relevant import categories, the most noteworthy elements are, in 2018, circuits, broadcasting equipment and telephones for “machines” (it is also a very pulverized category in this case), pharmaceuticals and fertilizers for “chemical products”, and also cars and vehicle parts for “transportation”.

Finally, though previously asserted that EU trade has a high degree of internalization, that is, occurring from EU countries to other EU countries, and that MERCOSUR countries have a somewhat low degree of internalization in this relative comparison, this is observed asymmetrically on the different sectors where these blocs trade. The share of internal trade of each sector in 2018 is represented in Table 9.

Table 9 – Share of exports and imports internally absorbed by each bloc in each sector in 2018

	MERCOSUR		EU	
	Exports	Imports	Exports	Imports
Animal Products	5%	41%	70%	75%
Vegetable Products	8%	66%	71%	61%
Animal/Vegetable Biproducts	6%	25%	69%	59%
Foodstuffs	5%	32%	59%	73%
Mineral Products	5%	8%	58%	26%
Chemical Products	20%	7%	52%	65%
Plastics and Rubbers	38%	18%	68%	73%
Animal Hides	3%	8%	48%	55%

Source: Author calculations on data from Gaulier and Zignago (2010) and Simoes and Hidalgo (2011).

Table 9 – Share of exports and imports internally absorbed by each bloc in each sector in 2018 (*cont.*)

	MERCOSUR		EU	
	Exports	Imports	Exports	Imports
Wood Products	2%	25%	64%	74%
Paper Goods	7%	34%	65%	80%
Textiles	20%	9%	65%	46%
Footwear and Headwear	23%	18%	68%	52%
Stone and Glass	19%	18%	60%	71%
Precious Metals	0%	1%	28%	27%
Metals	12%	16%	69%	68%
Machines	18%	6%	55%	59%
Transportation	41%	37%	55%	72%
Instrument	18%	3%	43%	52%
Weapons	2%	6%	30%	51%
Miscellaneous	27%	7%	67%	62%
Arts and Antiques	0%	1%	9%	10%

Source: Author calculations on data from Gaulier and Zignago (2010) and Simoes and Hidalgo (2011).

Thus, while 16 sectors of the EU have more than 50% of exports due to internal flows, and 17 imports-side, this is true for only one sector in the MERCOSUR, imports-side, “vegetable products”, where 66% of imports are sourced internally. At the 70% threshold level, there is still one sector exports-side for the EU, “vegetable products”, and 7 sectors imports-side for the same bloc, “animal products”, “foodstuffs”, “plastics and rubbers”, “wood products”, “paper goods”, “stone and glass” and “transportation”. Many of these sectors for the EU are agriculturally related, and thus the previously seen higher level of tariffs for those sectors may have some correlation with these internalized shares of imports.

The MERCOSUR, as seen in most previous analyzes, has a higher degree of variability, not only in exports and imports, but directionally as well. The most internalized exports-side category is transportation, which also appears relatively quite high in internalization on the imports-side, and this may help in understanding why there is relative stability on the share that this sector occupies on trade of the bloc. That is, there exists a relevant internal commerce of transport (mainly cars) that sustains somewhat the share of trade previously seen on the bloc’s gross totals. Moreover, it is also relevant to note that the some of the most important sectors for exports of the bloc, namely vegetable and animal products and foodstuffs are more internally dependent on the imports-side, but represent a very small share of the global exports done by the MERCOSUR. Thus, the international demand of the countries is relatively well met by the bloc’s internal production, but exports appear to be done mostly for serving international consumption.

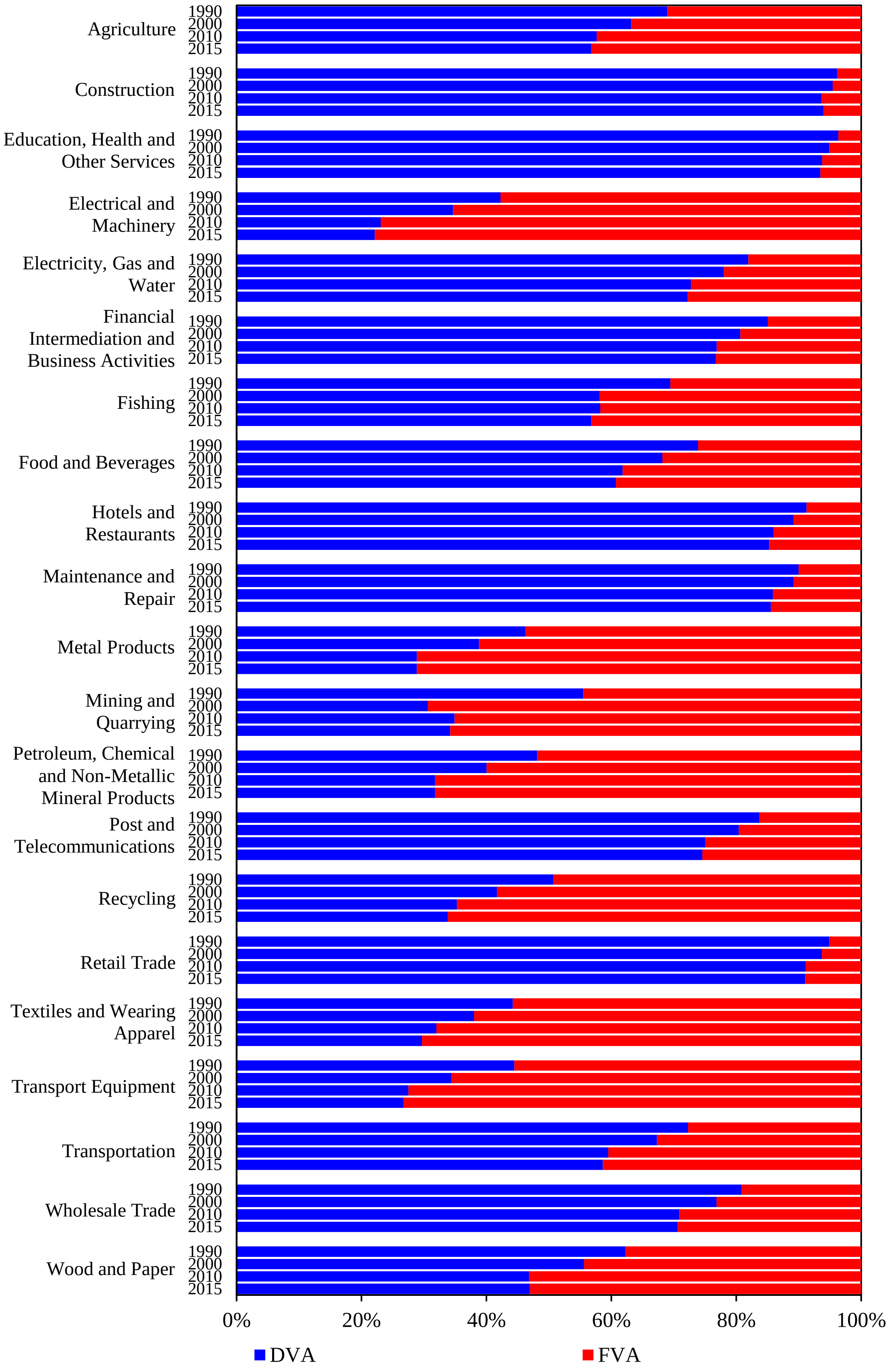
3.2 EUROPEAN UNION AND MERCOSUR ON GLOBAL VALUE CHAINS

To analyze trade flows through the value addition perspective, the integration of each bloc on GVCs can be assessed by using the previously defined VA measures of DVA, FVA and DVX. An initial analysis of the VA profile of EU and MERCOSUR countries on the last decades can be performed by breaking down their sectoral exports into where, in terms of country or economic bloc, the value embedded in their final figures was generated. In VA terms, this is equivalent to disaggregating exports into DVA, that represent the domestic addition of the value embedded in a country’s own exports, and FVA, that represent foreign addition of the value embedded in that country’s exports.

A second analysis consists of measuring all value generated by each country on a specific sector but not necessarily embedded in its own exports, and thus deriving how much each country generated in VAT worldwide, by comparing DVA with DVX, that represents the addition of the studied country of value that is embedded on the exports of an international trade partner.

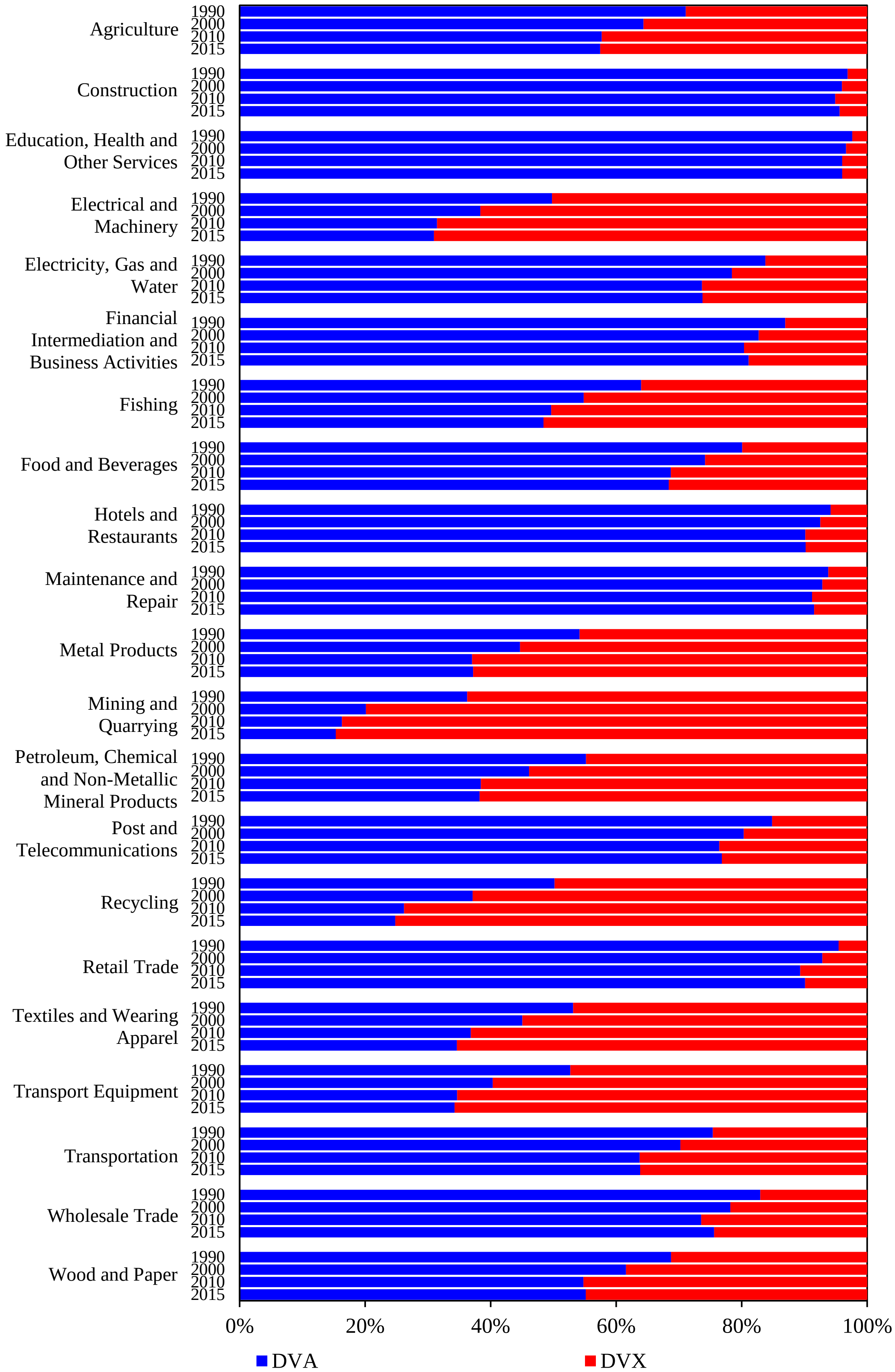
The breakdown of exports into DVA and FVA for the EU countries is represented on Figure 22, and the worldwide VA analysis of DVA and DVX for the same countries is represented on Figure 23. The correspondent analyzes for the MERCOSUR countries are represented on Figure 24 and Figure 25.

Figure 22 – Sectoral DVA and FVA of the EU



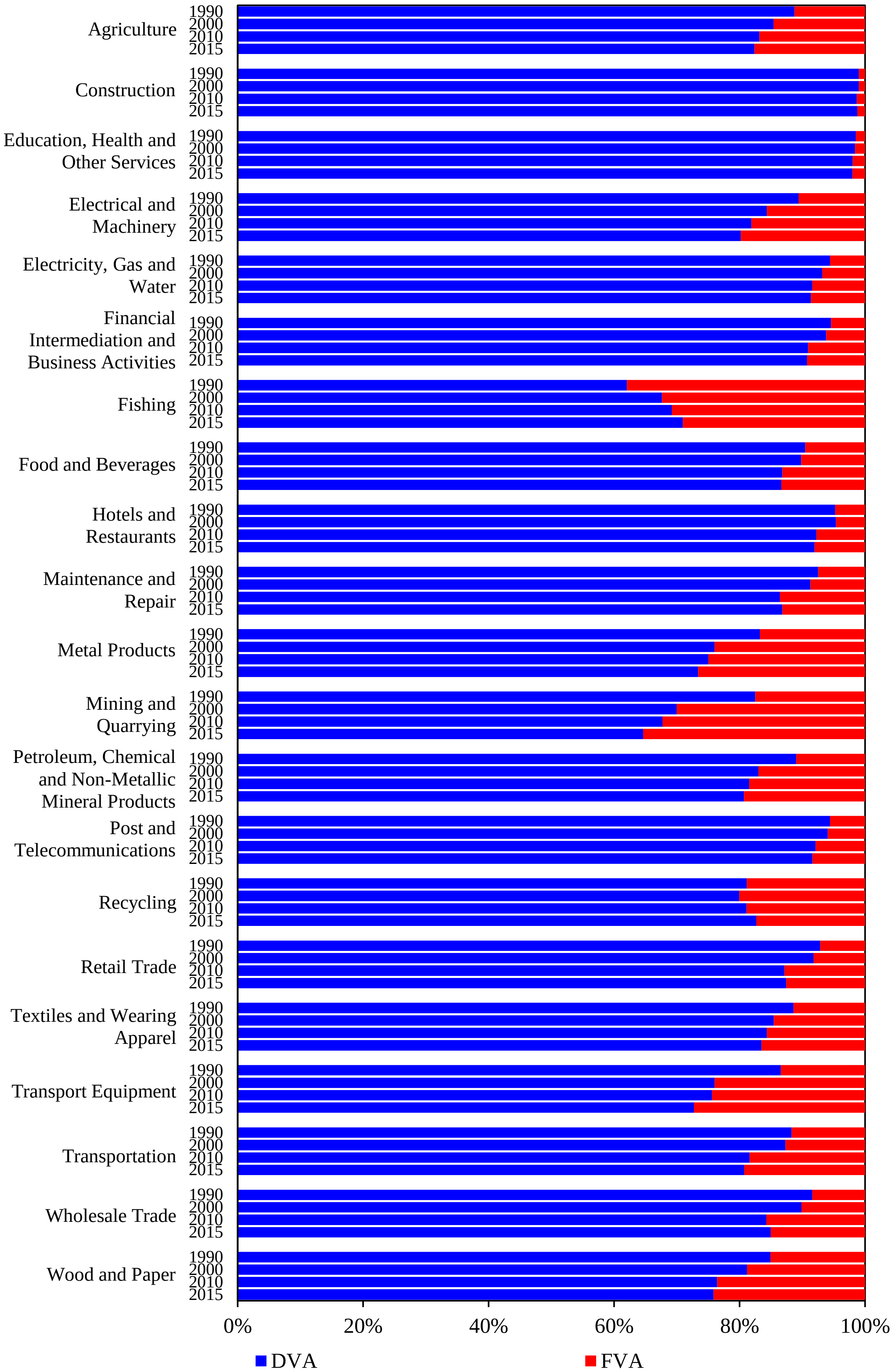
Source: Author calculations on data from Lenzen et al. (2012; 2013) and Aslam et al. (2017). Note: These values include intra-EU trade.

Figure 23 – Sectoral DVA and DVX of the EU



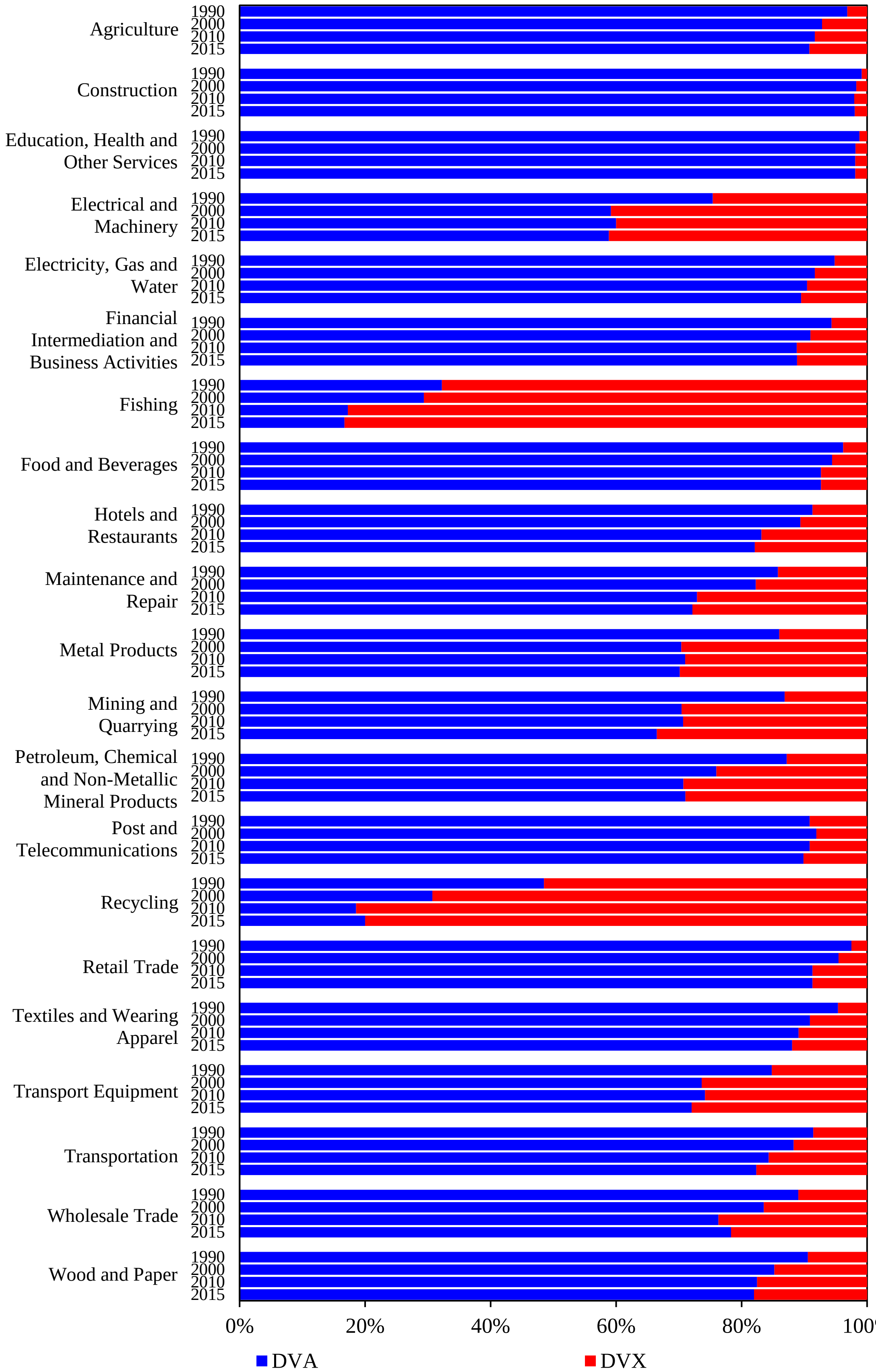
Source: Author calculations on data from Lenzen et al. (2012; 2013) and Aslam et al. (2017). Note: These values include intra-EU trade.

Figure 24 – Sectoral DVA and DVX of the MERCOSUR



Source: Author calculations on data from Lenzen et al. (2012; 2013) and Aslam et al. (2017). Note: These values include intra-MERCOSUR trade.

Figure 25 – Sectoral DVA and DVX of the MERCOSUR



Source: Author calculations on data from Lenzen et al. (2012; 2013) and Aslam et al. (2017). Note: These values include intra-MERCOSUR trade.

These summaries all rely on flows from four years, 1990, 2000, 2000 and 2015, as an attempt to capture the overall trends that driven each sector in each bloc and direction of value addition. Moreover, the set of sectors used is the one imposed by its source, the Eora26 MRIO database by Lenzen et al. (2012; 2013), with the data extraction into VA measurements done with the algorithm by Aslam et al. (2017).

The total number of sectors was reduced for simplicity, and the sectors here considered are: agriculture; construction; education, health and other services; electrical and machinery; electricity, gas and water; financial intermediation and business activities; fishing; food and beverages; hotels and restaurants; maintenance and repair; metal products; mining and quarrying; petroleum, chemical and non-metallic mineral products; post and telecommunications; recycling; retail trade; textiles and wearing apparel; transport equipment; transportation; wholesale trade; and wood and paper.

When analyzing the interplay between DVA and FVA or DVX, it is relevant to note that FVA plays the role of indicating backwards internationalization on GVCs, since it indicates a larger participation of international players on earlier (i.e., upstream) stages of production, that are thus embedded in a country's exports. Conversely, DVX plays the role of indicating forward internationalization, since it indicates a larger participation of the country on generating value embedded in other countries later (i.e., downstream) stages of production, that is then exported.

In this first breakdown of VA, almost all sectors, by both countries, and in both directions displayed a growth from 1990 to 2015 of gross internationalization (i.e., a growing role of FVA and DVX when compared to DVA). The only two sectors where this trend was not seen was in MERCOSUR's FVA, in the sectors of Fishing, that saw a decline in internationalization from its maximum level in 1990, and Recycling, with a decline from its maximum in 2000. Nevertheless, on a simple average of all sectors levels of internationalization, both directional flows grew in this period, reaching their maximum level in 2015. In this last year considered, this meant an average of 40% of internationalization of VA (in both directions) for the EU, and half this value, approximately 20%, of internationalization of VA (also in both directions) for the MERCOSUR.

Focusing on each directional flow and bloc, for the EU's FVA to DVA relation, almost all sectors reached their maximum level of backwards VA in 2015 (17 sectors, or 81% of all), with few others on 2010 (3, or 14%) and 2000 (only one, or 5%). This shift was marked by a decline of "low" integrated sectors, here defined as those with less than 25% of VA internationally, from 9 in 1990 to 6 in 2015, and an increase of “high” integrated sectors, here defined as those with more than 75% of VA internationally, from none in 1990 to one in 2015 (“Electrical and Machinery”). The sectors with the largest share of internationalization are, as of 2015, “Electrical and Machinery”, “Transport Equipment” and “Metal Products”, while the sectors with the smallest share are “Construction”, “Education Health and Other Services” and “Retail Trade”. However, when analyzing by the average growth rate in the period, the picture is inverted: the fastest growers were “Retail Trade” (average growth of 26% per decade), “Education, Health and Other Services” (26% as well), followed by “Hotels and Restaurants” and “Construction” (both with approximately 22% average growth). The slowest growers were “Textiles and Wearing Apparel” (only 9% average growth), followed by a tie between “Transport Equipment”, “Petroleum, Chemical and Non-Metallic Mineral Products”, “Metal Products” and “Recycling”, all with an average of 12% growth per decade.

Looking now in the EU’s DVX to DVA relation, most sectors reached their maximum forward VA internationalization in 2010 (12 sectors, or 57% of all), but many also reached this level in 2015 (9, or 43%). Of those who reached it in 2010, the average decline to 2015 was of 4%. This shift also drove the previously noted decline in “low” integrated sectors, from 11 in 1990 to 8 in 2015, and an increase in “high” integrated sectors, from none to 2 in the same period. The highest integrated sectors are “Mining and Quarrying”, “Recycling” and “Electrical and Machinery”, while the lowest integrated sectors are “Maintenance and Repair”, “Construction” and “Education, Health and Other Services”. When focusing on average growth rates of internationalization, the fastest sectors were “Retail Trade” (average growth of 41% per decade), followed by “Hotels and Restaurants” and “Education, Health and Other Services” (both with average growth of 24%). On the opposite side, the slowest growers were “Mining and Quarrying” (average of 12%), followed by a tie between “Textiles and Wearing Apparel”, “Electrical and Machinery”, “Metal Products” and “Petroleum, Chemical and Non-Metallic Mineral Products”, all with an average of 14% growth per decade.

When combining both directional analyzes, it is evident that the EU has a similar sectoral profile of its internationalization, possibly due to the previously discussed homogeneity of trade partners (i.e., most of the trade is done inside the bloc), that forces a similar pattern of which and how sectors are forward and backwards integrated on VAT terms (a disaggregation by trade partners on the internationalized sections of VA is presented afterwards). Additionally, it is also interesting to note that the fastest growing sectors appear to be also the ones with the smallest share of internationalization (and vice-versa), possibly meaning that increasing the role of worldwide VAT with sectors with low levels of integration is easier than with those already well integrated with international partners. An hypothesis that possibly addresses this idiosyncrasy is that sectors highly integrated into international VAT may have already offshored most of what can be internationalized, mainly when considering the FVA direction of integration, with only more central/key activities still being done domestically.

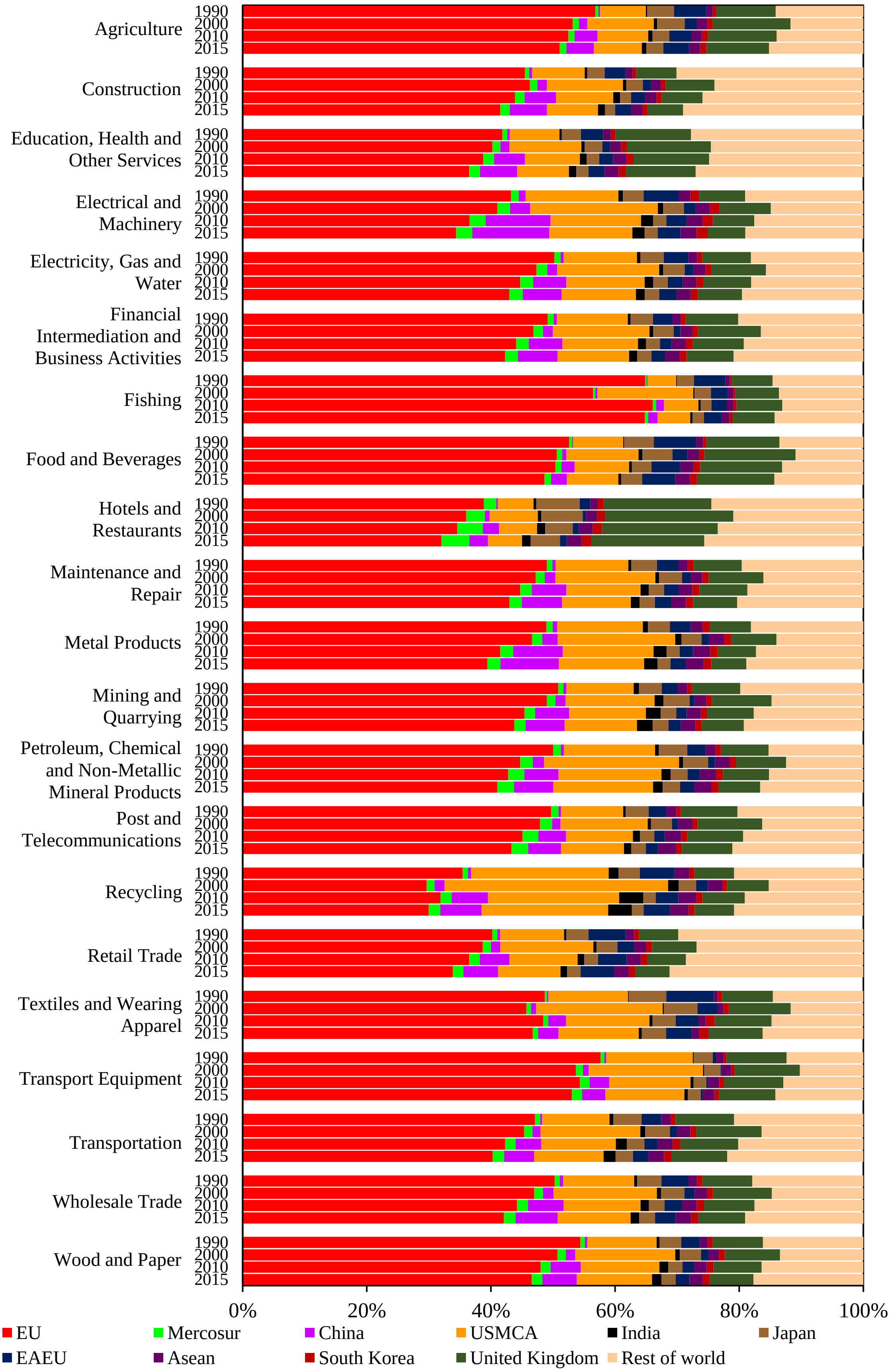
Turning to the MERCOSUR, for the FVA to DVA, almost all sectors reached their maximum level of internationalization on 2015 (15 sectors, or 71%), with a few on 2010 (4, or 19%) and only one in 2000 (“Recycling”) and one in 1990 (“Fishing”). There was also a decline of “low” integrated sectors, from 20 in 1990 to 17 in 2015, but the bloc does not have any sector with more than 50% of integration, thus implying no perceivable change on “high” integrated category of sectors. However, in the 26% to 50% band of VA integration, hereby defined as “medium-low” integrated sectors, there was an increase from only one sector in 1990 (“Fishing”) to 4 sectors in 2015. The highest integrated sectors are “Mining and Quarrying”, “Fishing”, “Transport Equipment” and “Metal Products”, while the lowest integrated are “Construction” and “Education, Health and Other Services”. However, differently from the shift seen in the EU’s analysis of growth, here the fastest growers are “Transport Equipment” and “Mining and Quarrying” (both with an average growth rate of 34% per decade), followed by “Wholesale Trade” (average of 29%), coinciding partially with the highest integrated sectors. There were two sectors that saw an average declining rate of VA internationalization as discussed previously, “Fishing” (average rate of decline of -9% per decade) and “Recycling” (average of -1%). The slowest sectors that still managed to grow, however, were “Education Health and Other Services” and “Construction” (both with an average growth of 13%) followed by “Food and Beverages” (average of 15%), also partially coinciding with the lowest integrated sectors.

Finally, focusing on MERCOSUR’s DVX to DVA, as was the case of the FVA analysis, most sectors reached their maximum level of integration in 2015 (15 sectors, or 71% of all), with only a handful in 2010 (6, or 29% of all). “Low” integrated sectors declined from 19 in 1990 to 13 in 2015, with an increase in “medium-low” sectors from none to 6 in the same period, and a shift of two sectors from the 51-75% band of integration (hereby defined as “medium-high”) to the “high” level of integration (“Fishing” and “Recycling”). The highest integrated sectors are “Fishing”, “Recycling” and “Electrical and Machinery”, and the lowest integrated sectors are “Education, Health and Other Services”, “Construction”, “Food and Beverages” and “Retail Trade”. Focusing on their average growth rates, the fastest growers were “Retail Trade” (average growth rate of 69% per decade), followed by “Agriculture” (average of 59%), “Mining and Quarrying” (52%), “Textiles and Wearing Apparel” (48%) and “Construction” (46%). The slowest growers were “Post and Telecommunications” (average growth rate of 3% per decade), “Fishing” (average of 9%), “Recycling” (20%), “Education, Health and Other Services” (22%) and “Electrical and Machinery” (26%). In this case, differently from the broad trend of the EU and the MERCOSUR FVA case, there was almost no correlation between level of integration and growth rate, with an heterogeneous mix of “high-fast”, “high-slow”, “low-fast” and “low-slow” sectors occurring.

When comparing both directions of the MERCOSUR VA integration, there is still some similarities on which sectors have a larger internationalized participation, but significantly less so than what was seen with the EU, especially on the low-end of current internationalization. When comparing growth rates, this directional heterogeneity is more evident. The apparent correlation between high integrated sectors and slow growers (and vice-versa) seen in the EU case is not seen in MERCOSUR countries, as previously discussed, where on one directional analysis fast growers are also highly integrated, and on the other directional analysis there is a high heterogeneity of the level of internationalization and its speed. Nonetheless, as initially shown, the average internationalization level across all sectors of the EU is the double of that of the MERCOSUR in 2015, and the latter bloc possesses almost no “high” or “medium-high” integrated sector: only 2 in both directions in 2015, against 16 in both directions in the same year of the EU. Thus, the hypothesis that some sectors may be already “too integrated”, thus hindering their speed of further integration, could still be valid, given that apparently few MERCOSUR sectors have managed to reach a high level of integration yet.

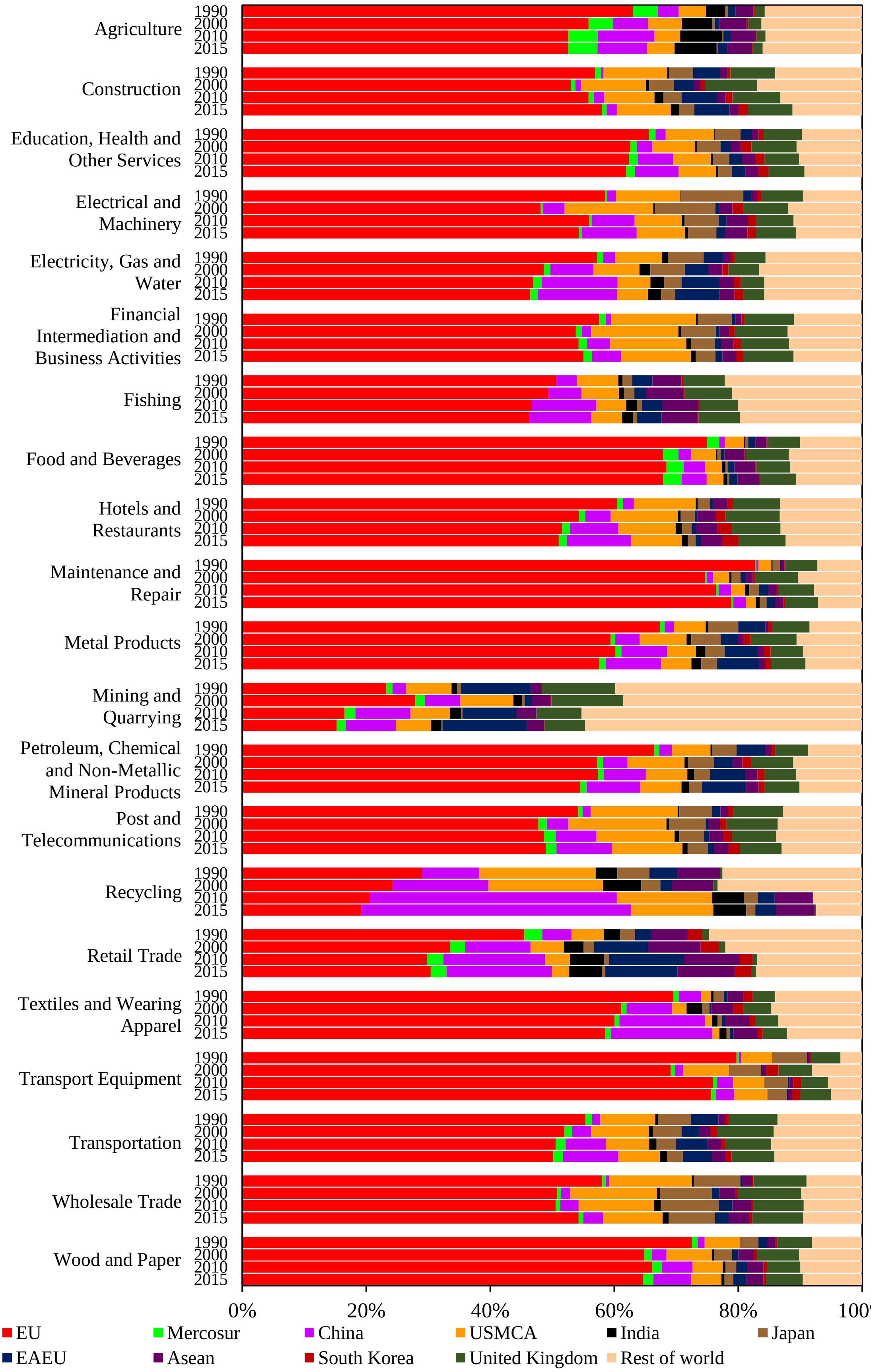
In order to develop a clearer picture of how this internationalization of each direction and bloc occurs, the international part of VAT (i.e., FVA and DVX) was disaggregated into where this value is generated from or to, with the same previously used set of possible partners: EU, MERCOSUR, China, USMCA, India, Japan, EAEU, ASEAN, South Korea and the UK. The EU’s FVA disaggregation by partner is represented on Figure 26, and the DVX disaggregation on Figure 27. For the MERCOSUR, the same corresponding breakdowns are represented in Figure 28 and Figure 29.

Figure 26 – Sectoral FVA by partner of the EU



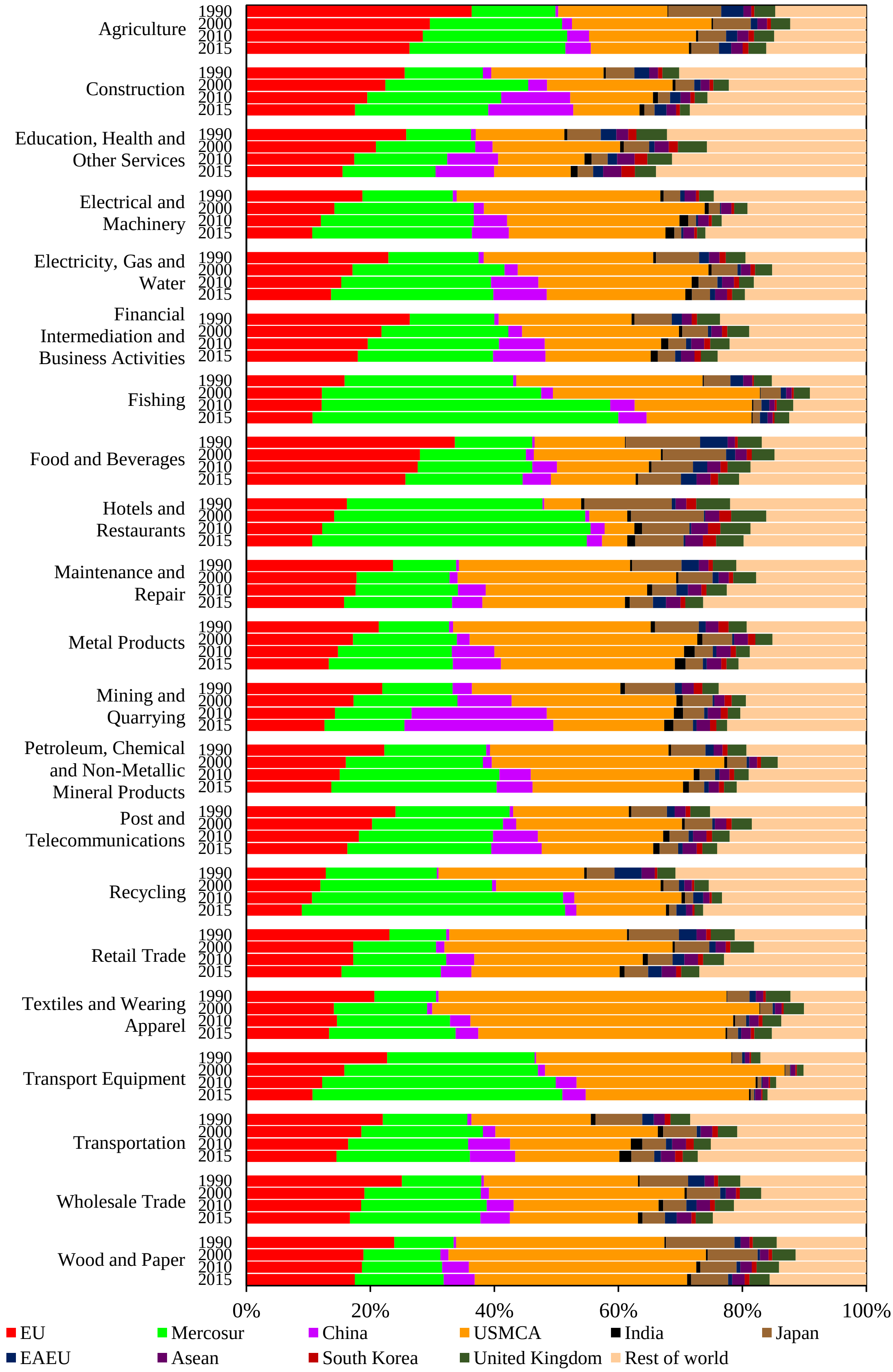
Source: Author calculations on data from Lenzen et al. (2012; 2013) and Aslam et al. (2017). Note: These values include intra-EU trade.

Figure 27 – Sectoral DVX by partner of the EU



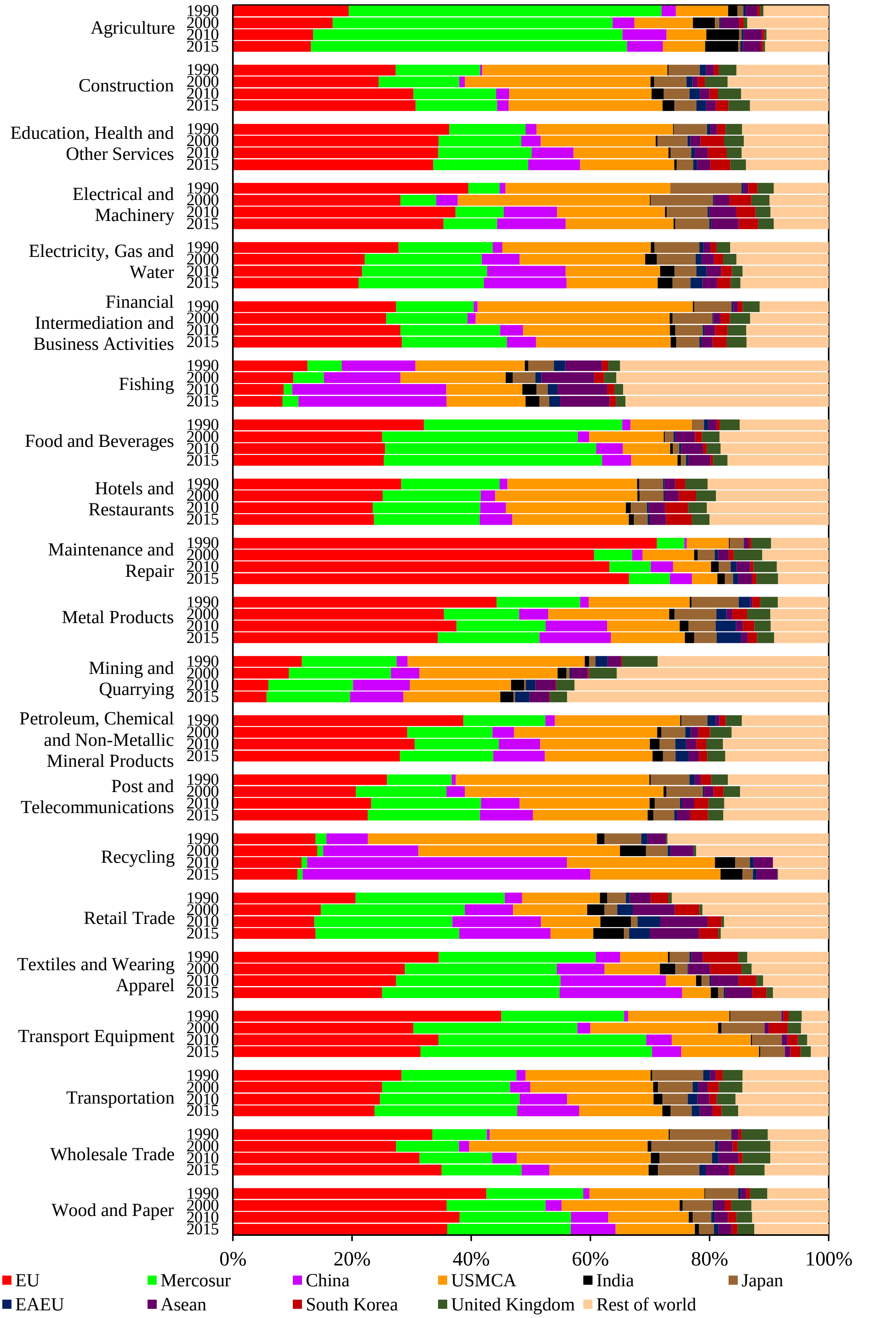
Source: Author calculations on data from Lenzen et al. (2012; 2013) and Aslam et al. (2017). Note: These values include intra-EU trade.

Figure 28 – Sectoral FVA by partner of the MERCOSUR



Source: Author calculations on data from Lenzen et al. (2012; 2013) and Aslam et al. (2017). Note: These values include intra-MERCOSUR trade.

Figure 29 – Sectoral DVX by partner of the MERCOSUR



Source: Author calculations on data from Lenzen et al. (2012; 2013) and Aslam et al. (2017). Note: These values include intra-MERCOSUR trade.

Focusing first on the EU's FVA breakdown by partner, it is apparent that the main source of value addition is performed by the bloc itself, being on average in the 4 years analyzed the partner that captures the largest share of VAT on all sectors. However, the bloc's captured shares are changing in a reducing manner: its average share across all sectors has been declining by approximately -4% per decade.

The second most relevant partner is the USMCA, appearing as the second highest partner in 17 sectors and as the third in 4, and at an increasing pace of growing approximately 9% across all sectors per decade. The third most relevant partner is the UK, being the second highest partner in 4 sectors and the third in the remaining 17, albeit at a somewhat stagnated rate of change on the "all-sectors average". Focusing solely on speed of growth, the fastest partners are China, that has been growing its average captured share across all sectors by 196% per decade, that is, almost tripling its share every 10 years, followed by India, with an average all-sectors growth rate of 63%, and the MERCOSUR, with a growth rate of 39%.

When analyzing the EU's DVX breakdown, the scenario is similar: the bloc itself appears again as the most relevant partner, capturing the largest share on average across the 4 years analyzed on 20 sectors, and as the second largest in the remaining sector. The all-sectors average change rate is also reducing for the bloc in this directional case, by declining approximately -5% per decade.

The second most relevant partner is, again, the USMCA bloc, being the second most relevant partner on average in 10 sectors and the third highest in another 6 sectors, and also with a declining rate of approximately -5% per decade on the all-sectors average. The third most relevant partner, if assessed only by "most appearances" as first, second or third most relevant partner on all sectors, is the UK, as was the case of the FVA analysis, appearing as the second highest in 5 sectors, and as the third highest in another 11 sectors, with also a declining rate of approximately -1%. However, when considering the partner with the average all-sectors highest share captured, the third most relevant partner is now China, replacing the UK, being the most relevant DVX partner for the EU in one sector ("Recycling"), and the second highest on 5 another sectors. The change rate for China in DVX on the all sectors average is also increasing very quickly, approximately by 95% per decade, and that country is, thus, also the fastest growing partner. The second fastest growing partner is India, as was also the case in the FVA analysis, with a growth average of 66%, and the third fastest is the EAEU, with an average growth rate of 48%.

Both directional analyzes considered, the VA breakdown by partners is very similar to the gross trade analyzes of trade done in Section 3.1 for the EU, and the main trade partners appear also as the main VAT partners for the EU (namely, the bloc itself, the USMCA, the UK, and, at a growing rate, China). However, when comparing the average change rate of representativeness of each partner, the results are more heterogeneous between the two analyzes. Nonetheless, the EU case is particularly interesting: it is its main trade partner and its main source of forward and backward VAT, however while the share of gross trade done internally has, on average, increased, the content of the trade in terms of VA source has been progressively less internal.

Looking now on the MERCOSUR breakdown for FVA, the main partner is the USMCA bloc, being the most relevant VAT partners in 11 sectors, the second most relevant in 6, and the third in another 3. That bloc's average share across all sectors has been declining, however, at an average pace of -4% per decade. The second main partner is the MERCOSUR itself, appearing as the most relevant VAT partner in 5 sectors, as the second most relevant in 8, and as the third in another 7. The bloc's all-sector average change of its share has, notwithstanding, increased by approximately 23% per decade, being the bloc also its third fastest growing partner. Finally, the third most relevant partner is the EU, being the most relevant partner in 5 sectors, the second most in 7, and the third most in 9. The EU share, however, also has been declining, as was the case of the USMCA, but at a faster rate: approximately -14% per decade on the all sectors average. The other fastest growing partners are, as was the case for the EU, China, with an all sector average growth of 170% per decade, and India, with an average of 49%.

On the DVX directional analysis, the most relevant partners are the same as in the FVA for the same bloc, but in a different order: the EU appears in the first place, by being the most relevant partner in 13 sectors, the second most in 5, and the third most in 3, the USMCA now occupies the second place, being the most relevant in 4 sectors, the second most in 9, and the third most in 7, and the MERCOSUR now is the third most relevant partner, being the most relevant in 3 sectors, the second most in 6, and the third most in 9. The all-sectors change average for the first two partners is declining: by -7% per decade for the EU, and by -11% per decade for the USMCA, while for the MERCOSUR the average share has been increasing, albeit at a slower pace than before, by 6%. The fastest growers are, again, China, by an average all-sectors increase of 115% per decade, and India, also by approximately the same rate of growth. The third fastest grower, however, is the EAEU, as was the case for the EU's DVX, with an average rate of 46%.

Combining both analyses, and comparing also with the previous discussion of gross trade partners of the MERCOSUR, the bloc also displays some homogeneity in its trade and VAT profiles, as was seen in the EU case, with its most relevant gross trade partners also being reflected as its main VAT partners. The only most relevant exception is China, that already figures prominently among trade partners of the bloc in gross terms, but less so on VAT terms, albeit on both cases that country has expressive growth rates of its captured shares of the MERCOSUR trade. Moreover, the opposite to what was seen for the EU is also observable now, when comparing the change rates of gross trade and VAT of the bloc with itself, since while the bloc has progressively less traded internally (even though at a slow pace of decline), the content of VAT internally done has increased.

Finally, when comparing the composition of VAT partners of the EU and the MERCOSUR on both directional flows, it is perceivable that the first bloc has, on relative terms, more dependence on a smaller number of partners (mostly with other EU countries), whereas the second bloc has a more diversified set of partners across the sectors here considered. Nevertheless, it must not be forgotten that the importance of foreign VAT for the MERCOSUR is much smaller than for the EU on average, thus whilst more diversified in the international VAT scenario, this factor is still not completely structurally relevant for the former bloc.

By combining the first analysis, of the degree of VAT internationalization, with the second analysis, of the composition of internationalized VAT by partner, it is possible to assess which are the most relevant trade partners for the most internationalized sectors of both blocs and in both directions. This is represented in Table 10 for the EU, and in Table 11 for the MERCOSUR.

Table 10 – Main partners and fastest growing partners of the EU highest VAT internationalized sectors

Rank	Sector	Main partner	Second highest	Third highest	Fastest grower	Second fastest	Third fastest
<u>FVA</u>							
1	Electrical and Machinery	EU	USMCA	UK	China	India	MERCOSUR
2	Transport Equipment	EU	USMCA	UK	China	India	MERCOSUR

Source: Author calculations on data from Lenzen et al. (2012; 2013) and Aslam et al. (2017). Note: the “rank” and subsequent order of sectors represent the decreasing order of most internationalized (i.e., with highest share of FVA/DVX when compared to DVA) sectors.

Table 10 – Main partners and fastest growing partners of the EU highest VAT internationalized sectors (*cont.*)

Rank	Sector	Main partner	Second highest	Third highest	Fastest grower	Second fastest	Third fastest
<u>FVA</u>							
3	Metal Products	EU	USMCA	UK	China	India	MERCOSUR
4	Textiles and Wearing Apparel	EU	USMCA	UK	China	India	MERCOSUR
5	Petroleum, Chemical and Non-Metallic Mineral Products	EU	USMCA	UK	China	India	MERCOSUR
<u>DVX</u>							
1	Mining and Quarrying	EU	UK	EAEU	EAEU	China	ASEAN
2	Recycling	China	EU	USMCA	China	India	EAEU
3	Electrical and Machinery	EU	USMCA	Japan	China	India	ASEAN
4	Transport Equipment	EU	USMCA	UK	South Korea	China	ASEAN
5	Textiles and Wearing Apparel	EU	China	UK	India	China	ASEAN

Source: Author calculations on data from Lenzen et al. (2012; 2013) and Aslam et al. (2017). Note: the “rank” and subsequent order of sectors represent the decreasing order of most internationalized (i.e., with highest share of FVA/DVX when compared to DVA) sectors.

Table 11 – Main partners and fastest growing partners of the MERCOSUR highest VAT internationalized sectors

Rank	Sector	Main partner	Second highest	Third highest	Fastest grower	Second fastest	Third fastest
<u>FVA</u>							
1	Fishing	MERCOSUR	USMCA	EU	China	MERCOSUR	India

Source: Author calculations on data from Lenzen et al. (2012; 2013) and Aslam et al. (2017). Note: the “rank” and subsequent order of sectors represent the decreasing order of most internationalized (i.e., with highest share of FVA/DVX when compared to DVA) sectors.

Table 11 – Main partners and fastest growing partners of the MERCOSUR highest VAT internationalized sectors (*cont.*)

Rank	Sector	Main partner	Second highest	Third highest	Fastest grower	Second fastest	Third fastest
<u>FVA</u>							
2	Mining and Quarrying	USMCA	EU	China	China	India	MERCOSUR
3	Metal Products	USMCA	EU	MERCOSUR	China	India	MERCOSUR
4	Transport Equipment	MERCOSUR	USMCA	EU	China	India	MERCOSUR
5	Wood and Paper	USMCA	EU	MERCOSUR	China	India	MERCOSUR
<u>DVX</u>							
1	Fishing	MERCOSUR	USMCA	EU	China	MERCOSUR	India
2	Recycling	MERCOSUR	USMCA	EU	China	MERCOSUR	India
3	Electrical and Machinery	USMCA	MERCOSUR	EU	China	India	MERCOSUR
4	Mining and Quarrying	USMCA	EU	China	China	India	MERCOSUR
5	Metal Products	USMCA	EU	MERCOSUR	China	India	MERCOSUR

Source: Author calculations on data from Lenzen et al. (2012; 2013) and Aslam et al. (2017). Note: the “rank” and subsequent order of sectors represent the decreasing order of most internationalized (i.e., with highest share of FVA/DVX when compared to DVA) sectors.

Thus, whether focusing on only the most internationalized sectors or on the previously discussed all-sector averages, the overall profile of VAT of both blocs is somewhat similar, in terms of who are the main and the fastest growing partners. If focusing, instead, on those sectors that are internationalizing the fastest, the same breakdown can be applied, trying to identify which partners have been the most relevant drivers of such internationalization. This is represented in Table 12 for the EU, and in Table 13 for the MERCOSUR.

Table 12 – Driving partners of EU's VAT fastest internationalizing sectors

Rank	Sector	Fastest grower	Second fastest	Third fastest
FVA				
1	Retail Trade	China	India	MERCOSUR
2	Education, Health and Other Services	China	India	MERCOSUR
3	Hotels and Restaurants	China	India	MERCOSUR
4	Construction	China	India	MERCOSUR
5	Mining and Quarrying	China	India	MERCOSUR
DVX				
1	Retail Trade	EAEU	China	India
2	Hotels and Restaurants	China	India	South Korea
3	Education, Health and Other Services	China	South Korea	India
4	Electricity, Gas and Water	China	India	ASEAN
5	Food and Beverages	India	China	ASEAN

Source: Author calculations on data from Lenzen et al. (2012; 2013) and Aslam et al. (2017). Note: the "rank" and subsequent order of sectors represent the decreasing order of most internationalized (i.e., with highest share of FVA/DVX when compared to DVA) sectors.

The countries driving growth rates in the fastest growing sectors are also mostly still the same as before, China and India, but also the MERCOSUR, ASEAN, and South Korea, of the considered set of possible partners. Thus, in all VAT analyzes performed, besides the expressive growing importance of China, and at a smaller rate and but still very relevantly, India, an additional factor, relevant to the study at hand, becomes evident: there are relevant VAT ties between the two studied blocs, the EU and the MERCOSUR, either already stablished (most relatively important for the MERCOSUR), or developing (at least in FVA terms, of the EU with the MERCOSUR).

Table 13 – Driving partners of MERCOSUR's VAT fastest internationalizing sectors

Rank	Sector	Fastest grower	Second fastest	Third fastest
FVA				
1	Transport Equipment	China	India	MERCOSUR
2	Mining and Quarrying	China	India	MERCOSUR
3	Wholesale Trade	China	India	MERCOSUR
4	Maintenance and Repair	China	India	MERCOSUR
5	Retail Trade	China	India	MERCOSUR
DVX				
1	Retail Trade	China	India	MERCOSUR
2	Agriculture	China	India	South Korea
3	Mining and Quarrying	China	India	MERCOSUR
4	Textiles and Wearing Apparel	China	India	MERCOSUR
5	Construction	China	India	MERCOSUR

Source: Author calculations on data from Lenzen et al. (2012; 2013) and Aslam et al. (2017). Note: the "rank" and subsequent order of sectors represent the decreasing order of most internationalized (i.e., with highest share of FVA/DVX when compared to DVA) sectors.

To better understand the importance of GVCs besides the simple proportion rates of these measurements on trade figures, the indicators developed by Koopman et al. (2010) of GVC position and participation were calculated for all sectors in 2000 and 2015 for both blocs. In addition to those, to further help in understanding the EU and MERCOSUR VAT integration with one another, a slight modification of the position and participation equations was done, as to assess their direct connections. These modifications led to the "local position" and "local participation" indexes, resulting in "local value chain" (LVC) indexes, calculated with the adjusted equations: [12]

$$Local\ Position_{ijn} = \ln\left(1 + \frac{DVX_{ijn}}{E_{in}}\right) - \ln\left(1 + \frac{FVA_{ijn}}{E_{in}}\right) \qquad i,j = EU, MERCOSUR \quad n = 1, \dots, 21 \tag{64}$$

$$Local\ Participation_{ijn} = \frac{DVX_{ijn} + FVA_{ijn}}{E_{in}} \qquad i,j = EU, MERCOSUR \quad n = 1, \dots, 21 \tag{65}$$

Where

- n are the 21 sectors here considered,
- FVA_{ijn} is the bilateral FVA in sector n,
- DVX_{ijn} is the bilateral DVX in sector n, and
- E_{in} is the total export of country i in sector n.

For all sectors considered, they are hereby defined as being "upstream" in GVCs if their position (or local position, for the LVC indicators) is bigger than zero, and "downstream" otherwise. They are considered with a "low" level of participation in GVCs if they are below the first quartile of the participation sample (divided between GVC and LVC observations), "average" if they are between the first quartile and the third, and "high" if they are above the third quartile. Thus, the participation "increased" from 2000 to 2015 if it changed from "low" to "average" or "high", or from "average" to "high", and "decreased" in the complementary scenarios.

Analyzing first the GVC indicators, the EU had mostly downstream sectors in both 2000 and 2015, with 16 of those against only 5 upstream sectors in the former year, and 17 against 4 in the latter year. In terms of participation, the bloc had predominantly "average" and "high" categories in both years; with 8 sectors in each category in 2000 (thus only 5 sectors being "low" in GVC participation), and 9 of each in 2015 (thus only 3 in the "low" status). Only one sector changed from upstream into downstream: "Post and Telecommunications". All other upstream sectors became even more upstream in GVCs, while almost all downstream sectors also became even more downstream (only two downstream sectors became less so:

[12] Both GVC and LVC indicators are represented graphically in Appendix B for all sectors of both blocs in 2000 and 2015.

"Agriculture" and "Textiles and Wearing Apparel"). In terms of change in participation, two sectors increased their participation into "average" from an initial "low" level, while one increased from "average" into "high" ("Wood and Paper"). Finally, the sectors with the highest participation levels were the same in both years: "Mining and Quarrying", upstream, "Recycling", also upstream, and "Electrical and Machinery", downstream. The less participative sectors were, in both years, "Retail Trade", upstream, "Education, Health and Other Services", downstream, and "Construction", also downstream.

Shifting to the MERCOSUR, the scenario is almost completely reversed; most sectors are upstream in both years, with 14 of those against 7 downstream sectors in 2000, and 13 against 8 in 2015. The only sector that changed category was "Education, Health and Other Services". The pattern of participation levels is also different: almost all sectors are in the "average" categorization; 11 in 2000, and 14 in 2015. The second most occurring category is "low" participation sectors, with 8 in 2000, although reducing to 5 in 2015. Nevertheless, all sectors that shifted from "low" participation became "average" sectors, and none increased from "average" into "high". No sector decreased in participation. Thus, only 2 sectors remained highly participative in GVCs in both years: "Fishing" and "Recycling", both upstream. In terms of positioning changes, also differently from the EU where most sectors became more clearly positioned on GVCs (i.e., upstream became more "up", downstream became more "down"), for the MERCOSUR approximately half upstream sectors became more "up", whilst the other half became less so. Downstream sectors became mostly more "down", however, with only one sector becoming less so in this time horizon ("Textiles and Wearing Apparel"). Finally, the sectors with the highest levels of participation on GVCs for this bloc in both years are all upstream: "Recycling", "Fishing" and "Electrical and Machinery". The sectors with the lowest levels of participation in common on both years are "Education, Health and Other Services" and "Construction", both also upstream.

Focusing now on the LVC indicators, the EU scenario in positioning becomes more well defined in this subsampling of VAT, being mostly composed of downstream sectors, with 17 of those against only 4 upstream in both years. In terms of participation, however, the levels are inverted to when compared with the GVC scenario for the bloc, with most sectors in 2000 being "low" (12) while some are also "average" (9). None are in the "high" category. When looking in 2015, there is some perceivable increase in the overall participation levels of the bloc, with 4 sectors shifting from "low" to "average", but none increased to "high" and there is no decrease whatsoever. As was the case for the bloc before, the trend in the changes of positionings is also seen here, being almost all towards a more well-defined position, and only two downstream sectors become less so (“Post and Telecommunications” and “Textiles and Wearing Apparel”), and only one upstream sector becoming less so as well (“Agriculture”). The sectors with highest level of participation are now “Mining and Quarrying”, upstream, “Agriculture”, also upstream, and “Petroleum, Chemical and Non-Metallic Mineral Products”, downstream. The least participative are all downstream: “Fishing”, “Education, Health and Other Services” and “Construction”. These did not change from 2000 to 2015.

For the MERCOSUR LVC indicators, they also become more clearly positioned than the GVC scenario in terms of positioning, being almost all upstream, with 17 sectors of those against only 4 downstream in both years. The reversal of participation is also seen: now most sectors in 2000 are “average” and “high” (10 of each, with only one “low”: “Construction”), and there is one increase from “low” to “average”, and one increase from “average” to “high”, thus making “high” participation the most common category in 2015. While the few downstream sectors become more “down” in this interval, the previously seen variability in this “deepening” of positionings is also evident here in the upstream sectors, with approximately half becoming more upstream (9) and half becoming less so (8). Interestingly, when highlighting the most and less participative sectors for this bloc they remain mostly the same as the GVC ones, including their VC positioning. The only change is of the third most participative sector in 2015, that for LVCs is “Maintenance and Repair”, upstream.

Comparing the changes when shifting from GVC to LVC, the overall positioning of sectors of both blocs appears mostly equal if not even more well defined than what was seen in GVCs (i.e., EU mostly downstream and MERCOSUR mostly upstream). However, the participation levels are reversed; whereas EU countries represented the highest levels of this index in the first indexes and the MERCOSUR the lowest levels, when focusing on their direct links, the latter bloc becomes the more participative while the former, the least. Thus, while EU countries appear to be more connected to global chains of production than the MERCOSUR, the chains that tie explicitly both blocs appear to be more significant for the latter. This should be considered only at a relative level, though, since the participation levels of GVCs are much higher than those calculated for LVCs (the average of this indicator for both blocs and years through all sectors is approximately 12 times higher than that of the first set of indicators than for the second one).

This scenario still agrees nonetheless with what was previously established in the sectoral disaggregation of VAT by foreign partner, where the EU appears as a relevant partner in most sectors for the MERCOSUR, while the opposite is not seen so ubiquitously. Moreover, the participation of the MERCOSUR in driving VAT growth in both blocs could not be directly detected in this analysis. Finally, it became clear that not only does the EU appears to be more key in GVCs as a downstream player, and the opposite for the MERCOSUR countries, but also between themselves this holds true.

Thus, while value chains between the blocs still have not been significantly developed, their future expansion could be fostered within this already established global role each plays, and leverage on the relevant growth that MERCOSUR has been pushing internationally alongside the more central node that the EU plays on the global economy.

3.3 THE EUROPEAN UNION AND MERCOSUR FREE TRADE AREA AGREEMENT

During the Group of Twenty's (G20) summit of 2019 in Osaka, Japan, on June 28, the heads of the G20's MERCOSUR and EU member states announced the end of negotiations for the establishment of a FTA agreement between the two blocs. This agreement has not yet been signed nor ratified, and it continues to be adjusted and expanded, as now it passes a legal and technical revision of its content before local governments and legislator bodies approve or disapprove it (GHIOTTO & ECHAIDE, 2019).

These negotiations are based on the groundwork initially developed by the "Interregional Framework Cooperation Agreement between the European Community and the MERCOSUR", that entered in force between the two blocs in 1999. This earlier agreement sought to increase bilateral market access and overall liberalization and harmonization of trade disciplines, besides cooperation and exchanges of information on various industries and sectors, and that on its own was being in discussion between the blocs as early as 1996 (EUR-LEX, 1996; 1999).

The progress in these past decades was not continuous, however, and faced periods of stagnation and hold-ups due to a repetitive cycle of periodic lack of interest of both parties in different moments, and was marked chiefly by difficulties in elaborating a balanced deal in agricultural terms, which was and still is one of the main exports of MERCOSUR countries, but faces difficulties in accessing the EU market (GHIOTTO & ECHAIDE, 2019; BALTENSPERGER & DADUSH, 2019), which, as seen before, still has asymmetrically large tariffs vis-à-vis other goods imported into this bloc.

During this prolonged period of talks, some of the cyclicality of interest arose, for example, from the Global Financial Crisis of 2009 and its regional developments in the European debt crisis, on the EU, and the various crises faced by the MERCOSUR countries in the 2010s that slowed down the rhythm of progress. Other factors also amounted in the first decade of negotiations, for example, with the swift growth of Asian economies like China, for example, that exogenously diverted the interest of the blocs in their own internal agreement.

The main shift to a more progressive pace for the positive conclusion of negotiations came mostly only on the previous few years that led to it, as discussed by Ghiotto and Echaide (2019), with structural changes on the political landscape. This was observed mainly on the MERCOSUR countries, where a more “internationalized” (as opposed to internalized or autarkic) developmental approach became one of the key pillars of their economic pursuits, sought to be achieved and through a diversification of partners (when compared to the dependence this bloc developed on trade with China, for example).

The agreement currently is composed of 23 chapters, from trade in services and goods, to competition, rules of origin, government procurement and sanitary and phytosanitary measures. It also has 6 annexes, additionally specifying export duties and monopolies, intellectual property and the dispute settlement mechanism, and covering industries locally relevant for the blocs: wine and spirits, and vehicles and its related equipment and parts. The content itself of each chapter and provision is most likely not final. As exemplified by Ghiotto and Echaide (2019), the “Comprehensive Economic and Trade Agreement” between the EU and Canada had almost 20% of its text changed during the technical and legal revision period in which the EU-MERCOSUR FTA currently is. Thus, the current lack of specificity of many articles, as discussed by the same authors, and the relevant problems that are hindering the progress of the agreement on topics such as the environmental issues should indicate that there is still plenty of development on the text and final form of the agreement itself before it is actually ratified and enforced.

On broad terms, however, the current agreement specifies that on agricultural goods that the MERCOSUR will remove tariffs on 93% of such goods, and the EU on 82%. On industrial goods the tariff reduction will be on 90% of goods by the MERCOSUR, and of 100% by the EU. The transitioning period into this new arrangement is of up to 15 years, varying accordingly to the sensitiveness of the industries for each bloc. It also includes mutual recognition of relevant industries from each bloc, and, for example, of hundreds of geographically recognized

EU products, and complete liberalization of important MERCOSUR exports such as orange juice, coffee, and fruits.

Some insights on the future development of the agreement arise from the previously reviewed empirical literature on the content of trade agreements and its impact on the development of VCs between signing partners and GVCs with third parties. More specifically, Laget et al. (2018) discusses the asymmetry of impacts that deep agreements should have on countries with different levels of development and, in that line, how more “diverse” deals (i.e., including WTO-X provisions for example) impact more “South-South” PTAs than “North-North” ones, since, in the latter case, local institutions are supposedly already robust. In specific terms, they note the possible impact that should arise from provisions such as those governing over investment and competition, and other “behind the border” policies that impact directly on local policymaking.

Boffa et al. (2018) empirically finds a positive relationship arising from the simple inclusion of the investment on the PTAs terms. Rubínová (2017) specifically studies the inclusion of investment, capital movement, intellectual property rights, competition and services provisions on agreements, all intuitively connected by the author to a possible driving effect on GVC trade either due to its direct role in facilitating the unbundling of production and flows of investments and capital in general, or indirectly by the standardization of institutions asymmetrically weak in developing and emerging countries, as previously discussed (i.e., the “behind the border” spillover effects onto local policymaking). The author finds that PTAs covering provisions that aim at liberalizing and facilitating services have a stronger effect on developing and emerging countries who sign deals containing them than the average provision, and that investment provisions in general are essential for increasing the participation of all parties in trade agreements on upstream industries and stages of value chains.

Thus, considering these intuitive and empirical results, some factors should be relevant for the final agreement, when it is reached, between the EU and the MERCOSUR. Mainly, due to the “North-South” paradigm of this deal and the asymmetries previously noted on content and role in upstream or downstream industries that each bloc has, it is particularly relevant to consider the role and the presence that provisions on investments, competition and services should have on the final text, as they may be essential for an optimal outcome to be achieved from the deal.

Finally, as noted by Baltensperger and Dadush (2019), the long-term result of the agreement in general should be positive, even when taking into consideration that the short-term effects that may prove themselves negative to some industries, but that should be somewhat mitigated by the long phasing-in step of the agreements' implementation process until the full FTA is enforced. The researchers point that,

> "Assuming the agreement is ultimately ratified, the quantifiable gains are likely to be small for Mercosur, because of the deal's modest scope in terms of liberalising trade in products such as beef and other sensitive agricultural products, and its correspondingly limited ambition to reduce tariffs on manufactured goods entering Mercosur. The quantifiable gains are smaller still for the EU on account of the modest liberalisation in agriculture and Mercosur's small size as an export destination for the EU. The less quantifiable and potentially much larger gains that might accrue from the agreement relate to its potential to drive reforms and long-term productivity improvement in Mercosur's manufacturing sector and the EU's agriculture sector. As always, specific sectors could see significant gains or losses from the agreement, even though the macroeconomic effects are small. The fact that the agreement will take years to ratify and its implementation schedule is gradual and linear over five to ten years, will make the changes on the ground virtually imperceptible in all but the most sensitive sectors, which should ease concerns about adjustment costs." (BALTENSPERGER & DADUSH, 2019)

Thus, in the long run, the FTA may be a key instrument for the blocs to perform and undergo structural domestic reforms in, most relevantly, environmental, industrial and agricultural terms, not only enabling a closer bilateral relationship and the exchange of best practices, with an underlying basis structured on trade of geographically specialized and efficiently produced goods and services, but also by enabling a more direct confrontation of practices and harmonized growth to tackle future problems such as climate change and the return to growth in the post-pandemic world order, where a more internationalized through diversified channels EU and MERCOSUR may more significantly appear in the central global stage as relevant players besides the now hegemonic USA and China.

4 MODELLING VALUE-ADDED TRADE

To assess the impacts that a trade agreement between the EU and the MERCOSUR could have on their economic integration via fostering the establishment of cross-bloc value chains and resulting in increased VAT, an econometric model using the Gravitational framework was estimated, and is presented in this chapter in section 4.1, which was later compared with an ANN, whose characteristics are presented in section 4.2, both using data of global recent VAT, described in section 4.3.

4.1 ECONOMETRIC MODEL

To model and evaluate the role of PTAs on GVCs through VAT indicators, the expanded Gravitational model in Equation 52 was used, in the adapted form:

$$VAT_{ijt} = \exp\left[\beta_0 PTA_{ijt} + \beta_1 \ln(y_{it}) + \beta_2 \ln(y_{jt}) + \beta_3 \ln(d_{ij}) + \alpha G_{ij} + \lambda_i + \mu_j + \nu_t\right] \varepsilon_{ijt} \tag{66}$$

Where

- VAT_{ijt} is a VAT variable focused on country i associated with any other country j measured at year t,
- PTA_{ijt} is a measurement of the presence or the depth of trade agreements between countries i and j at year t,
- y_{it} is country's i GDP at year t,
- d_{ij} is the distance between countries i and j,
- G_{ij} is a vector controlling for the Gravitational cost of trade between countries i and j at year t,
- λ_i, μ_j and ν_t are vectors controlling for the FE of country i, country j and year t respectively,
- ε_{ijt} is the error term, and
- $\beta_{0,1,2,3}$ and α are the stochastic parameters of the model.

Two dependent variables are used in this study, and are regressed in succession:

$$VAT_{ijt} = \begin{cases} FVA_{ijt} \\ DVA_{it} \end{cases} \tag{67}$$

Where

- FVA_{ijt} is the bilateral FVA at year t, and
- DVA_{it} is the DVA of country i at year t.

The role of the first dependent variable is to directly measure the capability of the different Gravitational measurements, and particularly of PTAs, on the establishment of bilateral VAT, while the role of the second variable is to try to asses if PTAs are capable of fostering also domestic development on trade in a more general manner.

The first independent variable takes six different structural forms, so divided due to a high correlation of the selected variables: [13]

$$PTA_{ijt} = \begin{cases} \max\left(CU_{ijt}, FTA_{ijt}, EIA_{ijt}, CUEIA_{ijt}, FTAEIA_{ijt}\right) \\ \delta_1 CU_{ijt} + \delta_2\, FTA_{ijt} + \delta_3\, EIA_{ijt} + \delta_4 CUEIA_{ijt} + \delta_5 FTAEIA_{ijt} \\ \sum_{a=1}^{52} Provision_{ijta} \\ \sum_{a=1}^{52} PEnforceable_{ijta} \\ \sum_{b=1}^{14} WTOPEnf_{ijtb} \\ \sum_{c=1}^{38} WTOXEnf_{ijtc} \end{cases} \tag{68}$$

Where

- CU_{ijt} is a dummy variable equal to 1 whenever there is only a customs union agreement (CU) between countries i and j at year t,
- FTA_{ijt} is a dummy variable equal to 1 whenever there is only a free trade area agreement (FTA) between countries i and j at year t,
- EIA_{ijt} is a dummy variable equal to 1 whenever there is only an economic integration agreement (EIA) between countries i and j at year t,

[13] The correlation of all variables is presented in subsection 4.2.4.

- $CUEIA_{ijt}$ is a dummy variable equal to 1 whenever there is a single agreement that encompasses both CU and EIA between countries i and j at year t,
- $FTAEIA_{ijt}$ is a dummy variable equal to 1 whenever there is a single agreement that encompasses both FTA and EIA between countries i and j at year t,
- $Provision_{ijta}$ are 52 dummy variables mapping each a different possible provision of trade agreements that are equal to 1 whenever their mapped provision is included in any agreement that exists between countries i and j at year t,
- $PEnforceable_{ijta}$ are 52 dummy variables mapping the same previous provisions, but equal to 1 whenever their mapped provision is not only included, but also legally enforceable and present on the "dispute settlement" provision of the agreement they are part of (hereby defined simply as "enforceable provisions"), considering all agreements that exists between countries i and j at year t,
- $WTOPEnf_{ijtb}$ are 14 dummy variables subdividing the enforceable provisions set by considering only WTO+ provisions, thus being equal to 1 whenever their mapped provisions are included and enforceable in any agreement that exists between countries i and j at year t,
- $WTOXEnf_{ijtc}$ are 38 dummy variables subdividing the enforceable provisions set by considering only WTO-X provisions, thus being equal to 1 whenever their mapped provisions are included and enforceable in any agreement that exists between countries i and j at year t, and
- $\delta_{1,2,3,4,5}$ are additional stochastic parameters of the model.

The role of the first two structural forms is to identify, firstly, the impact that the mere presence of a PTA has on the development of VAT between partners, and, secondly, address whether this behavior is due to any specific type of agreement and, if so, which agreements are found to be better at developing such economic evolution.

The third and fourth forms instead focus more specifically on the content of such agreements, whenever they exist, trying to assess first if the simple size of the agreement is enough or if legal depth (as in enforceability of the document) is required in order to better foster VAT.

The fifth and sixth forms further disaggregate this measurement of enforceable depth into whether reinforcing already WTO-bound policies or branching out into "out of scope" WTO-X policies are more useful in developing such integration.

For the sake of clarity in the statistical presentation of the model, the first structural form of the PTA_{ijt} variable will be hereafter called simply “PTA”, the second form will be untangled in 5 denominations representing respectively each type of agreement: “CU (only)”, “FTA (only)”, “EIA (only)”, “CU & EIA”, and “FTA & EIA”, the third form will be known as “Depth (all)”, the fourth form “Depth (only enforceable)”, the fifth form “Depth (WTO+)”, and the sixth “Depth (WTO-X)”.

The log-transformed GDPs and distance independent variables follow from the previously defined Gravitational equation structure, and are partial controls for MRTs and trade costs, and are assisted by the Gravitational vector here defined as:

$$G_{ij} = \begin{bmatrix} cont_{ij} \\ lang_{ij} \\ ccol_{ij} \\ col_{ij} \end{bmatrix} \tag{69}$$

Where

- $cont_{ij}$ is a dummy variable equal to one whenever countries i and j are contiguous,
- $lang_{ij}$ is a dummy variable equal to one whenever countries i and j share a common language,
- $ccol_{ij}$ is a dummy variable equal to one whenever countries i and j share or have shared a common colonizer, and
- col_{ij} is a dummy variable equal to one whenever countries i and j are or ever were in a colony-colonizer relationship.

With the stochastic parameters vector:

$$\alpha^t = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \end{bmatrix} \tag{70}$$

The FE terms, λ_i, μ_j and ν_t, used in the model control for the countries and years independently, in order to completely address the issue of MRTs, but not in pairs (e.g., FEs for country pairs and for each country in each role with years) as to avoid perfect multicollinearity with the Gravitational dummies.

4.2 ARTIFICIAL NEURAL NETWORK

For the evaluation of the dataset, some ANNs models were developed and studied. Its entry nodes, or independent variables, are the same as those presented in section 4.1, that is,

- The dummy variables controlling for the presence of any type of trade agreement, that is, CU_{ijt}, FTA_{ijt}, EIA_{ijt}, $CUEIA_{ijt}$, and $FTAEIA_{ijt}$,
- The count variables controlling for each class of enforceable provisions, that is, $WTOPEnf_{ijtb}$ and $WTOXEnf_{ijtc}$, and
- The standard gravitational variables: GDP (y_{it}), distance (d_{ij}), contiguity ($cont_{ij}$), language commonality ($lang_{ij}$), and colonial relationships ($ccol_{ij}$ and col_{ij}).

Conversely, the output node, or dependent variable, tested were the same as the previously defined VAT_{ijt}. The analysis was performed on three different ANN architectures. The first architecture is akin to those seen on the studies by Wohl and Kennedy (2018) and Ho et al. (2020) and contains one hidden layer with a number of neurons varying from 2, 3, 5 and 10, and one output variable. The second architecture tested is that similar to that proposed by Koffi and Li (2019), with four hidden layers of 10, 10, 5, and 5 nodes each, respectively. Finally, a third and intermediate architecture was assessed with two layers with either 3 or 5 nodes each. A representation of the general shape of the assessed architectures is presented on Figure 30.

4.3 DATA SOURCES

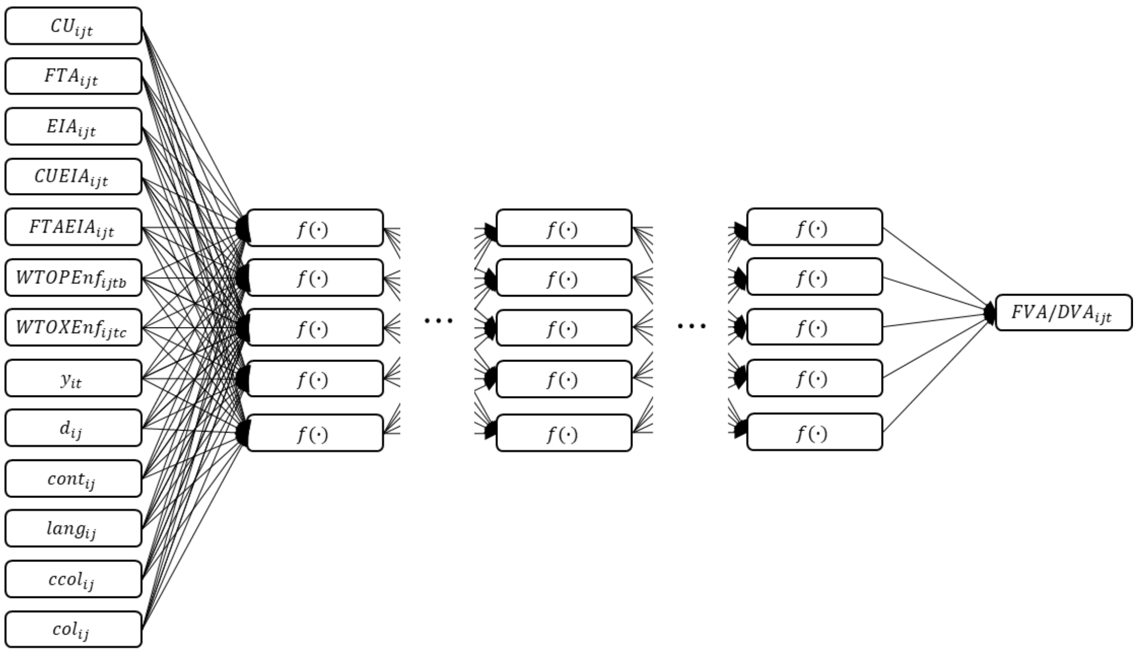
For the econometric regression of the stochastic parameters and the estimation of the neural network, a panel data sample was developed using data sourced from three different databases: one for the dependent VAT variables, whose selection is discussed in subsection 4.2.1, a second for PTAs and their contents, presented in subsection 4.2.2, and a third for the remaining independent Gravitational variables, presented in subsection 4.2.3.

4.3.1 Dependent value-added trade variables

The source for the dependent variables, bilateral FVA and DVA, is the UNCTAD-Eora database by Casella et al. (2019). This database was selected due to its extensive coverage both in terms of countries (189) and time horizon (from 1990 to 2019), which makes it unique when compared to other MRIO tables such as the Organization for Economic Co-operation and Development's (OECD) Trade in Value Added (TiVA) database, that includes only 64 countries in a shorter time horizon (2005-2015), and the EU-funded World Input-Output

Database (WIOD), covering also fewer countries (43) in an even smaller time dimension (2000-2014).

Figure 30 – General architecture of the tested ANN



Source: Author elaboration.

This large-scale coverage of both countries and years does come with an underlying necessity of modelling VAT flows, as different countries have had and currently still have different availabilities of data through time, which are, in turn, also heterogeneous when available. Thus, the database is a self-described "meta database", which combines different data sources and interpolates the available data as to construct its continuous large dimensions (Casella et al., 2019).

Nonetheless, as analyzed by Aslam et al. (2017) and Casella et al. (2019), the modelling assumptions used do not compromise its statistical quality vis-à-vis the smaller TiVA and WIOD. These authors find that, particularly for TiVA, the data available from Eora is generally consistent with it, and albeit individual data points of more heavily modelled countries (due to either simple absence of trade data, or absence of the data required for unpacking trade into its uses at destinations) may be less reliable, the overall trend of the database seems to be in accordance with the OECD's database. A similar pattern, of likeness of data trends, is seen also when comparing it with the WIOD database, with a high correlation at the individual country level where the same countries are available in both databases (Casella et al., 2019).

Finally, a last upside of the selected database is its empirical ease of use, as the VAT variables used in the regressions are available already at the source, thus computationally alleviating the research. The source imposes a dimensionality on the dependent variables, that are therefore measured in current US$ at any given year t.

4.3.2 Preferential trade agreement membership and depth

The source for the presence of PTAs through time, in the model represented by the 6 structural forms of the PTA_{ijt} independent variable, is the database from the World Bank (WB) by Hofmann et al. (2017). This database provides a comprehensive breakdown of 279 PTAs notified to the WTO between 1958 and 2015 into 52 provisions, being 14 of those categorized as WTO+, and the remaining 38 as WTO-X areas.

Moreover, the database also categorizes for each year and bilateral set of partners the type of PTA active between them as a FTA, EIA, CU or a combination of an FTA with an EIA or a CU with an EIA. The database also specifies for each included provision in each agreement whether they are merely included in the agreement's text or if they are legally enforceable due to the legal framework established, and among these, if they are excluded from the dispute settlement provision or included. Thus, it provides not only a categorical breakdown of types of agreements, but also an ordinal breakdown into 3 different levels of increasing legal depth of 52 different provisions[14].

4.3.3 Gravitational variables

Finally, for the data concerning the remaining Gravitational variables (i.e., GDPs, distance, contiguity, common language, common colonizer, and colony-colonizer relationship), they were are all sourced on the Centre d'Etudes Prospectives et d'Informations Internationales' (CEPII) "GeoDist" and "Gravity" databases, the first by Mayer and Zignago (2011), and the second by Head et al. (2010) and Head and Mayer (2014).

These databases cover 225 different countries that existed and currently exist, from 1948 to 2015, in bilateral measurements of nominal GDPs in current US$ at any year t, distance in kilometers measured as the distance between the "main cities" of each country (either the most populous or the capital) through the great circle formula, and the other dummy variables.

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[14] The provisions are listed, described, and categorized as either WTO+ or WTO-X in Appendix C.

4.3.4 Data treatment and summary

The final sampling used in this study is the result of the amalgamation of the previously described three databases and is thus constrained by the years and countries in common. The sample contains 520.572 individual bilateral observations of 142 different countries[15] permutated in pairs throughout the 26 years from 1990 to 2015. Table 14 presents the statistical summary of all independent and dependent variables considered. The correlation between all variables is presented in Table 15.

Table 14 – Statistical summary of the variables

Variable	Dimension	Mean	Standard deviation	Minimum value	Maximum value
<u>Dependent variables</u>					
FVA	Current US$	5.15×10^{10}	1.54×10^{11}	1.86×10^{7}	1.73×10^{12}
DVA	Current US$	1.44×10^{8}	1.44×10^{9}	0	1.08×10^{11}
<u>Independent variables</u>					
PTA	*Dummy*	0.094	0.291	0	1
CU (only)	*Dummy*	0.027	0.162	0	1
FTA (only)	*Dummy*	0.034	0.182	0	1
EIA (only)	*Dummy*	0.003	0.050	0	1
CU & EIA	*Dummy*	0.011	0.102	0	1
FTA & EIA	*Dummy*	0.019	0.137	0	1
Depth (all)	Number of provisions	2.485	8.607	0	48

Source: Author elaboration.

[15] The list of countries considered in this study is presented in Appendix D.

Table 15 – Statistical summary of all variables (*cont.*)

Variable	Dimension	Mean	Standard deviation	Minimum value	Maximum value
Independent variables					
Depth (only enforceable)	Number of provisions	1.685	6.579	0	45
Depth (WTO+)	Number of provisions	0.871	2.947	0	14
Depth (WTO-X)	Number of provisions	0.814	3.952	0	31
GDP	Current US$	3.12×10^{11}	1.21×10^{12}	1.26×10^{8}	1.80×10^{13}
Distance	Kilometers	7834	4401	60	19951
Language	*Dummy*	0.149	0.356	0	1
Common colonizer	*Dummy*	0.161	0.368	0	1
Colony-colonizer	*Dummy*	0.014	0.117	0	1
Contiguity	*Dummy*	0.018	0.135	0	1

Source: Author elaboration.

Table 15 – Correlations

	FVA	DVA	PTA	CU (only)	FTA (only)	EIA (only)	CU & EIA	FTA & EIA	Depth (all)	Depth (only enforceable)	Depth (WTO+)	Depth (WTO-X)	GDP	Distance	Language	Common colonizer	Colony-colonizer	Contiguity
FVA	1																	
DVA	0,241	1																
PTA	0,149	0,087	1															
CU (only)	0,100	0,014	0,518	1														
FTA (only)	0,017	0,020	0,588	-0,032	1													
EIA (only)	0,038	0,022	0,157	-0,008	-0,010	1												
CU & EIA	0,130	0,054	0,322	-0,017	-0,020	-0,005	1											
FTA & EIA	0,065	0,093	0,433	-0,023	-0,026	-0,007	-0,014	1										
Depth (all)	0,176	0,102	0,898	0,526	0,349	0,197	0,419	0,440	1									
Depth (only enforceable)	0,227	0,114	0,797	0,495	0,264	0,264	0,508	0,282	0,911	1								
Depth (WTO+)	0,195	0,108	0,920	0,478	0,422	0,208	0,424	0,437	0,948	0,938	1							
Depth (WTO-X)	0,234	0,110	0,641	0,468	0,125	0,285	0,530	0,144	0,810	0,966	0,815	1						
GDP	0,145	0,859	0,034	-0,003	-0,003	0,007	0,020	0,061	0,038	0,048	0,048	0,045	1					
Distance	-0,080	-0,001	-0,324	-0,230	-0,196	-0,070	-0,150	-0,018	-0,292	-0,295	-0,306	-0,263	0,019	1				
Language	0,026	0,000	0,083	0,077	0,055	-0,011	0,005	0,013	0,026	0,002	0,031	-0,020	0,031	-0,074	1			
Common colonizer	-0,017	-0,029	0,045	0,042	0,037	-0,022	0,000	0,006	0,001	-0,018	0,018	-0,043	0,025	-0,047	0,503	1		
Colony-colonizer	0,044	0,074	0,050	0,011	0,055	0,001	0,011	0,012	0,042	0,041	0,054	0,028	0,061	-0,049	0,153	-0,043	1	
Contiguity	0,168	0,026	0,231	0,188	0,121	0,027	0,100	0,023	0,170	0,173	0,202	0,138	0,014	-0,210	0,111	0,091	0,091	1

Source: Author elaboration.

5 EMPIRICAL RESULTS AND DISCUSSION

The statistical results of the econometric assessment via the model presented in section 4.1 are presented here, with the observed significance and interplay of the relevant variables for this study being discussed in section 5.1, whilst the results achieved with the studied ANNs presented in section 4.2 are presented and compared with the previous model in section 5.2. The relevance of the results found are discussed in light of the modern economic scenario of the EU and MERCOSUR, presented in Chapter 3, in section 5.3.

5.1 REGRESSED PARAMETERS

The econometric Gravitational model presented in Equation 64 was regressed with the sampled panel data described in section 4.3 with the PPML method, performed using the "*ppmlhdfe*" package for Stata, developed by Correia et al. (2020), with robust errors and clustering of the 10.001 country pairs done through the distance variable. Each dependent variable is regressed in 6 different scenarios, one for each of the different structural forms of the PTA_{ijt} variable, due to previously seen high correlation of parameters that made unfeasible, at last in order to acquire statistically significant parameters, to have them combined into fewer regressions.

The stochastic parameters signs and sizes are expected to be that, in accordance with all the reviewed empirical literature, trade agreements, i.e., concerning the "PTA" variable, have a positive and significant impact on VAT (BAIER & BERGSTRAND, 2007; HAYAKAWA & YAMASHITA, 2011; OREFICE & ROCHA, 2013; JOHNSON & NOGUERA, 2017; RUBÍNOVÁ, 2017; BOFFA, JANSEN, & SOLLEDER, 2018; LAGET, OSNAGO, ROCHA, & RUTA, 2018; OSNAGO, ROCHA, & RUTA, 2020), albeit all use differently sourced and combinations of independent and dependent variables than those employed in this study.

Concerning the type of agreement, i.e., concerning the "CU only", "FTA only", "EIA only", "CU & EIA", and "FTA & EIA" variables, Johnson and Noguera (2017) finds significant and positive parameters for both FTAs and "deep" agreements (by the authors defined as customs unions, common markets and economic unions), and that the latter category is, on average, twice as effective in driving growth when compared to the former. The number of provisions contained in the agreement, i.e., concerning the "depth (all)" variable, is also found to be positive and significant in the studies of Orefice and Rocha (2013), Boffa et al. (2018), Laget et al. (2018), and Osnago et al. (2020). The amount of legally enforceable provisions , i.e., concerning the "depth (enforceable only)" variable, is estimated as positive and significant in the results of Laget et al. (2018), while the parameters of the disaggregated WTO+, i.e., concerning the "depth (WTO+)" variable, and WTO-X, i.e., concerning the "depth (WTO-X)" variable, provisions are found to be in some scenarios positive and significant in the work of Orefice and Rocha (2013), and on average very similar to one another.

The regressed parameters are presented in Table 16 for the FVA dependent variable, and in Table 17 for the DVA dependent variable.

On the first six regressions with FVA as the dependent variable, the sign and the significance of most parameters were coherent with the expectations, with the only exception being the "language" dummy, that although positive is not statistically significant in the first two evaluations (and barely so in the other four). This insignificance may be caused by the relatively high correlation between this variable and the "common colonizer" dummy, which may have controlled for a similar bilateral variability, meaning that many countries with similar colonizer also share a same language, and thus the effect that these may cause on reducing cultural trade costs may have been double counted.

Conversely, regarding the significance of the parameters in the six regressions with DVA as dependent variable, they also are somewhat in conformity with expectations. Concerning the Gravitational parameters, the GDP of the partner country is indeed statistically insignificant, whilst most of the other parameters shift from statistically significance to insignificance in all different scenarios. The only Gravitational parameters that are strongly significant in all tests are the country's own GDP and the bilateral distance, albeit the latter having a relatively small effect on DVA.

The significance of the distance variable, on the DVA regressions, which is found to be positively correlated with the dependent variable on all tests, alongside with the signs of other Gravitational variables whenever they are significant (e.g. "common colonizer" in the "depth (WTO+)" case that has a significant and negative parameter, or "contiguity" in the first two cases that also has a significant, albeit moderately less so than the previous case, and negative parameter), do not appear to have a clear theoretical nor practical justification for their impact on the domestic performance of the sampled countries.

Table 16 – FVA PPML regression results

	FVA (Foreign Value Added)					
	(1)	(2)	(3)	(4)	(5)	(6)
PTA	0.38660*** (0.05010)					
CU (only)		0.44269*** (0.07328)				
FTA (only)		0.56706*** (0.07988)				
EIA (only)		0.59434*** (0.08651)				
CU & EIA		0.48790*** (0.07467)				
FTA & EIA		0.30361*** (0.05526)				
Depth (all)			0.01097*** (0.00152)			
Depth (only enforceable)				0.01191*** (0.00184)		
Depth (WTO+)					0.03088*** (0.00427)	
Depth (WTO-X)						0.01488*** (0.00273)
Log of GDP (country i)	0.28714*** (0.03516)	0.29247*** (0.03528)	0.31941*** (0.03239)	0.32242*** (0.03163)	0.30033*** (0.03402)	0.33578*** (0.03005)
Log of GDP (country j)	0.56580*** (0.02599)	0.57182*** (0.02557)	0.59099*** (0.02364)	0.59283*** (0.02318)	0.57767*** (0.02513)	0.60048*** (0.02238)
Log of Distance	-0.46183*** (0.02743)	-0.44206*** (0.02913)	-0.47193*** (0.02728)	-0.46424*** (0.02847)	-0.46552*** (0.02763)	-0.48339*** (0.02776)
Language	0.12794 (0.09013)	0.12572 (0.08927)	0.15589* (0.09021)	0.15957* (0.09016)	0.15047* (0.09028)	0.16676* (0.09104)
Common colonizer	0.23617*** (0.09049)	0.25823*** (0.09200)	0.22950** (0.09340)	0.20684** (0.09279)	0.18353** (0.09254)	0.22846** (0.09359)
Colony-colonizer	0.30160*** (0.08424)	0.30301*** (0.08244)	0.28042*** (0.08399)	0.28653*** (0.08521)	0.30162*** (0.08394)	0.25887*** (0.08787)
Contiguity	0.28948*** (0.08981)	0.30241*** (0.08906)	0.30339*** (0.09311)	0.30098*** (0.09234)	0.28423*** (0.09126)	0.30769*** (0.09422)
Observations	520.572	520.572	520.572	520.572	520.572	520.572
R^2	0.9705	0.9707	0.9701	0.9700	0.9703	0.9696
Country i FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Country j FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

Source: Author elaboration. Note: Robust standard errors clustered by country pairs in parentheses, "***" denotes statistical significance at the 1% level, "**" denotes statistical significance at the 5% level, "*" denotes statistical significance at the 10% level.

Table 17 – DVA PPML regression results

	DVA (Domestic Value Added)					
	(7)	(8)	(9)	(10)	(11)	(12)
PTA	0.01350*** (0.00277)					
CU (only)		0.00823** (0.00369)				
FTA (only)		0.01458*** (0.00307)				
EIA (only)		0.01014** (0.00398)				
CU & EIA		0.01751*** (0.00424)				
FTA & EIA		0.01362*** (0.00425)				
Depth (all)			0.00048*** (0.00008)			
Depth (only enforceable)				0.00038*** (0.00010)		
Depth (WTO+)					0.00090*** (0.00027)	
Depth (WTO-X)						0.00054*** (0.00014)
Log of GDP (country i)	0.56698*** (0.00273)	0.56707*** (0.00273)	0.56740*** (0.00273)	0.56688*** (0.00273)	0.56690*** (0.00273)	0.56677*** (0.00273)
Log of GDP (country j)	0.00027 (0.00471)	0.00044 (0.00472)	0.00035 (0.00471)	0.00014 (0.00472)	0.00017 (0.00472)	0.00010 (0.00472)
Log of Distance	0.00304*** (0.00064)	0.00292*** (0.00067)	0.00336*** (0.00058)	0.00261*** (0.00067)	0.00239*** (0.00071)	0.00224*** (0.00058)
Language	-0.00012 (0.00025)	-0.00011 (0.00029)	0.00053** (0.00025)	0.00038** (0.00019)	0.00027 (0.00019)	0.00038** (0.00017)
Common colonizer	-0.00018 (0.00025)	-0.00008 (0.00030)	-0.00065** (0.00029)	-0.00072*** (0.00026)	-0.00065*** (0.00025)	-0.00062*** (0.00024)
Colony-colonizer	0.00070* (0.00039)	0.00050 (0.00045)	0.00111*** (0.00042)	0.00111*** (0.00038)	0.00071** (0.00034)	0.00113*** (0.00036)
Contiguity	-0.00143** (0.00060)	-0.00139** (0.00066)	-0.00069 (0.00048)	-0.00089* (0.00048)	-0.00105** (0.00052)	-0.00063 (0.00045)
Observations	520.572	520.572	520.572	520.572	520.572	520.572
R^2	0.9964	0.9964	0.9964	0.9964	0.9964	0.9964
Country i FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Country j FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

Source: Author elaboration. Note: Robust standard errors clustered by country pairs in parentheses, "***" denotes statistical significance at the 1% level, "**" denotes statistical significance at the 5% level, "*" denotes statistical significance at the 10% level.

Nonetheless, the existence of agreements and their sizes and depths do appear to foster the development of both dependent variables, that is, driving the growth of VAT through both foreign participation in a country's content of trade but also in that country's own domestic enlargement for serving international trade.

Focusing first on the results of the structural forms of the PTA_{ijt} variable for the FVA dependent variable, the estimation implies that, in all cases sampled, having a PTA fosters VAT through the embedding of the partner country value generation in the origin country's exports, with an estimated increase of 47% in the volume of FVA. The type of the agreement appears to also determine this incentivizing pattern, and, among all types, this is most prominently saw with the "EIA (only)" agreements, that appear to be the most capable of doing so. However, these are also the rarest type of agreements in the sample, appearing only approximately in 0.3% of the observations. The agreements most common, "FTA (only)", with approximately 3.4% presence on all observations, and "CU (only)", with approximately 2.7%, are, nevertheless, also found to be strongly capable of driving growth, more so than the previous "PTA" generic indicator, with FTA presence indicating a significative growth of circa 76% in FVA, and CU agreements of circa 56%.

When considering the content of the agreements, in all scenarios it is verified that having more provisions stimulates FVA, with any additional provisions included in the agreement driving approximately 1.1% of extra growth. Making these additional provisions enforceable also increases the rate of growth, albeit marginally, to 1.2% of growth per provision. Having enforceable provisions under the WTO+ categorization appears at first glance to have a larger impact, of approximately 3.1% per provision, on FVA, when compared to an additional WTO-X provision, that have an approximate force of only 1.5%. However, if taken into consideration that the umbrella of the latter type of provisions is much larger than the former (the first has only 14 possible provisions, while the second has 38), the overall impact that can be achieved with outside-of-the-WTO provisions can be significantly higher than through only inside-WTO policies.

When focusing on the DVA analysis, the impact caused by the PTA measurements on this second variable are much smaller, although still positive and significant. Thus, having an agreement is found to foster on its own the domestic activities embedded in a country's exports by 1.4%. The type of agreement that now most drives growth is the "CU and EIA" combination, possibly due to it enforcing a more tightly knit communion of the partners that enables also domestic development, driving on its own a growth of approximately 1.8% on DVA. It is followed by "FTA (only)" agreements, with an approximate growth of 1.5%, and "FTA and EIA" agreements, with 1.4% of impact on growth.

The size of the agreements also incentivizes DVA, but the previously seen marginal increase caused by having the additional provisions being enforceable is not seen here, with the simple inclusion of provisions on the agreement driving individually 0.05% of growth, while enforceable provisions drive approximately 0.04%. This difference may be due to the fact that DVA is mostly an unilateral measurement of VAT, and thus the enforceability of provisions may be not so relevant in driving its growth when compared to the simple inclusions of provisions, that may have a positive larger spillover effect on the harmonization of policymaking in the originating country, in this way incentivizing the growth of domestic value addition through the internalization of "best practices" sourced internationally.

Moreover, the aforementioned pattern of WTO+ and WTO-X provisions is also observed here, with the former having a larger unitary impact than the latter, of approximately 0.09% for each WTO+ provision, and 0.05% for the WTO-X provisions, but when considering the larger size of the latter set, it again gains a larger possible role of driving DVA growth.

In both cases, this larger effect of outside-of-the-WTO provisions may be similarly justified to the impact seen of larger agreements (not necessarily enforceable) on the DVA variable. That is, harmonizing currently non multilateral policies via the inclusion of WTO-X provisions on agreements may have a large incentivizing role on both measures of VAT due to its setting of a commonplace of international policies (in the measurement used in this research, legally enforceable by PTA partners). This spillover into local policymaking, thus, via non-multilateral institutionalized decision-making, agrees with the initial discussion of the rise of PTAs as a solution to stagnated multilateral advancements, and thus further justifies the contemporary relevance of such agreements on driving, in the case here studied, VAT.

Finally, to benchmark the VAT estimations of the parameters, the same model was regressed in a more standard Gravitational way, by substituting the previously used dependent variables with yearly bilateral exports. This evaluation was done using the same structural form initially presented in Equation 55 and computational approach for its regression, and with the same countries and bilateral pairs, and the same Gravitational and PTA data. The data on exports comes from CEPII's "TRADHIST" database (FOUQUIN & HUGOT, 2016), and imposes a constraint on the previously used time horizon, which now is reduced by one year, to the period from 1990 to 2014[16]. The regressed parameters are presented in Table 19.

Due to the previously considered VAT dependent variables being a decomposition of bilateral exports, these three variables should be highly correlated with one another, irrespective of the different sources for the data. This relationship is presented in Table 18.

Table 18 – Correlation between exports, FVA and DVA

	Exports	FVA	DVA
Exports	1		
FVA	0.553	1	
DVA	0.206	0.242	1

Source: Author elaboration.

When comparing the estimated parameters on exports with the FVA results, the presence of a PTA in its first two different structural forms end up having very similar elasticities. There are only large absolute fluctuations in two types of agreements; the “CU (only)” and “CU & EIA” categories, where the exports’ elasticities are almost doubled. On the latter four forms, while their parameters vary in absolute terms on average by only a small amount (they increase, on average, by +0.01), they increase proportionately by a lot, with the measure of simple provisions having a +61% increase of its elasticity, the enforceable provisions changing by +78%, the WTO+ enforceable provisions with +38%, and the WTO-X enforceable provisions with +112%.

[16] The new correlation matrix and statistical summary of all variables, including the new bilateral exports dependent variable, are presented in Appendix E.

Table 19 – Exports PPML regression results

	Exports					
	(1)	(2)	(3)	(4)	(5)	(6)
PTA	0.41306*** (0.05717)					
CU (only)		0.85828*** (0.09344)				
FTA (only)		0.52313*** (0.09089)				
EIA (only)		0.59662*** (0.11869)				
CU & EIA		0.91858*** (0.09523)				
FTA & EIA		0.19999*** (0.06265)				
Depth (all)			0.01764*** (0.00189)			
Depth (only enforceable)				0.02120*** (0.00227)		
Depth (WTO+)					0.04265*** (0.00506)	
Depth (WTO-X)						0.03151*** (0.00376)
Log of GDP (country i)	0.69503*** (0.05210)	0.70382*** (0.04733)	0.72128*** (0.04617)	0.71898*** (0.04548)	0.70966*** (0.04877)	0.72687*** (0.04367)
Log of GDP (country j)	0.75210*** (0.04057)	0.75135*** (0.03973)	0.76708*** (0.04023)	0.76510*** (0.04024)	0.75887*** (0.04142)	0.77457*** (0.03977)
Log of Distance	-0.60794*** (0.03049)	-0.54539*** (0.03271)	-0.59056*** (0.03103)	-0.56924*** (0.03185)	-0.59398*** (0.03040)	-0.58097*** (0.03264)
Language	0.03029 (0.08665)	0.06776 (0.08061)	0.06667 (0.08396)	0.07500 (0.08415)	0.05913 (0.08547)	0.09010 (0.08502)
Common colonizer	0.26361** (0.11332)	0.28406*** (0.10458)	0.24230** (0.10957)	0.20434* (0.10837)	0.19179* (0.11175)	0.22749** (0.10803)
Colony-colonizer	0.22412* (0.13237)	0.28129** (0.12570)	0.26324** (0.12630)	0.29710** (0.12900)	0.26393** (0.12825)	0.27387** (0.13204)
Contiguity	0.56174*** (0.09245)	0.58451*** (0.09333)	0.59203*** (0.09448)	0.57924*** (0.09245)	0.54838*** (0.09169)	0.61304*** (0.09589)
Observations	500.550	500.550	500.550	500.550	500.550	500.550
R^2	0.9216	0.9232	0.9226	0.9229	0.9226	0.9222
Country i FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Country j FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

Source: Author elaboration. Note: Robust standard errors clustered by country pairs in parentheses, "***" denotes statistical significance at the 1% level, "**" denotes statistical significance at the 5% level, "*" denotes statistical significance at the 10% level.

The estimated parameters for the Gravitational variables, however, vary a lot between these two regressions. Most notably, both countries GDPs (i.e. the importer's and the exporter's) now have the same overall weight on explaining their bilateral exports. These parameters also increase, being on average higher than the average for the same measurements of GDP on the FVA regression. Other than GDPs, the contiguity dummy variable also on average sees its parameter almost doubled, and the distance becomes even more negatively correlated with the dependent variable, being on average 25% more negative than before. The other variables have more heterogeneous variations, but overall see their significance levels dwindle.

When comparing the exports evaluation with the DVA results, there are much higher fluctuations on elasticities found of these two regressions for almost all independent variables. Nonetheless, the overall variations observed when shifting from DVA towards the exports are similar to the same observed when shifting from the former to FVA, only with a larger magnitude, validating the previously seen heterogeneity on the parameters.

5.2 NEURAL NETWORK OUTPUTS

The ANNs described in section 4.2 were regressed with the same panel data dataset used for the econometric model, and their evaluation were performed within the Keras library (CHOLLET & OTHERS, 2015) for Python within the Anaconda framework. The activation function used follows Koffi and Li (2019) and Wohl and Kennedy (2018) and is the sigmoid function presented in Equation 54. To best fit this functional form, the continuous variables (FVA and DVA, GDPs and distance) are standardized to a mean of 0 and a standard deviation of 1. The models are run for 20 epochs and batches of 100, with a learning rate of 0.01 on an Adam optimization algorithm and a mean absolute error cost function. Each model is assessed against each other with respect to being good predictors through the comparison of their root mean square errors (RMSE) and are trained with a k-fold cross validation of ten folds.

The average RMSE of each architecture tested on each ten validation folds is presented for the FVA and DVA variables on Table 20. The RMSE of the econometric models are presented on Table 21, for comparison purposes.

Table 20 – Average RMSE of validation folds

Architecture	DVA (Current US$)	FVA (Current US$)
2	33.009,16 (2.448,07)	33.028,90 (2.510,23)
3	28.543,83 (2.201,24)	28.596,09 (2.228,04)
5	23.736,90 (1.679,75)	23.466,56 (1.855,46)
10	18.571,18 (1.476,70)	18.572,63 (1.372,21)
3/3	29.124,42 (3.040,92)	29.948,24 (1.476,15)
3/5	24.051,99 (2.349,14)	23.944,76 (2.503,33)
5/3	30.085,26 (3.940,39)	30.520,34 (3.338,03)
5/5	24.809,77 (1.832,27)	25.530,63 (3.207,18)
10/10/5/5	24.304,28 (2.494,41)	25.001,48 (2.490,49)

Source: Author elaboration. Note: Standard deviation of validation RMSE in parentheses.

Table 21 – RMSE of Gravitational Models

	DVA (Current US$)	FVA (Current US$)
PTA	1.039.509,8	5.233.405,7
CU/FTA/EIA/ CU&EIA/FTA&EIA	1.039.435,7	5.206.063,6
Depth (all)	1.039.348,3	5.285.221,7
Depth (only enforceable)	1.039.858,2	5.293.026,7
Depth (WTO+)	1.039.848,3	5.253.153,7
Depth (WTO-X)	1.039.943,5	5.338.648,6

Source: Author elaboration.

In line with other empirical findings, such as those by Wohl and Kennedy (2018) and Ho et al. (2020), the ANN performed remarkably better at being a particularly good estimator of VAT levels, with a significantly smaller average RMSE, even when considering the average error exclusively measured on each validation fold, when compared to the results previously described and achieved with the usage of standard gravitational functional form.

Moreover, the asymmetry between the higher precision of the DVA estimation when compared to the FVA, as already seen with the higher R^2 found for the former than the latter dependent variable, is once again confirmed for the results of the PPML estimation when comparing their RMSE. The ANN, in this sense, does not show such a bias for the domestic variable, and performs, on average, quite well and homogeneously between the two variables when considering the architectures used in each test.

Among the different tested architectures, however, there seemed to be a better overall performance, albeit marginal given the size of the errors found, on the architectures with fewer layers, in line with the findings discussed by Wohl and Kennedy (2018). However, to assess any possible bias due to a misspecification of some of the models' hyperparameters and try to measure the underlying sensitivity of the model to these variables, the best performing architectures for each dependent variable, measured as those with lower average and standard deviation (i.e., "most consistently good") validation-fold RMSE, were sensitized for batch sizes and number of epochs.

In this sense, the 1-layered 5 and 10 nodes architectures were selected for both DVA and FVA, together with the 2-layered with 5 nodes on each layer architecture for the DVA, and with the 2-layered with 3 nodes of the first layer and 5 on the second layer architecture for the FVA. Batches were sensitized for sizes of 10 and 1.000, besides the already tested 100, while epochs were sensitized for lengths of 5 and 100, besides the already tested 20. The results of these sensitivity tests are presented on Tables 22 through 24.

The curvature of the error surface on the assessed hyperparameters seems to clearly indicate a high sensitivity to both the sizes of the batches collected from the training folds, and the number of epochs available for training. In both dimensions, it is perceivable a very steep slope on the error gradient when migrating either horizontally, from fewer to more epochs, and vertically, from smaller to bigger batches, with an apparent minimum on longer training periods (i.e., more epochs), and small batches.

Table 22 – Sensitivity analysis of 1-layered, 5 nodes ANNs

	DVA (1 layer, 5 nodes)			FVA (1 layer, 5 nodes)		
	5	20	100	5	20	100
10	13.292,75 (1.070,72)	6.660,71 (551,77)	5.045,60 (517,59)	13.357,18 (1.032,03)	6.613,19 (488,37)	5.056,68 (483,78)
100	411.763,87 (37.054,85)	23.721,28 (1.655,90)	9.126,90 (675,02)	395.148,68 (50.267,80)	23.516,54 (1.758,37)	9.097,86 (651,16)
1000	116.836.634,58 (24.725.738,86)	14.233.134,29 (1.760.287,75)	44.110,11 (3.072,40)	124.954.832,51 (20.865.681,13)	13.683.972,66 (2.128.183,31)	44.766,24 (3.399,40)

Source: Author elaboration. Note: Number of epochs on the horizontal scales, sizes of batches on the vertical scale. Standard deviation of validation RMSE in parentheses.

Table 23 – Sensitivity analysis of 1-layered, 10 nodes ANNs

	DVA (1 layer, 10 nodes)			FVA (1 layer, 10 nodes)		
	5	20	100	5	20	100
10	10.501,03 (825,09)	4.945,55 (361,15)	4.371,84 (415,55)	10.484,12 (818,71)	4.943,03 (379,51)	4.339,73 (443,06)
100	264.094,23 (22.771,43)	18.561,31 (1.364,57)	7.381,94 (533,93)	257.111,61 (30.202,95)	18.280,95 (1.286,77)	7.311,65 (494.94)
1000	86.360.959,07 (12.011.495,85)	7.848.500,43 (1.796.446,85)	33.735,69 (2.632,88)	76.458.084,97 (14.913.560,02)	9.006.078,84 (1.358.318,86)	34.220,79 (2.432,90)

Source: Author elaboration. Note: Number of epochs on the horizontal scales, sizes of batches on the vertical scale. Standard deviation of validation RMSE in parentheses.

Table 24 – Sensitivity analysis of 2-layered ANNs

	DVA (2 layers, 5/5 nodes)			FVA (2 layers, 3/5 nodes)		
	5	20	100	5	20	100
10	13.514,13 (921,98)	6.733,45 (426,04)	5.573,47 (818,30)	13.610,07 (1.436,27)	6.640,08 (586,97)	5.157,74 (581,77)
100	420.817,45 (90.096,32)	25.096,15 (2.132,03)	9.732,17 (1.048,14)	413.448,64 (57.228,16)	24.241,41 (2.222,24)	9.329,83 (1.061,72)
1000	116.443.789,67 (30.876.566,94)	13.748.047,72 (3.109.114,97)	45.789,29 (5.898,12)	109.335.232,37 (20.045.848,93)	14.105.292,82 (3.267.790,75)	43.903,86 (3.592,74)

Source: Author elaboration. Note: Number of epochs on the horizontal scales, sizes of batches on the vertical scale. Standard deviation of validation RMSE in parentheses.

A possible explanation for the effect caused by the variation of the number of epochs on the average RMSE of the validation folds, is the tendency to increase fitness over repetitive training of the model on the same dataset, and may well be an indicator of the asymptotic behavior towards overfitting. Conversely, however, the effect of the size of the batch on the error surface is more unusual, as larger batches should lead to a smoother, albeit computationally slower, and efficient decent into lower minima points.

Nonetheless, the observable loss of performance detected on the bigger batches could be due to a higher necessity of longer training periods in order to improve the model's ability to converge, when compared to the more erratic (and stochastic) descent, combined with the ability of "jumping" between local minima, achieved by the smaller sized batches networks. In that way, the sudden drop in volatility observed in all architectures for the 1.000 sized batches analyzed in the 100 epochs scenarios could be an indicator of the smoother convergence of these models towards a possible global minimum.

When comparing the different tested architectures, however, the aforementioned higher performance among both dependent variables of the one hidden layer with 10 nodes design remained consistent in the assessed tests, with the same marginal better performance on the FVA models when compared to the DVA's, as previously detected.

Given the objective of assessing the quality and efficiency of utilizing modern solutions to attempt at tackling the complex issue of international trade and, more specifically to the content of the evaluations performed on this study, the role of production entanglement via the international addition of value to traded goods, the achieved results are, thus, very promising. In this way, while the ANN evaluation performed gave away the visibility of the results achieved on the different independent variables and their elasticities on VAT, as discussed on the results obtained through the Gravitational analysis, it exchanged it for a higher performance and a more definitive measurement of VAT given the same input variables.

Moreover, some different possible architectures for a VAT ANN were surveyed, and promising structures were found. This, together with the sampling realized on the topology of the error surface on the hyperparameters, should provide some insights into future studies, and some clear research areas to further extend these experimentations should be, for example, dedicated towards the selection of different independent variables, given the open-ended and open-functional form design of ANNs.

5.3 THE ROLE OF THE EUROPEAN UNION – MERCOSUR FREE TRADE AREA AGREEMENT ON VALUE-ADDED TRADE

Considering the results achieved in light of the current GVC and LVC scenario of the EU and the MERCOSUR, it becomes clear that the FTA agreement being developed between the blocs may have large positive impacts for all states involved, in terms of developing bilateral VAT, but also in domestic growth alone.

Even though the MERCOSUR is not the most relevant partner in value addition as-is for the EU, and has a still limited integration into GVCs, the accelerated rate of growth of this bloc (in terms of creating VAT internally and externally), combined with the higher centrality and size of the other are factors that, on their own, already indicate the advantages that the economic integration of both economies could have, by leveraging on these idiosyncratic asymmetric characteristics.

Thus, combining this paradigm with the observed incentivizing role that PTAs on general have been found to possess on VAT, the FTA agreement between the blocs could both play a role in reigniting growth of value addition in the EU, which has been more muted (most relevantly when relatively compared with the fast developers in China, India and the MERCOSUR), but also giving a more solid framework for the continued development of the MERCOSUR countries. In this case, the larger the agreement achieved, the larger the direct economic benefits in VAT that can be expected as seen econometrically, which could be fortuitous in generating additional positive spillovers in diverse policy areas, but most prominently, at least given modern concerns, in environmental and agricultural laws in each bloc.

Additionally, the agreement creates an advantageous position for EU countries, by opening their way into the MERCOSUR, where there is still plenty of room for large economies of scale to be developed, given its particular lack of trade agreements and overall trade openness, with its on average higher tariff levels. Moreover, it also means a closer relationship with one the fastest VAT growers, that is also relatively close to the EU in absolute geographic terms, thus easing the burden of trade costs on the development of the trade flows between the member states.

Conversely, from the MERCOSUR perspective, the opening to high VAT coming from EU countries and the development of DVA that is observed to arise from FTAs are positive factors that make the agreement economically interesting, besides the more evident qualitative gains from accessing economies of learning and best practices in industrial, business and governmental practices, and the also possibility of economy of scale with the preferential access of its most relevant exports to EU countries.

Overall, the FTA appears as an interesting approach for both blocs to leverage on the positive effects that are observable arising from such agreements on VAT and develop their own current economic scenarios, but also for stablishing a legal framework and the institutions required for enforcing more harmonization of policymaking and economic development and integration among two of the most relevant economic entities worldwide nowadays.

6 CONCLUSIONS

The overall goal of this research was to understand the recently approved FTA agreement expected to be established between the EU and the MERCOSUR blocs, and what economic impact could be expected and derive from this new political-economic development between two of the most important and largest economic agents on the modern global arena.

This goal was thus broken down into three distinct objectives: (1) qualitatively understanding where the agreement arises, (2) quantitatively assessing how agreements in general tend to affect the integration of partners, and (3) quantitatively assessing the best tools to measure such relationships.

In reviewing the recent theoretical and empirical literature when tackling the first objective, it was unraveled the rising importance of an economic integration based on a relatively new framework of globalization, that came about with the rise of ICT in the last decades. In this new paradigm, extremely fast and precise coordination, irrespective of the geographical location of where each step of value chains are performed, reshaped global production by bringing an accelerated easiness of dispersing activities worldwide, and thus changed the meaning of the economic internationalization of humankind in the so called “second unbundling” of production.

Thus, in this new scenario, the actual execution of production of each part and component of each good now can and is performed where costs and incentives are more attractive in a global perspective, with an ever-increasing lack of care to national borders. Production is, therefore, becoming strikingly unbundled in spatial terms. Moreover, the rise of this modern internationalization of production was also seen to be strongly associated with a rise of bilateralism in terms of policymaking and harmonization of trade rules, brought by the stagnation of multilateral institutions and multilateralism in general, thus setting the focal point of this research, the new FTA agreement, on the center of this modern productive and political landscape.

By and large, this research observed that this rise of unbundled production, measured as VAT, is in fact perceivable on the past and recent profile of the EU and the MERCOSUR, as measured on several trade terms. Nonetheless, the EU has had a significantly more prominent role on this new stage, with an already overall significant share of its production being done in such unbundled means. This is in a great deal explained by the internal integration of the bloc, and the predominance of VAT and cross-border production schemes that interweave the EU27 countries. Conversely, the rise of this paradigm has been seen to be much more muted in the MERCOSUR countries, where the economies are still relatively autarkic and more closed to international trade.

However, while this description of both blocs' economies is valid as a current "as-is" picture of each, when analyzing their growth rates and trends into future integration, the figure is reversed: the MERCOSUR bloc is becoming a relevant agent, at least recently, in driving new and further integration, while the EU has been much more muted and somewhat stagnated in doing the same.

Venturing into the second objective, when studying the role of trade agreements, this research found that, among almost 300 past signed PTAs and the economic development of VAT-based integration of more than 10 thousand bilateral combinations of countries through 26 years, international economic agreements played a strategic and relevant role in fostering and significantly raising the levels of unbundled integration. Different types of agreements were found to impact the results in different ways, but on average always increasing the total outcome, with larger and deeper agreements additionally fostering this outperformance when compared to bilateral partners lacking these PTA connections.

Lastly, and focusing on the third and final objective, while reviewing the tools most used for these analyses, the possibility of studying and testing the applicability of a more modern and possibly more robust strategy for engineering all the data collected into accurate and tangible expectations was perceived and exploited. With this objective in mind, thus, the results achieved showed a significant gain of accuracy when switching from the standard Gravitational model to ANNs. In this sense, this work presents very novel and unprecedented empirical research into studying PTAs and VAT through ANNs, and finds it an accurate and efficient tools for mapping their relationships.

There are still many further topics to be researched and questions to be answered, however, that arise intuitively from the interstices of this study:

From the analysis of the first objective, the hypothesis that the capability of increasing the share of FVA on total exports faces diminishing marginal returns could and should be further tested. Additionally, given the generalist approach here used for tackling the second objective, a complementary and more granular study on how the different sectors of each bloc may respond to this integration could be key for understanding the future progress of the agreement, especially when considering the impact it could have on some key sectors for both. This is two-sided: there are both sectors where clashing interests may be very relevant, such as the agricultural sector, where EU policies and interests may be severely impacted given the size of this industry for the MERCOSUR, and sectors where synergetic gains may be positive for both blocs, such as the automotive and aerospace industries.

Other empirical questions correlated to the second objective, and that should be tackled in future studies are: the time-effects of agreements, that is, if the anticipation period, the phasing-in, and the after-effects of their enforcement, a process that sometimes takes many years to be fully finished, have different impacts on VAT; how the “North-South” pattern of trade influences this deal, which is evidently one in such category; and the role that specific types of provisions, such as competition and environmental, could have on the results of its implementation.

Switching instead to possible new pathways for expanding the findings of the third objective, a more thorough evaluation of the topology of the hyperspace of the ANN’s tested hyperparameters could provide insights into the best possible design for dealing with VAT, and different architectures could prove themselves more efficient and/or precise. Additionally, given the openness of form proposed by neural networks in general, more diverse and uncorrelated independent variables could be included in the analysis, departing from the fixed form and empirically accepted variables typically suggested by the Gravitational framework.

Finally, there are many very relevant exogenous factors that may and will severely impact not only the outcome of the FTA, but also the modern trends of globalization, whose effects were also not considered here. Thus, for example, the discussion over the protection of the Amazon rainforest, and the overall concern with environmental policymaking in the MERCOSUR from some EU countries may hinder the development of the agreement. The Coronavirus pandemic Covid-19 caused by the SARS-Cov-2 virus that began in late 2019, early 2020, is also another massive exogenous shock that is expected to have an overwhelmingly negative effect on globalization in general, and GVCs and shared productive networks in particular, which on its own will also probably hinder the effects that could be obtained by the agreement on a different global scenario.

Nevertheless these exogeneous negative shocks, the FTA may still be an interesting tool for not only driving the economic progress, integration and openness of the EU and the MERCOSUR, but also in helping them to face many of the modern social and environmental preoccupations, together. In this view, thus, the agreement can be the commonplace for greater collective oversight and harmonization of policies, assisting both blocs on their future tackling of social and climate-related problems, while still representing one of the most interesting pathways for a post-pandemic diverse and robust economic development of all member states and their inhabitants, irrespective of their origins.

REFERENCES

ALMEIDA, P. R. (2011). História do Mercosul: do nascimento à crise [History of the Mercosur: from birth to crisis]. *Revista Espaço Acadêmico, 119*(10), 106-114.

AMADOR, J., & CABRAL, S. (2016). Global value chains: a survey of drivers and measures. *Journal of Economic Surveys, 30*(2), 278-301.

ANDERSON, J. E. (1979). A theoretical foundation for gravity equation. *American Economic Review, 69*(1), 106-116.

ANDERSON, J. E. (2011). The gravity model. *Annual Review of Economics, 3*(1), 133-160.

ANDERSON, J. E., & VAN WINCOOP, A. (2003). Gravity with gravitas: a solution to the border puzzle. *American Economic Review, 93*(1), 170-192.

ANTRÀS, P. (2005). Property rights and the international organization of production. *American Economic Review, 95*(2), 25-32.

ANTRÀS, P. (2015). *Global production: firms, contracts, and trade structure.* Princeton: Princeton University Press.

ANTRÀS, P., & STAIGER, R. W. (2012). Offshoring and the role of trade agreements. *American Economic Review, 102*(7), 3140-3183.

ASLAM, A., NOVTA, N., & RODRIGUES-BASTOS, F. (2017). *Calculating trade in value added.* Washington, DC: International Monetary Fund.

BACCHETTA, M., BEVERELLI, C., CADOT, O., FUGAZZA, M., GRETHER, J., HELBLE, M., . . . PIERMARTINI, R. (2012). *A practical guide to trade policy analysis.* Geneva: WTO Publications.

BAIER, S. L., & BERGSTRAND, J. H. (2007). Do free trade agreements actually increase members' international trade? *Journal of International Economics, 71*(1), 72-95.

BALDWIN, R. E. (2006). *Globalisation: the great unbundling(s).* Economic Council of Finland.

BALDWIN, R. E. (2011a). *21st century regionalism: filling the gap between 21st century trade and 20th century trade rules.* Geneva: World Trade Organization.

BALDWIN, R. E. (2011b). Trade and industrialisation after globalisation's 2nd unbundling: how building and joining a supply chain are different and why it matters. *Globalization in an Age of Crisis: Multilateral Economic Cooperation in the Twenty-First Century* (pp. 165-212). Cambridge: National Bureau of Economic Research.

BALDWIN, R. E., & GONZALEZ, J. L. (2015). Supply-chain trade: a portrait of global patterns and several testable hypotheses. *The World Economy, 38*(11), 1682-1721.

BALDWIN, R. E., & MARTIN, P. (1999). *Two waves of globalisation: superficial similarities, fundamental differences.* Tunbingen: Globalisation and Labour, J.C.B. Mohr for Kiel Institute of World Economics.

BALDWIN, R. E., & WYPLOSZ, C. (2020). *The economics of european integration.* London: McGraw-Hill Education.

BALTENSPERGER, M., & DADUSH, U. (2019). *The European Union-Mercosur free trade agreement: prospects and risks.* Brussels: Bruegel.

BERGSTRAND, J. H. (1985). The gravity equation in international trade: some microeconomic foundations and empirical evidence. *Review of Economics and Statistics, 67*(3), 474-481.

BERGSTRAND, J. H. (1989). The generalized gravity equation, monopolistic competition, and the factor-proportions theory in international trade. *Review of Economics and Statistics, 71*(1), 143-153.

BERGSTRAND, J. H., EGGER, P., & LARCH, M. (2015). Economic determinants of the timing of preferential trade agreement formations and enlargements. *Economic Inquiry, 54*(1), 315-341.

BOFFA, M., JANSEN, M., & SOLLEDER, O. (2018). Do we need deeper trade agreements for GVCs or just a BIT? *The World Economy, 42*(6), 1713-1739.

BOLT, J., INKLAAR, R., JONG, H., & ZANDEN, J. (2018). *Rebasing 'Maddison': new income comparisons and the shape of long-run economic development.* Groningen: University of Groningen.

BROWNLEE, J. (2017, July 3). *Gentle Introduction to the Adam Optimization Algorithm for Deep Learning*. Retrieved from Machine Learning Mastery: https://machinelearningmastery.com/adam-optimization-algorithm-for-deep-learning/

BROWNLEE, J. (2018, May 23). *A Gentle Introduction to k-fold Cross-Validation*. Retrieved from Machine Learning Mastery: https://machinelearningmastery.com/k-fold-cross-validation/

BROWNLEE, J. (2019, January 30). *How to Choose Loss Functions When Training Deep Learning Neural Networks*. Retrieved from Machine Learning Mastery: https://machinelearningmastery.com/how-to-choose-loss-functions-when-training-deep-learning-neural-networks/

CASELLA, B., BOLWIJN, R., MORAN, D., & KANEMOTO, K. (2019). Improving the analysis of global value chains: the UNCTAD-Eora database. *Transnational Corporations, 26*(3).

CAWLEY, G. C., & TALBOT, N. L. (2010). On over-fitting in model selection and subsequent selection bias in performance evaluation. *Journal of Machine Learning Research*, 2079-2107.

CHOLLET, F., & OTHERS. (2015). *Keras*. Retrieved from GitHub: https://github.com/fchollet/keras

CIBILS, A. B., WEISBROT, M., & KAR, D. (2002). *Argentina since default: the IMF and the depression.* Washington, DC: Center for Economic and Policy Research.

CORREIA, S., GUIMARÃES, P., & ZYLKIN, T. (2020). Fast poisson estimation with high-dimensional fixed effects. *The Stata Journal, 20*(1), 95-115.

DUMOR, K., & YAO, L. (2019). Estimating China's Trade with Its Partner Countries within the Belt and Road Initiative Using Neural Network Analysis. *Sustainability, 11*(5), 1449.

ENGEL, J., WINKLER, D., & FAROLE, T. (2016). *SACU in global value chains: measuring GVC integration, position, and performance of Botswana, Lesotho, Namibia, South Africa, and Swaziland.* Washington, DC: World Bank.

EUR-LEX. (1996, March 19). *Interregional Framework Cooperation Agreement between the European Community and its member states, of the one part, and the Southern Common Market and its party states, of the other part.* Retrieved from Access to European Union Law: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:21996A0319(02)

EUR-LEX. (1999, March 22). *Council decision of 22 March 1999 concerning the conclusion, on behalf of the European Community, of the interregional framework cooperation agreement between the European Community [...] and the Southern Common Market.* Retrieved from Access to European Union Law: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:31999D0279

FERRAZ, L. P., & RIBEIRO, M. B. (2018). New tools for the CGE analysis of PTAs in the era of non-tariff barriers and global value chains: the case of Mercosur and China. *Revista Brasileira de Economia, 72*(3), 330-360.

FILHO, F. H. (2017). A crise econômica de 2014/2017 [The economic crisis of 2014/2017]. *Estudos Avançados, 31*(89), 51-60.

FOUQUIN, M., & HUGOT, J. (2016). *Two centuries of bilateral trade and gravity data: 1827-2014.* Paris: Centre d'Études Prospectives et d'Informations Internationales.

FUNDACIÓN CÍRCULO DE MONTEVIDEO (FCM). (2000). *Mercosur: historia y perspectivas [Mercosur: history and perspectives].* Montevideo.

GAULIER, G., & ZIGNAGO, S. (2010). *BACI: international trade database at the product-level: the 1994-2007 version.* Paris: Centre d'Etudes Prospectives et d'Informations Internationales.

GHIOTTO, L., & ECHAIDE, J. (2019). *Analysis of the agreement between the European Union and the Mercosur.* Berlin, Buenos Aires, Brussels: The Greens/EFA.

GOODFELLOW, I., BENGIO, Y., & COURVILLE, A. (2016). *Deep Learning.* MIT Press.

HAYAKAWA, K., & YAMASHITA, N. (2011). The role of preferential trade agreements (PTAs) in facilitating global production networks. *Journal of World Trade, 45*(6), 1181-1207.

HEAD, K. (2003). *Gravity for beginners.* Vancouver: University of British Columbia.

HEAD, K., & MAYER, T. (2014). Gravity equations: workhorse, toolkit, and cookbook. *Handbook of International Economics, 4*, 131-195.

HEAD, K., MAYER, T., & RIES, J. (2010). The erosion of colonial trade linkages after independence. *Journal of International Economics, 81*(1), 1-14.

HO, D. C., CHAN, E. M., YIP, T. L., & TSANG, C.-W. (2020). The United States' Clothing Imports from Asian Countries along the Belt and Road: An Extended Gravity Trade Model with Application of Artificial Neural Network. *Sustainability, 12*(18), 7433.

HOFMANN, C., OSNAGO, A., & RUTA, M. (2017). *Horizontal depth: a new database on the content of preferential trade agreements.* Washington: World Bank.

HUMMELS, D., ISHII, J., & YI, K. (2001). The nature and growth of vertical specialization in world trade. *Journal of International Economics, 54*(1), 75-96.

INTERNATIONAL CENTRE FOR SETTLEMENT OF INVESTMENT DISPUTES (ICSID). (2019). *Database of bilateral investment treaties.* Retrieved from Investment Treaty Series: https://icsid.worldbank.org/en/Pages/Resources/Bilateral-Investment-Treaties-Database.aspx

INTERNATIONAL MONETARY FUND (IMF). (2020). *World economic outlook: the great lockdown.* Washington, DC: IMF.

JACKS, D. S., MEISSNER, C. M., & NOVY, D. (2011). Trade booms, trade busts and trade costs. *Journal of International Economics, 83*(2), 185-201.

JENSEN, J. K. (1906). Sur les fonctions convexes et les inégálites entre les valeurs moyennes [On convex functions and inequalities between mean values]. *Acta Mathematica, 30*(1), 175-193.

JOHNSON, R. C., & NOGUERA, G. (2012). Accounting for intermediates: production sharing and trade in value added. *Journal of International Economics, 86*(2), 224-236.

JOHNSON, R. C., & NOGUERA, G. (2017). A portrait of trade in value-added over four decades. *Review of economics and statistics, 99*(5), 896-911.

KOOPMAN, R. B., POWERS, W. M., WANG, Z., & WEI, S. (2010). *Give credit where credit is due: tracing value added in global production chains.* Cambridge: National Bureau of Economic Research.

KOOPMAN, R. B., WANG, Z., & WEI, S. (2014). Tracing value added and double counting in gross exports. *American Economic Review, 104*(2), 459-494.

KOVACECIC, M., & JAHIC, A. (2020). *COVID-19 and human development.* New York City: United Nations.

KRUGMAN, P. R., OBSTFELD, M., & MELITZ, M. J. (2018). *International economics: theory and policy.* Harlow: Pearson Education.

LAGET, E., OSNAGO, A., ROCHA, N., & RUTA, M. (2018). *Deep trade agreements and global value chains.* Washington, DC: World Bank.

LENZEN, M., MORAN, D., KANEMOTO, K., & GESCHKE, A. (2012). Mapping the structure of the world economy. *Environmental Science and Technology, 46*(15), 8374-8381.

LENZEN, M., MORAN, D., KANEMOTO, K., & GESCHKE, A. (2013). Building EORA: a global multi-region input-output database at high country and sector resolution. *Economic Systems Research, 25*(1), 20-49.

MATHIAS, M. (2010). *Paradoxos de uma política externa: por que o Mercosul? [Paradoxes of a foreign policy: why the Mercosur?].* Rio de Janero: E-papers.

MAYER, T., & ZIGNAGO, S. (2011). *Notes on CEPII's distance measures: the GeoDist database.* Paris: Centre d'Études Prospectives et d'Informations Internationales.

MELTZER, J. (2011). *The challenges to the world trade organization: it's all about legitimacy.* Washington: The Brookings Institution.

MERCOSUR. (2005, June 19). *Aprovação da adesão da República Bolivariana da Venezuela ao Protocolo de Ushuaia sobre o compromisso democrático no Mercosul, a República da Bolívia e a República do Chile e à declaração presidencial sobre o compromisso democrático no Mercosul.* Retrieved from Mercosur: https://web.archive.org/web/20150713022331/http://www.mercosur.int/msweb/Norma s/normas_web/Decisiones/PT/CMC_2005-06-19_NOR-DEC_16_PT_Ades%C3%A3o%20Venezuela.PDF

MERCOSUR. (2018, August 23). *Decisión sobre la suspensión de Venezuela en el Mercosur [Decision on the suspension of Venezuela from the Mercosur].* Retrieved from Mercosur: https://www.mercosur.int/documento/decision-sobre-la-suspension-de-venezuela-en-el-mercosur/

MINISTRY OF FOREIGN AFFAIRS, BRAZIL (MFA). (2012, December 7). *Protocolo de adesão do Estado Plurinacional da Bolívia ao Mercosul [Protocol of the accession of the Plurinational State of Bolivia to the Mercosur].* Retrieved from Notas a imprensa: http://www.itamaraty.gov.br/pt-BR/notas-a-imprensa/3248-protocolo-de-adesao-do-estado-plurinacional-da-bolivia-ao-mercosul

NEWTON, I. (1846). *The mathematical principles of natural philosophy.* (A. MOTTE, Trans.) New York: Adee.

NG, F., & YEATS, A. (1999). *Production sharing in east asia: who does what for whom, and why?* Washington, DC: World Bank.

OREFICE, G., & ROCHA, N. (2013). Deep integration and production networks: an empirical analysis. *The World Economy, 37*(1), 106-136.

ORGANIZATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT (OECD). (2020). *Foreign direct investment stocks.* Retrieved from OECD Data: https://data.oecd.org/fdi/fdi-stocks.htm#indicator-chart

OSNAGO, A., ROCHA, N., & RUTA, M. (2017). Do trade agreements boost vertical FDI? *The World Bank Economic Review, 30*(1), 119-125.

OSNAGO, A., ROCHA, N., & RUTA, M. (2020, January 28). Deep trade agreements and vertical FDI: the devil is in the details. *Canadian Journal of Economics, 52*(4), pp. 1558-1599.

RUBÍNOVÁ, S. (2017). *The impact of new regionalism on global value chains participation.* Geneva: Centre for Trade and Economic Integration.

RUDER, S. (2016). An overview of gradient descent optimization algorithms. *arXiv e-prints*.

SILVA, J. M., & TENREYRO, S. (2006). The log of gravity. *The Review of Economics and Statistics, 88*(4), 641-658.

SIMOES, A. J., & HIDALGO, C. A. (2011). The economic complexity observatory: an analytical tool for understanding the dynamics of economic development. *25th AAAI Conference on Artificial Intelligence.* San Francisco.

TINBERGEN, J. (1962). *Shaping the world economy: suggestions for an international economic policy.* New York: Twentieth Century Fund. Retrieved from http://hdl.handle.net/1765/16826

UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT (UNCTAD). (2013). *Global value chains and development: investment and value added trade in the global economy.* United Nations Publication.

UNITED NATIONS STATISTICS DIVISION (UNSD). (2019). *2018 Demographic Yearbook.* New York City: United Nations Publication.

UNITED NATIONS STATISTICS DIVISION (UNSD). (2020). *Output, gross value added, and fixed assets by industries at current prices.* Retrieved from National Accounts Official Country Data: http://data.un.org/Data.aspx?d=SNA&f=group_code%3A203

VIDO, E., & PRENTICE, B. E. (2003). The use of proxy variables in economic gravity models: a cautionary note. *Journal of the Transportation Research Forum, 57*(1), 123-137.

WANG, Z., WEI, S., & ZHU, K. (2013). *Quantifying international production sharing at the bilateral and sector levels.* Cambridge: National Bureau of Economic Research.

WOHL, I., & KENNEDY, J. (2018). *Neural Network Analysis of International Trade.* Washington, DC: US International Trade Commission.

WORLD BANK (WB). (2020a). *GDP (current US$).* Retrieved from World Development Indicators: https://data.worldbank.org/indicator/NY.GDP.MKTP.CD

WORLD BANK (WB). (2020b). *Foreign direct investment, net inflows (BoP, current US$).* Retrieved from World Development Indicators: https://data.worldbank.org/indicator/BX.KLT.DINV.CD.WD

WORLD BANK (WB). (2020c). *Exports of goods and services (current US$).* Retrieved from World Development Indicators: https://data.worldbank.org/indicator/NE.EXP.GNFS.CD

WORLD BANK (WB). (2020d). *Imports of goods and services (current US$).* Retrieved from World Development Indicators: https://data.worldbank.org/indicator/NE.IMP.GNFS.CD

WORLD BANK (WB). (2020e). *Exports of goods and services (% of GDP).* Retrieved from World Development Indicators: https://data.worldbank.org/indicator/NE.EXP.GNFS.ZS

WORLD BANK (WB). (2020f). *Imports of goods and services (% of GDP).* Retrieved from World Development Indicators: https://data.worldbank.org/indicator/NE.IMP.GNFS.ZS

WORLD TRADE ORGANIZATION (WTO). (2011). *World trade report 2011*. Geneva: WTO Publications.

WORLD TRADE ORGANIZATION (WTO). (2014). *World trade report 2014.* Geneva: WTO Publications.

WORLD TRADE ORGANIZATION (WTO). (2019a). *Global value chain development report 2019.* Geneva: WTO Publications.

WORLD TRADE ORGANIZATION (WTO). (2019b). *World tariff profiles 2019.* Geneva: WTO Publications.

WORLD TRADE ORGANIZATION (WTO). (2020). *Merchandise exports by product group and destination - annual (Million US dollar).* Retrieved from Time series: https://timeseries.wto.org/

APPENDIX A – SECTORAL DISAGGREGATION OF TRADE

Table A1 represents the sectoral breakdown of exports of the EU from 2000 to 2018. Table A2 represents the same breakdown for imports of the same bloc in the same period. Tables A3 and A4 represent the same breakdown of exports and imports on the same period for the MERCOSUR.

Table A1 – Sectoral breakdown of exports from the EU

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Animal Products	3%	3%	2%	2%	2%	2%	2%	2%	2%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
Vegetable Products	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	3%	2%	3%	3%	2%	2%
Animal and Vegetable Bi-Products	0%	0%	0%	0%	0%	0%	0%	0%	1%	1%	0%	1%	1%	1%	1%	1%	1%	1%	1%
Foodstuffs	4%	4%	4%	4%	4%	4%	4%	4%	4%	5%	4%	4%	5%	5%	5%	5%	5%	5%	5%
Mineral Products	4%	3%	3%	4%	4%	5%	6%	5%	7%	6%	6%	7%	8%	8%	7%	6%	5%	5%	5%
Chemical Products	12%	12%	13%	13%	13%	13%	13%	13%	13%	15%	14%	14%	14%	14%	14%	14%	14%	14%	14%
Plastics and Rubbers	5%	5%	5%	5%	5%	6%	6%	6%	5%	5%	6%	6%	6%	6%	6%	6%	6%	6%	6%
Animal Hides	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Wood Products	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Paper Goods	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	2%	2%	2%	2%	2%	2%
Textiles	5%	5%	5%	5%	4%	4%	4%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
Footwear and Headwear	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Stone And Glass	2%	2%	2%	2%	2%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Precious Metals	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	2%	2%	2%	2%	2%	2%	1%	1%
Metals	8%	8%	7%	8%	8%	9%	10%	10%	10%	8%	9%	9%	9%	8%	8%	8%	8%	8%	8%
Machines	27%	27%	26%	25%	26%	25%	25%	25%	25%	25%	24%	24%	23%	23%	23%	23%	23%	23%	23%
Transportation	16%	16%	16%	17%	16%	15%	15%	16%	15%	14%	14%	14%	14%	15%	15%	16%	17%	17%	16%
Instruments	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	4%	4%	4%	4%	4%
Weapons	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Miscellaneous	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
Arts and Antiques	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Source: Author calculations on data from Gaulier and Zignago (2010) and Simoes and Hidalgo (2011).

Table A2 – Sectoral breakdown of imports to the EU

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Animal Products	2%	2%	2%	2%	2%	2%	2%	2%	2%	3%	2%	2%	2%	3%	3%	3%	3%	3%	2%
Vegetable Products	2%	2%	3%	3%	2%	2%	2%	2%	2%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
Animal and Vegetable Bi-Products	0%	0%	0%	0%	0%	0%	0%	0%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Foodstuffs	3%	4%	4%	4%	4%	3%	3%	3%	3%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%
Mineral Products	10%	9%	9%	10%	10%	13%	14%	13%	16%	13%	15%	17%	18%	18%	16%	12%	9%	10%	12%
Chemical Products	9%	10%	11%	11%	11%	11%	10%	11%	11%	12%	12%	11%	12%	12%	12%	12%	12%	12%	12%
Plastics and Rubbers	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Animal Hides	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Wood Products	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Paper Goods	3%	3%	3%	3%	3%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
Textiles	6%	6%	6%	6%	5%	5%	5%	4%	4%	5%	5%	4%	4%	4%	5%	5%	5%	5%	5%
Footwear and Headwear	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Stone And Glass	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Precious Metals	2%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	2%	2%	1%	1%	1%	1%	1%	1%
Metals	8%	7%	7%	8%	9%	8%	10%	11%	10%	8%	9%	9%	8%	8%	8%	8%	8%	8%	9%
Machines	27%	27%	25%	25%	25%	24%	23%	23%	22%	22%	22%	21%	21%	21%	21%	23%	23%	23%	22%
Transportation	13%	13%	13%	14%	14%	13%	12%	13%	12%	12%	11%	11%	10%	10%	11%	12%	13%	13%	12%
Instruments	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	4%	3%	3%
Weapons	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Miscellaneous	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	3%	3%	3%
Arts and Antiques	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Source: Author calculations on data from Gaulier and Zignago (2010) and Simoes and Hidalgo (2011).

Table A3 – Sectoral breakdown of exports from the MERCOSUR

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Animal Products	5%	6%	6%	7%	7%	7%	7%	7%	7%	8%	7%	7%	7%	7%	9%	8%	8%	8%	8%
Vegetable Products	11%	13%	12%	12%	12%	11%	10%	12%	13%	13%	13%	15%	15%	17%	17%	19%	18%	19%	19%
Animal and Vegetable Bi -Products	3%	3%	4%	4%	3%	3%	3%	3%	4%	3%	3%	3%	3%	2%	2%	3%	3%	3%	2%
Foodstuffs	12%	14%	14%	14%	13%	12%	13%	12%	12%	16%	14%	14%	14%	14%	15%	15%	16%	14%	12%
Mineral Products	12%	12%	13%	13%	13%	15%	16%	17%	18%	17%	22%	23%	21%	18%	19%	14%	13%	16%	18%
Chemical Products	6%	5%	5%	5%	5%	5%	5%	5%	6%	6%	6%	6%	6%	5%	6%	6%	6%	6%	5%
Plastics and Rubbers	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	2%	2%	2%	3%	3%	3%	2%
Animal Hides	2%	3%	2%	2%	2%	2%	2%	2%	1%	1%	1%	1%	1%	1%	2%	2%	1%	1%	1%
Wood Products	2%	2%	2%	2%	3%	2%	2%	2%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Paper Goods	4%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	4%	4%	4%	4%
Textiles	2%	2%	2%	2%	2%	2%	2%	2%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Footwear and Headwear	2%	2%	2%	2%	1%	1%	1%	1%	1%	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%
Stone And Glass	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Precious Metals	2%	1%	1%	1%	1%	1%	1%	1%	1%	1%	2%	2%	2%	2%	2%	2%	2%	2%	2%
Metals	9%	8%	9%	9%	10%	10%	10%	9%	9%	7%	6%	7%	6%	5%	6%	6%	5%	6%	6%
Machines	10%	10%	9%	9%	9%	10%	10%	9%	8%	7%	6%	6%	6%	6%	6%	6%	6%	6%	6%
Transportation	12%	12%	10%	9%	11%	11%	11%	11%	10%	9%	9%	9%	9%	11%	8%	9%	11%	9%	10%
Instruments	1%	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Weapons	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Miscellaneous	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Arts and Antiques	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Source: Author calculations on data from Gaulier and Zignago (2010) and Simoes and Hidalgo (2011).

Table A4 – Sectoral breakdown of imports to the MERCOSUR

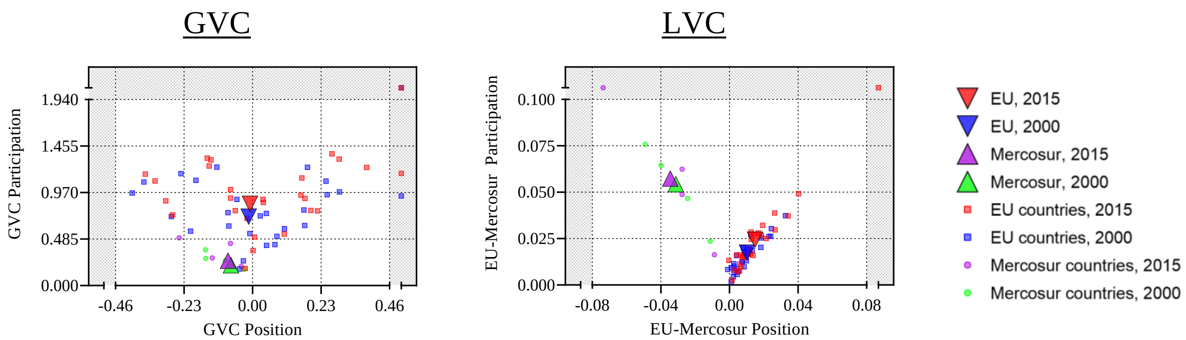
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Animal Products	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Vegetable Products	3%	3%	4%	4%	3%	2%	2%	2%	3%	2%	2%	2%	2%	2%	2%	2%	3%	3%	3%
Animal and Vegetable Bi -Products	0%	0%	1%	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	1%	1%
Foodstuffs	2%	2%	2%	2%	2%	2%	1%	1%	1%	2%	2%	2%	2%	2%	2%	2%	2%	3%	2%
Mineral Products	12%	11%	14%	14%	15%	16%	17%	16%	18%	13%	15%	17%	18%	19%	19%	14%	11%	14%	14%
Chemical Products	15%	16%	19%	20%	19%	16%	15%	16%	16%	16%	15%	14%	15%	15%	16%	17%	18%	18%	19%
Plastics and Rubbers	5%	5%	6%	6%	6%	6%	6%	6%	5%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%
Animal Hides	0%	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Wood Products	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Paper Goods	3%	3%	2%	2%	2%	2%	2%	2%	1%	2%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Textiles	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
Footwear and Headwear	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	1%	1%	1%	1%
Stone And Glass	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Precious Metals	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Metals	5%	5%	5%	5%	6%	6%	6%	7%	7%	6%	7%	6%	6%	6%	6%	6%	5%	5%	6%
Machines	32%	33%	30%	28%	28%	30%	30%	26%	27%	29%	28%	27%	26%	26%	26%	27%	27%	25%	24%
Transportation	10%	10%	9%	8%	10%	10%	11%	12%	12%	13%	14%	14%	14%	14%	12%	12%	13%	13%	13%
Instruments	3%	4%	4%	3%	3%	3%	3%	3%	3%	4%	3%	3%	3%	3%	3%	3%	3%	3%	3%
Weapons	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Miscellaneous	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	2%	2%
Arts and Antiques	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Source: Author calculations on data from Gaulier and Zignago (2010) and Simoes and Hidalgo (2011).

APPENDIX B – VALUE CHAIN POSITION AND PARTICIPATION OF THE EUROPEAN UNION AND THE MERCOSUR

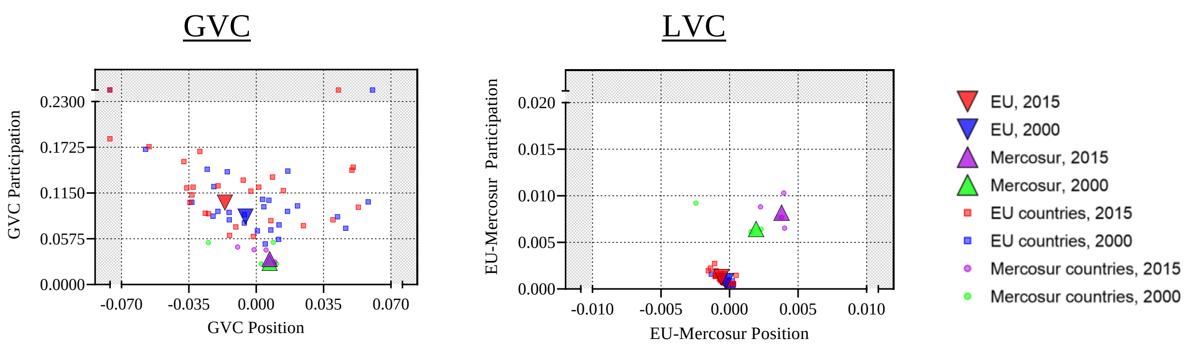
Figures B1 through B21 represent the GVC and LVC indicators calculated for the 21 sectors considered, in 2000 and 2015, for the blocs' averages and of each individual member state. The shaded areas on all graphs represent "out-of-bounds" observations.

Figure B1 – Agriculture



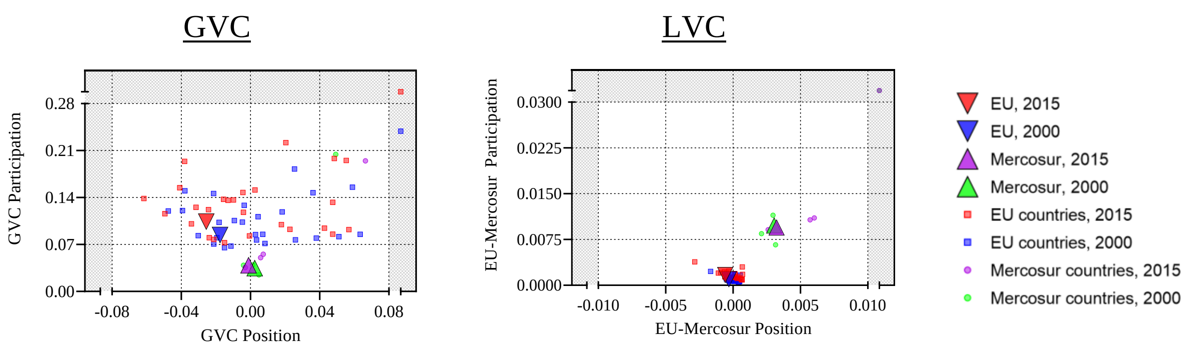
Source: Author calculations on data from Lenzen et al. (2012; 2013) and Aslam et al. (2017).

Figure B2 – Construction



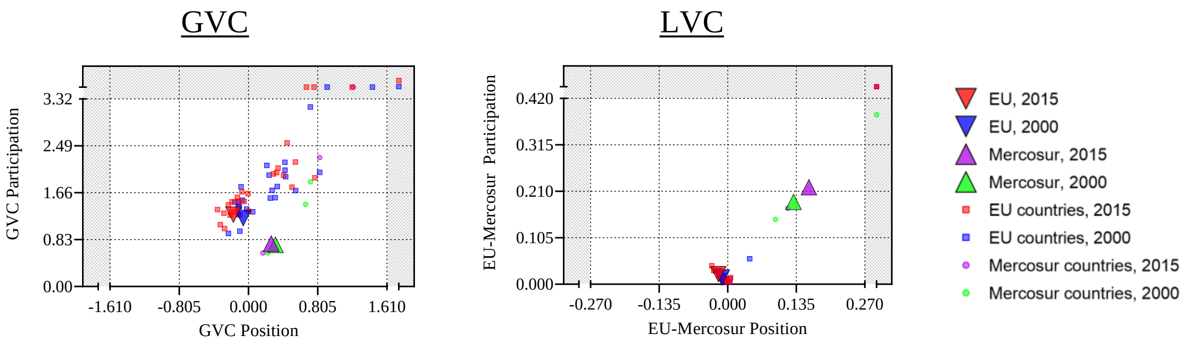
Source: Author calculations on data from Lenzen et al. (2012; 2013) and Aslam et al. (2017).

Figure B3 – Education, Health and Other Services



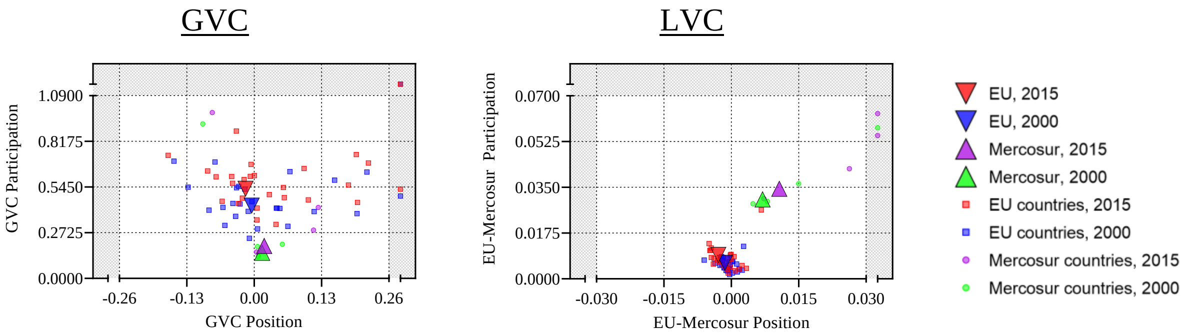
Source: Author calculations on data from Lenzen et al. (2012; 2013) and Aslam et al. (2017).

Figure B4 – Electrical and Machinery



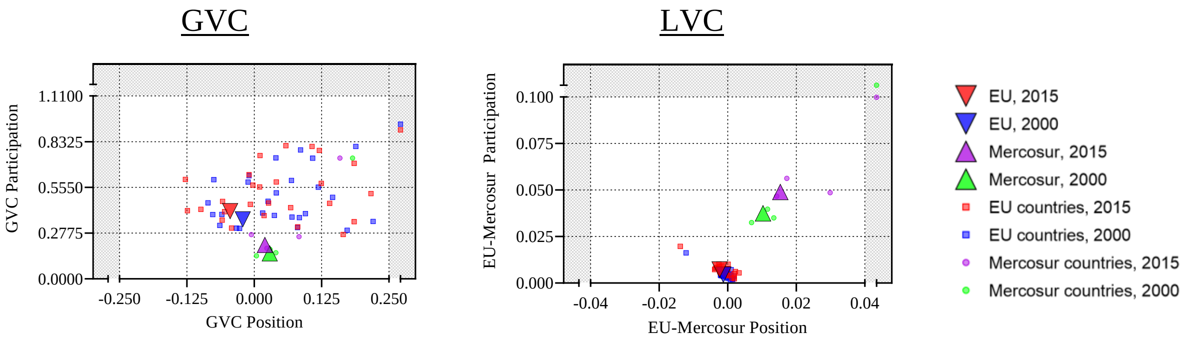
Source: Author calculations on data from Lenzen et al. (2012; 2013) and Aslam et al. (2017).

Figure B5 – Electricity, Gas and Water



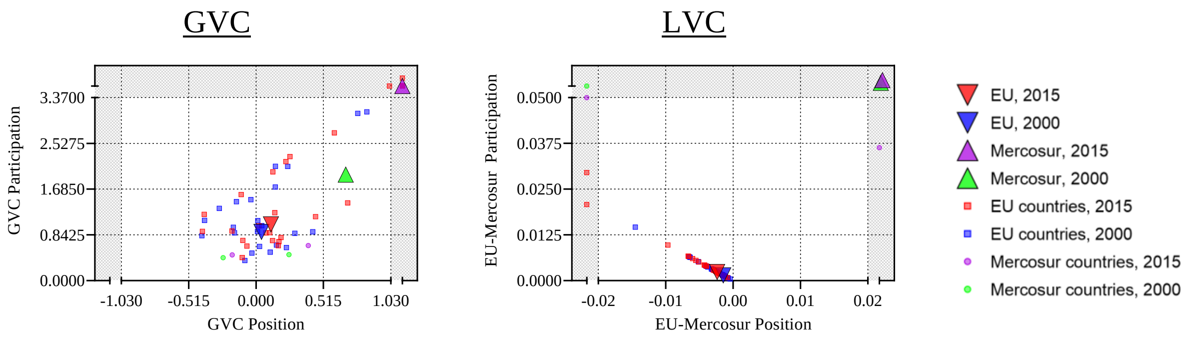
Source: Author calculations on data from Lenzen et al. (2012; 2013) and Aslam et al. (2017).

Figure B6 – Financial Intermediation and Business Activities



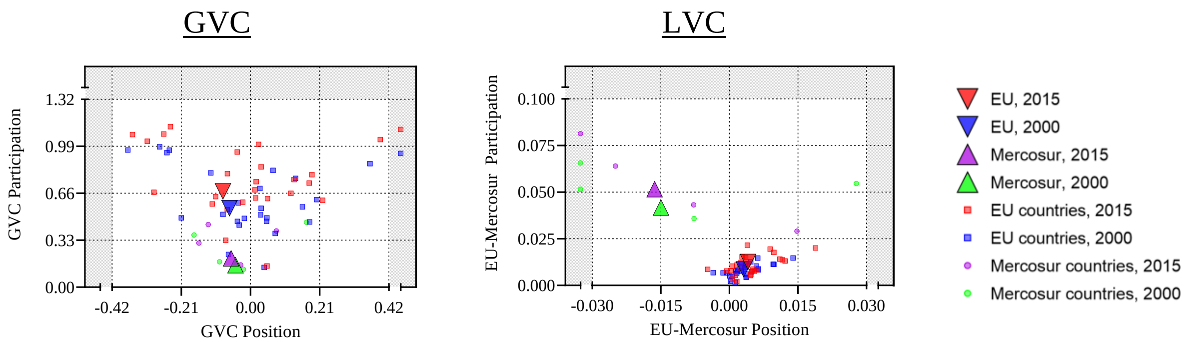
Source: Author calculations on data from Lenzen et al. (2012; 2013) and Aslam et al. (2017).

Figure B7 – Fishing



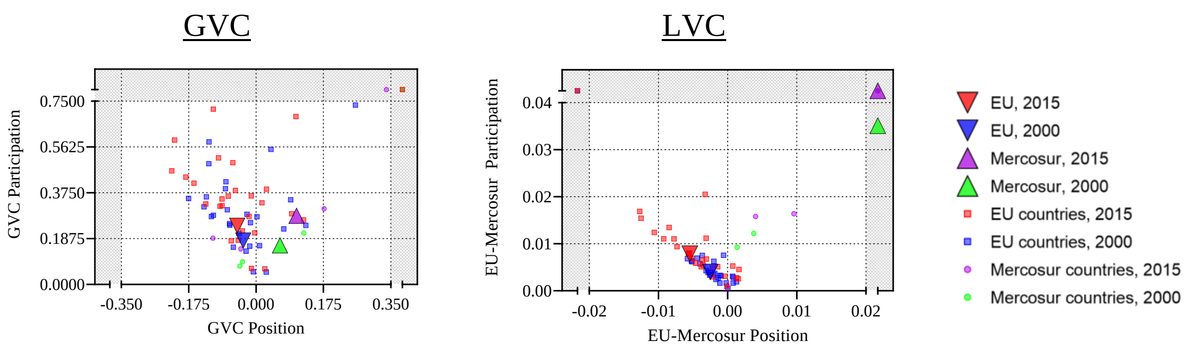
Source: Author calculations on data from Lenzen et al. (2012; 2013) and Aslam et al. (2017).

Figure B8 – Food and Beverages



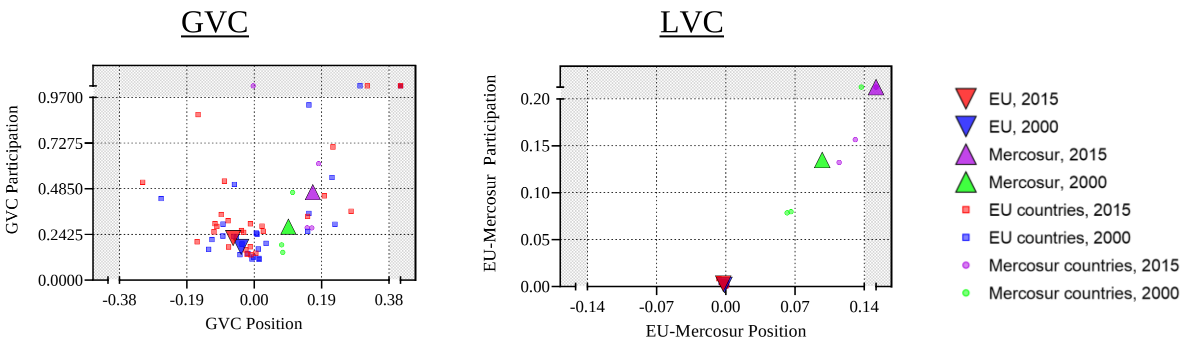
Source: Author calculations on data from Lenzen et al. (2012; 2013) and Aslam et al. (2017).

Figure B9 – Hotels and Restraurants



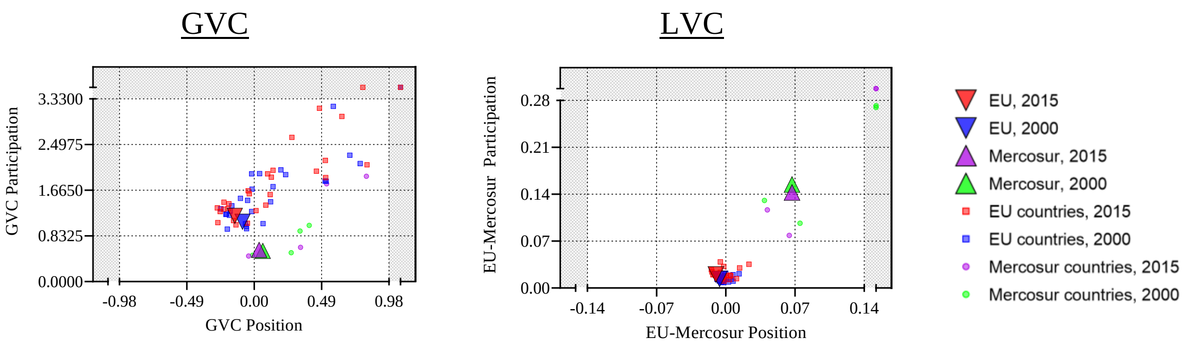
Source: Author calculations on data from Lenzen et al. (2012; 2013) and Aslam et al. (2017).

Figure B10 – Maintenance and Repair



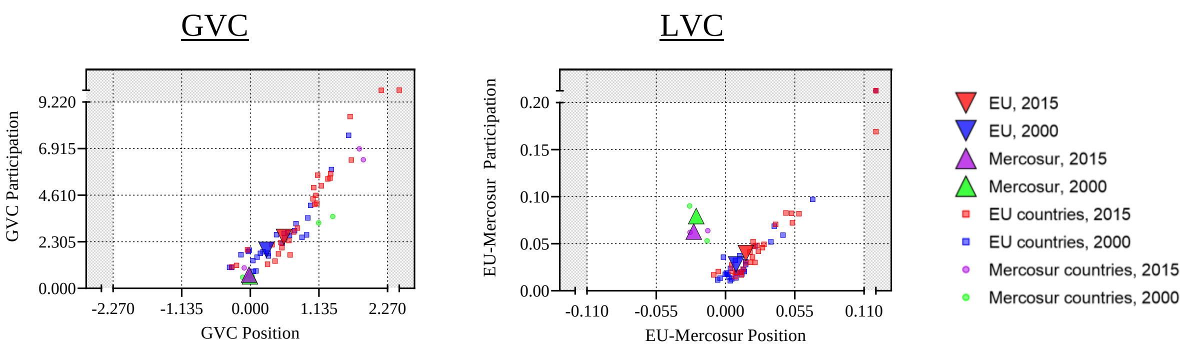
Source: Author calculations on data from Lenzen et al. (2012; 2013) and Aslam et al. (2017).

Figure B11 – Metal Products



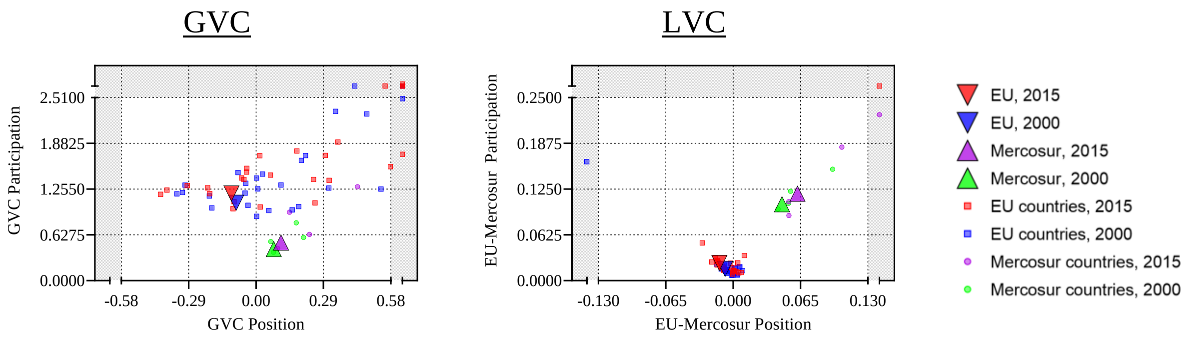
Source: Author calculations on data from Lenzen et al. (2012; 2013) and Aslam et al. (2017).

Figure B12 – Mining and Quarrying



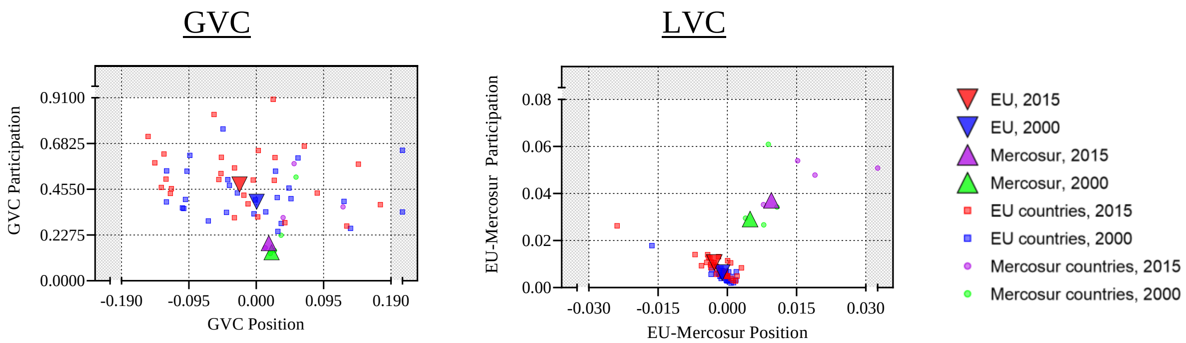
Source: Author calculations on data from Lenzen et al. (2012; 2013) and Aslam et al. (2017).

Figure B13 – Petroleum, Chemical and Non-Metallic Mineral Products



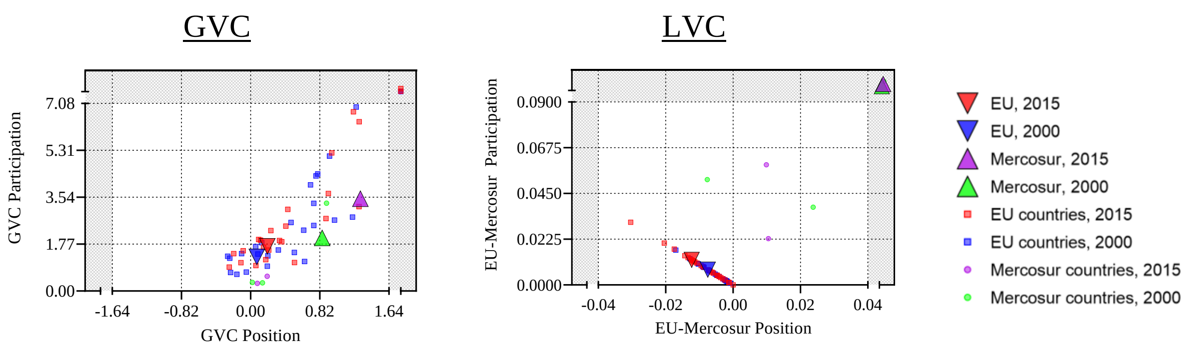
Source: Author calculations on data from Lenzen et al. (2012; 2013) and Aslam et al. (2017).

Figure B14 – Post and Telecommunications



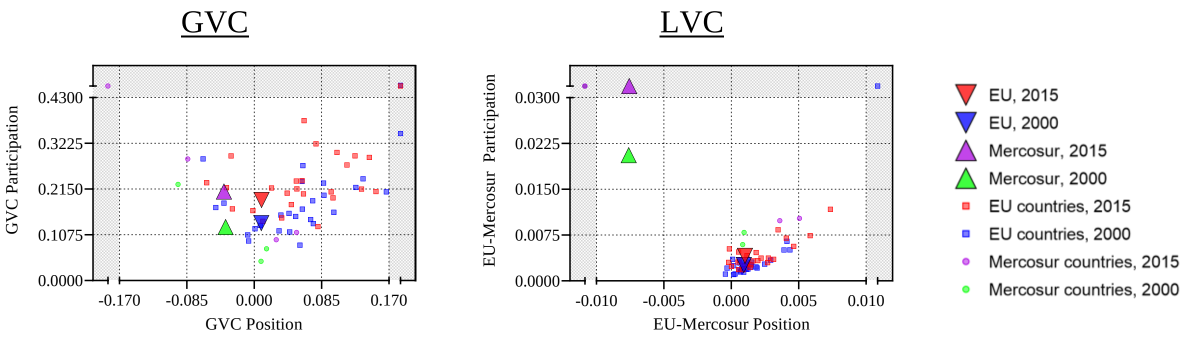
Source: Author calculations on data from Lenzen et al. (2012; 2013) and Aslam et al. (2017).

Figure B15 – Recycling



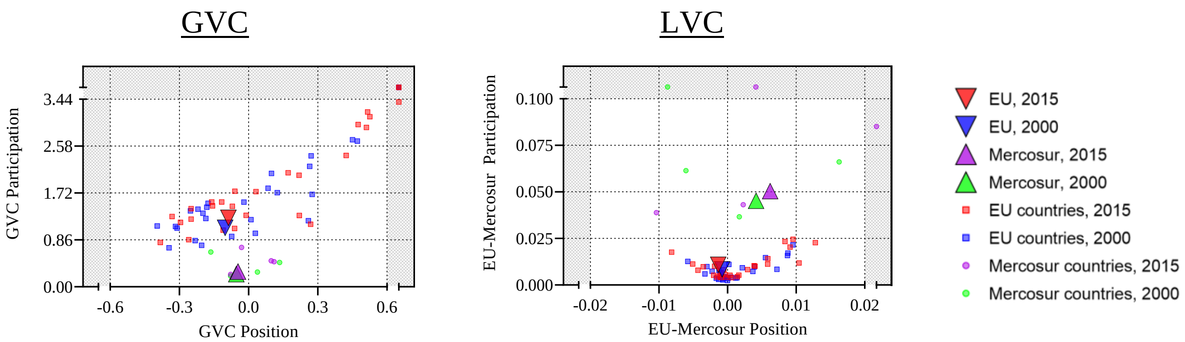
Source: Author calculations on data from Lenzen et al. (2012; 2013) and Aslam et al. (2017).

Figure B16 – Retail Trade



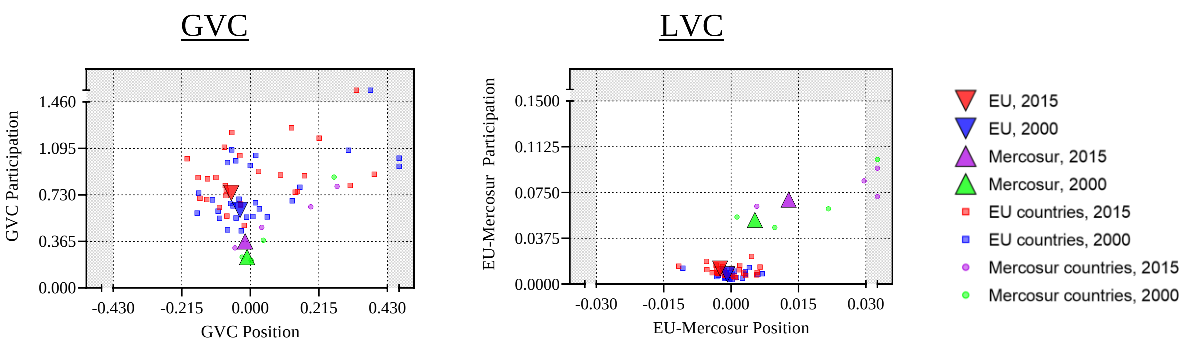
Source: Author calculations on data from Lenzen et al. (2012; 2013) and Aslam et al. (2017).

Figure B17 – Textiles and Wearing Apparel



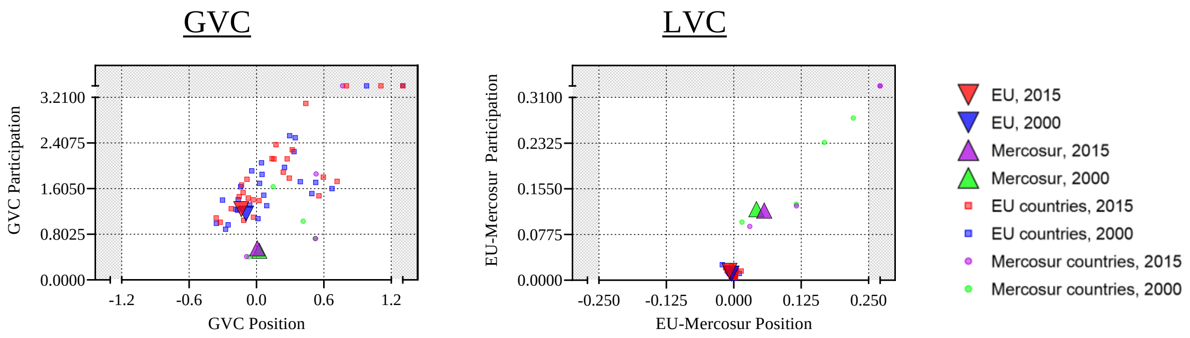
Source: Author calculations on data from Lenzen et al. (2012; 2013) and Aslam et al. (2017).

Figure B18 – Transportation



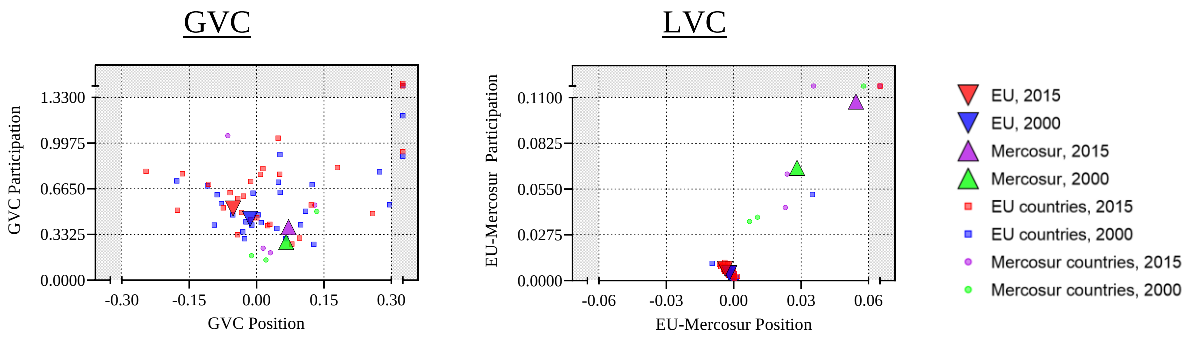
Source: Author calculations on data from Lenzen et al. (2012; 2013) and Aslam et al. (2017).

Figure B19 – Transport Equipment



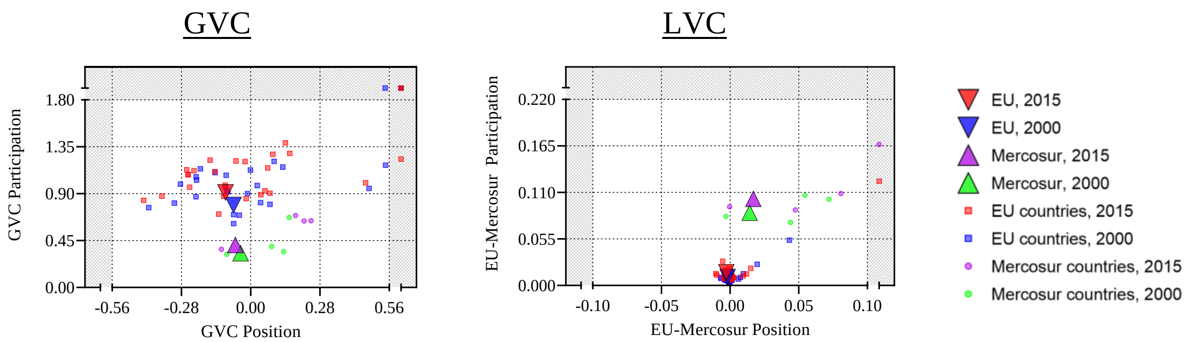
Source: Author calculations on data from Lenzen et al. (2012; 2013) and Aslam et al. (2017).

Figure B20 – Wholesale Trade



Source: Author calculations on data from Lenzen et al. (2012; 2013) and Aslam et al. (2017).

Figure B21 – Wood and Paper



Source: Author calculations on data from Lenzen et al. (2012; 2013) and Aslam et al. (2017).

APPENDIX C – PREFERENTIAL TRADE AGREEMENTS PROVISIONS

Table C1 presents the categorization of provisions in the database by Hofmann et al. (2017), used in the econometric regression for the different measurements of presence or depth of agreements.

Table C1 – Provisions of PTAs and description

#	Name	Description
WTO+		
1	FTA Industrial	Tariff liberalization on industrial goods; elimination of non-tariff measures
2	FTA Agriculture	Tariff liberalization on agriculture goods; elimination of non-tariff measures
3	Customs	Provision of information; publication on the Internet of new laws and regulations; training
4	Export Taxes	Elimination of export taxes
5	SPS	Affirmation of rights and obligations under the WTO Agreement on SPS; harmonization of SPS measures
6	TBT	Affirmation of rights and obligations under WTO Agreement on TBT; provision of information; harmonization of regulations; mutual recognition agreements
7	STE	Establishment or maintenance of an independent competition authority; nondiscrimination regarding production and marketing condition; provision of information; affirmation of Art XVII GATT provision
8	AD	Retention of Antidumping rights and obligations under the WTO Agreement (Art. VI GATT).
9	CVM	Retention of Countervailing measures rights and obligations under the WTO Agreement (Art VI GATT)
10	State Aid	Assessment of anticompetitive behavior; annual reporting on the value and distribution of state aid given; provision of information
11	Public Procurement	Progressive liberalization; national treatment and/or non-discrimination principle; publication of laws and regulations on the Internet; specification of public procurement regime

Source: Hofmann, Osnago and Ruta (2017).

Table C1 – Provisions of PTAs and description (*cont.*)

#	Name	Description
WTO+		
12	TRIMs	Provisions concerning requirements for local content and export performance of FDI
13	GATS	Liberalization of trade in services
14	TRIPs	Harmonization of standards; enforcement; national treatment, most-favored nation treatment
WTO-X		
1	Anti-Corruption	Regulations concerning criminal offence measures in matters affecting international trade and investment
2	Competition Policy	Maintenance of measures to proscribe anticompetitive business conduct; harmonization of competition laws; establishment or maintenance of an independent competition authority
3	Environmental Laws	Development of environmental standards; enforcement of national environmental laws; establishment of sanctions for violation of environmental laws; publications of laws and regulation
4	IPR	Accession to international treaties not referenced in the TRIPs Agreement
5	Investment	Information exchange; Development of legal frameworks; Harmonization and simplification of procedures; National treatment; establishment of mechanism for the settlement of disputes
6	Labor Market Regulation	Regulation of the national labor market; affirmation of International Labor Organization (ILO) commitments; enforcement
7	Movement of Capital	Liberalization of capital movement; prohibition of new restrictions
8	Consumer Protection	Harmonization of consumer protection laws; exchange of information and experts; training
9	Data Protection	Exchange of information and experts; joint projects
10	Agriculture	Technical assistance to conduct modernization projects; exchange of information

Source: Hofmann, Osnago and Ruta (2017).

Table C1 – Provisions of PTAs and description (*cont.*)

#	Name	Description
WTO-X		
11	Approximation of Legislation	Application of EC legislation in national legislation
12	Audio Visual	Promotion of the industry; encouragement of co-production
13	Civil Protection	Implementation of harmonized rules
14	Innovation Policies	Participation in framework programs; promotion of technology transfers
15	Cultural Cooperation	Promotion of joint initiatives and local culture
16	Economic Policy Dialogue	Exchange of ideas and opinions; joint studies
17	Education and Training	Measures to improve the general level of education
18	Energy	Exchange of information; technology transfer; joint studies
19	Financial Assistance	Set of rules guiding the granting and administration of financial assistance
20	Health	Monitoring of diseases; development of health information systems; exchange of information
21	Human Rights	Respect for human rights
22	Illegal Immigration	Conclusion of re-admission agreements; prevention and control of illegal immigration
23	Illicit Drugs	Treatment and rehabilitation of drug addicts; joint projects on prevention of consumption; reduction of drug supply; information exchange
24	Industrial Cooperation	Assistance in conducting modernization projects; facilitation and access to credit to finance
25	Information Society	Exchange of information; dissemination of new technologies; training

Source: Hofmann, Osnago and Ruta (2017).

Table C1 – Provisions of PTAs and description (*cont.*)

#	Name	Description
WTO-X		
26	Mining	Exchange of information and experience; development of joint initiatives
27	Money Laundering	Harmonization of standards; technical and administrative assistance
28	Nuclear Safety	Development of laws and regulations; supervision of the transportation of radioactive materials
29	Political Dialogue	Convergence of the parties' positions on international issues
30	Public Administration	Technical assistance; exchange of information; joint projects; Training
31	Regional Cooperation	Promotion of regional cooperation; technical assistance programs
32	Research and Technology	Joint research projects; exchange of researchers; development of public-private partnership
33	SME	Technical assistance; facilitation of the access to finance
34	Social Matters	Coordination of social security systems; non-discrimination regarding working conditions
35	Statistics	Harmonization and/or development of statistical methods; training
36	Taxation	Assistance in conducting fiscal system reforms
37	Terrorism	Exchange of information and experience; joint research and studies
38	Visa and Asylum	Exchange of information; drafting legislation; training

Source: Hofmann, Osnago and Ruta (2017).

APPENDIX D – COUNTRIES CONSIDERED IN THE STUDY

Table D1 presents the selected 142 countries sampled and used in the econometric regression.

Table D1 – List of countries

Angola	Djibouti	Laos	Qatar
Albania	Denmark	Lebanon	Romania
United Arab Emirates	Dominican Republic	Liberia	Russian Federation
Argentina	Algeria	Sri Lanka	Rwanda
Armenia	Ecuador	Lesotho	Saudi Arabia
Antigua and Barbuda	Egypt	Lithuania	Senegal
Australia	Spain	Luxembourg	Singapore
Austria	Finland	Latvia	Sierra Leone
Azerbaijan	Fiji	Macao	El Salvador
Burundi	France	Morocco	Suriname
Belgium	Gabon	Madagascar	Slovakia
Bangladesh	United Kingdom	Maldives	Sweden
Bulgaria	Georgia	Mexico	Swaziland
Bahrain	Ghana	North Macedonia	Seychelles
Bahamas	Gambia	Mali	Chad
Belize	Greece	Malta	Togo

Source: Author elaboration.

Table D1 – List of countries (*cont.*)

Bolivia	Guatemala	Mozambique	Thailand
Brazil	Hong Kong	Mauritius	Tajikistan
Barbados	Honduras	Malawi	Turkmenistan
Brunei Darussalam	Haiti	Malaysia	Trinidad and Tobago
Bhutan	Hungary	Namibia	Tunisia
Botswana	Indonesia	Niger	Turkey
Central African Republic	India	Nigeria	Taiwan
Canada	Ireland	Nicaragua	Tanzania
Switzerland	Iceland	Netherlands	Uganda
Chile	Israel	Norway	Ukraine
China	Italy	Nepal	Uruguay
Côte d'Ivoire	Jamaica	New Zealand	United States
Cameroon	Jordan	Oman	Uzbekistan
Democratic Republic of the Congo	Japan	Pakistan	Viet Nam
Colombia	Kazakhstan	Panama	Vanuatu
Cape Verde	Kenya	Peru	Samoa
Costa Rica	Kyrgyzstan	Philippines	South Africa

Source: Author elaboration.

Table D1 – List of countries (*cont.*)

Cyprus	Cambodia	Poland	Zambia
Czech Republic	South Korea	Portugal	
Germany	Kuwait	Paraguay	

Source: Author elaboration.

APPENDIX E – STATISCAL SUMMARY OF THE BILATERAL EXPORTS GRAVITATIONAL REGRESSION

Table E1 presents the statistical summary of all independent and dependent variables considered, while the correlation between all variables is presented in Table E2.

Table E1 – Statistical summary of the variables

Variable	Dimension	Mean	Standard deviation	Minimum value	Maximum value
Dependent variable					
Exports	Current US$	2.21×10^8	2.56×10^9	0	2.84×10^{11}
Independent variables					
PTA	*Dummy*	0.090	0.286	0	1
CU (only)	*Dummy*	0.027	0.161	0	1
FTA (only)	*Dummy*	0.033	0.179	0	1
EIA (only)	*Dummy*	0.002	0.050	0	1
CU & EIA	*Dummy*	0.010	0.101	0	1
FTA & EIA	*Dummy*	0.017	0.129	0	1
Depth (all)	Number of provisions	2.369	8.399	0	48
Depth (only enforceable)	Number of provisions	1.619	6.462	0	45
Depth (WTO+)	Number of provisions	0.834	2.892	0	14
Depth (WTO-X)	Number of provisions	0.784	3.878	0	31

Source: Author elaboration.

Table E1 – Statistical summary of the variables (*cont.*)

Variable	Dimension	Mean	Standard deviation	Minimum value	Maximum value
GDP	Current US$	3.05×10^{11}	1.18×10^{12}	1.26×10^{8}	1.74×10^{13}
Distance	Kilometers	7834	4401	60	19951
Language	*Dummy*	0.149	0.356	0	1
Common colonizer	*Dummy*	0.161	0.368	0	1
Colony-colonizer	*Dummy*	0.014	0.117	0	1
Contiguity	*Dummy*	0.018	0.135	0	1

Source: Author elaboration.

Table E2 – Correlations

	Exports	PTA	CU (only)	FTA (only)	EIA (only)	CU & EIA	FTA & EIA	Depth (all)	Depth (only enforceable)	Depth (WTO+)	Depth (WTO-X)	GDP	Distance	Language	Common colonizer	Colony-colonizer	Contiguity
Exports	1																
PTA	0,095	1															
CU (only)	0,036	0,528	1														
FTA (only)	0,015	0,590	-0,031	1													
EIA (only)	0,015	0,159	-0,008	-0,009	1												
CU & EIA	0,057	0,324	-0,017	-0,019	-0,005	1											
FTA & EIA	0,094	0,419	-0,022	-0,024	-0,007	-0,013	1										
Depth (all)	0,092	0,899	0,537	0,353	0,201	0,420	0,423	1									
Depth (only enforceable)	0,115	0,798	0,499	0,268	0,267	0,505	0,273	0,913	1								
Depth (WTO+)	0,118	0,919	0,485	0,427	0,211	0,425	0,423	0,949	0,939	1							
Depth (WTO-X)	0,104	0,645	0,470	0,129	0,288	0,525	0,140	0,814	0,966	0,819	1						
GDP	0,199	0,034	-0,002	-0,002	0,007	0,020	0,061	0,039	0,049	0,049	0,046	1					
Distance	-0,049	-0,325	-0,229	-0,196	-0,069	-0,147	-0,019	-0,293	-0,293	-0,306	-0,260	0,018	1				
Language	0,037	0,085	0,077	0,055	-0,011	0,006	0,015	0,028	0,003	0,032	-0,019	0,031	-0,074	1			
Common colonizer	0,009	0,047	0,042	0,038	-0,022	0,001	0,008	0,004	-0,017	0,020	-0,043	0,025	-0,047	0,503	1		
Colony-colonizer	0,043	0,049	0,011	0,055	0,001	0,010	0,011	0,041	0,040	0,053	0,028	0,062	-0,049	0,153	-0,043	1	
Contiguity	0,127	0,234	0,189	0,122	0,028	0,099	0,024	0,173	0,175	0,205	0,138	0,013	-0,210	0,111	0,091	0,091	1

Source: Author elaboration.