Macro-economic imbalances in the Eurozone
An input-output analysis of the core-periphery divergence

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Sebastiaan Leysen
31/08/2015, Delft
Executive summary

With stagnating growth rates among a majority of its members, soaring unemployment figures and an increased risk of deflation, the economic conditions of the European economy do not strongly reflect a stronger and more united Europe as was intended by the monetary unification in 2001. On the contrary, the recent painstaking negotiations between Greece and its bailout creditors pushed Greece on the brink of leaving the Eurozone and seriously questioned the sustainability of the European monetary union.

This research is an attempt to shed new light on the structural evolution of the main Eurozone economies in the years leading up to and following the monetary unification by means of a detailed data analysis using the recently released World Input-Output Database and adopting an inter-country input-output model. This database offers many insights in the productive structures of economies as well as the international interrelatedness in productive and demand structures. By empirically getting an appraisal on both the historical evolution and current structure of the Eurozone’s economy, this thesis furthermore aims at providing new lines of thought to the European policy makers in their search for industrial policy solutions to reduce the macro-economic imbalances and achieve a sustained recovery of the Eurozone economy.

The first part of our findings basically all support the overall message that a substantial economic restructuring among the main Eurozone countries has been taking place in the last two decades. We collected various structural insights which all to a greater or lesser extent point out that the monetary unification in 2001 reinforced a process of structural divergence between mainly Germany and the peripheral, or Southern European, economies both in terms of their productive and trade structures and reflected on the surface by a growing divergence between their overall current account balances. Germany has gradually been intensifying its technological capabilities by building up a strong comparative advantage in the production and export of high and medium-high technology manufacturing goods, while the periphery has been technologically stagnant and got locked-up in specializing in low and medium-low tech manufacturing industries as well as several non-traded industries including construction and tourism to name just a few.

The second part addresses the important question on how to deal with this structural problem, by presenting several broad policy suggestions and lines of thought substantiated by empirical and theoretical arguments. These scenario’s include: laissez-faire (let the process happen without strongly interfering), introduce a Eurozone central fiscal stabilization mechanism, and try to exploit intra-Eurozone trade spillovers. Especially this last scenario is carefully empirically examined for the year 2011, the most recent year in the World Input-Output Database. A two-folded conclusion can be drawn from this analysis. Firstly, a ‘coordinated Eurozone-level domestic demand-led strategy’ (by targeted industrial and income policies) could potentially be beneficial in supporting a general sustained recovery of the recession in the Eurozone, because the empirical results reveal that the intra-Eurozone spillovers can significantly be exploited to increase the overall gains from coordinated action. Moreover, our analysis points out that stimulation of the manufacturing industries yields significant
more benefits for each Eurozone country, in comparison to scenarios in which all industries would be stimulated. Secondly, with regards to reducing the macro-economic imbalances between the core and peripheral countries, our analysis suggests that it is not feasible to help re-balancing the Eurozone industrial structure by such spillover generating coordinated programs of domestic public investments. The results of our stimulus scenarios clearly suggest that the intra-Eurozone spillover effects generate much smaller impacts on the peripheral countries while contributing much more to the core countries.
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Introduction

“...To desire and strive to be of some service to the world, to aim at doing something which shall really increase the happiness and welfare and virtue of mankind - this is a choice which is possible for all of us; and surely it is a good haven to sail for.

Henry Van Dyke (American author, educator, and clergyman, 1921)

Seven years after Lehman Brothers filed for bankruptcy and initiated the global financial crisis of 2008-2009, which in turn triggered the European sovereign debt crisis, the economic conditions of the European economy remain critical. With stagnating or negative growth rates among a majority of the European members, soaring unemployment figures and an increased risk of deflation, the European economy is not showing immediate signs of a strong revival. Furthermore, the recent painstaking negotiations between Greece and its bailout creditors known as the Troika – and made up of the European Central Bank (ECB), the European Commission (EC), and the International Monetary Fund (IMF) – about a third bailout program, even pushed Greece on the brink of leaving the Eurozone (referred to as a ‘Grexit’) and seriously questioned the sustainability of the European monetary union.

In addition, the picture of Europe’s economy sharply contrasts with those of its main international competitors. While all the other big economies, and in particular the U.S., are clearly walking along the path of recovery, Europe is still nervously trying the clamber out of the through. According to The Economist, the second largest economy in the world could even be heading towards a scenario of prolonged stagnation and deflation (The Economist, 2014).

Remarkable about this Euro crisis is its concentration on a relatively small set of countries, often referred to as the Southern European economies or Europe’s periphery and generally including Greece, Portugal, Italy and Spain. These countries were - and still are - seriously hit by the crisis because they were in an economically unfit position to efficiently cope with the exogenous shock that originated from the global financial crisis. On the contrary, the Northern economies also often referred to as Europe’s core and led by Germany, recovered much more quickly from the crisis because they had a healthier economy and were more competitive compared to the periphery.
Numerous studies have investigated the substantial macro-economic imbalances between these two groups of the Eurozone and the associated increase in degree of polarization. Many of these studies as well as the main focus in current policy discussions about the Eurozone generally treat each country as a separate economy whose overall performance is measured simply by analyzing that economy in isolation of the other Eurozone economies and the rest of the world. The overall fitness of each economy is determined by comparing a set of economical indicators describing its current state to a set of benchmarks believed to be indicating a healthy and welfare-creating climate that every country should be trying to pursue. Based upon this assessment appropriate policy measures are then put forward to steer the economy in the right direction.

This pattern of reasoning is clearly reflected in the Eurozone policy responses to the crisis implemented up until today, in which the troubled countries were forced to copy Germany’s economic model. Troubled countries unable to refinance their debts were only rescued by a European bailout program if they accepted to implement extensive fiscal austerity measures, including among others an extensive labour market reform. The decision to choose the path of austerity compared to that of fiscal stimulus was largely motivated by Germany’s ability to efficiently recover form the crisis. Many European policymakers considered the German economic model to be the benchmark against which to compare all other European economies. By forcing the peripheral countries to copy the German model, so they reasoned, the Eurozone as a whole would gain competitiveness and develop a growth-fostering climate.

These analyses are of course necessary and highly relevant, but they leave one important consideration underexposed: the existence of potentially large mutual trade dependencies among the economies. With more and more companies outsourcing parts of their activities to other countries in order to exploit a wide range of efficiency gains, production chains have become globally fragmented and have made economies increasingly interrelated on an industrial level. For example, a German sector could perfectly have simultaneous trade relationships (both up- and downwars in the supply chain) with: (1) companies from other German sectors (i.e. intra-country trade), (2) companies in other Eurozone countries via import and export (i.e. intra-Eurozone trade), and (3) companies outside the Eurozone, via import and export (i.e. extra-Eurozone trade). These trade relationships give rise to cross-border spillover effects of government demand stimuli. For example, please imagine that the German government decides to increase the final demand for the output of a particular German sector. In response, the overall output of that sector will increase, because the producers in that sector will decide to produce more to meet the increase in demand. This will, in turn, initiate an increase in the output of all the suppliers of these producers, as they experience an increase in demand for their products. These effects are often referred to as multiplier effects. Since these suppliers could be located all around the world, it immediately becomes clear that a government stimulus from one country will likely impact a wide range of both domestic and foreign industries. Gaining insights in these cross-country industrial linkages is therefore of great importance for both the analysis of economical structures as well for the analysis of all sorts of economic policies.

Realizing the importance of quantifying these interdependencies, the European Commission funded a project to develop the first public database describing the industrial flows of goods and services between 35 sectors in 40 countries, known as the World Input Output Database (Timmer et al., 2012). The project was finished in 2012 and pools together so-called national input-output tables from countries across all parts over the world, covering
the period of 1995-2011. The database contains a large amount of valuable new information on the trade interdependencies of economies on a sectoral level. This enables us to obtain detailed insights on the evolution of economical structures and the sizes of the multiplier effects. Furthermore, despite simply offering descriptive information on the evolution of worldwide producer-consumer relationships, this database also lays out the foundation for the practical implementation of an important type of economic trade models, known as input-output models. This opens the door to a wide array of input-output applications, including impact analyses of various government stimulus scenarios.

In light of the macro-economic imbalances within the Eurozone that were highlighted above and the recent availability of detailed sectoral trade flows over a large period, this research project is basically aimed at using the World Input Output Database to get an appraisal on the evolution of the Eurozone’s sectoral trade structure and consequently offer new avenues, or line of thoughts, to the policy makers at the European level with respect to better understanding the Eurozone’s underlying economic developments – and possible structural asymmetries – and finding solutions to regain economic growth among in the various Eurozone economies. To be a little more concrete, this research project is an attempt to make a detailed contribution to the hypothesis going around more often in academic circles nowadays that the Eurozone problem is essentially a structural problem which is strongly linked to technological structure of production of the various Eurozone members (see for example Storm and Naastepad (2014a) for a detailed appraisal of this hypothesis). According to this theory, the Eurozone problems were already embedded among the Eurozone countries long before the outbreak of the financial crisis and mainly developed in the years leading up to the monetary unification as well as in the period after the unification and before the financial crisis. During the booming years of the mid-2000s the Eurozone’s underlying patterns of structural divergence were largely masked by positive growth figures and a general sense of consumer optimism. The first genuine adverse exogenous shock brought about by the financial crisis was only said to have uncovered the already present economic imbalances within the Eurozone. By analyzing the structural evolution of the various protagonists in the Eurozone story in terms of their industry specialization, export structures, global trade interdependencies, and trade spillover effects, this research project’s overall endeavor is to provide a detailed appraisal on the Eurozone’s hypothesized structural problem and to provide appropriate policy suggestions that should be considered in order to (partially) solve the problem. The project is both scientifically as well as socially relevant for several reasons.

From a scientific perspective this graduation project is relevant for at least two main reasons. Firstly, the database that will be used for this project was released relatively recently (in the middle of 2012) and collects input-output data from countries from all over the world. This means that there are still many new insights to be gained from this data, especially into the productive structure of various economies as well as the international interrelatedness in productive and demand structures. Secondly, as will become clear from the literature research, this project will help to close an important gap in the current literature body: linking insights on the sectoral production linkages between countries to the current Eurozone crisis and the persistent macroeconomic imbalances between the Northern and Southern European countries.

The project is also relevant from a societal perspective. The Eurozone debt crisis is the most severe crisis in the history of the European Union. There rests no doubt that in future history textbooks this crisis will described as an important milestone in the history of
Europe. As already mentioned earlier, most signs indicate that the decisions made by the European political decision-makers so far have failed in greatly improving Europe’s economical conditions after the outbreak of the global financial crisis. To this day, the question of what can and should be done remains highly relevant. By providing new insights and testing alternative policy scenarios this research aims at making a valuable contribution to this question. In the end, we must not forget that all these theoretical and empirical observations will impact the lives of millions of businesses and ordinary people. I’m therefore confident that this research project has a high societal relevance.
This chapter discusses the research objective and associated research questions that are addressed in this graduate project. In light of the research gap that was briefly described in the introduction – and which will be extensively discussed during the literature review in the next chapter – the main objective of this graduate project can be formulated as follows:

**Research objective:** Investigation of the structural evolution of the main Eurozone economies in terms of their productive structures, trade structures, and intra-Eurozone as well as global trade interdependencies, over the period 1995-2011. The aim of this investigation is identifying possible structural asymmetries that arose in the years leading up to and following the monetary unification and providing new lines of thought to the European policy makers in their search for industrial policy solutions to reduce the macro-economic imbalances and regain economic growth in the various Eurozone members.

In order to get an appraisal of the structural aspects mentioned in the research objective description above, use is made of the recently released World Input-Output Database (WIOD) – the first public database describing the industrial flows of goods and services between 35 sectors of 40 countries, developed and funded by the 7th Framework Programme of the European Commission. By constructing a so-called ‘multi-country linear input-output model’ around this data the aim is to derive a variety of structural indicators or ‘metrics’ from this data. By graphically visualizing these metrics for a selection of Eurozone countries and aggregated higher-level industries, the hope is to obtain useful visual representations on the evolution on the technological structure of production and the other structural aspects of the main Eurozone economies which furthermore are easy to communicate to, and interpret by, the European policy makers.

To work towards the research objective in a targeted manner, three main research questions are formulated together with several associated sub-questions. The first research question addresses the analysis of the historical evolution of the economic structures and trade interdependencies of the Eurozone’s main protagonists. In other words, this first research question demands a solid empirical analysis on the evolution of the Eurozone’s economic environment and its main driving forces. The results from this analysis constitute the factual basis in which the consequent policy suggestions and general lines of thought are to be rooted. This first research question and its associated three sub-questions are formulated as follows:
Main question 1: How did the economical structure of the main Eurozone countries develop on the sectoral level between 1995 and 2011?

Sub-question 1.1: What are the major developments in the countries’ production structure (i.e. industry specialization) both in terms of total industry output and domestic value added created? How do Europe’s core and peripheral countries relate to one another in this respect? In which industries do the countries reveal a comparative advantage?

Sub-question 1.2: What are the major developments in the countries’ trade structure (i.e. trade specialization) in terms of value added imports, exports, and bilateral trade balances, both within and outside the Eurozone, on a sectoral level? How do Europe’s core and peripheral countries relate to one another in this respect? In which industries do the countries reveal a comparative advantage?

Sub-question 1.3: Can any structural asymmetry developments be observed among the Eurozone countries? Is the event of the monetary unification reflected in the aforementioned structural indicators?

The answers to the questions formulated above should provide an understanding on the evolution of the internal dynamics within the Eurozone and the associated specialization of production activities among its various members. The convergence and or divergence patterns resulting from this analysis should provide insights and guidance to the design of targeted industrial and income policies aimed at achieving a sustained recovery of the Eurozone economy.

Because any new policy will influence the current economic reality it is of great importance to also get a clear image on the current economic structural interdependencies and internal dynamics between the Eurozone economies. To this end, an analysis on the current intra-Eurozone trade spillovers – resulting from a rise in global production and finance – and their effect on the creation of intra-Eurozone value added and employment is important to determine the impacts of future policy suggestions on each member of the Eurozone. Put differently, the current state of affairs concerning the sectoral specialization of production and trade among the various Eurozone members is of great importance to the assessment of aggregate outcomes (i.e. the overall Eurozone) for income, employment, and general societal welfare. Because the most recent data captured by the World Input-Output Database is from the year 2011, the assumption is made that the patterns contained in that year’s data describe the ‘current’ economic reality and hence reflect the present economic structure and sectoral interdependencies. The following research question captures this second part of the research:

Main question 2: What do the current (i.e. 2011) structural trade interdependencies between the main economies of the Eurozone look like?

Sub-question 2.1: How much extra value added would be created in the various industries of these Eurozone members by a unit-size demand stimulation of any chosen industry in any of these countries? In other words, what do the industry stimulation spillovers among the various Eurozone members look like? Which spillovers are the most important and do we notice particular asymmetries?

Sub-question 2.2: How much value added is created in the various industries of these Eurozone members by the actual buying decisions of the final consumers of
any of these countries? In other words, what do the final consumer stimulation spillovers among the various Eurozone members look like? Which spillovers are the most important and do we notice particular asymmetries?

Based on the diagnostics obtained from the aforementioned first two research questions, the last part of this graduate project focuses on putting forward several main lines of thought and policy suggestions that could be useful for the European decision-makers to consider in their search for solutions to achieve a sustained recovery of the Eurozone economy. The aims of this part of the analysis can be described by the following research questions:

Main question 3: Based on the insights collected by the answers on the first two research questions, which industrial policy and trade policy suggestions could be supported by the empirical findings to be useful in helping to (partially) solve the Eurozone’s macroeconomic imbalances problem? In particular, to which extent could the two scenarios outlined in the two sub-questions below be feasible in helping to solve the problem?

Sub-question 3.1: Could the Eurozone’s under-performing peripheral countries benefit from a growth stimulus from the core countries? Which sectors in the core would have to be stimulated and which sectors in the peripheral countries would be impacted most? And roughly how large would the magnitude of these impacts be?

Sub-question 3.2: Could a coordinated Eurozone growth-stimulus in any way effective in exploiting the intra-Eurozone trade spillovers as to giving the Eurozone economy a stronger boost while reducing the imbalances between the core and periphery? Which sectors would have to be stimulated in which countries?

With respect to the last sub-question, the idea of a coordinated policy stimulus described in sub-question 3.2 above has been suggested by several studies and prominent voices in the academic literature. These studies argue that the macroeconomic imbalances in the Eurozone have been growing too excessively in order for the problem to be solved on a national level and argue that the only feasible policy strategies are those that are internationally coordinated (i.e. policies coordinated at the supranational Eurozone level), see for example Wagner (2013a).

Having explained the research objective and associated research questions, the next chapter provides a review on the academic literature that is considered relevant for this graduation project. Its basic aim is to evaluate the overall theoretical context of both the Eurozone problems and the measurement of trade and production structures as well as to identify the literature gap that is being addressed by this research.
This section presents an overview of the current body of knowledge that is considered to be relevant for the analysis of the research objective and associated research questions that were formulated in the previous chapter. The goal of this chapter is to outline the theoretical context around which the research is centered. Several topics will be covered. Firstly, the evolution of the European economic and monetary integration will be examined. Attention will be paid to both the predictions that were made before the monetary unification of the Eurozone occurred, as well as to the degree in which the unification is considered to have been successful so far. Secondly, two mainstream theories will be presented on the causes of the Eurozone crisis. Thirdly, some theory concerning global fragmentation and measurement of trade in value added will be presented.

3.1. The European monetary integration

This section examines the question to which extent the creation of the monetary union favoured convergence among the Eurozone members. The economical literature does not provide a clear unequivocal answer to this question (Wagner, 2013a). The answers vary depending on what exactly is being covered by the term ‘convergence’ and on the time period being considered.

The term ‘convergence’ between countries could in principle be related to a variety of aspects. One could think of, among other things, convergence in: GDP (i.e. income) per capita levels (as they are an indicator for the standard of living), GDP growth, inflation, labour costs, labour productivity, institutions, social protection and labour rights, policy coordination, etc. Important is to make a distinction between the trends in national macro-economic indicators, and the trends in the underlying sector-level indicators, which are often less visible. Wagner implicitly makes this distinction when he refers to ‘real convergence as the “catching up in
Gross National Income (GNI) per capita as well as convergence in institutions and socio-economic structures” (Wagner, 2013b, p. 185). He refers to ‘institutional convergence’ as the harmonization and alignment of rules and institutions, and clarifies the term ‘structural convergence’ as the alignment in product or labour markets, administrative capacity, political governance, etc. According to Wagner his definition captures the “alignment of standards of living at a high level in the participating states”, which is considered by the European Commission to be one of the key long-term objectives of the European Integration process (EU-Commission, 1996; Wagner, 2013b).

Wagner also argues that a convergence in high-level macro-economic indicators (such as GNI per capita) cannot be sustainable if it is not accompanied by institutional and structural convergence. The effect of the global financial crisis on the Eurozone economy perfectly illustrates this argument, as many economists argue that the financial crisis uncovered several important underlying structural differences between Europe’s core and peripheral countries. These differences gradually built up over the decade before the crisis, but remained largely obscured for a long time by a positive performance of most macro-economic indicators (see also next section).

Before the advent of the financial crisis many academics considered the Euro project, and the European integration in general, to be relatively successful (Landesmann, 2013; Wyplosz, 2006). Financial markets were also relatively optimistic as the spreads between long-term interest rates of government obligations from Eurozone countries were low, indicating that financial investors did not see large country-specific bankruptcy risks.

There is no doubt that after the outbreak of the financial crisis the macro-economic imbalances between the Eurozone members increased enormously. Never before in the history of the European Union were the differences between Europe’s core and periphery so pronounced. This is clearly reflected by divergence in: GDP growth rates, government debt-to-GDP ratios, fiscal deficits, long-term interest rates, reputation levels, current account balances, unemployment rates, etc. The previously optimistic views on the gradual convergence between the Eurozone countries have disappeared entirely, as the integration process has been increasingly characterized by severe divergence.

The potential benefits of a European economic and monetary union were, of course, investigated extensively before the eventual decision was made. The results of these discussions were published in a report from the Commission of the European Communities (Emerson et al., 1992). The likely impact of a monetary integration included: micro-economic efficiency, macro-economic stability, and an increase in equality between countries and regions.

Before the European monetary union was established, many prominent economists also emphasized the substantial risks of such an undertaking. They argued it would exhibit several fundamental fragilities. Much criticism went to the absence of a federal (i.e. European) fiscal union and the elimination of national exchange rates as monetary policy instrument to influence the macro-economic environment by devaluations and revaluations. For an overview on the most noteworthy publications on potential concerns regarding a European monetary integration that were published during the decades prior to the unification in 1999, see Eichengreen (2012).

Several studies from the 1990’s used theory in combination with empirical observations from the United States (an existing monetary union) in order to investigate plausible scenarios for the development of a European monetary union (Bayoumi and Eichengreen, 1992; Krugman, 2001; Sala-i Martin and Sachs, 1991). Bayoumi & Eichengreen conclude that
Europe could experience difficulties with the operation of a monetary union compared to the U.S. Their results indicated that “underlying [negative demand] shocks were increasingly more idiosyncratic across EU countries than across the U.S. region”. Krugman similarly concluded that a European monetary union would produce severe and permanent regional stabilization problems. He argued that the increase in market integration and trade liberalization would lead to regional concentrations of industrial activities. This would make regions and countries more sensitive to asymmetric, idiosyncratic shocks. Together with an increase in factor mobility (both labour and capital), theory and evidence from the United States suggested that these shocks would lead to a permanent divergence of the growth rates of the regions and countries, as production factors would leave faster from a negatively to a positively affected region. As a monetary union would eliminate the use of national monetary policy tools that could normally help in restoring stabilization after an asymmetric demand shock, and because a one-size-fits-all European monetary policy would be incapable of dealing with fixing these regional imbalances, Krugman advocated for the introduction of a federal fiscal budget and of associated inter-regional (or inter-country) redistribution mechanisms.

De Grauwe critized Krugman’s analysis on two grounds (Krugman, 2001). Firstly, he argues that the degree of labour mobility in Europe would stay significantly lower compared to the U.S., due to relatively strong barriers in culture and linguistics among member form the Eurozone (this argument was also put forward in (Eichengreen, 2012, p. 133). As a result, he argued, a negative demand shock would less be accommodated by a movement in production factors and more by a downward pressure on the country’s relative real wages (i.e. relative unit labour costs). Secondly, the necessity for a centralized federal fiscal budget would be less urgent for the Eurozone compared to the U.S., since the national governments from the Eurozone would still have several regional stabilization policy instruments available (such as national budgetary policies and income policies) which could not be invoked by states in the U.S. This last argument was also made by the Commission of the European Communities (Emerson et al., 1992, p. 11).

Despite these critics, De Grauwe also expressed his concerns about the plans for a European monetary union. For example, in an article from 1996 he argued that the prior convergence criteria that were outlined in the Maastricht Treaty did not have a solid theoretical basis and would “almost certainly lead to a Great Divide in the European Union”. Entry to the monetary union was made conditional on these criteria, which focused on price stability, government finances, exchange rates and long-term interest rates.

3.2. The European Debt crisis

This section is based in the story line presented by Storm & Naastepad (Storm and Naastepad, 2014b, 2015). Broadly taken the academic literature concerning the causes of the Eurozone debt crisis and associated macro-economic imbalances can be divided in two groups. A similar storyline combining the arguments presented by both groups can be found in Dadush and Stancil (2011).

The first group argues that the divergence between Europe’s core and periphery is due to the grown differences between their relative cost competitiveness positions (and in particular relative unit labour costs), which started to build up after the creation of the monetary union in 2001. In the peripheral countries the unit labour costs rose too fast because the wages in these countries grew faster than the growth in labour productivity. This disproportionate wage growth was due to excessive wage increases in the salaries of the public sector, and
because the unions successfully negotiated higher private sector wages (which was possible because companies were generally performing well and a positive business climate prevailed) causing ‘pro-worker disturbances’ in the periphery labour markets which were generally known to be rather rigid and inflexible (or ‘sclerotic’). On the other hand, the unit labour costs of the core countries (and especially Germany) decreased significantly after the monetary integration. In Germany this was largely facilitated by a domestic reform of the labour market, known as the Hartz-reforms, which essentially reduced growth in real wage, while maintaining growth in labour productivity.

The second group does not consider the change in relative cost competitiveness positions to be the cause of the crisis, but instead considers it to be a consequence. According to their logic, the Eurozone crisis can be linked an unsustainable debt-driven increase in the domestic demand of the peripheral countries that was largely financed by capital from the core countries. This external financial capital mostly ended up in non-traded low-tech segments. An additional causal factor, according to this group, is the significant structural asymmetries (i.e. in production capabilities and associated export strengths) between the core and periphery. Germany is dominant in high-tech tradable (manufacturing) activities and it has a strong export performance in these types of goods, whereas the periphery is dominant in non-traded and lower-tech sectors (e.g. construction, real estate, tourism, etc.). Germany is better positioned to benefit from global demand evolutions and global income growth as it is exporting high-prices, technological complex goods (for which there is less competition) to fast-expanding global markets (like the BRIC countries). The periphery, on the other hand, is much more dependent on the domestic market demand and has to compete much more with countries like China, because of its export specialization in low-tech goods.

According to Storm & Naastepad the European monetary unification has enforced the structural asymmetries in production structures and export specializations between Europe’s core and periphery. In other words, the structural differences were already existent before the introduction of the single currency, but the monetary integration increased these differences and thus facilitated a process of intra-Eurozone divergence on a sectoral level.

**3.3. Krugman’s centripetal and centrifugal forces**

So far it has become clear that the main hypothesis behind the creation of the monetary union and its associated single currency constituted the occurrence of a convergence process between the various Eurozone members. Convergence was expected and aimed for in terms of mainly growth and inflation as well as in terms of the harmonization of rules and institutions and the alignment of product and labour markets, administrative capacity and political governance. Economic stability was the overall goal behind this unification, shifting the union from a regulatory state to a stabilization state by establishing and institutionalizing sound money and finance, securing price stability, and imposing tight financial and budgetary discipline (Dyson, 2002).

Before the member countries joined the monetary union, each of them walked along a different path of economical, social and political development, steered by a variety of driving factors including, among others, competitive advantages, historical and geographical factors, increasing returns and transportation costs. Consequently, this gave rise to a strong variety of economic structures which developed in a path dependent manner and which uniquely characterized each of the acceding members when they entered the monetary union.

In his model of the ‘new geographical economics’, the Nobel Prize-winning economist
Paul Krugman stated that a process of uneven regional development and industrial concentration can be characterized as a tension between two basic opposing forces: centripetal and centrifugal forces. Centripetal forces “tend to pull population and production into agglomerations” while centrifugal forces “tend to break such agglomerations up” (Krugman, 1996, p. 243). Centripetal forces include natural advantages (e.g. rivers, central locations, harbors,...), knowledge spillovers, access to markets, access to intermediate inputs and final products, economies of scale, the presence of a ‘thick’ labour market supplying a large variety of specialized skills (allowing for better matches between jobs and workers), etc. (Krugman, 1990; Marshall, 1892). Centrifugal forces include rents, transportation costs, commuting costs, pollution, congestion, etc. Applying Krugman’s insights to the Eurozone economy and the historic, path dependent economic developments of its member countries, each individual member can be modeled as such a ‘region’ upon which these two types of opposing forces are exerted. The relative strength of the centripetal and centrifugal forces is what determines if overall convergence or divergence will occur between the Eurozone countries (Krugman, 1991). This can be easily understood. Centripetal forces stimulate companies from an industry to locate in the same region (country) nearby similar companies in their industry which fosters convergence (Kolko, 2002). Centrifugal forces, on the other hand, give companies incentives to move away from similar companies to other regions (countries) thereby fostering divergence.

Undoubtedly, these centripetal and centrifugal forces – and hence the associated processes of convergence and divergence – were influenced by the creation of the European monetary union, both in the years leading up to the unification as well as during the whole period after it. Moreover, several authors have hypothesized a potential link between these forces and the sector technology intensity of the various countries. Storm and Naastepad (2014a) have suggested for example that Germany and the rest of the Eurozone core have been specializing in the production of high-tech products, while the Eurozone periphery has been getting more and more locked up in to low- and medium-technology activities products and non-tradable goods and services. He concludes that “while Germany managed to further strengthen its technological capabilities, which in turn resulted in higher productivity growth and greater non-price competitiveness, the Eurozone periphery fell further behind”.

3.4. Global fragmentation and trade in value added

Nowadays, production has become increasingly internationally fragmented as more parts of the value chain are being outsourced to foreign countries. This broad phenomenon is often termed global (or cross-border) fragmentation, vertical specialization in international trade (Timmer et al., 2013) or global value chains (Amador et al., 2014). A general definition describes a global value chain as follows:

**Global value chain:** Describes the full range of activities undertaken to bring a product or service from its conception to its end use and how these activities are distributed over geographic space and across international borders.

Sydor (2011)

In the Eurozone this process has been given a further boost as the European unification led to a Eurozone-wide spatial separation and regional specialization of business activities. Recognizing this phenomenon several authors argue that the use of traditional gross import
and export values to measure specialization patterns of countries will increasingly produce biased results. To see this one has to simply realize that the export value of a country or region is not equal to the value that is this country or region adds to the production-process. In short, traditional export statistics are not capable to fully capture the real value added of a country or region in international fragmented production. To correct for this bias we should thus start measuring export values according to their value added sources (Koopman et al., 2010; Stehrer, 2012). Such analyses are referred to as ‘vertical specialization’ analyses and they can aid in analyzing the interconnectedness of countries and their sectors by analyzing their production linkages (Oehler-Sincai, 2014). Hummels et al. (2001) define the term vertical specialization as follows:

**Vertical specialization:** The increasing interconnectedness of production processes in a vertical trading chain that stretches across many countries, with each country specializing in particular stages of a good’s production sequence.

Hummels et al. (2001)

Over the last decade serious progress has been made in the development of indicators and frameworks to measure a country’s vertical specialization and participation in global value chains. A large driver behind this progress has been the simultaneous advancement within the domain of input-output modeling with the creation of the first practical applicable global multi-regional inter-industry schemes, like the World Input-Output Database project. The most noteworthy publications on these methodological advances include the initial concepts developed in Feenstra and Hanson (1999) and Hummels et al. (2001), as well as the more comprehensive frameworks to measure and decompose trade in value added suggested in Koopman et al. (2010), Johnson and Noguera (2012), and Stehrer (2012). It should be noted, however, that these various authors all have adopted their own notation throughout the mathematical derivation of their framework and/or trade metrics which surprisingly all vary extensively with the standard notation adopted in Miller and Blair’s classical textbook and essential reference on input-output research.

In recent years, only a few studies have applied the advancements in measuring trade in value added and the practical opportunity to calculate sector-level intra-Eurozone trade linkages via data supplied by the World Input-Output Database to the specific context of the Eurozone problems that arose after the global crisis of 2008-2009. Amador et al. (2014) have presented an initial attempt along these lines by comparing the main characteristics of global value chains in the Euro area with those of other key players and by placing the global value chains in the context of the economic integration. They adopt a three-fold distinction to measure vertical specialization: the foreign value added content of exports (FVAix), the domestic value added content of exports (DVAix) and the re-exported domestic value added in imports (RDVAim). Based on these measures, they then analyze the role and importance of global fragmentation in influencing the European economic and monetary integration process. They make several important observations. Firstly, the share of foreign value added in exports for the Euro area strongly increased over the period 2000-2011, which shows that the external suppliers’ relevance grew over this period. In other words, the Eurozone is characterized by a relatively high relevance of global fragmentation compared to other major trade blocks. Secondly, for most Eurozone countries the largest source of foreign value added is originates from within the Euro area, which indicates the importance of the production-linkages within the Eurozone. Thirdly, based on the value added flows between the Eurozone
countries they conclude that Germany plays a central role in the Eurozone’s production linkages and that manufacturing retains the most prominent role in those linkages. Finally, the services sector is observed to have increased its importance in the global value chains of most countries. Apart from these results, their conclusions strongly remain on the surface and don’t present any details on individual Eurozone countries or particular disaggregated (i.e lower-level) industries.

A second study, of Garbellini et al. (2014a), presents an attempt towards a multi-regional input-output assessment of the domestic demand and global production in the Eurozone. Their approach relates more strongly to the focus of this research project in the sense that they also use a set of structural indicators to measure the intra-Eurozone trade spillovers caused by the dynamics of final demand. It differs from this research in that its main focus is constrained to the effects of the Great Recession of 2008-2009 and the Eurozone crisis of 2011-2012. Their general conclusions state that ‘during the Eurozone crisis, the cross-country spillovers have had a moderate impact when compared with the role of domestic sources of final demand’ and secondly that ‘a strategy of coordinated fiscal austerity cannot be sustained by empirical evidence’ (Garbellini et al., 2014a, p. 1).

Having discussed the body of academical knowledge considered relevant to this research project, our story continues in the next chapter with the presentation of a conceptual research model that formalizes an important subset of the causal chain underlying the basic Eurozone problem into a theoretical causal-relationship model. Furthermore, that chapter also discusses the literature gap addressed by this research project. As an application of the model, the end of that chapter explains the story line on the evolution of the macro-economic imbalances within the Eurozone, that was presented in this chapter, using the reasoning structure presented by the conceptual model.
This section discusses the conceptual model around which the research project is basically centered. Figure 4.1 shows a causal diagram of the model’s main variables and associated causal relations. The variables and relations outside of the dotted circled area constitute the part that is already established in the literature and has already been tested empirically extensively. Every textbook covering the principles of macro-economics addresses the majority of these relations in one form or another. The variables inside the circled area constitute the extension that is hypothesized (and will be empirically analyzed) in this research project. In other words, the circled area basically constitutes the literature gap that will be addressed by this research project.

As can be seen in Figure 4.1, essentially all relations in the conceptual model are directed towards one main dependent variable: a country’s current account balance. The model was deliberately constructed to reason towards this particular variable, because a broad consensus exists in the academic literature that the growing current account imbalances between the Eurozone’s core (dominated by Germany) and peripheral countries (mainly Greece, Italy, Ireland, Portugal, and Spain) are at the root of the experienced Eurozone problems. Several authors even argue that the growing current account imbalances are the indication of an ongoing process of economic divergence (Holinski et al., 2012; Storm and Naastepad, 2014a). Because these imbalances are unsustainable over the long-term (especially for the deficit countries) they will ultimately have to necessarily be reversed. In one possible scenario, when the surplus countries are not incentivized to reduce their surplus, the deficit countries will be forced to reduce their deficit, which under the fixed exchange rate regime of the Eurozone can only be achieved by seriously cutting their spending on investment, consumption, and imports – a devaluation of the nominal exchange rate to quickly gain competitiveness is impossible for any individual Eurozone member – with all its unpleasant consequences. This is mainly what is happening nowadays. Hence, now that we have an understanding on the importance of the current account balance problem in the Eurozone, the subsequent sections walk the reader through the conceptual research model and its application to the Eurozone problems in order to get a clear image on the underlying determinants of the observed macro-economics imbalances.

The rest of this chapter is organized as follows. Firstly, the conceptual model presented in Figure 4.1 is discussed in detail. All variables and causal relations will be carefully defined and explained one after another. Focus is first put on the set of relations which are already
broadly accepted in the literature, after which an extension of the model is presented which introduces two extra hypotheses. It is this extension around which the rest of the research project will be centered. Secondly, an application of the conceptual model is presented which provides an explanation to the observed trend in the Eurozone’s core-periphery current account imbalances.

4.1. Presentation of the conceptual model

This section provides an outline of the conceptual model around which the research project is centered. The first subsection discusses the relations that are already established in the literature, while the subsection thereafter discusses an extension of the model which the empirical part of this graduate project will implicitly focus on. Essentially the extension aims at investigating if and how a country’s productive structure and international trade interdependencies moderate the determination of a country’s current account balance.

Existing relations

The main dependent variable whose determinants and moderating factors will be analyzed during this research is the current account balance of a country (the top right variable in Figure 4.1). Focus is put on this variable in particular because many authors in the literature emphasize that the observed ‘core-periphery dualism’ – a term used by Cesaroni and De Santis (2014) – is manifested and caused by the growing current account differences between the various members of the Euro area since the middle of the 1990’s. The current account balance is a critical indicator used in the formulation of many of a country’s national and international economic policies as it signals the relative competitiveness of a country. The current account is a statistic national account, a paraphrase of the definition provided by the IMF’s (International Monetary Fund) Balance of Payments Manual is given below:

**Figure 4.1:** The conceptual research model
4.1. Presentation of the conceptual model

Current account: captures the flows of goods, services, primary income, and secondary income between residents and nonresidents. It consists of three main accounts. The goods and services account shows transactions in goods and services. The primary income account shows amounts payable and receivable in return for providing temporary use to another entity of labor, financial resources, or non-produced non-financial assets. The secondary income account shows redistribution of income (e.g. personal transfers, current international assistance, ...).

adapted from IMF, 2007

The current account balance is the overall balance on the three sub-balances of the current account, or more formally:

Current account balance: captures the sum of a country’s net exports (total exports minus total imports) and net income (total income receivable minus total income payable, both primary and secondary).

The balance of goods and services (i.e. net exports) is often referred to as the country’s balance of trade. This part usually accounts for the majority of the current account balance. If the current account balance is positive then the country is running a current account surplus (i.e. positive or favorable balance) with the rest of the world. Conversely, if the balance is negative then the country is running a current account deficit (i.e. negative or unfavorable balance) with the rest of the world.

The current account is one of the key accounts constituting the balance of payments account. A country’s balance of payments captures all transactions, both public and private, occurring between residents and nonresidents during a particular period. According to the nature of the resources being exchanged, three accounts can be distinguished within this account: the current account, the capital account, and the financial account, as is illustrated in Table 4.1. The capital account records purchases and sales of non-produced non-financial assets and capital transfers between residents and nonresidents, while the financial account shows the acquirement and disposition of financial assets and liabilities (IMF, 2007). In this research project we specifically focus on the determinants of the balance of trade component (i.e. net exports) of the current account balance. This is highlighted in Table 4.1 by the dotted green box, and in Figure 4.1 by number 1.

Table 4.1: Illustration of a country’s Balance of Payments national account. The dotted box highlights the part that will be focused on during the research project

<table>
<thead>
<tr>
<th>Balance of Payments</th>
<th>Credits</th>
<th>Debits</th>
<th>Balance (= Credits - Debits)</th>
<th>Balance label</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Account</td>
<td></td>
<td></td>
<td></td>
<td>Current Account Balance</td>
</tr>
<tr>
<td>Goods and Services</td>
<td></td>
<td></td>
<td></td>
<td>Balance of Trade (or Net Exports)</td>
</tr>
<tr>
<td>Income (Primary and Secondary)</td>
<td></td>
<td></td>
<td></td>
<td>Income Balance (or Net Income)</td>
</tr>
<tr>
<td>Capital Account</td>
<td></td>
<td></td>
<td></td>
<td>Capital Account Balance</td>
</tr>
<tr>
<td>Financial Account</td>
<td></td>
<td></td>
<td></td>
<td>Financial Account Balance</td>
</tr>
</tbody>
</table>

Next, we turn our focus to the main determinants of net exports. As is illustrated in Figure 4.1, the literature broadly distinguishes at least four main explanatory factors for net exports: export restrictions (i.e. trade barriers), the real exchange rate, foreign demand for domestic goods and services, and domestic demand.
The first variable, export restrictions, is formally defined by the OECD (Organisation for Economic Co-operation and Development) in their glossary of statistical terms and can be paraphrased as follows:

**Export restrictions:** indicates restrictions limiting the ability of firms to export. These restrictions may originate from governments, a cartel agreement, agreements negotiated by the import country, or from licensing agreements in which the firm who is granted the license is prohibited to export the product in competition with other licensees.

adapted from OECD, 2008

The negative relation between export restrictions and net exports – number 2 in Figure 4.1 – states that restrictive export barriers, such as quotas, tariffs and bans, negatively affect net exports. This is a straight-forward relation that is mentioned in many textbooks covering macro-economic principles, see for example Gupta (2004, p. 139) or Gans et al. (2011, p. 702).

The next three explanatory variables of net exports – numbers 3 to 5 in Figure 4.1 – are adopted from the causal framework for net exports proposed by Abel et al. (2008) in their book covering macroeconomic theory for policy makers and researchers. They provide the following explanations for each of these hypothesized net export determinants in their model. The first explaining variable is the country’s real exchange rate. The real exchange rate between two countries represents the exchange rate adjusted for the inflation difference between these two countries. Again, based on the OECD’s glossary of statistical terms, we formally define this variable as follows:

**Real effective exchange rate:** the price of the currency of one country in comparison to another, taking into account any price level differences between the two countries. In other words, the real exchange rate essentially captures the price of domestic goods in relation to foreign goods. Movements in this variable indicate how a country’s external price competitiveness evolves over time.

adapted from OECD, 2008

Simply put, the real exchange rate between two countries indicates how much foreign goods can be bought with one domestic good. Generally, a negative relation exists between the real exchange rate and net exports. A higher real exchange rate makes domestic goods and services more expensive in relation to foreign goods and services, which increases imports and hence lowers net exports. Put differently, the real exchange rate is the relative price of a country’s products. An increase in this variable stimulates domestic and foreign residents to purchase more products from abroad and less from domestic production.

The second variable, **foreign demand for exports**, refers to the overall demand of consumer groups in foreign countries for domestic goods and services produced by the home country and exported abroad. Logically, a positive relation exists between this variable and net exports: higher foreign demand for domestic goods and services directly increases net exports. Equivalently, one could also implicitly identify this variable by referring to foreign output, because ultimately aggregate demand and aggregate supply equal each other in equilibrium. This variable would refer to the real output of every trading partner of our domestic country. A similar positive relation exists: higher foreign output increases the level of foreign income which increases the foreign demand for exports, and hence increases net exports.
The last explaining factor of net exports mentioned by Abel et al. (2008) and that is considered in our conceptual model is the country’s aggregate domestic demand (i.e. national expenditures), number 7 in Figure 4.1. This relation postulates that net exports is negatively influenced by domestic demand. The argumentation behind it is that higher domestic demand leads to higher domestic demand for imports, and hence decreases in net exports, as indicated by Farnham (1999, p. 74). Equivalently, we could also refer to this factor implicitly as the aggregate real domestic output or real GDP, because ultimately aggregate demand and aggregate supply will be equal in equilibrium. This variable is formally defined in the OECD’s glossary of statistical terms, and we paraphrase it as follows:

**Real domestic output:** an aggregate production indicator which can be defined in three theoretically identical ways: (1) the sum of the values added of all resident institutional units engaged in production (the output-definition), (2) the sum of the final uses of goods and services, except intermediate consumption, less the value of imports (the expenditure-definition), and (3) the sum of primary incomes distributed by resident producer units (the income definition).

Higher real domestic output increases the level of domestic income which increases the domestic demand for imports, and hence lowers net exports. Put differently, a rise in real domestic output (which is equivalent to domestic income) will encourage consumers to spend more on goods and services, including imports, which hence lowers net exports.

In order to better understand this last relation, we now turn our attention to the identification of the key explaining factors for a country’s domestic demand (or equivalently, domestic output) that are broadly identified in the literature. Factors influencing a country’s aggregate domestic demand are covered in nearly every textbook covering basic macroeconomic principles. Often these factors are presented within the framework of the ‘aggregate demand - aggregate supply’ (AD-AS) model, the Keynesian aggregate expenditure model, or the IS-LM model. The four factors listed in Figure 4.1 are all commonly cited factors in the literature and are chosen in accordance with the mainstream story lines and theories on how the current account imbalances in the Eurozone built up. In other words, these four factors are not meant to present an exhaustive enumeration of possible factors influencing domestic demand, but instead are chosen based on several existing explanations for the European core-periphery dualism dominating the existing literature. A more extensive literature analysis on a wider array of determinants explaining changes in a country’s domestic demand is done by Coffin (2003), in which 19 textbooks on macroeconomic principles are examined in order to conciliate the various explaining factors presented by the different authors. The four factors presented in our conceptual model are all substantially agreed upon by most authors analyzed in Coffin’s study.

The first explaining variable for domestic demand listed in our model is consumer optimism. This variable captures the purchasing plans of households in the economy, together with their current economic situation and their expectations on the economic situation in the immediate future. This variable is usually measured by a consumer confidence index obtained via (qualitative) consumer opinion surveys, see for example OECD (2015). As indicated by number 6 in Figure 4.1, a higher level of consumer optimism increases the level of domestic demand. The second explaining factor is the real interest rate. Based on the definition presented in the OECD’s list of main economic indicators, the real interest rate can be defined as follows:
Real interest rate: the price paid by a borrower for the usage of funds saved by the lender and the compensation of the lender for the deferral of his expenditures. The compensation consists of two parts: a payment equal to the principal’s loss of purchasing power during the period of the loan, and a balance capturing the real interest accrued to the lender.

adapted from OECD (2015)

As indicated by relation 7, a negative causal relation is assumed between the real interest rate and domestic demand, which can be explained as follows: a higher interest rate incentives people to save more (because they can earn more interest) while at the same time it discourages people to borrow money (because a higher interest rate increases the cost of borrowing). The third explaining variable is Net government spending. This variable captures the general expenditures made by the government in order to steer the economy and influence the aggregate demand minus the total amount of taxes collected by the government. It includes expenditures on defence, public order and safety, education, health, etc. A formal breakdown of a country’s total general government expenditures into ten categories is provided by the OECD as the Classification of Functions of Government (COFOG), providing measures to compare expenditures on particular functions. Higher levels of net government spending cause the domestic demand to increase, as is indicated by positive relation 8 in Figure 4.1. The fourth and last explaining factor in our model is credit availability. This factor refers to the amount of money (or credit) that is available for someone to borrow at any given time. An increase in credit availability is assumed to increase the overall investment activities in the economy, and hence increases the level of domestic demand, as indicated by relation 9.

4.1.1. Extending the basic conceptual model: the literature gap
This section focuses on the extension of the conceptual model described in the previous section, around which the empirical analysis of this graduate project is basically centered. The extension is denoted by the dotted circled area in Figure 4.1 and broadly emphasizes the literature gap that will be addressed in the research project. Essentially it hypothesizes to add two moderating factors to the model, influencing the relation between net exports and several of its determinants.

The first of these two proposed moderating factors is a country’s trade specialization, which refers to the composition and concentration of a country’s export. For example, some countries might be exporting relatively much natural resources in relation to their total exports, while other countries might be specialized in exporting relatively much complex and high-technological products. The hypothesis is that the composition of a country’s export basket conditions the effect of the relation between net exports and several of its determining factors. In other words, the hypothesis is that a country’s trade specialization matters for net exports, and hence for its current account. More specifically, in our conceptual model a country’s trade specialization is assumed to influence: (1) the causal relation between the real exchange rate and net exports, (2) the causal relation between foreign demand for exports and net exports, and (3) the causal relation between domestic demand and net exports. This is indicated in Figure 4.1 by relations 10, 11, and 12 respectively. The first of these three relations has already been demonstrated empirically for the Eurozone by Wierts et al. (2014). The authors of this article conclude that a lower share of high technology exports in a country’s overall exports increases the effect of a real exchange rate over- or undervaluation on total exports. The effect reduces the higher is the share of high technology exports. The
other two moderating effects will be analyzed during the research project.

Trade specialization, in turn, is determined in part by a country’s industry specialization (equivalently, industry structure or productive structure). A country’s industry specialization refers to the mix of goods and services produced by that country and hence its specialization in specific product categories. Put differently, the industry specialization of an economy refers to the producing specialization that occurs in that economy, where specialization is defined as the distribution of weights for each industry in the economy (i.e. the share of total production taken by each industry) (Aiginger, 1999). Countries in which a relatively small number of industries accounts for the majority of the country’s total production are referred to as highly specialized countries. Countries where a large number of industries are responsible for total production are referred to as diversified. In open (and especially larger) economies, a country’s domestic industry structure is generally closely linked with its trade specialization as industries have to be competitive on an international scale: if a country has a comparative advantage in a particular industry segment, then its domestic production structure will become more concentrated in this segment and so will its trade specialization. Hughes (1986) considers theoretical and empirical analyses on the determinants of a country’s export composition (i.e. trade specialization) and concludes that, among other factors, industry structure variables provide an explanation for a country’s trade specialization. This confirms relation 13 in Figure 4.1.

We are especially interested in the moderating effects of a country’s specialization in technological intensive manufacturing industries (i.e. a country’s technological capabilities), because the technological effort required to produce certain products is broadly considered to be a key determinant of an economy’s productivity growth as well as international competitiveness (OECD, 2007, p. 219). This focus is made explicit in our conceptual model by the causal relation between technological intensity and industry specialization, as is shown by relation 14 in Figure 4.1. We define a country’s technological intensity according to the formal technology intensity classification provided by the OECD Directorate for Science, Technology and Industry (OECD, 2011a). This widely accepted classification distinguishes manufacturing industries according to their technology intensity by looking at their direct research and development (R&D) intensity. This measure is based on the original paper by Hatzichronoglou (1997) in which he is the first to formally define the four manufacturing categories listed above. To be more precise, the four categories are determined by looking at two technology intensity indicators for each industry (for a selected set of 12 OECD countries and covering the period 1991-1999): (1) R&D expenditures divided by value added, and (2) R&D expenditures divided by production. Based on this technology intensity definition the manufacturing industries are classified into one of the following four categories: ‘Low-technology’, ‘Medium-low-technology’, ‘Medium-high-technology’, and ‘High-technology’.

The second proposed moderating factor is a country’s global sectoral interdependence. This factor refers to a country’s sectoral trade dependencies, both domestically as well as internationally with all its trading partners. This factor tries to capture the increasing trend of international fragmentation of production chains which establishes so-called global value chains, a well-recognized observation in the literature. The hypothesis is that a country’s embeddedness in global value chains (i.e. interdependence on trade with other sectors around the world) conditions the causal relation between the world demand for domestic goods (both domestic and foreign) and the home country’s net exports, as is indicated by relations 15 and 16 in Figure 4.1. During the research project focus will be put on
4. Conceptual model

empirically analyzing this moderating effect and on discovering which trade linkages (both intra-Eurozone and extra-Eurozone) are the most important.

4.2. Explaining the Eurozone’s core-periphery divergence using the unextended conceptual model

In this section the basic conceptual model from the previous section – i.e. without considering the two moderating relations that were introduced in the previous section – is used to explain the observed diverging trend in the current account balances of the various Eurozone members after the year 2000, especially between the core and peripheral countries.

Most mainstream storylines explaining the observed macroeconomic divergence in the Eurozone trace the starting point of the divergence problems to the completion of the Economic and Monetary Union (EMU) in 1999. From that moment onwards the member states of the Eurozone enjoyed the Euro as their new single currency, while the European System of Central Banks started conducting its single monetary policy (Nello, 2009). Several authors argue that the design of this monetary union contained several severe construction failures which would have promoted the divergence process. We now go through these argued root causes and use our conceptual model to explain how each cause triggered a causal chain of events which eventually reinforced the current account imbalances between the Eurozone countries.

The first construction failure embedded in the design of the monetary union was the absence of credibility concerning the no bailout clause, Article 104 (b) in the Maastricht Treaty, which essentially states that non of the European institutions including the ECB can be held responsible for the debts and other liabilities of central governments or regional, local or other public authorities of any member state in the Eurozone, nor can other member states be held liable for the debts and other public commitments of another member state (European Union, 1992). This clause was not considered to be credible because the Treaty did not cover any exit options (Dieter, 2014) and because of the absence of a central fiscal authority to enforce the no bailout rule (Storm and Naastepad, 2014c). Put differently, because the Treaty of Maastricht did not make any explicit provision around the event of a Eurozone member facing insolvency, the financial markets did not expect the no bailout rule to be binding (Dieter, 2014; Storm and Naastepad, 2014c; Wagner, 2013a; EEAG, 2013). Hence, membership of the monetary union significantly reduced the country’s specific bankruptcy risks in the peripheral countries (as perceived by banks, investors and rating agencies), which reduced country specific risk premiums for these countries. This resulted in lower real interest rates in the periphery and made government bonds of any member state closer substitutes to the safe German government bonds (Wagner, 2013a; Storm and Naastepad, 2014c; EEAG, 2013), resulting in record low interest rate spread levels between securities from the core and the periphery. As indicated by relation (7) in Figure 4.1 these lower interest rates increased the periphery’s domestic demand as it encouraged people to borrow more (lower borrowing costs makes credit cheaper) while discouraging saving, which both stimulated domestic consumption behaviour.

A second failure was the presence of large differences between the financial structures of the various member states, which caused the monetary transmission mechanisms in the Eurozone to function differently (Gros, 2012). In particular, a major differential in local credit conditions existed between the periphery and the core, both in credit accessibility and
in interest rates. For example, in Germany mortgages were usually limited to 60% of the property value and fixed at long-term interest rates, whereas in Spain and Ireland mortgages often had a loan-to-value exceeding 100% and were usually linked to short-term rates, like the LIBOR (Gros, 2011, 2012). Hence in summary, at the time of the monetary unification credit accessibility was significantly higher in the periphery in comparison to the core. As indicated by relation (9) in Figure 4.1, this higher credit accessibility led to an increase in the periphery’s level of domestic demand, because it stimulated the overall investment activities in these countries.

A third failure associated with the design of the EMU was its creation of overly optimistic expectations about a relatively quick convergence (and associated future growth) of the peripheral countries catching-up the richer countries from the core (EEAG, 2013; Blanchard and Giavazzi, 2002; Lane and Pels, 2012), while in fact new members were not given enough incentives to further implement the necessary structural reforms in order for productivity and competitive levels to converge across the Eurozone once they became member of the monetary union (Fernandez-Villaverde et al., 2013; Bonatti and Fracasso, 2013; Pickford et al., 2014). (These reforms were postponed even further by the low real interest rates and abundance of credit availability in the periphery, whose causes were discussed above.) Put differently, membership of the monetary union slowed down the necessary structural reforms in the periphery while (paradoxically) creating overly optimistic expectations about a rapid convergence process in which the periphery would be forced to, among other things, equalize their price and wage levels with those of the more disciplined core (Bonatti and Fracasso, 2013). As indicated by relation (6) in Figure 4.1, this increase in optimistic expectations about the future of the peripheral economies induced an excessive increase in domestic demand, as consumers and private investors were stimulated to spend more as well as increase their investments.

To summarize, the three design failures discussed above are all responsible for increasing the aggregate domestic demand in the peripheral countries (via relations (7), (9) and (6) in our conceptual model) and hence shared responsibility in creating the observed investment- and credit-boom in the periphery in the early 2000’s. This increase in aggregate demand in turn induced a strong increase in the periphery’s demand for imports, as was empirically pointed out by Gros (2012) and Storm and Naastepad (2014c), and explained in our model by relation (5).

Another channel through which the monetary unification reinforced the current account imbalances in the Eurozone is via its impact on the members’ real exchange rates. The real exchange rate between two countries is simply the product of the nominal exchange rate and the inflation differential between these two countries. From the monetary unification and the adoption of the single currency onwards, the members of the Eurozone were governed by a single common monetary policy, controlled by the European Central Bank (ECB), and hence lost direct national control over the policy interest rate and nominal exchange rate. Consequently, the real exchange rates of these countries became directly dependent on the domestic inflation as these countries lost their ability to control their nominal exchange rate (a policy instrument often used to stabilize the economy). Hence, the influence of a country’s current account balance through changes in its real exchange rate (mediated by net exports, see relations (3) and (1) in Figure 4.1) essentially became completely controlled by the level of domestic inflation (Johnston and Regan, 2014) and the policy decisions of the European Central Bank after the monetary unification.
With regards to the price developments in the Eurozone, an already existing difference between low inflation levels in the core versus high inflation levels in the periphery was reinforced after the monetary unification because of at least two main causes. Firstly, the investment- and credit boom in the periphery prompted the governments and enterprises of the peripheral countries to agree on wage increases and welfare gifts (Wagner, 2013a) and drove up inflation levels (EEAG, 2013). Secondly, the ECB lowered its policy interest rate in the years after the monetary unification, which was mainly a response to the macroeconomic conditions of the core countries in the Eurozone, as shown by Storm and Naastepad (2014c): inflation in the core was too low – significantly below the ECB’s optimal target of just below 2% – and there was no immediate sign of a strong inflation revival. By lowering its interest rate, the ECB mainly aimed at increasing inflation in the core. But by doing this the ECB unwillingly also stimulated the already high inflation levels of the peripheral countries which negatively influenced their current account balances through the impact on the periphery’s real exchange rates, as was explained above.

Having explained the existing basic conceptual research model, its hypothesized extension for this graduate project, and its application to explain the experienced core-periphery divergence in the current accounts of the Eurozone countries, the remainder of this research project will focus on investigating the two moderation relationships indicated by the dotted circle in Figure 4.1 for the case of the Eurozone. Using data from the World Input-Output Database the aim is to get an appraisal on the industry and trade specialization patterns of the Eurozone members (relations 10 to 14 in the figure) as well as the intra-Eurozone sectoral trade interdependences (relations 15 and 16) and relate the resulting findings to the core-periphery current account divergence in order to discover potential asymmetry patterns which would empirically confirm the existence of these moderating relations. To this end, the next chapter starts by discussing the input-output methodology which is used to model the various economies and their industries and to obtain the set of structural indicators upon which the empirical analysis will be based.
Methodology and data

“Essentially, all models are wrong, but some are useful.”

George Box (English statistician, 1987)

This chapter discusses the research methodology upon which the empirical analysis for this graduate project relies. In light of the overall research objective of gaining insights into the production and trade structure of the Eurozone economy from which to distill relevant policy suggestions – which we described in chapter 2 – an important general question arises about which data and econometric model would be best qualified in helping us meet this objective. The answer to this question depends both on the inherent strengths and weaknesses of the model as well as on the data availability. The author’s choice to apply input-output modeling in combination with the recently published World Input-Output Database can be defended on several grounds. Of course any method has its limitations, but the input-output modeling technique is characterized by some key strengths which make the model a perfect fit for analyzing the Eurozone structure. These will be fully elaborated on later in this chapter, but for now it suffices to say that the model’s key strength is probably its focus on the productive structures of economies as well as the international interrelatedness in productive and demand structures. Until recently, a major limitation was the unavailability of internationally standardized input-output tables covering a sufficient large period. Fortunately, the public release of the World Input-Output Database has overcome this burden and has given researchers the opportunity to gain a lot of insights into the economic structure of and between various economies on an industrial level.

The author would like to note that he is fully aware that this chapter is pretty technical and extensive, especially given the fact that not everything presented in this chapter is invented from scratch. However, while reading background documents on the subject of input-output modeling to become familiar with this methodology – especially with regards to the whole domain of measuring trade in value added terms – the author saw himself confronted with a variety of mathematical notations on this subject. Because a clear and consistent mathematical basis is crucial for the derivation of structural indicators and the entire subsequent empirical analysis, he developed a consistent notation from scratch that
moreover aims to be a logical and coherent extension of the input-output notation used by Miller and Blair (2009), the must-read reference for all input-output research. In section 5.7 of this chapter, a table is presented that summarizes the critical indicators and associated mathematical definitions that really matter for the analysis of the Eurozone structure. The first six sections of this chapter together are working towards allowing the reader to understand these definitions.

5.1. Single-region input-output model

Input-output modeling is an important tool in quantitative economics. The original development of the model is credited to Wassily Leontief, who received the Nobel Prize in Economics for this work in 1973 (Dietzenbacher and Lahr, 2004). The description that follows is based on the textbook of Miller and Blair (2009), a classical reference for input-output research and applications. For clarity, the discussion in this section is limited to a single economy (i.e. discussion of a single-region input-output model). Later, the analysis will be extended to include multiple regions (or countries) when we start focussing explicitly on the construction of a global input-output framework to analyse the structural interdependencies in the Eurozone.

Essentially an input-output model abstracts an economy as a system of interrelated processes (Leontief, 1974). Most processes produce a particular amount of output as inputs to other processes while at the same time consuming a specific amount of inputs supplied by other processes. These processes are generally modeled as industries and final consumers. The overall economic system functions as a circular flow (Leontief, 1991). Each industry is assumed to produce a single good or service and the model analyses the flow of these goods and services between various production industries and final consumers (Miller and Blair, 2009). The steel industry, as an example, uses a combination of energy and other raw materials to produce steel. Part of this produced steel flows to other industries, like the car industry, while the other part is directly consumed.

5.1.1. Basic input-output concepts

Data on the input-output flows is collected in a so-called input-output table (or transactions table). An input-output table shows the flows of goods and services that were produced in an economy over a particular time period. The length of this time period is usually one year. A simplified input-output table is depicted in Figure 5.1. The table models an economy with just three industries (A, B and C) and four sources of final demand. The monetary value of the sale from industry $i$ to industry $j$ is denoted by $z_{ij}$. In other words, the $z_{ij}$'s capture the inter-industry (or intermediate) transactions of goods and services between every two industries. The final demand for the product of industry $i$ is denoted by $f_i$. In the table above, each of these final demands is decomposed into four separate sources: household consumption, private investment, government investment and exports from outside the economy. The first three of these sources are referred to as domestic final demand. The fourth source (exports) is the foreign final demand.

A further distinction is made between processing and payments sectors. Processing sectors refer to the real production industries that use inputs to produce their output (A, B and C in the table). Think of agriculture, manufacturing, services, etc. Payments sectors refer to non-industrial input suppliers. This covers all the factor-payments (i.e. value-added) and
imported purchases from foreign suppliers. In other words, the payments sectors category lists all the payments by the industry to non-industrial suppliers (such as holders of capital, employees, etc.). Note that Figure 5.1 represents only a simplified version of real-life input-output tables. The value-added category, for instance, would normally not be limited to include only capital and labour as one could think of several other payments, including: interest, dividends, taxes, rents, depreciation, profits, losses, etc.

The input-output table can basically be interpreted in two ways. One way the table can be read is by taking a sales perspective and following any of the table’s rows. According to this interpretation an industry sells its total output to a variety of consumers: part of the output flows to other industries as intermediate inputs, the other part is delivered as final product to the final demand purchasers. It is assumed that each industry produces exactly the amount demanded by its purchasers (i.e. supply and demand balance). For the processing sectors rows, the formula-equivalent for this interpretation is:

$$ x_i = z_{i1} + z_{i2} + \ldots + z_{in} + f_i = \sum_{j=1}^{n} z_{ij} + f_i $$

(5.1)

where $n$ denotes the number of processing industries in the economy, and $f_i$ is the total final demand for the product of industry $i$. The row-sum $x_i$ quantifies the total output produced by industry $i$.

The other interpretation follows any of the table’s columns. This is a purchases perspective. According to this interpretation an industry purchases intermediate inputs from other domestic industries together with primary inputs (here: labour and capital) and imported inputs, in order to produce its output. For the processing sectors columns, the formula-equivalent is:

$$ x_j = z_{1j} + z_{2j} + \ldots + z_{nj} + l_j + n_j + m_j = \sum_{i=1}^{n} z_{ij} + l_j + n_j + m_j $$

(5.2)

where $l_j$ denotes industry $i$’s total payments for labour (salaries, wages, etc.), $n_j$ denotes industry $i$’s total payments for capital (dividends, profit, etc.), and $m_j$ is the total amount.

### Table 1: Basic input-output table, all entries are expressed in US dollar units (adapted from Miller and Blair (2009))

<table>
<thead>
<tr>
<th>Processing sector</th>
<th>Outputs</th>
<th>Final demand sources</th>
<th>Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2) A</td>
<td>(3) B</td>
</tr>
<tr>
<td>Industry A</td>
<td>$z_{11}$</td>
<td>$z_{12}$</td>
<td>$z_{13}$</td>
</tr>
<tr>
<td>Industry B</td>
<td>$z_{21}$</td>
<td>$z_{22}$</td>
<td>$z_{23}$</td>
</tr>
<tr>
<td>Industry C</td>
<td>$z_{31}$</td>
<td>$z_{32}$</td>
<td>$z_{33}$</td>
</tr>
<tr>
<td></td>
<td>(4) Value-added</td>
<td>(5) Labour income</td>
<td>(6) Capital income</td>
</tr>
<tr>
<td></td>
<td>$l_1$</td>
<td>$l_2$</td>
<td>$l_3$</td>
</tr>
<tr>
<td></td>
<td>$n_1$</td>
<td>$n_2$</td>
<td>$n_3$</td>
</tr>
<tr>
<td></td>
<td>$m_1$</td>
<td>$m_2$</td>
<td>$m_3$</td>
</tr>
</tbody>
</table>

**Figure 5.1:** Basic input-output table, all entries are expressed in US dollar units (adapted from Miller and Blair (2009))
of goods and services imported from outside the economy. The column-sum \( x_j \) quantifies the total inputs purchased by industry \( i \).

Figure 5.2 visualizes the functioning of an industry in an input-output model as was described above. It shows how each industry is fully characterized by a production function which translates inputs from the processing and payments sectors into output which can be used both as intermediate input for other processing industries as well as for final demand consumption purposes.

![Input-Output Diagram](image)

**Figure 5.2**: Illustration of the functioning of an industry in a (single-region) input-output model

### 5.1.2. Properties of input-output tables

An input-output table exhibits several important properties. Firstly, the sum of each row equals to sum of each corresponding column. In other words, for each industry the monetary value of its total output equals the monetary value of its total inputs. This equality essentially arises because of the accounting conventions that are used to construct the input-output table. The data in input-output table originates from national income accounts. These accounts rest on the basic principle of double-entry accounting. Hence, when an industry makes a sale and records its revenue, another industry or final consumer will always record an associated expense. The account of the former will be credited while the account of latter will be debited by the same amount.

Secondly, the total final demand is equal to the total payments to the payments sectors. In other words:

\[
C + I + G + E = L + N + M
\]

Rewriting this equation gives:

\[
C + I + G + (E - M) = L + N = GDP
\]

This equation shows the traditional definitions of gross domestic product that are embedded in the input-output table. The left side indicates the total expenditures on goods and services in the economy (i.e. the expenditure definition of GDP; or the economy’s aggregated
demand) and the right side indicates the total factor payments in the economy (i.e. the income definition of GDP). It can be easily inferred that the following equation also holds:

\[
\sum_{i=1}^{n} f_i = \sum_{i=1}^{n} (l_i + n_i + m_i)
\]  

(5.5)

This expression essentially says the same as equation (5.3) above: total final demand is equal to the total payments to the payments sectors.

It should be noted a key instrument in providing the equality between total demand and total output in the economy (i.e. equation (5.3)) is the functioning of the inventories in the economy. Excesses and surpluses of final demand over output are absorbed by changes in inventories. Inventories can be considered that act as a kind of reservoir (Miller and Blair, 2009, p. 133): demand excesses are eliminated by inventory liquidation, while demand shortages are absorbed by inventory accumulation.

5.1.3. Basic linear input-output model

Fundamental in order to be able to make a linear input-output model and perform an input-output analysis is the basic assumption of constant returns to scale. It is assumed that each producing sector uses fixed input proportions in order to produce its output. More specifically the nature of the relation between the inter-industry flows \( z_{ij} \) and total industry output \( x_j \) is assumed to be given by:

\[
a_{ij} = \frac{z_{ij}}{x_j}
\]  

(5.6)

The coefficients \( a_{ij} \) are referred to as technical coefficients and are assumed to be constant. These coefficients reflect the current state of the production technology of industry \( j \) with respect to inputs from industry \( i \). A more precise definition of \( a_{ij} \) is: the amount of input from industry \( i \) that is required to produce one unit of industry \( j \)’s output.

We are now in a position to introduce simple linear algebra notation in order to describe the previously introduced equations in a compact manner. If we let \( x \) denote the column-vector containing the elements \( x_i \) for \( i = 1, \ldots, n \) then the set of basic inter-industry relations from equation (5.1) can be rewritten as:

\[
x = \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_n \end{bmatrix} = \begin{bmatrix} z_{11} & z_{12} & \cdots & z_{1n} \\ z_{21} & z_{22} & \cdots & z_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ z_{n1} & z_{n2} & \cdots & z_{nn} \end{bmatrix} \begin{bmatrix} l_1 \\ l_2 \\ \vdots \\ l_n \end{bmatrix} = Z i + f
\]  

(5.7)

where

\[
Z = \begin{bmatrix} z_{11} & z_{12} & \cdots & z_{1n} \\ z_{21} & z_{22} & \cdots & z_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ z_{n1} & z_{n2} & \cdots & z_{nn} \end{bmatrix},
\]  

(5.8)

\( i \) is a column-vector with all elements equal to 1 and of size \( n \), and

\[
f = \begin{bmatrix} f_1 \\ f_2 \\ \vdots \\ f_n \end{bmatrix},
\]  

(5.9)
The matrix $Z$ is called the *inter-industry matrix* (or *transactions table*) and is highlighted in Figure 5.1. This matrix shows the monetary flows of goods and services between the producing sectors in the economy for a given time period. The vector $f$ is called the *final demand* vector and represents the purchases for final consumption.

The technical coefficients $a_{ij}$ defined earlier can be incorporated into equation (5.7) by first collecting them in a matrix $A$:

$$
A = \begin{bmatrix}
a_{11} & a_{12} & \ldots & a_{1n} \\
a_{21} & a_{22} & \ldots & a_{2n} \\
\vdots & & & \vdots \\
a_{n1} & a_{n2} & \ldots & a_{nn}
\end{bmatrix}
$$

(5.10)

This matrix is called the *technology matrix* or *direct requirements matrix* (Miller & Blair, 2009). This matrix shows the purchases of inputs by a particular industry from all industries to produce one dollar worth of output. It can easily be checked that this matrix $A$ can be derived as follows:

$$
A = Z\hat{x}^{-1}
$$

(5.11)

where the hat-symbol ($\hat{}$) denotes the operator that converts vector $x$ to a square diagonalized matrix containing the elements of $x$ on its diagonal and zeros everywhere else, and $^{-1}$ denotes the matrix inverse operator. The matrix $A$ is essentially a simple rewriting of $Z$ in intensive terms, i.e. per unit of sector output. Simply put, matrix $A$ is derived by dividing each element in matrix $Z$ by its associated row sum.

From equation (5.11) the following derivation can be made:

$$
\begin{align*}
A &= Z\hat{x}^{-1} \\
\Rightarrow Z &= A\hat{x} \\
\Rightarrow Z_i &= A\hat{x}i \\
\Rightarrow Z_i &= Ax
\end{align*}
$$

(5.12)

Equation (5.11) can now be rewritten by substituting equation (5.12), resulting in:

$$
x = Ax + f
$$

(5.13)

Rewriting this equation gives:

$$
\begin{align*}
(I - A)x &= f \\
\Rightarrow x &= (I - A)^{-1}f \\
\Rightarrow x &= Lf
\end{align*}
$$

(5.14)

where the $n \times n$ matrix $L = (I - A)^{-1}$ is called the *Leontief inverse* (or *total requirements matrix*). Equation (5.14) is the fundamental input-output formula. It represents the solution of an $n \times n$ system of $n$ linear equations in $n$ unknowns $(x_1, x_2, \ldots, x_n)$.

We now make the extra assumption that the technology (represented by the coefficients in matrix $A$) stays unchanged over the short-term. If we have two consecutive periods 0 and
1, then this assumption can be mathematically expressed by saying:

\[ A^0 = A^1 = A, \text{ and hence also } L^0 = L^1 = L \] (5.15)

We know from (14), and using (15), that:

\[ x^0 = L^0 f^0 = Lf^0 \] (5.16)

and

\[ x^1 = L^1 f^1 = Lf^1 \] (5.17)

Hence:

\[ \Delta x = x^1 - x^0 = Lf^1 - Lf^0 = L(f^1 - f^0) = L\Delta f \] (5.18)

This last equation illustrates the basic effect that is captured by the Leontief inverse \( L \): if the final demand for the product of one or more industries changes by a particular dollar amount (represented by the elements of \( f \)), then pre-multiplication by \( L \) gives the total impact of this/these change(s) on the output of each industry in the economy.

It is important to note that the model used in this thesis is a *quantity or demand-pull model* (in contrast to a cost-push model) measured in *monetary units* (in contrast to physical units). The basic input-output formula for this model is \( x = (I - A)^{-1} f \). In this model it is assumed that the final demand is an exogenous variable and that the sectors produce exactly the amount that is being demanded. An overview of the alternative three models and their associated formula can be found in Miller and Blair (2009, p. 54).

We can even be a little more precise about the exact interpretation of the Leontief inverse \( L \). The value of any element \( l_{ij} \) from \( L \) indicates the total increment in the output of industry \( i \) that is caused by an increment in the final demand for industry \( j \) by one unit. The elements of \( l_{ij} \) can, thus, be interpreted as being a partial derivative (Miller and Blair, 2009, p. 21):

\[ l_{ij} = \frac{\partial x_i}{\partial f_j} \] (5.19)

The elements \( l_{ij} \) are also referred to as sector-to-sector output multipliers because they show by how much a unitary increase in the final demand of sector \( j \) boosts the output of sector \( i \) by ‘multiplying’ its way through the entire economy (i.e., capturing all the direct and indirect effects). Essentially a *multiplier* measures the total change that is generated throughout the economy from a unit change in the final demand for one particular industry. We will now investigate this multiplier concept more thoroughly as it conceals the power of all input-output analyses.

### 5.1.4. Basic multiplier concept

To understand the multiplier concept, imagine that the final demand of industry \( i \) (which we assume to be exogenous to the economy) increases by a particular amount \( f_i \) from period 0 to period 1, while the final demands of the other industries stay unchanged. As we assumed that all producing sectors exactly supply the amount of their product that is being demanded (i.e., demand-pull model), industry \( i \) will increase its output to match the increase in its
final demand. This will trigger an increase in the output of all the industries that supply their output as intermediate inputs to industry $i$. This will in turn trigger an increase in the output of all the industries that supply their output as intermediate inputs to the industries that supply to industry $i$, and so on. It should be noted that in this process the output of industry $i$ could be required to increase further, as industry $i$ could be a supplier of some of the industries whose output was stimulated by the original increase in industry $i$’s output.

The total multiplier effect measures the total increase in industry $i$’s output that is triggered by an increase in industry $i$’s demand. This total effect can be separated as the sum of two effects: a direct effect and an indirect effect.

- The *direct effect* measures the extra amount that needs to be produced to meet the increase in industry $i$’s demand if it is assumed that all of industry $i$’s output is fully available for final demand purposes, i.e. if it is assumed that none of industry $i$’s output flows back as intermediate inputs to other industries. The direct effect simply captures the initial increase in spending that is triggered by the original increase in demand.

- The *indirect effect* captures the additional increase in industry $i$’s output that is caused by the inter-industry flows that arise in order to meet the original increase in demand.

5.2. **Strengths of input-output models**

The input-output methodology has several strengths and limitations. This section covers the most important strengths, while the next section focuses on the limitations. The following main advantages can be identified:

1. **Captures economy-wide effects**
   
   An input-output model describes a full macro-economic system on a detailed sectorial level. In other words, the model is able to capture full-system, economy-wide effects, while maintaining the sectorial diversity that is present in the economy.

2. **Captures intra- and inter-industry relations**
   
   Input-output models capture the inter-industry relations, or sectorial linkages, in the economy. Both the interdependencies between sectors in the same economy (i.e. intra-region linkages) as well as between sectors of different economies (i.e. inter-region linkages) are captured in these models.

3. **Numerical quantification of direct and indirect stimulus effects**
   
   Input-output models furthermore provide the ability to numerically quantify these inter-industry connections and to separate the direct from the indirect effects of changes in final demand. The multipliers, which can be computed from these models, offer valuable insights on the magnitude and direction of various production spill-overs between countries and their industries.

4. **Reliance on real-world data and macro-economic accounting principles**
   
   Input-output applications inherently rely on comprehensive real-world data, like for example the World Input-Output Database, in their analysis of the economy. This data is rooted in several important principles of macro-economic accounting, like double entry.
bookkeeping and requiring total income to equal total expenditure (see Miller and Blair (2009, p. 133-134)) for a clarification of these and several other principles). Hence, instead of purely lingering in the theoretical sphere using only theoretical arguments, these applications find their strength in the analysis of empirical observations concerning real production and consumption patterns in the economy.

5. Facilitates structural change analyses

Input-output models offer the opportunity to analyze and decompose the structural changes observed in the economy. The term ‘structural change’ in the input-output literature often refers to the analysis of changes in the technical coefficients matrix of an economy over time (Miller and Blair, 2009, p. 304) with the overall aim of determining changes in the inter-industry linkages and international trade. Often, this is achieved by means of a structural decomposition analysis (SDA). The general idea behind this type of analysis is to decompose a change in a particular economic variable (like output, employment, value-added or energy figures) into the separate contributions of its major components. As an example, changes in sectoral output can initially be decomposed into two main components: final demand changes and technology changes (i.e. changes in the Leontief inverse matrix). On a more detailed level, these components can be further disaggregated into smaller contributing factors (e.g. changes in direct input coefficients versus changes in the product mix, and changes in the final demand level versus changes in the final demand’s composition, respectively).

6. Clear and transparent methodology

The input-output methodology is relatively clear and transparent and does not require advanced mathematical techniques. Once the model’s parameters and aggregation choices are determined, and the sectorial data collected and processed into input-output tables, calculation of multiplier values or other structural metrics proceeds relatively easy and is not time consuming.

7. Allows for trade in value added to be traced

Input-output models provide the ability to analyze trends in the value-added production chains of the economy because the sectorial interdependencies captured by the model essentially disclose the supply chain linkages that are present in the economy. Whereas traditional trade measures are often restricted to the analysis and comparison of an economy’s gross trade figures (like imports and exports), input-output models thus offer the opportunity to analyze (the more detailed) trade in value-added between the various sectors and regions in the economy.

8. Allows for the analysis of what-if scenario’s

Input-output models provide a tool for governments to analyze (a first approximation of) the consequences of what-if scenarios during the design of various investment policies and fiscal stimuli packages. Input-output models provide valuable information to decision-makers about which sectors to stimulate as well as about the magnitude of the feedback and spill-over effects to other sectors and regions of these stimulus programs.
5.3. Assumptions and limitations

Throughout the previous discussion on the input-output fundamentals several assumptions were made, both implicitly and explicitly. This section aims at providing an overview of these assumptions as well as of the general shortcomings and limitations of input-output models. This discussion is a collection of arguments drawn from several sources in the literature: (Bess and Ambargis, 2011; Christ, 1955; Miller and Blair, 2009; ten Raa, 1994).

1. No supply constraints and fixed prices

One of the assumptions made in input-output models and the calculation of the multipliers is the absence of any supply-side constraints. Basically, it is assumed that there is an abundance of primary resources and that the economy is not running at its full capacity (Ghosh, 1958). In other words, there are no constraints on the availability of any of the inputs. Hence, if a producing sector wants to increase its output then there will always be sufficient factors of production available to realize this increase. The absence of resource scarcity furthermore implies that no competition will occur over any resources. Therefore, as there is no need for prices to perform their traditional signaling role as a mechanism to allocate scarce resources, prices in input-output models are fixed.

2. No budget constraints

In standard input-output models no consideration is given to the fact that firms, households and governments are all subjected to budget constraints that limit their consumption and hence the size and possibilities of the exogenous demand expenditures. For example, every household has a limited income, or budget, which restricts the set of consumption bundles it can afford.

With respect to demand stimuli from governments, Guerra and Sancho (2011) furthermore mention the importance of what they call expenditure substitution effects. They emphasize that in reality the expansionary effect of a new government demand stimulus will partially be crowded out by reallocation effects associated with the government’s financing mechanisms that are due to inevitable liquidity constraints. I.e. higher taxes might partially be crowding out private spending decisions, higher debt financing might partially be crowding out private investment demand, etc. These expenditure substitution effects are not considered in the traditional input-output models.

3. Homogeneous good and only one production recipe

Input-output tables present an abstracted picture of the economy. The unit of analysis adopted in these input-output tables is that of the homogeneous sector. The assumption of homogeneity implies that each sector is modeled as producing one ‘product’, which could be a good or a service, and that each product is produced by exactly one sector (Christ, 1955; Miller and Blair, 2009; ten Raa, 1994). In other words, joint products are non-existent in input-output tables and each single product has exactly one production recipe. Consider the car industry as an example. In input-output tables this industry is assumed to be simply producing ‘cars’. In this process it uses, among many other inputs, ‘steel’ from the steel industry and ‘energy’ from the energy industry. In reality, of course each individual firm in the industry will produce different types of cars and will have its own unique production process. Essentially, the assumption of
homogeneity aggregates the production characteristics of these various firms into one common production process whose output represents an average commodity (i.e. a ‘car’) that captures the total variety of cars that are being produced by all firms in this industry.

4. Constant returns to scale and no substitution of inputs

The assumption of constant returns to scale is a fundamental assumption made in all input-output models (Christ, 1955; Hackman, 2007; Miller and Blair, 2009; ten Raa, 1994). It supposes that each sector’s homogeneous production function is linear in nature. In other words, an increase in the sector’s input levels results in a proportionate increase in its output. Furthermore, it is assumed that there will be no substitution of inputs. Regardless of the price of the inputs as well as the sector’s output level, the same fixed input proportions will always be maintained. Hence, all inputs of each producing sector are perfect complements. A capital-intensive sector, as an example, will not partially substitute its inputs by more labour-intensive alternatives, regardless of its output level.

The fixed proportions production functions embodied in input-output models are also referred to in the literature as Leontief production functions, or also Leontief technologies or fixed-coefficients technologies (Hackman, 2007, p. 53). A Leontief technology has an elasticity of scale of one (constant returns to scale), and an elasticity of input substitution of zero (Hackman, 2007, p. 54).

The constant technical coefficients $a_{ij}$ that were defined earlier quantify these input proportions for each of the sectors. They provide a full description of each sector’s production function, i.e.

$$z_{ij} = a_{ij}x_j$$

This equation shows that the amount of product from industry $i$ that industry $j$ requires for its production ($z_{ij}$) is fully dependant on the constant proportion $a_{ij}$ of what industry $j$ is required to produce in total ($x_j$).

5. Demand-pull model and exogenous final demand

As was already mentioned earlier, the standard input-output model assumes that the prices of all inputs and outputs are fixed. Quantities are the changing variables in this model. This type of input-output model is formally referred to as a Leontief demand-pull model (Miller and Blair, 2009, p. 54). The basic algebraic representation for this model is: $x = (I - A)^{-1}f$. In this model all sources of final demand are assumed to be exogenous to the economic system. The purchasing plans of all final consumer groups are assumed to be given, and are handled as a specific ‘bill of goods’ (Christ, 1955, p. 193). Any changes in final demand are passed along completely as intermediate production changes to all producing sectors. These sectors, in turn, are assumed to pass on these production changes by changing the quantity of their demanded inputs accordingly. The imposed quantities of final demand are considered to be part of the model’s initial conditions.

The demand-pull model is contrasted by its opposite: the cost-push model. In this model all quantities are supposed to be unchanging. Instead prices are the changing variables. The basic formula for these models is: $\hat{p} = (I - A')^{-1}v_c$, where the $\hat{p}$
denotes the output prices for each producing sector, and \( v_c \) denotes the total expenditures on value-added per unit of output by each producing sector (Miller and Blair, 2009, p. 43-44). The exogenous values in these input-output models are the costs of the primary inputs (i.e. the value-added payments captures by \( v_c \)).

In a way a comparison can be made between the Keynesian notion of the entrepreneurs’ ‘animal spirits’ – with the associated Keynesian multipliers – and the origins of changes in final demand in the demand-pull input-output models – with the associated input-output multipliers (Bess and Ambargis, 2011). In a classical Keynesian model of an economy, investment decisions of all the entrepreneurs are assumed to be autonomous and based on instincts and feelings, rather than on facts or rationally determined expected future profits (Black et al., 2012). Keynes refers to these instincts as animal spirits and describes these as referring to ‘habits, instincts, preferences, desires, and passions’ and other non-rational decisions (Keynes, 1979). Input-output models in effect also assume that the imposed final demands are determined partially by animal spirits. (I write ‘partially’ because the total final demand is also influenced by other exogenous factors, including expenditure programs from the government, etc.).

6. Absence of any individual behaviour assumptions

Input-output models describe the relations between industries and final demand purchasers without incorporating any kind of preference structure or utility function of the individuals in the economy. Hence, demand schedules are non-existent in these models as these are determined by the willingness to pay of the individual consumers in the economy. Instead of focusing on individual preferences, input-output models purely focus on technical production characteristics. As put by Christ (1955, p. 139): “input-output analysis per se deals with technology only, not with the preferences of economic organisms among different states of affairs”. Consequently, any type of optimizing behavior is not included in these models, and hence any notion of equilibrium is essentially non-existing.

5.4. The general inter-country input-output (ICIO) model

In this section the mathematical notation is introduced of the global inter-country input-output model that will be used to analyze the research questions for this graduate project. The discussion that follows builds further on the fundamentals of the single-region input-output model that were described at the beginning of this chapter.

Before diving into the mathematical model building, we first provide an illustration of how multi-country input-output models abstract the overall economy. Figure 5.3 illustrates the input-output modeling of an economy with three countries (France, Italy and Spain). For illustration purposes we assume that we are dealing with a closed economy, and hence do not consider any foreign trade with countries outside of this economy. Each country has several industries and final demand purchasers. The trade dependencies between the various groups are depicted by the various colored arrows.

We will extend the basic inter-industry equation (equation (5.7)) to the general case where multiple countries (also referred to as regions) are present in the overall economy. To this end, we first have to define the multi-country equivalents of the basic variables that were introduced in the single-region model.
5.4. The general inter-country input-output (ICIO) model

5.4.1. Generalization of notation

We let \( n \) denote the number of processing sectors in each country. We assume that the sectors are numbered from 1 to \( n \) in a same fashion in each country. For instance, if sector 1 refers to the car industry in one country, then each car industry in every other country will be labelled as sector 1. We let \( k \) denote the number of countries in the global input-output model.

We let the variable \( z_{r,i,j}^{r,s} \) denote the monetary value of the inter-country flow of intermediate goods produced by sector \( i \) in country \( r \) to sector \( j \) in country \( s \), over the period considered by the model (usually a year). If \( s = r \) then this variable represents the intra-country flows in country \( r \), while if \( s \neq r \) it represents the inter-country flows from country \( r \) to country \( s \).

The variable \( x_{r,i}^{r} \) denotes the monetary value of total output produced by sector \( i \) in country \( k \).

We let \( f_{i,u}^{r,s} \) refer to the demand in country \( s \) by final demand group \( u \) for final goods produced by sector \( i \) in country \( e \). In accordance with the distinction made in the WIOD database, we distinguish between three main groups \( u \) of final demand purchasers: private consumption \((c_p)\), government consumption \((c_g)\), and gross capital formation \((gcf)\). Hence, \( u = \{c_p, c_g, gcf\} \). Note that we have no fourth final demand component capturing foreign exports from outside of the economy, because we will be modelling the world economy. In other words we are dealing with a closed economy.
used domestically or internationally as either an intermediate good or a final good. 

This equation essentially states that all output produced by sector \( i \) in country \( r \) from the single-region model (equation (5.1)), which describes the distribution of goods from producing sector \( i \) in country \( r \):

\[
x_i^r = \sum_{j=1}^{j=n} \alpha_{i,j}^r + \sum_{j=1}^{j=n} \beta_{i,j}^r 
\]

\[
+ f_{i,c_p}^r + f_{i,c_g}^r + f_{i,gcf}^r 
\]

\[
\forall s \in \{1, 2, \ldots, k\} - \{r\}
\]

The multi-country equivalent of the single input-output table is shown in Figure 5.4. For simplicity the table is reduced to three countries containing each three industries. The real input-output tables from the World Input-Output Database that will be used for this research project contain 40 countries and 35 industries.

![Figure 5.4](image)

**Figure 5.4:** Inter-country input-output table, all entries are expressed in US dollar units

### 5.4.2. Total production accounting identity

Having introduced the multi-country equivalents of the basic input-output variables from the single case, we are now in a position to start the rewriting of the accounting identity from the single-region model (equation (5.1)), which describes the distribution of goods from producing sector \( i \) in country \( r \):

\[
x_i^r = \sum_{j=1}^{j=n} \alpha_{i,j}^r + \sum_{j=1}^{j=n} \beta_{i,j}^r 
\]

\[
+ f_{i,c_p}^r + f_{i,c_g}^r + f_{i,gcf}^r 
\]

\[
\forall s \in \{1, 2, \ldots, k\} - \{r\}
\]

This equation essentially states that all output produced by sector \( i \) in country \( r \) must be used domestically or internationally as either an intermediate good or a final good.
To introduce the algebraic equivalent of this equation we define the following two matrices:

\[
Z_{r,s}^{r,s} = \begin{bmatrix}
  z_{r,s}^{1,1} & z_{r,s}^{1,2} & \ldots & z_{r,s}^{1,n} \\
  z_{r,s}^{2,1} & z_{r,s}^{2,2} & \ldots & z_{r,s}^{2,n} \\
  \vdots & \vdots & \ddots & \vdots \\
  z_{r,s}^{n,1} & z_{r,s}^{n,2} & \ldots & z_{r,s}^{n,n}
\end{bmatrix}
\]  

(5.21)

\[
F_{r,s}^{r,s} = \begin{bmatrix}
  f_{r,s}^{1,c,p} & f_{r,s}^{1,c,g} & f_{r,s}^{1,g,c} \\
  f_{r,s}^{2,c,p} & f_{r,s}^{2,c,g} & f_{r,s}^{2,g,c} \\
  \vdots & \vdots & \vdots \\
  f_{r,s}^{n,c,p} & f_{r,s}^{n,c,g} & f_{r,s}^{n,g,c}
\end{bmatrix}
\]  

(5.22)

The matrix \( Z_{r,s}^{r,s} \) captures the monetary values of the trade in intermediate products from country \( r \) to country \( s \). When \( r \neq s \), \( Z_{r,s}^{r,s} \) describes the gross exports of intermediates produced by industries in country \( r \) to industries in country \( s \). The vector \( F_{r,s}^{r,s} \) is the final demand matrix capturing the three sources of final demand in country \( s \) for goods produced in country \( r \). When \( r \neq s \), \( F_{r,s}^{r,s} \) describes the gross exports of final products produced by industries in country \( r \) to final demand buyers in country \( s \). The linear equations described above can now be compactly rewritten as:

\[
x_r^{r} = \begin{bmatrix}
x_1^r \\
x_2^r \\
\vdots \\
x_n^r
\end{bmatrix} = \sum_{s=1}^{s=k} (Z_{r,s}^{r,s}i + F_{r,s}^{r,s}i)
\]  

(5.23)

where \( x_r^r \) denotes the total output produced by each producing sector in country \( r \). Total production in the world economy, i.e. by the \( k \) countries together, can now be defined as:

\[
x = \begin{bmatrix}
x_1^1 \\
x_2^2 \\
\vdots \\
x_k^k
\end{bmatrix} = Zi + Fi
\]  

(5.24)

where:

\[
Z = \begin{bmatrix}
  Z^{1,1} & Z^{1,2} & \ldots & Z^{1,k} \\
  Z^{2,1} & Z^{2,2} & \ldots & Z^{2,k} \\
  \vdots & \vdots & \ddots & \vdots \\
  Z^{k,1} & Z^{k,2} & \ldots & Z^{k,k}
\end{bmatrix}
\]  

(5.25)

\[
F = \begin{bmatrix}
  F^{1,1} & F^{1,2} & \ldots & F^{1,k} \\
  F^{2,1} & F^{2,2} & \ldots & F^{2,k} \\
  \vdots & \vdots & \ddots & \vdots \\
  F^{k,1} & F^{k,2} & \ldots & F^{k,k}
\end{bmatrix}
\]  

(5.26)

and the vectors \( i \) are summation-vectors of appropriate dimension. Equation (5.24) is the multi-country definition of the basic accounting identity upon which the input-output tables are based. For clarity, the matrices defined above are visualized in Figure 5.5.
Methodology and data

Table 3: Inter-country input-output table (matrix notation)

<table>
<thead>
<tr>
<th></th>
<th>Country 1</th>
<th>Country 2</th>
<th>Country 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A B C</td>
<td>D E F</td>
<td>G H I</td>
</tr>
<tr>
<td>Outputs (vector)</td>
<td>$v^1$</td>
<td>$v^2$</td>
<td>$v^3$</td>
</tr>
<tr>
<td>Total outlays</td>
<td>$x^1$</td>
<td>$x^2$</td>
<td>$x^3$</td>
</tr>
<tr>
<td>Industry A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Country 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industry B</td>
<td>$Z^{1,1}$</td>
<td>$Z^{1,2}$</td>
<td>$Z^{1,3}$</td>
</tr>
<tr>
<td>Industry C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industry A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industry B</td>
<td>$Z^{2,1}$</td>
<td>$Z^{2,2}$</td>
<td>$Z^{2,3}$</td>
</tr>
<tr>
<td>Industry C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industry A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industry B</td>
<td>$Z^{3,1}$</td>
<td>$Z^{3,2}$</td>
<td>$Z^{3,3}$</td>
</tr>
<tr>
<td>Industry C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Value-added (vector)</td>
<td>$c_p$</td>
<td>$c_q$</td>
<td>$gc_f$</td>
</tr>
</tbody>
</table>

Figure 5.5: Link between the matrices and the inter-country input-output table

5.4.3. Global Leontief formula

The assumption that each sector in each country is fully characterized by a Leontief production function translates into the multiple-country equivalent definition of the fixed technical coefficients (or input-output coefficients):

$$a_{rs}^{ij} = \frac{s_{ij}}{x_j^i}$$ (5.27)

Similar to the single-region case, the variable $a_{rs}^{ij}$ denotes the amount of input from industry $i$ in country $r$ that is required to produce one unit output of industry $j$ in country $s$. The values $a_{rs}^{ij}$ and $a_{rs}^{ij}$ are intra-regional input-output coefficients, whereas $a_{rs}^{ij}$ (with $s \neq r$) are the inter-regional trade coefficients. It is easy to see that each technical coefficients matrix $A^{rs}$, defined as:

$$A^{rs} = \begin{bmatrix} a_{1,1}^{rs} & a_{1,2}^{rs} & \cdots & a_{1,n}^{rs} \\ a_{2,1}^{rs} & a_{2,2}^{rs} & \cdots & a_{2,n}^{rs} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n,1}^{rs} & a_{n,2}^{rs} & \cdots & a_{n,n}^{rs} \end{bmatrix}$$ (5.28)

can be derived from matrix $Z^{rs}$ by the operation:

$$A^{rs} = Z^{rs} \left( x^s \right)^{-1}$$ (5.29)

And equivalently on a more general level, if we define the matrix $A$ as the partitioned matrix composed of:

$$A = \begin{bmatrix} A^{1,1} & A^{1,2} & \cdots & A^{1,k} \\ A^{2,1} & A^{2,2} & \cdots & A^{2,k} \\ \vdots & \vdots & \ddots & \vdots \\ A^{k,1} & A^{k,2} & \cdots & A^{k,k} \end{bmatrix}$$ (5.30)
then this matrix can be derived from matrix $Z$ as:

$$A = Zx^{-1} \quad (5.31)$$

In inter-country input-output applications, matrix $A$ is often referred to as the *global sourcing matrix* ([Landesmann, 2013, p.52]). It describes the global flows of intermediate goods and services between every processing sector in every country (i.e. the matrix captures both domestic and foreign trade relationships).

As was shown earlier in the single-region discussion (see the derivation of equation (5.12)), the equation above is equivalent to:

$$Zi = Ax \quad (5.32)$$

Therefore, using this equation we can rewrite equation (5.24) to:

$$x = Ax + Fi \quad (5.33)$$

or in its more detailed version:

$$x = \begin{bmatrix} x^1 \\ x^2 \\ \vdots \\ x^k \end{bmatrix} = \begin{bmatrix} A^{1,1} & A^{1,2} & \cdots & A^{1,k} \\ A^{2,1} & A^{2,2} & \cdots & A^{2,k} \\ \vdots & \vdots & \ddots & \vdots \\ A^{k,1} & A^{k,2} & \cdots & A^{k,k} \end{bmatrix} \begin{bmatrix} x^1 \\ x^2 \\ \vdots \\ x^k \end{bmatrix} + \begin{bmatrix} F^{1,1} & F^{1,2} & \cdots & F^{1,k} \\ F^{2,1} & F^{2,2} & \cdots & F^{2,k} \\ \vdots & \vdots & \ddots & \vdots \\ F^{k,1} & F^{k,2} & \cdots & F^{k,k} \end{bmatrix} i \quad (5.34)$$

This equation represents the general inter-country input-output system with $n$ sectors and $k$ countries in matrix notation. Solving this equation for $x$ results in the equation:

$$x = (I - A)^{-1} Fi \quad (5.35)$$

or in its more detailed version:

$$x = \begin{bmatrix} I - A^{1,1} & -A^{1,2} & \cdots & -A^{1,k} \\ -A^{2,1} & I - A^{2,2} & \cdots & -A^{2,k} \\ \vdots & \vdots & \ddots & \vdots \\ -A^{k,1} & -A^{k,2} & \cdots & I - A^{k,k} \end{bmatrix}^{-1} \begin{bmatrix} F^{1,1} & F^{1,2} & \cdots & F^{1,k} \\ F^{2,1} & F^{2,2} & \cdots & F^{2,k} \\ \vdots & \vdots & \ddots & \vdots \\ F^{k,1} & F^{k,2} & \cdots & F^{k,k} \end{bmatrix} i \quad (5.36)$$

If, as we did in the single-region case, we define the matrix $L$

$$L_{(kn \times kn)} = \begin{bmatrix} L^{1,1} & L^{1,2} & \cdots & L^{1,k} \\ L^{2,1} & L^{2,2} & \cdots & L^{2,k} \\ \vdots & \vdots & \ddots & \vdots \\ L^{k,1} & L^{k,2} & \cdots & L^{k,k} \end{bmatrix} \quad (5.37)$$

by the formula: $L = (I - A)^{-1}$ (the *global Leontief inverse* matrix, or total requirements coefficients matrix), and if we define vector $F^{r,s} = F^{r,s}i$ and vector $F^r$ (denoting the global demand for final goods produced by country $r$) as:

$$F^r_{(n \times 1)} = \sum_{s=1}^{s=k} F^{r,s} \quad (5.38)$$
then the system’s solution can be rewritten as:

\[
x = \begin{bmatrix}
x^1 \\
x^2 \\
\vdots \\
x^k \\
\end{bmatrix} = \begin{bmatrix}
L_{1,1}^{r,s} & L_{1,2}^{r,s} & \cdots & L_{1,k}^{r,s} \\
L_{2,1}^{r,s} & L_{2,2}^{r,s} & \cdots & L_{2,k}^{r,s} \\
\vdots & \vdots & \ddots & \vdots \\
L_{k,1}^{r,s} & L_{k,2}^{r,s} & \cdots & L_{k,k}^{r,s} \\
\end{bmatrix} \begin{bmatrix}
f^1 \\
f^2 \\
\vdots \\
f^k \\
\end{bmatrix}
\]

This is the compact solution of the general inter-country input-output system. This equation allows us to calculate the required gross outputs in each country for a particular (exogenously given) level of final demands provided by one or more countries. Hence, this equation tells us how assumed changes in final demand are translated via the Leontief inverse to associated output changes in the processing sectors throughout the global economy.

Each sub-matrix \( L_{r,s}^{r,s} \) captures the total impacts (direct and indirect) in country \( r \) that are caused by unitary final demand changes in country \( s \). In other words, it captures the total gross output requirements in country \( r \) caused by a unit increase in country \( s \)’s final demand. To be more specific, any particular element \( l_{i,j}^{r,s} = L_{i,j}^{r,s}[i,j] \) of matrix \( L_{r,s}^{r,s} \) can be interpreted as saying that each unit of final demand for the output of sector \( j \) in country \( s \) requires \( l_{i,j}^{r,s} \), worth of output from sector \( i \) in country \( r \) as input. In other words

\[
l_{i,j}^{r,s} = \text{the total additional output that sector } i \text{ in country } r \text{ has to produce in order to meet a unit (i.e. a dollar’s worth) increase in the final demand for the output of sector } j \text{ in country } s.
\]

In effect, the inter-country effects captured by \( L_{r,s}^{r,s} \) touch upon the very essence of any inter-country input-output model: these values quantify the direct and indirect production spillover effects among any two sectors in any two countries. The elements of this Leontief inverse essentially constitute a first set of multipliers: they are multi-country sector-to-sector output-multipliers as they relate final demand for output of sector \( j \) in country \( s \) to output of sector \( i \) in country \( r \).

As a notation note, matrix \( L \) and its sub-matrices \( L_{r,s}^{r,s} \) could also be named \( \mathbf{M}_o \) and \( \mathbf{M}_o^{r,s} \), respectively. The ‘\( M \)’ refers to the fact that the matrix captures multiplier values, and the ‘\( o \)’ subscript denotes the fact that the matrix captures output multipliers. This notation allows for a consistent introduction of several multiplier variants, such as the value added multiplier matrix \( \mathbf{M}_v \) that will be introduced later in this chapter. Hence, \( \mathbf{M}_o^{r,s} = L_{r,s}^{r,s} \) captures the sector-demand-to-sector-output multipliers. Similarly, we can define the row-vector \( \mathbf{m}_o^{r,s} \) as \( \mathbf{m}_o^{r,s} = \mathbf{i} \mathbf{M}_o^{r,s} \) denoting the sector-demand-to-economy-wide-output multipliers.

In order to be able to reason about how value added is created and traded between the various countries and industries we now focus on incorporating the value added figures, provided by the input-output table, into the calculations that were derived so far.

### 5.4.4. Incorporating value added

Almost at the bottom of the input-output table a row with the value added values \( v_j^s \) is listed. Each particular element \( v_j^s \) denotes the total domestic value added generated by industry \( j \) in country \( s \) (over the period considered by the input-output table). Consequently, the row-vector \( \mathbf{v}^s = [v_1^s \ v_2^s \ \cdots \ v_n^s] \) captures the value added generated by each industry in country \( s \), and \( \mathbf{v} = [\mathbf{v}^1 \ \mathbf{v}^2 \ \cdots \ \mathbf{v}^k] \) captures the value added generated by each industry in each country.
From the column accounting identities used to construct the input-output table we know that the following relation holds:

\[ x_j^s = \sum_{r=1}^{r=k} \left( \sum_{i=1}^{i=n} x_{i,j}^r \right) + v_j^s \]  
(5.40)

Hence it becomes easy to see that vector \( v^{s'} \) can be defined as:

\[ v^{s'}_{(1 \times n)} = x^{s'} - \sum_{r=1}^{r=k} i' Z^{r,s} \]  
(5.41)

and similarly for the more general vector \( v' \):

\[ v'_{(1 \times kn)} = x' - i' Z \]  
(5.42)

For reasons that will become clear later on, we want to express the value added figures in proportional terms with respect to the total output of each industry, similar to the way we introduced the technical coefficients \( a_{i,j}^{r,s} \) in equation (5.27). In other words, we want to express value added as a share of total output. To this end, we define for each value added figure \( v_j^s \) a corresponding value added coefficient \( v_{c,j}^s \) as follows:

\[ v_{c,j}^s = \frac{v_j^s}{x_j^s} \]  
(5.43)

Each element \( v_{c,j}^s \) represents the share of domestic value added in the total output of industry \( j \) in country \( s \). The associated value added coefficient vector \( v_{c}^{s'} \) is then defined as follows:

\[ v_{c}^{s'}_{(1 \times n)} = [v_{c,1}^{s'} \cdots v_{c,n}^{s'}] = v^{s'} \left( x^s \right)^{-1} \]  
(5.44)

and similarly for the more general value added coefficient vector \( v_{c}' \):

\[ v_{c}'_{(1 \times kn)} = [v_{c,1}' \cdots v_{c,kn}'] = v' \left( \hat{x} \right)^{-1} \]  
(5.45)

The vectors \( v_{c}^{s'} \) can also be expressed as a function of the input-output coefficients \( a_{i,j}^{r,s} \) by combining equation (5.41) with equation (5.44) and making the following derivation:

\[
\begin{align*}
\nu_{c}^{s'} &= \nu^{s'} \left( \hat{x}^s \right)^{-1} \\
\Leftrightarrow \quad &= \left( x^{s'} - \sum_{r=1}^{r=k} i' Z^{r,s} \right) \left( \hat{x}^s \right)^{-1} \\
\Leftrightarrow \quad &= i' - \sum_{r=1}^{r=k} i' Z^{r,s} \left( \hat{x}^s \right)^{-1} \\
\Leftrightarrow \quad &= i' - \sum_{r=1}^{r=k} i' A^{r,s} \hat{x}^s \left( \hat{x}^s \right)^{-1} \\
\Leftrightarrow \quad &= i' - \sum_{r=1}^{r=k} i' A^{r,s} 
\end{align*}
\]  
(5.46)

Similarly vectors \( v_{c}' \) can also be expressed as a function of the input-output coefficients by...
combining equation (5.42) with equation (5.45) as follows:

\[ V'_c = V'(\tilde{x})^{-1} \]
\[ \equiv \quad \left(x' - i'Z(\tilde{x})\right) \left(\tilde{x}\right)^{-1} \]
\[ \equiv \quad i' - i'A(\tilde{x})^{-1} \]
\[ \equiv \quad i' - i' \quad \text{(5.47)} \]
\[ \equiv \quad i'(I - A) \]
\[ \equiv \quad i'L^{-1} \quad \text{(5.48)} \]

Equations (5.46) and (5.47) essentially both state that each value added coefficient \( v_{cj}^s \) is equal to 1 minus the sum of all the intermediate input-output coefficients associated with industry \( j \) in country \( s \) (i.e. \( v_{cj}^s = 1 - \sum_{r=1}^{R} \sum_{i=1}^{N} a_{r,i,j}^c, \forall r, i \)).

If we transform the global value added share vector \( v \) into a diagonal matrix \( \hat{v}_c \) and premultiply \( x = Lf \) by this matrix, we get vector \( v \). This feature is proved by the following derivation:

\[ \hat{v}_cLf = \hat{x}\hat{v}_c\hat{x}^{-1}Lf \]
\[ = \hat{x}\hat{v}_c\hat{x}^{-1}x \]
\[ = \hat{x}\hat{v}_ci \]
\[ = \hat{x}\hat{v}_c \]
\[ = (v'_c\hat{x})' \]
\[ = (v')' \]
\[ = v \quad \text{(5.49)} \]

The equation \( v = \hat{v}_cLf \) that is just derived can be considered to be the global Leontief formula for the creation of value added. It quantifies how exactly the exogenous final demand of any consumer group in any country triggers the creation of value added in any industry of any country, similar to how the original global Leontief formula, i.e. \( x = Lf \), describes how final consumer groups trigger the creation of output in any industry of any country.

5.5. Measuring consumption impacts in the ICIO model

As we just concluded in the previous section, an important feature of input-output models is that they allow for the precise calculation of the impact that the demand of any final consumer group in any country has on the production of output and the creation of value added creation of each industry in each country to satisfy this final demand. All the final-demand-to-output and final-demand-to-value-added-creation relationships are essentially captured by the formula \( x = Lf \) and \( v = \hat{v}_cLf \) respectively. In this section we focus on defining indicators that measure the impacts of exogenously determined final consumption behavior on the production of gross output and the creation of value added.

5.5.1. Gross output decomposition by final demand activators

To decompose global gross output \( x \) into its activating sources of final demand, we simply replace vector \( f \) by matrix \( F \) in the global Leontief formula given by equation (5.39). By doing this, we essentially disaggregate final demand values of each industry in each country.
into the various final demand consumer groups. This results in the following formula:

$$
\mathbf{X} = \begin{bmatrix}
X_{1,1} & X_{1,2} & \cdots & X_{1,k}
\end{bmatrix}
\begin{bmatrix}
L_{1,1} & L_{1,2} & \cdots & L_{1,k}
\end{bmatrix}
\begin{bmatrix}
F_{1,1} & F_{1,2} & \cdots & F_{1,k}
\end{bmatrix}
$$

(5.50)

or

$$
\mathbf{X} = \mathbf{L}\mathbf{F}
$$

(5.51)

The matrix \( \mathbf{X} \) is often called the *gross output decomposition* matrix. Each sub-matrix \( \mathbf{X}^{r,s} \) is defined as:

$$
\mathbf{X}^{r,s} = \sum_{q=1}^{k} \mathbf{L}^{r,q}\mathbf{F}^{q,s}
$$

(5.52)

and has the form:

$$
\mathbf{X}^{r,s} = \begin{bmatrix}
x_{1,1}^{r,s} & x_{1,2}^{r,s} & \cdots & x_{1,k}^{r,s}
x_{2,1}^{r,s} & x_{2,2}^{r,s} & \cdots & x_{2,k}^{r,s}
\vdots & \vdots & \ddots & \vdots
x_{n,1}^{r,s} & x_{n,2}^{r,s} & \cdots & x_{n,k}^{r,s}
\end{bmatrix}
$$

(5.53)

Hence, to be very explicit, writing out matrix \( \mathbf{X} \) completely looks like:

$$
\mathbf{X} = \begin{bmatrix}
x_{1,1}^{1,1} & x_{1,1}^{1,1} & x_{1,1}^{1,1} & \cdots & x_{1,1}^{1,1} & x_{1,1}^{1,1} & x_{1,1}^{1,1}
\vdots & \vdots & \cdots & \vdots & \vdots & \vdots & \vdots
x_{1,1}^{k,1} & x_{1,1}^{k,1} & x_{1,1}^{k,1} & \cdots & x_{1,1}^{k,1} & x_{1,1}^{k,1} & x_{1,1}^{k,1}
\vdots & \vdots & \cdots & \vdots & \vdots & \vdots & \vdots
\end{bmatrix}
$$

(5.54)

Any element \( x_{i,u}^{r,s} \) denotes the total gross output produced by industry \( i \) in country \( r \) that is activated or induced by final demand component \( u \) in country \( s \) (this value thus captures both the direct and indirect effects). The matrix \( \mathbf{X} \) thus decomposes the total output vector \( \mathbf{x} \) into its ultimate absorbers. That is, each element \( x_i^r \) of vector \( \mathbf{x} \) is decomposed into its final demand activators (or absorbers) as follows:

$$
x_i^r = x_{i,c}^{r,1} + x_{i,c}^{r,1} + x_{i,c}^{r,1} + \cdots + x_{i,c}^{r,k} + x_{i,c}^{r,k} + x_{i,gcf}^{r,k}
$$

(5.55)

Hence it is clear that \( \mathbf{x} = \mathbf{X}\mathbf{i} \), i.e. the row-sums of matrix \( \mathbf{X} \) equal the corresponding values of vector \( \mathbf{x} \).

On a more detailed level, equation (5.52) shows that each element \( x_{i,u}^{r,s} \) in turn can be decomposed as the following summation:

$$
x_{i,u}^{r,s} = \sum_{q=1}^{k} \sum_{i=1}^{n} (i_{i,j}, q_{j,u})
$$

(5.56)
This equation states that value of each \( x_{i,u}^{r,s} \) can be written as a sum of \( l_{i,j}^{r,q} f_{j,u}^{q,s} \) terms. The general \( l_{i,j}^{r,q} f_{j,u}^{q,s} \) term has a clear interpretation. Remember that \( l_{i,j}^{r,q} \) denotes the total additional output that industry \( i \) in country \( r \) has to produce in order to meet a unit increase in the demand for the output of industry \( j \) in country \( q \), and \( f_{j,u}^{q,s} \) denotes the demand in country \( s \) by final demand group \( u \) for final goods produced by industry \( j \) in country \( q \). It then follows that the product of these two factors, \( l_{i,j}^{r,q} f_{j,u}^{q,s} \), denotes the part of gross output produced by industry \( i \) in country \( r \) that is activated indirectly via industry \( j \) in third country \( q \) by final demand component \( u \) in country \( s \). Of course one or more of the countries \( q, r \) or \( s \) could also equal each other.

Figure 5.6 provides an illustration of the full decomposition of the gross output vector \( \mathbf{x} \) that was just explained. This figure makes it clear how each element of vector \( \mathbf{x} \) is in essence determined by a translation of final demand elements via the appropriate Leontief output multipliers to corresponding output values.

\[
\begin{align*}
\text{Level 0} & : \quad \mathbf{x} \\
\text{Level 1} & : \quad \mathbf{x}^1 \ldots \mathbf{x}^r \ldots \mathbf{x}^k \\
\text{Level 2} & : \quad \mathbf{x}_1 \ldots \mathbf{x}^r \\
\text{Level 3} & : \quad x_{i,c_p}^{r,1} + x_{i,c_q}^{r,1} + x_{i,gef}^{r,1} + \ldots + x_{i,c_p}^{r,s} + x_{i,c_q}^{r,s} + x_{i,gef}^{r,s} + \ldots + x_{i,c_p}^{r,k} + x_{i,c_q}^{r,k} + x_{i,gef}^{r,k} \\
\text{Level 4} & : \quad \ldots \sum_{q=1}^{q=k} \left( \sum_{j=1}^{j=n} \frac{l_{i,j}^{r,q} f_{j,u}^{q,s}}{m_{oi,j}} \right) \ldots
\end{align*}
\]

**Figure 5.6:** Decomposition of gross output \( \mathbf{x} \) into its final demand activators

The gross output decomposition described above provides the basic explanation and essential insights into how the gross output of any particular sector is distributed throughout the global input-output system and how the final demand purchasing activities by different groups in various countries trigger production activities throughout the whole economy.

### 5.5.2. Value added decomposition by final demand activators

To decompose the value added vector \( \mathbf{v} \) into its activating sources of final demand, we first define the matrix \( \mathbf{V}_c \), a diagonal matrix with all the domestic value added coefficients of each country listed along its diagonal:
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If we multiply matrix $\mathbf{V}_c$ with the gross output decomposition matrix $\mathbf{X}$ that we defined earlier, we get the value added decomposition matrix (or value added production matrix) $\mathbf{V}$:

$$
\mathbf{V} = \mathbf{V}_c \mathbf{X}
$$

The matrix $\mathbf{V} = [v_{i,u}^{r,s}]$ describes the domestic value added created in each industry of each country as a response to the initial exogenous shock in final demand. To be more precise, each element $v_{i,u}^{r,s} = v_{c}^{r,s}x_{i,u}^{r,s}$ of matrix $\mathbf{V}$ indicates the total domestic value added that is created in industry $i$ of country $r$ by the purchasing activities of final demand group $u$ of country $s$. In other words, $v_{i,u}^{r,s}$ represents the domestic value added produced by industry $i$ of country $r$ that is ultimately absorbed by final demand group $u$ in country $s$.

Each sub-matrix $\mathbf{V}^{r,s}$ is thus defined as

$$
\mathbf{V}^{r,s} = \mathbf{V}_c \mathbf{X}^{r,s} = \mathbf{V}_c \sum_{q=1}^{k} \mathbf{F}^{r,s}
$$

and has the form:

$$
\mathbf{V}^{r,s} = 
\begin{bmatrix}
    v_{1,c}^{r,s} & v_{1,ge}^{r,s} & v_{1,cf}^{r,s} \\
    v_{2,c}^{r,s} & v_{2,ge}^{r,s} & v_{2,cf}^{r,s} \\
    \vdots & \vdots & \vdots \\
    v_{n,c}^{r,s} & v_{n,ge}^{r,s} & v_{n,cf}^{r,s}
\end{bmatrix}
$$

This matrix captures the total production of domestic value added in country $r$ that is ultimately absorbed by final demand groups in country $s$. When $r = s$ then the matrix captures the domestic value-added ultimately absorbed at the home. When $r \neq s$ then the matrix captures the domestic value-added ultimately absorbed by foreign country $s$.

Essentially matrix $\mathbf{V}$ decomposes the value added vector $\mathbf{v}$ into its ultimate activating sources of final demand (or equivalently its ultimate absorbers of value added), similar to
how matrix $X$ decomposes the gross output vector $x$ into its final demand activators. To see this, realize that each row of $V = V_cX$ is a decomposition of element $v_i^r$ of vector $v$ into its final demand absorbers:

$$v_i^r = v_{ci}x_i^r = v_{ci} \left( x_{i,c,p}^r + x_{i,c,q}^r + \ldots + x_{i,c,gf}^r + x_{i,c,g}^r \right) = v_{ci}x_{i,c,p}^r + v_{ci}x_{i,c,q}^r + \ldots + v_{ci}x_{i,c,g}^r + v_{ci}x_{i,c,gf}^r \tag{5.61}$$

This last step exactly equals the sum of the elements along any row in matrix $V$. It is therefore clear that $v = Vi$, i.e. the row-sums of matrix $V$ equal the corresponding values of vector $v$. Notice the similarity with $x = Xi$.

We can further decompose matrix $V$ on a more detailed level by using the decomposition of matrix $X$ as follows: $V = V_cX = V_c(LF) = (V_cL)F = M_vF$, with:

$$M_v = \begin{bmatrix} M_v^{1,1} & M_v^{1,2} & \ldots & M_v^{1,k} \\ M_v^{2,1} & M_v^{2,2} & \ldots & M_v^{2,k} \\ \vdots \\ M_v^{k,1} & M_v^{k,2} & \ldots & M_v^{k,k} \end{bmatrix} = V_cL \tag{5.62}$$

Each sub-matrix $M_v^{r,s}$ is thus defined as:

$$M_v^{r,s} = \hat{v}_cL^{r,s} \tag{5.63}$$

The matrix $M_v^{r,s}$ captures the value added created in country $r$ caused by unitary final demand changes in country $s$. To be more specific, any particular element $m_{vij}^{r,s} (= M_v^{r,s}[i,j] = v_{ci}I_j^{r,s})$ of matrix $M_v^{r,s}$ can be interpreted as saying that each unit of final demand for the output of sector $j$ in country $s$ generates $m_{vij}^{r,s}$ worth of value added in sector $i$ in country $r$. In other words:

$$m_{vij}^{r,s}$$

is the extra value added that is created in sector $i$ in country $r$ in order to meet a unit (i.e. a dollar’s worth) increase in the final demand for the output of sector $j$ in country $s$.

The matrix $M_v$ is essentially a transformation of the final-demand-to-output multipliers captured by $L$ (which we also defined as $M_v$) into a matrix capturing the final-demand-to-value-added multipliers. So similar to the way we calculated the gross output decomposition matrix $X$ by pre-multiplying the final demand matrix $F$ by the output-multiplier matrix $L$, we calculate the value added decomposition matrix $V$ by pre-multiplying $F$ by the value-added multiplier matrix $M_v$. Matrix $M_v$ is also referred to as the value-added by source share matrix, because it captures the value-added shares by source of production. Similar to the way we defined vector $m_v^{o,s}$, we can now also define the row-vector $m_v^{r,s}$ as:

$$m_v^{r,s} = i'M_v^{r,s} = i'\hat{v}_cL^{r,s} = v_c^r/L^{r,s} \tag{5.64}$$

capturing the sector-demand-to-economy-wide-value-added-created multipliers.

Matrix $M_v$ has the property that each of its columns sum up to one, i.e. $i'M_v = i'$. This can be intuitively understood by realizing that all value added created must ultimately be absorbed either at the home country or somewhere abroad. More formally this property can also be proved as follows:
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\[ i'M_v = i'VL \]
\[ = v'Jv \]
\[ = i'L^{-1}L \]
\[ = i' \]

Figure 5.7 provides an illustration of the decomposition of the value added vector \( v \) that was explained above. This figure makes it clear how each element of vector \( v \) is in essence determined by a translation of final demand elements via the appropriate value added multipliers to corresponding output values.

**5.5.3. Domestic value added absorbed by foreign final demand**

In the subsection above we saw how total value added created by a country \( r \) can be distributed over the various final demand groups of the various countries according to how much of this value added is activated (or absorbed) by each of these final consumer groups. This information is captured by the value added production matrix \( V \). To be more precise, each sub-matrix \( V^{r,s} \) of matrix \( V \) captures the value added of country \( r \) that is absorbed by final demand groups in country \( s \) (preserving industry and consumer groups distinctions). Hence readily interpreted, for \( s \neq r \) this matrix denotes 'exports of value added' from country \( r \) to final demand groups in country \( s \). In this subsection and the next, we will consecutively focus on two special cases of this measure for value added absorption: (1) this subsection analyzes the domestic value added that is absorbed by foreign final demand, (2) the next subsection analyzes the foreign value added that is absorbed by domestic final demand.

As a general remark, the absorption flow definitions will always be provided on several levels by making two distinctions. The first distinction differentiates between absorption flows from one country to another (i.e. bilateral flows) and absorption flows from one country to the rest of the world. For each of the two options from the first distinction, the second
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distinction categories absorption flows into three different levels of abstraction: (1) industry and final demand groups distinction (= matrix definitions), (2) industry distinction only (= vector definitions), and (3) single value aggregation (= value definitions). In moving from the former to the latter, the flow data gets more and more aggregated. The matrix-level definitions preserve the highest level of detail and keep the distinction between the three types of final demand groups. The vector-level definitions aggregate the three final demand groups into one overall group, but keeps the distinction between the various industries. The single-value-level definitions aggregate both the final demand groups as well as the industries and provide a sum of single values.

As a final note before starting with the analysis, it might be instructive to emphasize that in this section (but also in the rest of this document if not mentioned otherwise) the symbol $r$ always denotes the home country in the analysis, while $s$ and $q$ are used to denote foreign countries.

In our analysis of domestic value added absorbed by foreign final demand we start with the bilateral case: absorption of domestic value added by another country. To this end, we make the observation that matrix $V^{r,s}$ exactly captures the domestic value added of home country $r$ (playing the role of producer) absorbed by foreign final demand consumer groups in partner country $s$ (playing the role of consumer), with of course $s \neq r$. Since $V^{r,s}$ was already defined in the previous section as:

$$V^{r,s}_{(n \times 3)} = \sum_{q=1}^{q=k} M^{r,q}_{v} F^{q,s}_{v} = \sum_{q=1}^{q=k} V^{r,q}_{c} L^{r,q}_{c} F^{q,s}_{c}$$  \hspace{1cm} (5.65)

(see equation 5.59), we immediately obtain the formula for the bilateral 'exports' of domestic value added created in home country $r$ to the foreign consumers of country $s$. This is the matrix-level definition. To obtain the vector-level definition we simply have to post-multiply equation 5.65 by the summing vector $B$, which results in:

$$V^{r,s}_{(n \times 1)} = \sum_{q=1}^{q=k} M^{r,q}_{v} F^{q,s}_{v} = \sum_{q=1}^{q=k} V^{r,q}_{c} L^{r,q}_{c} F^{q,s}_{c}$$  \hspace{1cm} (5.66)

The value-level definition is obtained by pre-multiplying equation 5.67 by the summing row-vector $i'$, resulting in:

$$v^{r,s}_{(1 \times 1)} = i' V^{r,s} = \sum_{q=1}^{q=k} m^{r,q}_{v} F^{q,s}_{v} = \sum_{q=1}^{q=k} V^{r,q}_{c} L^{r,q}_{c} F^{q,s}_{c}$$  \hspace{1cm} (5.67)

By conditioning over the value of $q$ in the three definitions above, we can decompose the bilateral value added absorption flow into three components. The first component corresponds to the case where $q = r$, the second component to the case where $q = s$, and the third component to the remaining case where $q \neq r$ and $q \neq s$. This categorization results into
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The following decomposition formula:

\[ v^{r,s} = M_v^{r,r} F^{r,s} + M_v^{r,s} F^{s,s} + \sum_{q \neq r,s} M_q^{r,q} F^{q,s} \]  

\[ v^{r,s} = M_v^{r,r} F^{r,s} + M_v^{r,s} F^{s,s} + \sum_{q \neq r,s} M_q^{r,q} F^{q,s} \]  

\[ v^{r,s} = m_v^{r,st} F^{r,s} + m_v^{r,sn} F^{r,s} + \sum_{q \neq r,s} m_q^{r,q} F^{q,s} \]

The first components in each of the three equations above captures the domestic value added of country \( r \) that is embodied in the final products produced by country \( r \) that directly flow to final demand purchasers in country \( s \). The second components captures the domestic value added of country \( r \) that is embodied in the intermediate products produced by country \( r \) that flow to industries in country \( s \) to be used to create final products that are consumed by the final demand purchasers of this importing country \( s \). The third components captures the domestic value added that is embodied in the intermediate products produced by country \( r \) that flow to industries in countries other than country \( r \) or \( s \) to be eventually used to create final products that are consumed by the final demand purchasers of this importing country \( r \).

The first two components hence represent the domestic value added of the producing country that is directly absorbed by the importing country \( s \), either directly as final products or indirectly as intermediates transformed by the importing country into final products for its domestic market. The last component represents the indirect absorption of domestic value added from country \( r \) by country \( s \) via third countries. For illustration purposes, Figure 5.8 provides an abstract illustration of the previous decomposition discussion. It assumes a global closed economy with only three countries and shows the three absorption flows that together constitute the domestic value added absorbed by final demand of a foreign country. Figure 5.9 provides a schematic illustration of the vector-level decomposition formula.

The definitions and decompositions derived above can be generalized from the bilateral case to the overall (i.e. rest of the world) case. To this end, we introduce matrix \( V^{r,*} \) to denote the domestic value added created by country \( r \) that is absorbed by foreign final demand (we thus consider all foreign countries instead of only one as we did in the bilateral case), and define it by summing over all partner countries \( s \) as follows:

\[ V^{r,*} = \sum_{s \neq r} V^{r,s} \]  

Using the definitions and decomposition formula of \( V^{r,s} \), \( v^{r,s} \), and \( v^{r,s} \) that were derived earlier, it is easy to check that the following formula define and decompose a country’s
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Country r

Country s

Country q

Figure 5.8: Illustration of the decomposition of domestic value added absorbed by final demand of a foreign country into three absorption flows.

Figure 5.9: Illustration of the decomposition of domestic value added absorbed by foreign final demand of another country into three absorption categories.

overall domestic value added absorbed by foreign final demand:

$$V'^{r,s} = \sum_{s \neq r}^{k} M^{r,r,s} F^{r,s} + \sum_{s \neq r}^{k} M^{r,s} F^{s,s} + \sum_{s \neq r}^{k} \sum_{q \neq r,s}^{k} M^{r,q} F^{q,s} \quad (5.72)$$

$$V^{r,s} = \sum_{s \neq r}^{k} M^{r,r,s} F^{r,s} + \sum_{s \neq r}^{k} M^{r,s} F^{s,s} + \sum_{s \neq r}^{k} \sum_{q \neq r,s}^{k} M^{r,q} F^{r,s} \quad (5.73)$$

$$v^{r,s} = \sum_{s \neq r}^{k} m^{r,s} F^{r,s} + \sum_{s \neq r}^{k} m^{r,s} F^{s,s} + \sum_{s \neq r}^{k} \sum_{q \neq r,s}^{k} m^{r,q} F^{r,s} \quad (5.74)$$
5.5. Measuring consumption impacts in the ICIO model

An illustration of the vector-level decomposition of the absorption flows that constitute the domestic value added absorbed by total foreign final demand is provided by Figure 5.10.

![Figure 5.10: Illustration of the decomposition of domestic value added absorbed by total foreign final demand](image)

5.5.4. Foreign value added absorbed by domestic final demand

To analyze foreign value added absorbed by domestic final demand, we start by making the observation that matrix $V^{s,r}$ exactly captures the value added created by foreign country $s$ that is absorbed by domestic final demand consumer groups in home country $r$, where again of course $s \neq r$. Hence all the bilateral formula introduced in the previous subsection, concerning the domestic value added absorbed by foreign final demand, can directly be adapted to define and decompose bilateral foreign value added absorbed by domestic final demand simply by changing $s$ by $r$ and $r$ by $s$. Hence, we get the following formula for the bilateral case:

$$V^{s,r} = M^{s,s}F^{s,r} + M^{s,r}F^{r,r} + \sum_{q \neq r,s}^{k} M^{s,q}F^{q,r}$$ (5.75)

$$v^{s,r} = M^{s,s}f^{s,r} + M^{s,r}f^{r,r} + \sum_{q \neq r,s}^{k} M^{s,q}f^{q,r}$$ (5.76)

$$u^{s,r} = m^{s,s}f^{s,r} + m^{s,r}f^{r,r} + \sum_{q \neq r,s}^{k} m^{s,q}f^{q,r}$$ (5.77)

The interpretation of each of the three components in the three definitions above follows a reasoning that is similar to the discussion of the three components of domestic value added absorbed by foreign final demand that is provided in the previous subsection. The first component captures the value added created in foreign country $s$ that is absorbed directly by the home country $r$ via final products. The second component captures the value added of
foreign country $s$ that is embodied in intermediate products that are imported from country $s$ to industries of home country $r$ to be used to create final products that are absorbed by final consumers of the home country $r$. Finally, the third component captures the value added of foreign country $s$ that is embodied in intermediate products produced that are imported from country $s$ to industries of a third country $q$ to be eventually used to create final products that are absorbed by final consumers of home country $r$.

Similar to what we did in the previous subsection, the definitions and decompositions derived above can be generalized from the bilateral case to the overall (i.e. rest of the world) case. To this end, we introduce matrix $V^{*,r}$ to denote the foreign value added created that is absorbed by domestic final demand of home country $r$, and define it by summing over all partner countries $s$ as follows:

$$V^{*,r} = \sum_{s \neq r} V^{s,r}$$  \hspace{1cm} (5.78)

Applying this definition to the decomposition formula for $V^{s,r}$, $V^{s,r}$, and $V^{s,r}$ that we derived above results into the following formula for a country's overall foreign value added absorbed by domestic final demand:

$$V^{*,r} = \sum_{s \neq r} M_v^{s,s} F^{s,r} + \sum_{s \neq r} M_v^{s,r} F^{r,r} + \sum_{s \neq r} M_v^{s,q} F^{q,r}$$  \hspace{1cm} (5.79)

$$V^{*,r} = \sum_{s \neq r} M_v^{s,s} F^{s,r} + \sum_{s \neq r} M_v^{s,r} F^{r,r} + \sum_{s \neq r} M_v^{s,q} F^{r,r}$$  \hspace{1cm} (5.80)

$$V^{*,r} = \sum_{s \neq r} M_v^{s,r} F^{s,r} + \sum_{s \neq r} M_v^{s,r} F^{r,r} + \sum_{s \neq r} M_v^{s,q} F^{q,r}$$  \hspace{1cm} (5.81)

An illustration of the vector-level decomposition of the absorption flows that constitute overall foreign value added absorbed by domestic final demand is provided by Figure 5.11.

5.6. Measuring trade in the ICIO model

This section aims at providing the appropriate matrix definitions that are necessary to analyze the sector-level trade flows between the various countries, building on the matrix definitions that were introduced in the previous section. Broadly, this section analyzes these trade flows from two perspectives in a consecutive manner: in the first subsection trade is analyzed in gross terms, and in the next subsection trade is analyzed in value added terms by providing a decomposition of gross trade into its value added content. This last subsection focuses on deriving the matrix-formula for identifying the domestic and foreign value added that is embodied in a country's exports and imports (maintaining a sectoral level of detail).
5.6. Measuring trade in the ICIO model

5.6.1. Gross trade measures

In this section we introduce several gross trade indicators that can be derived from the global input-output model.

Gross exports

If we let the vector \( \mathbf{e}^{r,s} \) capture the bilateral gross exports from country \( r \) to country \( s \) by each industry in country \( r \), then this vector can be immediately calculated from the input-output model, by summing over all the intermediates and final products that flow from country \( r \) to \( s \), as follows:

\[
\mathbf{e}^{r,s} = \mathbf{Z}^{r,s} \mathbf{i} + \mathbf{F}^{r,s} \mathbf{i} \tag{5.82}
\]

\[
\Leftrightarrow \quad \mathbf{e}^{r,s} = \mathbf{A}^{r,s} \mathbf{x}^s + \mathbf{f}^{r,s} \tag{5.83}
\]

(with of course \( r \neq s \)). Each element from this vector denotes the gross exports by industry \( i \) in country \( r \) to all industries and final demand groups in country \( s \). This vector is referred to as a bilateral trade vector because it captures trade from one country to another. Similarly, we can also define trade from one country to the rest of the world, which we refer to as overall trade values. To denote the ‘rest of the world’ we use the wild-card symbol *. Hence, the vector \( \mathbf{e}^{r,*} \) captures the gross exports from country \( r \) to all other countries in the world and can be defined as follow:

\[
\mathbf{e}^{r,*} = \sum_{s \neq r}^{k} \mathbf{e}^{r,s} \]

\[
\Leftrightarrow \quad \mathbf{e}^{r,*} = \sum_{s \neq r}^{k} (\mathbf{A}^{r,s} \mathbf{x}^s + \mathbf{f}^{r,s}) \]

\[
\Leftrightarrow \quad \mathbf{e}^{r,*} = \sum_{s = 1}^{k} (\mathbf{A}^{r,s} \mathbf{x}^s + \mathbf{f}^{r,s}) - (\mathbf{A}^{r,r} \mathbf{x}^r + \mathbf{f}^{r,r}) \]

\[
\Leftrightarrow \quad \mathbf{e}^{r,*} = (\mathbf{I} - \mathbf{A}^{r,r}) \mathbf{x}^r - \mathbf{f}^{r,r}
\]

Each element from this vector denotes the gross exports by industry \( i \) in country \( r \) to all industries and final demand groups in all other countries in the world.

While the vector definitions of an indicator preserve the sectoral distinction, we can also move up to a higher level of abstraction by aggregating over all industries. This results in a single-value equivalent of the vector definition. Aggregating a vector definition of an indicator into its single-value equivalent can generally be accomplished by premultiplying the input-output model.

In this section we introduce several gross trade indicators that can be derived from the global input-output model.
of country $r$’s total gross exports can be defined as follows:

$$
\tilde{e}^{r,s}_{(n \times 1)} = \frac{1}{e^{r,s}} e^{r,s} \quad (5.86)
$$

$$
\tilde{e}^{r,s} = \frac{e^{r,s}}{e^{r,s}} \quad (5.87)
$$

Generally we will let the $\tilde{\cdot}$ operator define the relative counterpart of a trade measure that is expressed in absolute (i.e. U.S. dollars) terms. In other words, if vector $x$ measures a part of exports, then $\tilde{x} = \frac{1}{e^{r,s}} x$ is the definition of this vector’s relative counterpart. Similarly, if vector $x$ measures a part of imports in absolute terms, then $\tilde{x} = \frac{1}{i^{r,s}} x$ is the definition of this vector’s relative counterpart (where $i^{r,s}$ denotes country $r$’s overall gross imports value as we will see in the next section).

**Gross imports**

This subsection constitutes the counterpart of the previous subsection as it focuses on a country’s gross imports of its exports (as we analyzed previously).

The definition of a country’s bilateral gross imports is very similar to the gross exports definition. To see this, we simply have to realize that what is imported from country $s$ into country $r$ is equal to what is exported from country $s$ to country $r$. Hence, if we let vector $i^{r,s}$ denote country $r$’s bilateral gross import by industry from country $s$ (with $s \neq r$), then we can define this vector as follows:

$$
i^{r,s}_{(n \times 1)} = e^{s,r} \quad (5.88)
$$

$$
i^{r,s} = A^{s,r} x^{r} + f^{s,r} \quad (5.89)
$$

The vector $i^{r,*}$ capturing country $r$’s gross imports from all the other countries in the world, can then be defined as follows:

$$
i^{r,*}_{(n \times 1)} = \sum_{s \neq r}^{k} i^{r,s} \quad (5.90)
$$

$$
i^{r,*} = \sum_{s \neq r}^{k} A^{s,r} x^{r} + f^{s,r} \quad (5.91)
$$

Similar to the gross exports case, by aggregating over all industries the value equivalents of the two definitions above are given by:

$$
i^{r,s} = \tilde{i^{r,s}} \quad (5.92)
$$

$$
i^{r,*} = \tilde{i^{r,*}} \quad (5.93)
$$

Expressed as a share of total gross imports, we get the following two counterparts of the absolute bilateral definitions above:

$$
\tilde{i^{r,s}}_{(n \times 1)} = \frac{1}{i^{r,*}} i^{r,s} \quad (5.94)
$$

$$
\tilde{i^{r,*}} = \frac{\tilde{i^{r,s}}}{\tilde{i^{r,*}}} \quad (5.95)
$$
5.6.2. Gross trade decomposition into value added content

In this section we provide industry-level decomposition formula of the gross exports and gross imports indicators that were introduced in the previous section. Both decompositions separate the domestic from the foreign value added content that is embodied in the respective gross trade measures.

Gross exports decomposition

In this subsection we will decompose a country’s gross exports by industry, i.e. the vector $e^{r,*}$, into its value added components. The resulting decomposition will have the form

$$e^{r,*} = e^{r,*}_\text{DVA} + e^{r,*}_\text{FVA}$$  \hspace{1cm} (5.96)

where $e^{r,*}_\text{DVA}$ captures the \textit{domestic value added content} by industry embodied in country $r$’s gross exports, and $e^{r,*}_\text{FVA}$ captures the \textit{foreign value added content} by industry embodied in country $r$’s gross exports. This decomposition will therefore show how exactly a gross exports figure of a country is biased upwards by capturing more than just the exports of domestic value added.

The decomposition of vector $e^{r,*}$ starts by making the following observation:

$$e^{r,*} = \hat{e}^{r,*}_i$$  \hspace{1cm} (5.97)

That is, summing along the rows of a diagonal matrix results in a vector that contains the diagonal elements of that matrix. Using the following identity:

$$i' = \sum_{s=1}^{s=k} \hat{v}M_{s,r}, \quad \forall r$$

$$\Leftrightarrow$$

$$v_{s_r}L_{s,r}, \quad \forall r$$

$$\Leftrightarrow$$

$$v_{s_r}m_{s_r}, \quad \forall r$$

$$i = \sum_{s=1}^{s=k} m_{s_r}, \quad \forall r$$  \hspace{1cm} (5.98)

(following from the property: $i'M_v = i'$), we can now rewrite equation (5.97) as follows:

$$e^{r,*} = \hat{e}^{r,*} \left( \sum_{s=1}^{s=k} m_{s_r} \right)$$

$$= \sum_{s=1}^{s=k} \hat{e}^{r,*}m_{s_r}$$

$$= \hat{e}^{r,*}m_{r} + \sum_{s \neq r}^{s=k} \hat{e}^{r,*}m_{s_r}$$  \hspace{1cm} (5.99)

$$= e^{r,*}_\text{DVA} + e^{r,*}_\text{FVA}

where we defined $e^{r,*}_\text{DVA}$ and $e^{r,*}_\text{FVA}$ as:

$$e^{r,*}_\text{DVA} = \hat{e}^{r,*}m_{r}$$

$$= \hat{e}^{r,*}L_{r,r}v_{c}$$  \hspace{1cm} (5.100)
The vector $e_{r,s}^{FVA}$ captures the foreign value added content by industry embodied in country $r$’s gross exports, and $e_{r,s}^{FVA}$ captures the foreign value added content by industry embodied in country $r$’s gross exports. Each term in the summation of $e_{r,s}^{FVA}$’s definition denotes the value added of country $s$ (with $s \neq r$) that is embedded in country $r$’s gross exports. If we denote this term by $e_{FVA,s}^{r,r}$ then we get:

$$
e_{FVA,s}^{r,r} = \sum_{s \neq r}^k e_{r,s}^{FVA} \in (n \times 1)$$

(5.103)

$$e_{FVA}^{r,r} = \sum_{s \neq r}^k e_{FVA,s}^{r,r}$$

(5.102)

The domestic value added content vector $e_{DVA}^{r,r}$ can be further decomposed into three components: direct domestic value added, indirect domestic value added and re-imported value added. These three components can be defined respectively as follows:

$$e_{DVA,ddc}^{r,r} = \sum_{s \neq r}^k e_{DVA,s}^{r,r}$$

(5.104)

$$e_{DVA,iddc}^{r,r} = \sum_{s \neq r}^k e_{DVA,s}^{r,r}$$

(5.105)

$$e_{DVA,irdc}^{r,r} = \sum_{s \neq r}^k e_{DVA,s}^{r,r}$$

(5.106)

It is immediately clear that the sum of these three components constitute the total domestic value added content embodied in gross exports, i.e.

$$e_{DVA}^{r,r} = e_{DVA,ddc}^{r,r} + e_{DVA,iddc}^{r,r} + e_{DVA,irdc}^{r,r}$$

(5.107)

Let us discuss each of these three components. The first component, vector $e_{DVA,ddc}^{r,r}$ denotes the direct domestic value added by industry embodied in a country’s gross exports. To be more specific, for each industry in country $r$ this vector captures the value added that is directly contributed (i.e. created) by this industry in its production of goods and services to be exported to other countries. The second component, vector $e_{DVA,iddc}^{r,r}$ denotes the indirect domestic value added by industry embodied in a country’s gross exports. For each industry in country $r$ this vector captures the contribution in this industry’s production of goods and services to be exported made by the other domestic industries, who are positioned higher in the production chain and supply their output as intermediate inputs to this industry. Finally, vector $e_{DVA,irdc}^{r,r}$ denotes the re-imported domestic value added by industry embodied in a country’s gross exports. For each industry in country $r$ this vector captures the domestic value added that was initially exported by country $r$ to a foreign country, embodied in intermediates, and later returned to the home country embodied in intermediate imports to serve as input for the respective industry.

The complete industry-level decomposition of gross exports described in the paragraphs above is summarized and visually illustrated in Figure 5.12. While this decomposition was
derived absolute terms (i.e. all values in the vectors are expressed as million of U.S. dollars),
the decomposition can also be expressed in relative terms as a percentage of the country’s
overall gross exports. To obtain this decomposition we simply have to replace each vector
by its relative counterpart by writing a ~ above all the vectors.

\[
\begin{align*}
\text{Level 0} & \quad \text{gross exports definition:} & \quad \text{gross exports decomposition:} \\
\begin{bmatrix} e^{r,*} \end{bmatrix} & = (I - A^r) x^r - f^{r,*} & \quad \begin{bmatrix} e^{r,*} \end{bmatrix} & = \begin{bmatrix} e^{r,*}_{DVA} \end{bmatrix} + \begin{bmatrix} e^{r,*}_{FVA} \end{bmatrix} \\
= \text{domestic value added embodied in gross exports} & \quad = \text{foreign value added embodied in gross exports} \\
\begin{bmatrix} \hat{e}^{r,*} \end{bmatrix} & = \begin{bmatrix} \hat{e}^{r,*}_{DVA} \end{bmatrix} + \begin{bmatrix} \hat{e}^{r,*}_{FVA} \end{bmatrix} \\
= \hat{e}^{r,*} \begin{bmatrix} \hat{I}^{r,r} \end{bmatrix} \begin{bmatrix} \hat{v}^r \end{bmatrix} \\
\quad \text{level 1} & \quad \text{level 2} & \quad \begin{bmatrix} \hat{e}^{r,*}_{DVA,idec} \end{bmatrix} & = \begin{bmatrix} \hat{e}^{r,*}_{DVA,idec} \end{bmatrix} \\
= \text{direct domestic value added content embodied in gross exports} & \quad = \text{indirect domestic value added content embodied in gross exports} \\
= \hat{e}^{r,*} \begin{bmatrix} \hat{I}^{r,r} \end{bmatrix} \begin{bmatrix} \hat{v}^r \end{bmatrix} \\
\quad \text{level 2} & \quad \text{level 2} & \quad \begin{bmatrix} \hat{e}^{r,*}_{DVA,idec} \end{bmatrix} & = \begin{bmatrix} \hat{e}^{r,*}_{DVA,idec} \end{bmatrix} \\
= \text{re-imported domestic value added content embodied in gross exports} & \quad = \text{re-imported domestic value added content embodied in gross exports} \\
\end{align*}
\]

Figure 5.12: Gross export decomposition into domestic and foreign value added content (preserving industry-level detail)

**Gross imports decomposition**

This subsection constitutes the counterpart of the previous subsection. We will decompose
a country’s gross imports by industry, i.e. the vector \( i^{r,*} \), into its value added components.
The resulting decomposition will have the form

\[
i^{r,*} = i^{r,*}_{DVA} + i^{r,*}_{FVA} \quad (5.108)
\]

where \( i^{r,*}_{DVA} \) captures the *domestic value added content* by industry embodied in country
\( r \)'s gross imports, and \( i^{r,*}_{FVA} \) captures the *foreign value added content* by industry embodied
in country \( r \)'s gross imports. This decomposition will therefore show how exactly a gross
imports figure of a country is biased upwards by capturing more than just the imports of
foreign value added.

The decomposition of \( i^{r,*} \) essentially follows exactly the same steps as the derivation of
the decomposition of \( e^{r,*} \) in the previous subsection because of the following observation:

\[
i^{r,*} = \hat{e}^{r,*} i = \hat{e}^{r,*} \left( \sum_{s=1}^{k} m_{s}^{* r} \right) \quad (5.109)
\]
This is the exact same start of our derivation in the previous section, only with vector $\mathbf{e}^{r,s}$ now being replaced by $\hat{\mathbf{i}}^{r,s}$. Hence adapting the decomposition from the previous section to this case of gross imports results in the following definitions:

\begin{align*}
i_{DVA}^{r,s} & = \hat{\mathbf{i}}^{r,s} \mathbf{L}^{r,r'} \mathbf{v}^r_c \quad (5.110) \\
i_{FVA_s}^{r,s} & = \hat{\mathbf{i}}^{r,s} \mathbf{L}^{s,r'} \mathbf{v}^s_c \quad (with \ s \neq r) \quad (5.111) \\
i_{FVA}^{r,s} & = \sum_{s \neq r} i_{FVA_s}^{r,s} \quad (5.112)
\end{align*}

A schematic illustration of the gross imports decomposition derived above is given by Figure 5.13.

**Level 0**

- gross imports definition:
  \[ i^{r,s} = \sum_{s \neq r} A^{s,r} x^r + f^{s,r} \]

**Level 1**

- gross imports decomposition:
  \[ \begin{align*}
i_{DVA}^{r,s} & = \hat{\mathbf{i}}^{r,s} \mathbf{L}^{r,r'} \mathbf{v}^r_c \\
i_{FVA}^{r,s} & = \sum_{s \neq r} i_{FVA_s}^{r,s} = \sum_{s \neq r} \hat{\mathbf{i}}^{r,s} \mathbf{L}^{s,r'} \mathbf{v}^s_c
\end{align*} \]

**Figure 5.13:** Gross imports decomposition into domestic and foreign value added content (preserving industry-level detail)

### 5.6.3. Trade balances in gross and value added terms

This section discusses the measurement of a country’s bilateral trade balances by partner country and overall trade balance with the rest of the world both in gross and value added terms and by industry. It uses the vector-level definitions of gross exports, gross imports, domestic value added absorbed by foreign final demand, and foreign value added absorbed by domestic final demand in order to formulate the trade balance definitions. Essentially the idea is that by subtracting gross imports from gross exports and foreign value added absorbed by domestic final demand from domestic value added absorbed by foreign final demand, we get the trade balances balances in respectively gross and value added terms.

**Trade balance in gross terms**

Using the gross exports by industry and gross imports by industry formula, we can now define the bilateral and overall trade balance in gross terms by industry of a country with each of its trade partners, i.e. the net trade of a country with its foreign partners in gross terms.

For the bilateral case, we let vector $\mathbf{b}^{r,s}$ capture the bilateral gross trade balance between
5.6. Measuring trade in the ICIO model

country \( r \) and country \( s \) (on an industry level), and define it as follows:

\[
\mathbf{b}_{r,s}^{r,s} = \mathbf{e}_{r,s}^{r,s} - \mathbf{i}_{r,s}^{r,s}
\]  

(5.113)

Hence, the gross bilateral trade balance of country \( r \) with partner country \( s \) is simply the net gross exports of from country \( r \) to country \( s \). One of the advantages of this vector metric is that it captures the gross bilateral trade positions for each two countries by product (i.e. by industry). This metric will therefore allow us to inspect the degree of concentration of these gross bilateral trade balances in one or several industries.

Similar to how we approached the previous sections, we can also define the overall bilateral gross trade balance \( \mathbf{b}_{r,s}^{r,s} \) as

\[
\mathbf{b}_{r,s}^{r,s} = \mathbf{e}_{r,s}^{r,s} - \mathbf{i}_{r,s}^{r,s}
\]

(5.114)

by which we aggregate all industries into one value. If \( \mathbf{b}_{r,s}^{r,s} > 0 \) then country \( r \) runs a bilateral trade surplus (= positive or favorable balance) with country \( s \) in gross terms. And conversely, if \( \mathbf{b}_{r,s}^{r,s} < 0 \) then country \( r \) runs a bilateral trade deficit (= negative or unfavorable balance) with country \( s \) in gross terms.

The overall gross trade balance of country \( r \) with the rest of the world on an industry level, \( \mathbf{b}_{r,*}^{r,*} \), can be defined as:

\[
\mathbf{b}_{r,*}^{r,*} = \mathbf{e}_{r,*}^{r,*} - \mathbf{i}_{r,*}^{r,*}
\]

(5.115)

And similarly the overall value added trade balance of country \( r \), can be defined as:

\[
\mathbf{b}_{r,*}^{r,*} = \mathbf{e}_{r,*}^{r,*} - \mathbf{i}_{r,*}^{r,*}
\]

(5.116)

**Trade balance in value added terms**

To derive the trade position of a country with its partner countries in value added terms, we will rely on the observation that the domestic value added absorbed by the final demand of a foreign country \( \mathbf{v}_{r,s}^{r,s} \), and a foreign country’s value added absorbed by the final demand of the home country \( \mathbf{v}_{s,r}^{s,r} \) (where \( r \) denotes the home country and \( s \) a foreign country) can be readily interpreted as denoting respectively the bilateral ‘exports of domestic value added’ and the bilateral ‘imports of foreign value added’. Hence, if we let \( \mathbf{b}_{v_a}^{r,s} \) denote the bilateral trade balance of country \( r \) with partner country \( s \) by industry in value added terms, then this vector can be defined as follows:

\[
\mathbf{b}_{v_a}^{r,s} = \mathbf{v}_{r,s}^{r,s} - \mathbf{v}_{s,r}^{s,r} \quad \forall s \neq r
\]

(5.117)

Again, one of the advantages of expressing this indicator as a vector is that it captures the value added trade positions by each industry. This metric will therefore allow us to inspect the degree of concentration of the value added bilateral trade balances towards one or several industries.

Similarly, we can again also define the overall value added trade balance of country \( r \) with the rest of the world on an industry level by subtracting the overall foreign value
added absorbed by domestic final demand from the overall domestic value added absorbed by foreign final demand as follows:

$$b_{va}^{r,s} = v^{r,s} - v^{*,r}$$  \hspace{1cm} (5.118)

Aggregating over all industries to obtain value-level definitions of the trade balance indicators results into the following two formula:

$$b_{va}^{r,s} = v^{r,s} - v^{*,r} \hspace{1cm} \forall s \neq r$$  \hspace{1cm} (5.119)

$$b_{va}^{r,*} = v^{r,*} - v^{*,r}$$  \hspace{1cm} (5.120)

The difference between the gross and value added bilateral trade positions by industry is then defined as:

$$b_{diff}^{r,s} = b_{va}^{r,s} - b^{r,s} = v^{r,s} - v^{*,r} - e^{r,s} + i^{r,s}$$  \hspace{1cm} (5.121)

$$b_{diff}^{r,*} = b_{va}^{r,*} - b^{r,*} = v^{r,*} - v^{*,r} - e^{*,s} + i^{r,*}$$  \hspace{1cm} (5.122)

For the overall case (with the rest of the world), the trade balance difference between gross and value added terms can be defined as follows:

$$b_{diff}^{r,*} = b_{va}^{r,*} - b^{r,*} = v^{r,*} - v^{*,r} - e^{*,r} + i^{r,*}$$  \hspace{1cm} (5.124)

$$b_{diff}^{r,*} = b_{va}^{r,*} - b^{r,*} = v^{r,*} - v^{*,r} - e^{*,r} + i^{r,*}$$  \hspace{1cm} (5.125)
5.7. Summary of the main indicators and their definition

This section provides an overview on the most critical indicators and their mathematical formula introduced throughout this chapter. The result are tabulated in Figure 5.14. All the formulas listed in this tables are in vector-level notation, meaning that their results capture the indicator value for each separate industry. The aggregated value-level definitions can be obtained by premultiplying these vectors with the summing vector $\mathbf{i}'$.

<table>
<thead>
<tr>
<th>Metric</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gross exports</strong></td>
<td></td>
</tr>
<tr>
<td>Bilateral gross exports</td>
<td>$\mathbf{e}^{r,s} = \mathbf{A}^{r,s} \mathbf{x}^{s} + \mathbf{f}^{r,s}$</td>
</tr>
<tr>
<td>Overall gross exports</td>
<td>$\mathbf{e}^{r,*} = (\mathbf{I} - \mathbf{A}^{r,r}) \mathbf{x}^{r} - \mathbf{f}^{r,r}$</td>
</tr>
<tr>
<td><strong>Gross imports</strong></td>
<td></td>
</tr>
<tr>
<td>Bilateral gross imports</td>
<td>$\mathbf{i}^{r,s} = \mathbf{A}^{s,r} \mathbf{x}^{r} + \mathbf{f}^{s,r}$</td>
</tr>
<tr>
<td>Overall gross imports</td>
<td>$\mathbf{i}^{r,*} = \sum_{s \neq r} (\mathbf{A}^{s,r} \mathbf{x}^{r} + \mathbf{f}^{s,r})$</td>
</tr>
<tr>
<td><strong>Value added exports</strong> (= domestic value added activated by foreign final demand)</td>
<td></td>
</tr>
<tr>
<td>Bilateral value added exports</td>
<td>$\mathbf{v}^{r,s} = \sum_{q=1}^{q=K} \mathbf{M}^{r,q} \mathbf{f}^{q,s} = \sum_{q=1}^{q=K} \mathbf{v}_{c}^{q} \mathbf{L}^{r,q} \mathbf{f}^{q,s}$</td>
</tr>
<tr>
<td>Overall value added exports</td>
<td>$\mathbf{v}^{r,*} = \sum_{s \neq r} \sum_{q=1}^{q=K} \mathbf{M}^{r,q} \mathbf{f}^{q,s} = \sum_{s \neq r} \sum_{q=1}^{q=K} \mathbf{v}_{c}^{q} \mathbf{L}^{r,q} \mathbf{f}^{q,s}$</td>
</tr>
<tr>
<td><strong>Value added imports</strong> (= foreign value added activated by domestic final demand)</td>
<td></td>
</tr>
<tr>
<td>Bilateral value added imports</td>
<td>$\mathbf{v}^{s,r} = \sum_{q=1}^{q=K} \mathbf{M}^{q,r} \mathbf{f}^{q,r} = \sum_{q=1}^{q=K} \mathbf{v}_{c}^{q} \mathbf{L}^{s,q} \mathbf{f}^{q,r}$</td>
</tr>
<tr>
<td>Overall value added imports</td>
<td>$\mathbf{v}^{s,*} = \sum_{s \neq r} \sum_{q=1}^{q=K} \mathbf{M}^{q,r} \mathbf{f}^{q,r} = \sum_{s \neq r} \sum_{q=1}^{q=K} \mathbf{v}_{c}^{q} \mathbf{L}^{s,q} \mathbf{f}^{q,r}$</td>
</tr>
<tr>
<td><strong>Gross trade balance</strong></td>
<td></td>
</tr>
<tr>
<td>Bilateral gross trade balance</td>
<td>$\mathbf{b}^{r,s} = \mathbf{e}^{r,s} - \mathbf{i}^{r,s}$</td>
</tr>
<tr>
<td>Overall gross trade balance</td>
<td>$\mathbf{b}^{r,<em>} = \mathbf{e}^{r,</em>} - \mathbf{i}^{r,*}$</td>
</tr>
<tr>
<td><strong>Value added trade balance</strong></td>
<td></td>
</tr>
<tr>
<td>Bilateral value added trade balance</td>
<td>$\mathbf{b}_{va}^{r,s} = \mathbf{v}^{r,s} - \mathbf{v}^{s,r}$</td>
</tr>
<tr>
<td>Overall value added trade balance</td>
<td>$\mathbf{b}_{va}^{r,<em>} = \mathbf{v}^{r,</em>} - \mathbf{v}^{s,*}$</td>
</tr>
</tbody>
</table>

Figure 5.14: An overview on the most important metrics and their formula.

After having described the conceptual research model and the research methodology, we now start focusing on the analysis of the input-output data with respect to the main research questions that were formulated earlier. This chapter essentially addresses the first research question: “How did the industry structure of the Eurozone develop on the sectoral level between 1995 and 2009?”. It should be noted that this chapter is written in a very factual manner, presenting visual data and interpreting what can be seen in the diagrams. Putting together all these individual ‘puzzle pieces’ is left to the research conclusion chapter in which the overall findings are presented and eventually molded into one storyline backed-up by existing economic theory.

This chapter is the first of two empirical analysis chapters. The aim of this chapter is to factually analyze the evolution of the sectoral composition and trade-relationships within the Eurozone, to determine if any structural convergence or divergence occurred after the monetary unification and the introduction of the Euro. In line with the core-periphery dualism between the strong-performing surplus countries and the weak-performing deficit countries highlighted by many authors in the literature and outlined earlier, particular emphasis will be put on identifying potential structural asymmetries between these two groups. The remainder of this chapter is structured into two sections. The first section analyzes the evolution in the domestic industrial structures of the various Eurozone members (Germany versus periphery in particular). Their sector distribution will be analyzed by inspecting both the relative total output produced by each of their industries as well as the domestic value added created by each industry. For each country the industry concentration will be determined as well as the effects of the introduction of the Euro. The second section analyzes the evolution in trade specialization. Both the exports structures as well as the trade balances will be inspected.

The main results from the empirical analysis of this chapter can be summarized as follows. This chapter undeniably confirms the observation of a growing structural asymmetry between Germany (the protagonist of the core region) and the GIPS or peripheral countries (Greece, Italy, Portugal, and Spain): a substantial structural heterogeneity between Germany and the periphery in terms of both their industrial capacities as well as their trade specialization has been gradually developing over the last two decades. Moreover, the empirical evidence clearly
suggests that these structural difference have widened after the monetary unification and the introduction of the common currency. In essence, the asymmetry entails that Germany has gradually been building up a strong comparative advantage in the production and export of high and medium-high technology manufacturing goods, while the periphery got locked-up in specializing in low and medium-low technology manufacturing industries as well as several non-traded services industries often including construction and tourism.

6.1. Evolution in domestic industrial structures

We start this section by briefly examining the size of the Eurozone economy and its three main regions and how it compares to the rest of the world economy. Figure 6.1 shows the size of all the main trading blocks in terms of the total value added they produce as a percentage of the total value added produced in the world. The reported values are averages calculated over the period 1995-2009. It is important to note – and this applies to all figures in constant prices that will follow – that all values are expressed in constant prices from the year 2001. In other words, all values are corrected for the inflation that occurred over the whole period and hence are expressed in real terms. This allows for volume comparisons, i.e. when the output value of an industry in any of the graphs changes from one year to the next, then this change fully captures the change in production volume, because the effect of a change in prices has already been controlled for. Figure 6.1 shows that over the period 1995-2009 the Eurozone has accounted on average for 19% (around one-fifth) of the total value added produced world-wide. Including the non-Euro countries, the European Union covers around one-fourth of the total value added produced. A further breakdown of the Eurozone segment

The following abbreviations apply: NAFTA = North American Free Trade Agreement countries (Canada, Mexico, and United States), CHN = China, EA = East Asian countries (Japan, South Korea, Taiwan), BRIIAT = Brasil Russia India Indonesia Australia and Turkey, ROW = Rest Of the World
shows that the Eurozone core has been responsible for 8% of the world’s total value added creation, while the periphery and Continental Europe accounted for 6% and 4% respectively.

Figure 6.2 presents the intra-Eurozone GDP distribution. It shows that the Eurozone is clearly dominated by four main countries: Germany, Italy, Spain and France. The figure also shows that the core takes up for 45% of the Eurozone’s total value added creation, while the periphery and Continental Europe account for 32% and 23% respectively. It can furthermore be noticed that Germany is by far the biggest economy of the core: with a GDP of 30% of the Eurozone’s total GDP, Germany contributes around 67% to the total size of the core. With GDP shares of 17% and 10% respectively, Italy and Spain are by far the biggest players in the periphery. Together, these two countries cover over 80% of the periphery’s total GDP (53% and 30% respectively). Continental Europe is the most strongly concentrated region with France capturing no less than 93% of its total GDP. Our focus in this chapter will mainly be on seven Eurozone economies: Germany (the most important player in the core), the five periphery countries (Greece, Italy, Ireland, Portugal, and Spain) and France (the most important player in the periphery). Together these six countries account for 83% of the Eurozone’s total GDP. We now turn to the analysis of the domestic industrial structures.

### Size of Eurozone economies: share of Eurozone’s total GDP

(averages for the period 1995-2009, calculated in constant prices of 2001)

![Size of Eurozone economies: share of Eurozone's total GDP](image)

67% of Core 14% of Core 53% of Periphery 30% of Periphery 93% of Continental Europe

Core, 45% Periphery, 32% Continental Europe, 23%

**Figure 6.2:** The average sizes of the various Eurozone members as a percentage of the total value added produced in the Eurozone shows the dominance of Germany, Italy, Spain and France (Source: WIOD, author’s calculations)

### 6.1.1. Sector distribution in terms of total industry output

In this subsection we analyze the total industry output for Germany and the periphery (i.e. GIIPS) countries. The sector distribution for each of these six countries is shown in Figure 6.3. The total output of an industry captures both the intermediates as well as the final output produced by that industry for both domestic and foreign consumers. Hence, Figure 6.3 essentially visualizes the total output vector \( x^r_i \), where \( r \) denotes the particular country and where the original output values \( x^r_i \) produced by each producing sector \( i \) are summed together in order to obtain the aggregated industry output values.

It should be noted that throughout the analysis a carefully selected color-code will be maintained to easily differentiate between the thirteen aggregated industries. This code is

Figure 6.3: Total industry output $x^t$, aggregated to 13 high-level industries for Germany and the five peripheral countries, and covering the period 1995-2009. (Source: WIOD, author’s calculations)

shown below:

where the following abbreviations apply: PRIMARY = the primary industry, HT = high technology manufacturing industries, MHT = medium-high technology manufacturing industries, MLT = medium-low technology manufacturing industries, LT = low technology manufacturing industries, UTIL = utilities industry, CONSTR = construction industry, WRR = wholesale, retail and repair industries, HOTELS & RESTAU = hotels and restaurants industry, TRANSP & TRAV = transport and travel industries, ICT = post and telecom industries, FIRE = financial services, insurance services and real estate industry, PUBLIC SEC = public sector services.

Comparing the production structures depicted in the graphs of Figure 6.3, two important common observations quickly become apparent. Firstly, the primary sector (agriculture and mining) is negligible small in almost all six countries. Secondly, it seems like over the whole period the division between the secondary sector (manufacturing) and tertiary sector (services) has been roughly 30% vs. 70% on average. Greece’s division has been somewhat
stronger (roughly 20% vs. 80%), while the ratio between manufacturing and services for Germany and Ireland has been a little more balanced (roughly 40% vs. 60% and 45% vs. 55% respectively).

With respect to the core-periphery dualism, several important differences between these two regions become apparent. Firstly, Germany’s share of high technology and medium-high technology manufacturing industries has always been much higher compared to the GIPS countries (Ireland is the one important exception). Secondly, nearly every periphery country’s manufacturing sector (Ireland again being the one exception) is dominated by low tech and medium-low tech industries, bearing at least 50% of the total manufacturing output in each of these countries. Compare this to Germany, whose share of manufacturing output originating from high technology and medium-high technology industries has always stayed significantly above 50%. To summarize, it seems like the core has always been more specialized in high technology and medium-high technology industries compared to the periphery. Thirdly, Ireland is the only periphery country whose production structure shows a strong difference with the other peripheral countries: it’s share of high-technology manufacturing output accounts for more than half of the total manufacturing industry and has significantly increased in the decade following the introduction of the Euro. Its specialization in high technology industries strongly exceeds that of Germany. As a related observation, it should be noticed that Ireland’s medium-high tech industry is relatively small and far below average compared to the other countries. Fourthly, in each of the peripheral countries the construction industry is much more prevalent in comparison to Germany’s construction sector. This is especially true for Spain and Portugal. Interestingly, Spain and Ireland have experienced a significant increase in the real output of their construction industry in the years following the introduction of the Euro. Fifthly, Italy, Greece (and Portugal to a lesser extent) have a stronger wholesale, retail and repair sector compared to Germany. Finally, over the observed period the FIRE (Finance, Insurance and Real Estate) industry gained significant importance in especially Italy, Ireland, Portugal and Spain. For Germany the FIRE industry seems to always have been an important service industry whose size has remained roughly stable over the whole period. Interestingly, most of the FIRE industry’s growth in these peripheral countries occurred in the years following the introduction of the Euro.

The previous analysis suggests that there seems to exist a productive asymmetry between Germany, specializing in high and medium-high technology manufacturing, and the periphery countries (except for Ireland), specializing in lower technology manufacturing and several non-traded industries including mainly construction and wholesale, retail and repair services. In order to deepen our understanding about this potential asymmetry we now introduce a variation on the Balassa index to analyze each country’s comparative advantage in terms of industry output.

The revealed comparative advantage (RCA) index is defined as a country’s advantage or disadvantage in a certain industry or class of products. The traditional way of measuring this index is by analyzing and comparing industry gross exports proportions of a country to the equivalent world exports proportions. The traditional index is commonly referred to as the Balassa index, after its inventor Béla Balassa (Balassa, 1965). Instead of analyzing a country’s exports one could perfectly adapt the RCA formula to use total production values instead of gross exports values, as is done in this section. To be more concrete, the following formula calculates a country’s global revealed comparative advantage in terms of total
production for industry $i$ of country $r$ in year $t$:

$$\text{RCA}_\text{prod}^i_r(t) = \frac{x^i_r / \sum_{r=1}^k x^i_r}{\sum_{r=1}^k x^i_r / \sum_{i=1}^n \sum_{r=1}^k x^i_r} = \frac{x^i_r / (x^r)}{\sum_i x^i_r / (x^r)}$$

(6.1)

where we defined $x_i = \sum_{r=1}^k x^i_r$, $i'$ denotes the standard summation vector of appropriate size (a row-vector), and all vectors contain data from the world input-output table from year $t$. As can be derived from the equation, our RCA index for year $t$ first calculates the proportion of total output produced by industry $i$ of country $r$ in that year and then divides this value by the associated proportion of world total output for that type of industry. It is said that a comparative advantage for industry $i$ is revealed if $\text{RCA}_\text{prod}^i_r(t) > 1$. Otherwise, the country has a comparative disadvantage in that industry. Figure 6.4 shows the resulting RCA values of the thirteen high-level industries for Germany and the five peripheral countries over the period 1995 to 2009. We will now discuss the main observations for each of these six countries.

Inspecting Germany’s RCA graph it becomes immediately clear that the country has a strong comparative advantage in its medium-high technology manufacturing industries and that it retains this advantage in the whole period after the introduction of the Euro (at least as far as the most recent data of 2009 can show us). It has had a strong disadvantage in primarily its primary sector, as well as in its wholesale, retail and repair, and construction sectors to a lesser extent. Remarkable as well is the gradual but significant decrease in its construction sector in the first five years after the introduction of the Euro. A final observation is that the remainder of industries are all relatively strongly concentrated around the value 1 (all between 0.8 and 1.2), which indicates that Germany doesn’t have a strong advantage nor disadvantage in these industries.

The RC graph of Greece presents a significant different image for this country in comparison to Germany. It shows that Greece has a strong comparative advantage in the hotels and restaurants sectors. This result illustrates the relative importance of the tourism industry for this country. Equally striking is the significant disadvantage in the high technology and medium-high technology industries as well as the FIRE industry. Also noticeable is that the RCA patterns for the Greece’s various industries are much more volatile and less concentrated in comparison to Germany. In the years after the introduction of the Euro several industries gain significant comparative advantage. Both the transport and travel sectors as well as the wholesale, retail and repair sector rise a good deal during this period, while the construction sector maintains a strong advantage over the whole period until the outset of the financial crisis. Simultaneously the country deepened its comparative disadvantage in the high technology and FIRE industry in the years following the unification.

The graph of Italy shows that the country does not excel in one particular industry in contrast to what we learned for Germany and Greece. Most sectors do not have a significant comparative advantage or disadvantage, except for the primary sector which has been fluctuating around 0.4 throughout the whole period. The graph also shows that Italy has smaller comparative advantages in the medium-low technology manufacturing, low technology manufacturing, transport and travel, and hotels and restaurants industries, which all fluctuate around values between 1.2 and 1.4 over the whole period. After the monetary unification not so much chained in Italy’s revealed comparative advantage figures, apart for two important exceptions: both Italy’s high technology and medium-high technology manufacturing industries gradually but significantly deteriorated during the decade after the unification.
the high technology manufacturing industry created a strong comparative disadvantage over this period.

At first sight one would be tempted to say that the graph of Ireland presents a distinct story compared to the other four peripheral countries. This is true for one observation: the graph shows a strong comparative advantage in its high technology manufacturing industry, whereas nearly all the other peripheral countries have a strong disadvantage in this industry. Remarkable however – and this is in line with every other peripheral country – is the significant decline in this industry in the years following the introduction of the Euro. Furthermore, Ireland demonstrates a relatively strong comparative advantage in its low technology manufacturing and construction industries which is also in line with most of the other peripheral countries. Also worth mentioning is the observation that the majority of Ireland’s industries
exhibit relatively strong comparative disadvantages throughout the whole period, indicating that the country’s sector distribution is strongly concentrated in a relatively small set of dominant industries, which matches our observations made earlier in this section.

Portugal reveals relatively strong comparative advantages in its low-technology manufacturing, construction, hotels and restaurants, and utilities sector. Its strongest comparative disadvantages are located in the high technology and medium-high technology manufacturing industries. After the monetary unification a large deterioration of Portugal’s high technology manufacturing industries takes place, combined with small but noticeable decreases in the construction and hotels and restaurants industries (even though these industries retain a comparative advantage). Simultaneously, significant increases occur after the unification in the utilities, ICT and transport and travel industries. Especially the utilities and ICT industries acquire a comparative advantage over this period.

Spain, finally demonstrates strong comparative advantage in the construction and hotels and restaurants industries. It furthermore has weaker comparative advantages in the low technology manufacturing, medium-low manufacturing and transport and travel industries. After the introduction of the Euro significant decreases in its high technology manufacturing and medium high technology manufacturing industries is noticeable, accompanied by a strong increase in the comparative advantage of its construction industry.

The analysis above confirms the earlier presumption about a potential productive asymmetry between Germany and peripheral countries. It strengthens the hypothesis that the higher technology manufacturing sectors in the peripheral countries have been loosing out strongly in comparison to Germany (the strongest performer in the Eurozone’s core).

6.1.2. Sector distribution in terms of value added created

This section continues the analysis from the previous section but now focuses on the amount of domestic value added created by each industry in a particular country (i.e. the income or gross domestic product by industry), instead of the industry’s gross output (i.e. the total intermediate and final goods and services produced by the industry). The value added created by an industry represents all the factor-payments made by the industry to all the domestic non-industrial suppliers, such as holders of capital, employees who are compensated for their supplied labour, etc. The difference between the gross output and value added produced by any industry fully reflects the costs of all the industry’s intermediate inputs. This includes the costs of raw materials, energy, semi-finished goods, etc. Formally this value added indicator was defined previously in the research methodology chapter by the following formula:

\[ \mathbf{v}^{r'} = \mathbf{x}^{r'} - \sum_{s=1}^{s=k} \mathbf{i}^{s'} \mathbf{z}^{s,r} \]  \hspace{1cm} (6.2)

One would expect that the distribution patterns in value added shows similar results in comparison to the gross output produced by each industry. The aim of this section is to determine if this is indeed the case and to identify the major dissimilarities.

Figure 6.5 shows the total amount of domestic value added created in each industry for Germany and the five peripheral countries over the period 1995-2009. The value added graphs in many ways look indeed very similar to the total industry output graphs discussed earlier. Hence, these graphs largely reinforce the results and conclusions about the main characteristics, specialization patterns and productive asymmetry characterizing the core and peripheral countries (as were extensively discussed in the previous section).
Despite the many similarities between the total output graphs and the value added equivalents, there are still several important differences that can be observed and are worth noting. Firstly, the FIRE sector and public sector both gain significant importance in size when measuring their size in terms of the share of domestic value added contributed by these sectors (instead of looking at the shares of total output as we did previously). Secondly, for all countries the service sectors become more important in size when measuring their share of value added created instead of their share of total industry output produced. This increase (logically) goes at the expense of relatively smaller manufacturing industries. Nevertheless, for most countries the relative decrease in size of the manufacturing industry (i.e. from measurement in total output terms to measurement in value added terms) is roughly uniformly spread over the four technologically categorized sub-industries. Hence, analyzing the specialization patterns in the manufacturing sector provides the same conclusions in both total output and value added graphs. Finally, it should be noted that the boom of Spain’s construction sector after the introduction of the Euro that we observed earlier by inspection of the industry’s total output is not strongly confirmed by the value added graphs: the amount of value added created by the construction sector has remained roughly the same throughout the entire period.

Figure 6.5: Total domestically created value added $V^*$, aggregated to 13 high-level industries for Germany and the five peripheral countries, and covering the period 1995-2009. (Source: WIOD, author’s calculations)
6.2. Evolution in trade structures

We now turn our attention to the analysis of the various trade structures of the core and peripheral countries. In summary, we will provide a detailed decomposition of the various export structures, analyze the dependence on exports and imports, and decompose the trade balances both by contributing sectors and partner countries. The overall aim of this section is to determine if the observed increases divergence in the Eurozone industry structures also shows up in a growing asymmetry in trade specializations as would be expected because trade specializations and domestic industrial structures often tend to mutually reinforce each other (Storm and Naastepad, 2014a, p. 13).

Before we start formally analyzing the trade structures of the Eurozone countries, we first explain the important difference of measuring trade in **gross terms** versus **value added terms**. Measuring trade in gross terms is the traditional way of measuring trade between countries. Basically, a gross trade flow from A to B measures how much intermediate and final products flow directly from A to B. The problem with measuring trade in gross term is the double counting that occurs because of the trade in intermediate goods potentially crossing borders multiple times. A trade flow in value added from A to B, on the other hand, measures the value added that is created in A because of buying activities of final demand consumers in B. This includes all the value added created by the indirect effects, multipliers and trade linkages with third countries (which is discusses in more detail in the research methodology chapter). Put differently, it captures the value added from A ‘absorbed’ by B. Hence, value added exports from A to B essentially correspond to the domestic value added created in A that is embodied in foreign final demand originating from B, while similarly value added imports correspond to the foreign value added embodied in domestic final demand. Measuring trade in value added in this way recognizes that goods and services are often created using inputs from various countries and that industries are therefore part of so-called ‘global value chains’. The measure essentially aims at capturing the true value added created by an industry within a country and providing a clearer picture on the country-to-country relationships established by these global value chains.

6.2.1. Exports: general evolution

This section analyzes the exports evolution of the Eurozone countries. We start the analysis with inspecting the dependence on exports in both gross and value added terms. Thereafter, we analyze the exports structures by performing a sector decomposition in value added terms.

**Exports dependence**

Exports dependence is traditionally measured as the share of gross exports in GDP. Since the WIOD database provides us the opportunity to analyze trade in both gross and value added terms, we decided to calculate the exports dependence of selected Eurozone countries in both terms. The top two graphs in Figure 6.6 show the exports dependence in both terms for Germany, the five peripheral countries, and France. The bottom two graphs show averages for the three main Eurozone regions as a whole again in both gross and value added terms.

On a country-level the first thing that immediately catches the eye is Ireland’s strong above-average dependence on exports. In gross terms the indicator’s value gradually rose from 70% in the middle 1990’s to over 110% of its GDP in 2009. It should be noted that in gross terms the exports dependence indicator can indeed reach values above 100%.
see this, remember that GDP is essentially defined as the sum of four main components, including net exports \((E-M)\). The only way exports \(E\) can exceed GDP is when imports \(M\) are large enough. Often the main reason why exports exceed GDP is because of an increase in re-exporting activities (Akyz, 2011). Secondly, Germany is clearly more dependent on exports compared to any of the peripheral countries as well as to France. Thirdly, Greece is the least dependent on exports, fluctuating around a mere 10% of GDP in value added terms over the whole period. Fourthly, nearly every country’s dependence on exports has gradually risen over the period. Germany and Greece’s dependence has increased the most – both by around 15% in value added terms over the complete period – while the peripheral countries and France all gradually increased their dependence by only 5 to 10%. Furthermore, the gap between Germany’s and the periphery’s dependence on exports has significantly increased (in fact, nearly doubled) in the years following the monetary unification: roughly from 10% in 2001 to 20% in 2007 in gross terms, and from 5% to 10% in value added terms.

The average export dependence values calculated for the three main Eurozone regions confirm the country-level analysis and show a clear distinction between core and peripheral countries. Both in gross and value added terms we observe that the periphery is significantly less dependent on exports in comparison to the core and continental European countries. This trade asymmetry becomes even stronger when excluding Ireland from the periphery region and only focusing on the GIPS countries for a moment. This is indicated by the dotted orange line in Figure 6.6. As can be seen in the bottom-left graph the core and continental European countries are almost completely equally dependent on exports in value added terms on average, whereas the average of the GIPS countries indicates that in each year the peripheral countries (excluding Ireland) are roughly 18% less dependent on exports in terms

Exports sector decomposition

Figures 6.7 and 6.8 show the sector decomposition of the exports structure from Germany and the five peripheral countries in terms of gross exports and value added exports respectively. Comparing the Figures several global, country-wide differences between the graphs in gross terms and the graphs in value added terms can be distinguished.

Firstly, the exports of the service industries become relatively much more significant when measured in value added terms. To understand why this is generally the case we have to go back to the definitions of gross and value added trade. Remember that the value added exports of any industry in a country to any other foreign country measures how much domestic value added is created by that industry due to all the buying activities by the foreign final consumers of that foreign country. Because relatively few output from the services sector can be properly traded and hence exported to other countries, the traditional gross exports values consequently indicate that services only account for a relatively small portion of each country’s total gross exports. The growth in significance when measured in value added terms hence largely boils down to the nature of the value added trade indicators which not just simply capture real traditional trade between two parties but instead focuses on the value added that is created (or triggered if you like) by a particular group of final demand purchasers.

Secondly, the trends (i.e. increases and decreases) in the total exports values remain as good as the same when comparing gross and value added terms (even though the scales are different of course). Thirdly, the relative importance of the four technology groups within the manufacturing industry remains reasonably the same when comparing gross and value added terms. Hence, analyzing the specialization patterns that have occurred within the manufacturing industry should give approximately the same results when using gross exports data or value added exports data. Finally, in Greece, Italy and Portugal the primary sector gets somewhat more importance in value added terms compared to the gross terms graphs. We now turn our attention to inspecting the export structure characteristics for each of the individual countries.

Germany’s concentration in medium high technology and high technology manufacturing exports was already high in the middle of the 1990’s, and its exports became even more concentrated in these two segments between 2003 and 2007 – roughly the period between the monetary unification and the onset of the financial crisis – reaching coverage levels of around 2/3 of the total manufacturing industry. Its exports of services (particularly in gross terms) accounts for a much smaller part of its total exports compared to all the peripheral countries. Furthermore, Germany’s specialization in low technology manufacturing exports has always been significantly smaller compared to the low technology exports shares of any of the peripheral countries.

Greece shows a vastly different export structure compared to Germany. What is immediately striking about Greece’s exports graphs is that the services sectors are responsible for a large majority of the country’s total exports, and that by far the largest contributing sector to the country’s overall growth in exports is also the services sector. After the introduction of the Euro, the manufacturing sector barely grew in real terms, while the service industry experienced an enormous boom that nearly doubled its total exports between the year 2000
6.2. Evolution in trade structures

Figure 6.7: Export structure in gross terms absolute values for Germany and the five peripheral countries, covering the period 1995-2009. (Source: WIOD, author’s calculations)

and 2007 (both in gross and value added terms). Greece’s low share of manufacturing exports and severe dependence on services exports even outperforms any of the other peripheral countries by far. Inspecting its relatively small manufacturing exports Greece shows a strong specialization in low technology and medium low technology manufacturing exports.

Italy’s manufacturing industry dominates its exports, similarly to the case of Germany. Its manufacturing industry is fairly heterogeneous and equally distributed (especially in value added terms). Furthermore, its export structure shows no significant changing patterns: the proportions of its exports accounted for by each industry have remained stable over the whole period. Compared to Germany, Italy shows only one but important difference in its export structure: its share of low technology manufacturing has always been significantly higher: around 40% of its total manufacturing exports, versus around 1/6th on average for Germany.

As expected from the analysis of its industry structure, Ireland is a strong exporter of high technology goods while its exports of medium-low and medium-high technology goods are almost negligible. In the years following the introduction of the Euro Ireland has experienced a strong increase in the exports of its low technology manufacturing and services industries. Nearly all the extra growth in the real value of its overall exports experienced in the years after 2000 (both gross and value added) are attributable to growth in its low technology and services exports.

Figure 6.8: Export structure in value added terms absolute values for Germany and the five peripheral countries, covering the period 1995-2009. (Source: WIOD, author’s calculations)

Portugal’s services and manufacturing exports each account for roughly 50% of its total exports over the complete period. Inspecting its manufacturing exports Greece shows a strong specialization in low technology manufacturing exports which it maintains throughout the complete period, while its high technology share of exports is significantly below that of Germany. The only noticeable change after the monetary unification is the gradual increase in its medium-low technology exports.

Spain’s exports picture, finally, reveals an interesting difference between its gross exports and value added exports structure. If one would solely analyze Spain’s gross exports then it would be tempting to conclude that Spain’s export structure fairly matches with that of Germany: its share of services exports only constitute a small part of its total exports and its manufacturing exports are relatively dominated by the medium-high and high technology manufacturing industries. Switching to the value added exports graph, however, reveals a rather different story. Whereas the German value added exports structure confirms Germany’s dominance in high technology and medium-high technology exports, Spain’s value added exports structure reveals that in value added terms its high technology exports become much less important and instead its primary sector gains significance size.
Revealed comparative advantages in terms of value added exports

In line with what we did when analyzing the production structures of the Eurozone countries, we now focus on analyzing each country’s revealed comparative advantage in terms of value added exports. This indicator is again a variation on the classical Balassa index to measure revealed comparative advantages. This time the difference lies in the measurement of exports: whereas the traditional index analyzes and compares industry gross exports proportions of a country to the equivalent world exports proportions, this variation uses value added export values instead of the gross export values. To be more concrete, the following formula calculates a country’s global revealed comparative advantage in terms of value added exports for industry \(i\) of country \(r\) in year \(t\):

\[
RCA_{VAexp}^r(t) = \frac{\frac{e_i^r}{\sum_{r=1}^n e_i^r}}{\frac{\sum_{i=1}^k e_i^r x_i^r}{\sum_{i=1}^k e_i^r}} = \frac{e_i^r / (Ve^r)}{e_i / (Ve)} \tag{6.3}
\]

where we defined \(e_i = \sum_{r=1}^n e_i^r\), \(Ve\) denotes the standard summation vector of appropriate size (a row-vector), and all vectors contain data from the world input-output table from year \(t\). As can be derived from the equation, the RCA index for year \(t\) first calculates the proportion of overall value added exported by industry \(i\) of country \(r\) in that year and then divides this value by the associated proportion of world value added exports for that type of industry. Similar to the previous variation, it is said that a comparative advantage for industry \(i\) is revealed if \(RCA_{VAexp}^r(t) > 1\). Otherwise, the country has a comparative disadvantage in that industry. Figure 6.9 shows the resulting RCA values of the thirteen high-level industries for Germany and the five peripheral countries over the period 1995 to 2009.

It should be noted that if we would have calculated the RCA index in terms of gross exports it would not be of much importance to calculate the comparative advantage of the construction, public services, utilities and hotels and restaurants industries because these industries are usually considered to be producing ‘non-tradables’. However, since we are calculating the comparative advantages in terms of value added exports with its associated underlying meaning of value added creation (refer to the discussion earlier in this section), the author believes it does make sense to include these industries into the analysis. We will now discuss the main observations for each of these six countries.

Germany has a strong comparative advantage in terms of value added exports in mainly the medium-high technology manufacturing industry. It used to also have a relatively strong comparative advantage in its high technology manufacturing industry, but this position has gradually deteriorated over the period.

Greece’s RCA graph is characterized by a lot of volatility. Its transport, construction ICT and WRR sectors have experienced strong comparative advantages over the whole period, although it must be mentioned that these industries experienced strong fluctuations in their comparative advantages. Conversely, the countries’ high technology and medium-high technology sectors are characterized by strong comparative disadvantages over the complete period. In the years following the introduction of the Euro, sharp increases can be noticed in the construction, WRR, government, utilities and hotels and restaurants industries. Lastly, a gradual but strong and long-term decrease occurs in the RCA index for the low technology industry turning a small comparative advantage in a significant comparative disadvantage.
Italy exhibits the strongest comparative advantages in its construction, medium-low technology and low technology industries. The RCA values of these last two industries have remained stable over the whole period, whereas the comparative advantage of the construction sector has experienced an immense increase in the years following the monetary unification. Simultaneously, its low technology manufacturing sector has been rising strongly after the unification, creating a large comparative disadvantage in this industry. Finally a sharp long-term increase in the comparative advantage of the ICT sector can be observed.

Ireland’s graph is also characterized by significant volatility. The country has a strong comparative advantage in terms of value added exports in the high technology manufacturing, hotels and restaurants, FIRE and low technology manufacturing industries. As expected the

**Figure 6.9:** Global revealed comparative advantage in terms of value added exports RCA_{VAexp}^{r}, of the 13 high-level industries for Germany and the five peripheral countries, and covering the period 1995-2009. (Source: WIOD, author’s calculations)
graph also reveals strong comparative disadvantages in both the medium-high and medium low technology manufacturing industries. In the years following the introduction of the Euro most of the important changes in trends occur: the country experiences a strong decline in the RCA of its high technology manufacturing industry and ICT industry, while it simultaneously experiences a strong increase in th RCA of its low technology manufacturing industry.

In line with most of the other peripheral trends, Portugal exhibits a strong comparative disadvantage in its high technology industry, whereas its low technology industry has a strong comparative disadvantage. The years following the monetary unification show a strong decrease in the RCA values of the high technology and hotels and restaurants industries, while they also show a significant increase in the medium-low technology, construction, transport and travel, and ICT industries.

Spain’s RCA values of its various industries are much more stable and densely concentrated compared to the other peripheral countries. The most important observations from its graph are completely in line with the previous analyses: it demonstrates a strong comparative advantage in mainly the construction sector and medium-low technology industry, whereas it created a strong comparative disadvantage in its high technology industry in the years following the Euro introduction.

6.2.2. Imports: general evolution

This section briefly analyzes the import structure of the various Eurozone countries. It only focuses on the import dependence and does not decompose the countries’ gross or value added imports nor does it compare any RCA index. The main reason why imports are only analyzed briefly and on only a single dimension is because the section hereafter decomposes the trade balance in a very detailed manner. The combination of the results from that section with the conclusions from the exports analysis essentially covers all the important aspects of the countries’ trade structure and would make a separate imports analysis largely redundant.

Imports: general evolution

Figure 6.10 shows the dependence on imports as a % of GDP for selected Eurozone countries and regions. The top two graphs in Figure 6.10 show the imports dependence in both terms for Germany, the five peripheral countries, and France. The bottom two graphs show averages for the three main Eurozone regions as a whole again in both gross and value added terms.

Several observations can be made. Firstly, in gross terms Ireland is has always been far more dependent in imports compared to any other of the countries being analyzed. Its gross imports dependence grew significantly from around 50% in 1995 to nearly 100% of GDP in 2008. Remarkable however, is that Ireland’s strong dependence on imports is only weakly reflected when inspecting its dependence in terms of value added imports. Ireland still scores among the highest of all countries, but there is much less of an excessive gap between this country and the other countries in the graph. Secondly, in value added terms Germany, Italy and France all are among the countries which are least dependent in imports. Thirdly, in the years after the monetary unification an increase in the value added imports dependence of Spain and Ireland can be observed. Fourthly, the region averages show that the dependence on imports has been gradually increasing for every Eurozone region at a similar pace (both in gross and value added terms). Furthermore the averages show that the core and periphery

Figure 6.10: Imports dependence as % of GDP in gross and value added terms for Germany and the five peripheral countries as well as the three main Eurozone regions, covering the period 1995-2009. (Source: WIOD, author’s calculations)

have been more or less equally dependent on imports over the entire period, whereas the continental European region has been much more dependent on imports.

6.2.3. Trade balances: overall evolution

This section analyzes the various overall trade balances of the Eurozone countries. As was mentioned in the literature review and the discussion of the theoretical conceptual model, diverging trends in trade balances between the core and periphery occurred in the years following the monetary unification. The core countries were building up large trade surpluses on their overall trade balance, while the peripheral countries were building up large trade deficits on their overall trade balance. This evolution is a general accepted fact, but one that is often shown in nominal terms – i.e. without correction for inflation. Also in real terms this trend can be clearly observed as illustrated by figures 6.11 and 6.12. Figure 6.11 shows the overall trade balances for a selected set of Eurozone countries in absolute values expressed in constant prices of the year 2001 – in other words: in real terms, corrected for inflation. Figure 6.12 expresses these same balances in terms of averages for each of the three main regions. These two graphs clearly confirm the overall current account imbalance problems experienced within the Eurozone between the core and peripheral countries.
6.2. Evolution in trade structures

6.2.4. Trade balances: contribution of exports and imports

This section aims at determining how much the value added exports and imports influence the year-on-year changes in the trade balance of each Eurozone country. Figure 6.13 shows the graphs used for this analysis. Each gray bar in every graph denotes the absolute (in real
terms) change in the country’s overall trade balance with all its foreign trade partners from one year to the next. The red and blue stacked bars on the right of each gray bar show how value added exports and imports respectively contributed to this total change in the trade balance.

**Figure 6.13:** Relative contribution of exports and imports to the year-on-year changes of trade balances of Germany and the five peripheral countries, covering the period 1995-2009. (Source: WIOD, author’s calculations)

As expected, Germany shows nearly uninterrupted significant positive changes in its trade balance from one year to the next. It quickly becomes clear that these changes are for the largest part due to Germany’s growing value added exports. Its imports also change throughout most of the years, but by much smaller amounts. Especially in the years following the introduction of the Euro (particularly 2003 - 2007), Germany’s year-on-year increase in its overall trade balance with the rest of the world was mostly the result of its significant year-on-year real growth of its value added exports.

Greece is showing a radical different picture on this indicator in comparison to Germany. As expected, throughout the majority of the years Greece’s overall trade balance changes negatively from one year to the next. As the graph clearly shows, these negative changes in the country’s overall trade balance are for the largest part due to continuous strong year-on-year growth in its value added imports throughout the complete period. Hence, Greece’s deterioration of its trade balance is not so much caused by a decrease in its exports – real
term exports values even gradually rose during the majority of the years – but instead it is mainly caused by a significant increase in its imports.

The graphs of Italy, Spain, and Portugal strongly resemble the picture of Greece. In both these three countries the overall trade balance with the rest of the world seriously deteriorates from year to year during most of the period – or at best only slightly increases or does not change as occasionally happens in Portugal – and this decline is mostly due to continuous strong year-on-year growth in their imports. Their exports do, fortunately, barely decline and even slightly rise during the majority of the years. However, unfortunately these increases are simply entirely wiped out and outpaced by much stronger import growth performances. Especially in the years following the Euro introduction (particularly 2001 - 2006 for these two countries) do the value added imports of these countries rise significantly.

Ireland is (again) the single little outsider of the periphery region on this indicator. Similarly to most of the other four peripheral countries, Ireland’s value added imports significantly rise during the years following the introduction of the Euro. However, in contrast to its peripheral partners Ireland’s exports also grow significantly throughout that period at roughly the same size as its imports. As a result, its changes in its overall trade balance with the rest of the world remain very small with values fluctuating consistently around zero over that period.

A finale observation worth mentioning, is the clear and strong impact of the financial crisis on the trade balances of the various peripheral countries. All six graphs in Figure 6.13 show a strong reversal in the year-on-year changes of imports and exports for the year 2008. In nearly all countries the exports values deteriorate significantly over that year, while the imports of each of these countries receive an enormous boost.

### 6.2.5. Trade balances: contribution by trade partners

This section investigates the decomposition of the overall trade balances of Germany and the five peripheral countries by the contributions made to these balances by the main world-wide trading blocks in real terms and over the period 1995-2009, which is presented by Figure 6.14. In line with the previous sections of this chapter the analysis is based on trade in value added terms. Before discussing the results presented by Figure 6.14, we first briefly described how the graphs in this figure have been constructed and how they should be interpreted.

Each of the graphs shown in Figure 6.14 basically shows the bilateral trade balances of the country under investigation with each of the main global trading blocks over the period 1995-2008, together with the resulting overall trade balance of that country. Remember that a country’s bilateral trade balance with one of its trade partners is simply defined as the difference between the country’s exports destined to that trading partner and the country’s imports originating from that trading partner. Since we are measuring all trade in value added terms, the exports, imports and the resulting bilateral trade balances are all expressed in value added terms. Hence, the bilateral trade balances presented in Figure 6.14 show the net trade benefits (or losses) a country receives from doing trade with each of its trading partners. Because a bilateral trade surplus/deficit essentially implies that the foreign trading partner helps creating the associated benefits/losses, we decided to use the term trade balance ‘contribution’ to refer to these balances. In line with the mathematics introduced in our research methodology chapter, the following formula provides the equation
used to calculate the bilateral trade contribution shown in Figure 6.14:

\[
L^{r,s}_{v_0} = v^{r,s} - v^{s,r}
\]

\[
= \sum_{q=1}^{q=k} m^{r,q}_{v} q^{r,s} - \sum_{q=1}^{q=k} m^{s,q}_{v} q^{s,r}
\]

\[
= \sum_{q=1}^{q=k} v^{r} L^{r,q} q^{s} - \sum_{q=1}^{q=k} v^{s} L^{s,q} q^{r} (6.4)
\]

where we are relying on the key observation that the value added of country \( r \) activated by the final demand of a foreign country \( s \), defined by \( v^{r,s} \), can be interpreted as denoting the bilateral exports of value added from country \( r \) to country \( s \) or conversely the bilateral imports of value added from country \( r \) into country \( s \).

We can now start with investigating the trade balance graphs presented in Figure 6.14. We start with investigating Germany’s graph. For this graph (and only this graph) we decided to further decompose the periphery contribution into the individual contributions of the five peripheral members, in order to get a better and more detailed image of the trade relationships between Germany and the peripheral countries. Several observations can be made from this graph. Firstly, the graph clearly shows that Germany experienced a significant increase in
its trade balance surplus from mainly Spain, Italy, the non-Euro part of the EU, and the rest of the world region. The contribution of East Asia quickly rose around the introduction of the Euro and remained more or less stable thereafter. We can conclude that in the years following the Euro introduction the two most important peripheral countries, Spain and Italy, both significantly increased their bilateral trade deficit with Germany, creating an equally large bilateral trade surplus for Germany, and accounted for a substantial share of Germany’s overall trade balance surplus accumulation during that period. Secondly, since the mid-2000’s we can observe that Germany experienced rising bilateral trade deficits with both China and East Asia which substantially grew in size between 2004 and 2007. Nevertheless, these two trade deficits did not hamper the growth of Germany’s overall trade surplus over that period because these two setbacks were fully offset by an increase in the trade surpluses with the dominant surplus contributors that we listed above.

The graph of Greece shows that the country experienced trade deficits with virtually all its main trading partners throughout the whole period. The deterioration of Greece’s overall trade balance over the period is due primarily to a gradual increase in its bilateral trade deficits with the Eurozone core, China, NAFTA, and other peripheral countries. Furthermore, the graph shows that the Eurozone core is the most important contributor to Greece’s trade balance deficit, followed by the other peripheral countries, and East Asia. Summarized, we can conclude that Greece’s growth of its trade balance deficit in the years following the introduction of the Euro was primarily the result of an increase in the negative contribution of the Eurozone core and the growing trade deficit with China.

Spain’s graph reveals that the country’s strongest decline of its overall trade balance occurred in the period following the years of the Euro introduction, evolving from a small positive to a substantial negative balance. The graph shows that the Eurozone core region is by far the most dominant negative contributor to Spain’s trade deficit. In the years leading up to the monetary unification we observe that Spain experienced a quick and strong increase in its trade deficit with the Eurozone core region (practically its only substantial deficit in those years). In the years following the introduction we see that the county experiences a strong deterioration of its trade balance which is primarily caused by increasing trade deficits with the Eurozone core region, China and East Asia. The graph finally reveals that Spain experienced a small but stable trade surplus with the Eurozone periphery region and NAFTA over the whole period.

Ireland’s overall trade balance in real terms gradually increased in the years leading up to the Euro introduction and subsequently gradually declined again in the years following the Euro introduction, but it remained slightly positive over the whole period. The graph reveals that Ireland has positive bilateral trade balances with most of its trading partners and that the contributions of the three Eurozone regions remained very stable over the whole period. The deterioration of its trade balance after the monetary unification was mostly due to a strong increase in its trade deficit with the non-Euro countries of the EU (further investigation revealed that the UK is the most dominant negative contributor among the members of this group, which makes great sense as it is Ireland’s direct neighbor). A significant amount of this growing trade deficit was offset by a growing trade surplus between Ireland and the rest of the world region, which explains why the country’s overall trade balance only declined gradually and remained positive.

The graph of Portugal reveals that the country experienced a trade deficit with virtually each of its main trading partners over the whole period. Furthermore, the graph also reveals
that the Eurozone core and other peripheral countries are responsible for more than half of Portugal’s total trade deficit. Further investigation reveals that the strong link with the rest of the periphery is largely explained by Portugal’s strong dependence on Spain. The short improvement of Portugal’s trade balance in the period 2001-2003 was almost entirely due to a decrease in its bilateral trade deficit with the other Eurozone periphery regions. Remarkable is that the increase in Portugal’s trade deficit in the years following 2003 is almost exclusively due to an increase in the bilateral trade deficit between Portugal and the Eurozone core region. A small growth in the trade deficit with East Asia and China explain the remainder of Portugal’s trade balance deterioration.

Finally, Spain’s graph shows that the country experienced a trade deficit with virtually each of its main trading partners over the whole period. Furthermore, the graph shows that after the years following the monetary unification, Spain’s overall trade deficit substantially increased and that this was mainly caused by growing bilateral trade deficits with the Eurozone core, NAFTA, China, and East Asia. Again, similar to the graphs of the other GIPS countries, the Eurozone core is one of the most dominant negative contributors to Spain’s overall trade balance. Also striking is the observation that throughout the whole period Spain has had a more or less zero bilateral trade balance with the rest of the Eurozone periphery region.

6.2.6. Trade balances: contribution by sector

Whereas in the previous section we analyzed the decomposition of the overall trade balances of Germany and the five peripheral countries by the contributions made to these balances by the main trading regions in the world, this section is aimed at analyzing how each of the main industry categories contributes to the overall trade balances of these six countries. In other words, this section investigates which sectors dominated the trade balances of Germany and the peripheral countries, and how these contributions changed over the period 1995 - 2009. The goal is to provide insights about the degree of concentration of the value added bilateral trade balances towards one or several industries and the evolution of this pattern over time. Before discussing the results presented by Figure 6.15, we first briefly describe how the graphs in this figure have been constructed and how they should be interpreted.

Each of the graphs shown in Figure 6.15 basically shows the bilateral trade balances of the country under investigation decomposed by the contribution made by each of its main industries to the overall trade balance over the period 1995-2009 and measured in value added trade terms. Hence, the bilateral trade balances presented in Figure 6.15 essentially show the net trade benefits (or losses) that are the result of the foreign trade flows generated by each industry category of a particular country. In line with the mathematics introduced in our research methodology chapter, the following formula provides the equation used to calculate the industry contributions to a country’s overall gross trade balance as shown in Figure 6.15:

\[
\mathbf{b}_{v,s}^{r} = \mathbf{v}^{r} - \mathbf{v}^{s,r} = \sum_{s \neq r} \sum_{q=1}^{k} M_{v}^{r,q}F_{v}^{q,s} - \sum_{s \neq r} \sum_{q=1}^{k} M_{v}^{s,q}F_{v}^{q,r} = \sum_{s \neq r} \sum_{q=1}^{k} \mathbf{\hat{v}}_{v}^{r}L_{v}^{r,q}F_{v}^{q,s} - \sum_{s \neq r} \sum_{q=1}^{k} \mathbf{\hat{v}}_{v}^{s}L_{v}^{s,q}F_{v}^{q,r}
\] (6.5)
6.2. Evolution in trade structures

where \(\mathbf{v}^{r,t}\) represents country \(r\)'s overall value added exports to the rest of the world, and \(\mathbf{v}^{r,t}\) represents country \(r\)'s overall value added imports from the rest of the world. The elements of the resulting vector \(\mathbf{b}^{r}_{\alpha}\) capture country \(r\)'s overall trade balance on an industry level for each major industry category expressed in value added trade terms. In order to better be able to compare the results of the various countries in Figure 6.15 we normalized the overall trade balances and their contributions by dividing all values by the GDP of the country under investigation for the corresponding year.

\[
\text{Trade balance (VA terms), as \% of GDP, } \\
\text{Germany, 1995-2009} \\
\text{(calculated in constant prices of 2001)}
\]

\[
\text{Trade balance (VA terms), as \% of GDP, } \\
\text{Greece, 1995-2009} \\
\text{(calculated in constant prices of 2001)}
\]

\[
\text{Trade balance (VA terms), as \% of GDP, } \\
\text{Ireland, 1995-2009} \\
\text{(calculated in constant prices of 2001)}
\]

\[
\text{Trade balance (VA terms), as \% of GDP, } \\
\text{Portugal, 1995-2009} \\
\text{(calculated in constant prices of 2001)}
\]

\[
\text{Trade balance (VA terms), as \% of GDP, } \\
\text{Spain, 1995-2009} \\
\text{(calculated in constant prices of 2001)}
\]

**Figure 6.15:** Trade balance contribution in value added terms to the overall trade balances of Germany and the GIIPS countries by each of the various sectors, expressed as a percentage of the countries’ GDP and covering the period 1995-2009. *(Source: WIOD, author’s calculations)*

We can now start with investigating the trade balance graphs presented in Figure 6.15. We start with investigating Germany’s graph. This graph reveals that the gradual increase of Germany’s overall trade balance mainly occurred because of increases in the net value added exports of its medium-high tech and services industries. Especially for the years following the introduction of the Euro do we observe that Germany’s overall trade surplus of its medium-high tech and services industry categories significantly increase as a percentage of its GDP, while the percentages of the other industries remain more or less constant over this period.

The graph of Greece shows that all of its industry categories significantly negatively contribute Greece’s trade balance, with total negative percentage values which largely exceed
those experienced by any of its other peripheral partners as we will see further on (apart from Ireland). Furthermore, the graph reveals that the deterioration of Greece’s overall trade balance after the monetary unification is mainly the result of an increase in the overall trade deficits in its high tech and low-tech manufacturing industries.

Italy’s graph reveals several important observations. Firstly, the country’s overall trade deficit that it developed during the years following the Euro introduction is much smaller when expressed as percentages of its GDP. Secondly, the decline its overall trade balance after the Euro introduction is mainly the result of a gradual increase in the overall trade deficit of its high tech industry category, and a simultaneous gradual decrease in the overall trade surplus of its low-tech industry category. Finally, whereas in the years leading up to the monetary unification Italy exhibited a small overall trade surplus in its services industry category, after the unification this surplus vanished entirely and was reduced to a zero balance which remained so during any of the subsequent years.

Ireland’s case shows a result which could be expected from what we learned previously about this country’s production and export structure: Ireland’s trade balance is strongly dominated by a substantial trade surplus in its high tech industry category, which fluctuates between 10% and 15% of the country’s total GDP over the entire period. Furthermore, in the years following the Euro introduction the country also gradually increased its trade surplus in its low tech industry category. Its overall trade balance of its services industry category deteriorated from a small but stable positive balance to a gradual negative balance in the years following the monetary unification. The overall trade balances of the country’s other main industry categories are all negligible and fluctuate closely around zero balances over the whole period.

Portugal’s graph reveals that the country’s overall trade balance deteriorated much more gradually when expressed as a percentage of its GDP. The graph shows that Portugal has had a negative overall trade balance in each of its main industry categories. The very gradual decline in its trade balance which can be observed in the years following the introduction of the Euro are mainly the result of an increase in the overall trade balance of its high tech industry.

The graph of Spain, finally, shows several important observations. Firstly, even when expressed in terms of the country’s GDP, Spain’s overall trade balance still declines strongly and rapidly in the years following the introduction of the Euro. In other words, while we concluded that the trade balances of the other peripheral countries declined much more gradually when expressed in terms of their GDP, this is much less the case for Spain. Secondly, the deterioration of its trade balance after the monetary unification is mainly the result of an increase in the value added trade balance of its high-tech and services industry categories (and low-tech to a smaller degree). The other industry categories also negatively contribute to the country’s overall trade balance but these values remained more or less stable over the period after the unification.
6.2.7. Trade balances: Intra-Eurozone bilateral balances

In this last big trade balance investigation section we focus on analyzing the bilateral value added trade balances of Germany and the five peripheral countries on an sectoral-level and only among the 19 Eurozone members. In other words, this section is aimed at investigating the intra-Eurozone bilateral trade balances and their possible concentration towards particular industry categories. To analyze the possible effects of the introduction of the Euro, we compare the bilateral balances of these six countries for two years: 2000 (the year prior to the introduction of the Euro), and 2007 (the year just before the effects of the financial crisis are started to be felt in the Eurozone). The result are shown in figures 6.16 and 6.17. Before discussing the results presented by these figures, we first briefly describe how the graphs in this two figures have been constructed and how they should be interpreted.

Each of the graphs shown in figures 6.16 and 6.17 basically shows the bilateral trade balances, in value added terms, of the country under investigation with every other member of the Eurozone, for the years 2000 (left graph) and 2007 (right graph). Both the total bilateral trade balances as well as their sector decompositions are presented in the graphs. In each graph the trade partner Eurozone countries are listed on the x-axis and are sorted according the the value of their bilateral trade balance with the country represented by the graph: the Eurozone trade partner with the highest positive trade balance is listed on the leftmost position in the graph, while the the trade partner with the highest negative trade balance is listed on the rightmost position. All other members are lying sorted between these two extremes. For completeness and as extra information, each graph also lists the country’s overall trade balance and intra-Eurozone trade balance – both in absolute real terms expressed in constant prices of 2001 and as a percentage of the country’s GDP. In line with the mathematics introduced in our research methodology chapter, the following formula provides the equation used to calculate the data shown in figures 6.16 and 6.17 (obviously, the formula is respectively applied on input-output data from 2000 and 2007 to get the graphs for the two different years):

\[
\mathbf{b}_{va}^{r,s} = \mathbf{v}_{va}^{r,s} - \mathbf{v}_{va}^{s,r}
\]

\[
= \sum_{q=1}^{k} \mathbf{M}_{v}^{r,q} \mathbf{F}_{v}^{r,s} - \sum_{q=1}^{k} \mathbf{M}_{v}^{s,q} \mathbf{F}_{v}^{s,r}
\]

\[
= \sum_{q=1}^{k} \mathbf{v}_{c}^{r,q} \mathbf{L}_{c}^{r,q} \mathbf{F}_{c}^{r,s} - \sum_{q=1}^{k} \mathbf{v}_{c}^{s,q} \mathbf{L}_{c}^{s,q} \mathbf{F}_{c}^{s,r}
\]

(6.6)

where \(\mathbf{b}_{va}^{r,s}\) represents the bilateral value added trade balance of country \(r\) with country \(s\) on a sectoral level. To get the total, industry-aggregated, values we simply summed over all the elements of \(\mathbf{b}_{va}^{r,s}\) as follows:

\[
\mathbf{b}_{va}^{r,s} = \mathbf{1} \cdot \mathbf{b}_{va}^{r,s} = \mathbf{v}_{va}^{r,s} - \mathbf{v}_{va}^{s,r}
\]

(6.7)

To construct the graphs in figures 6.16 and 6.17 we always fixed country \(r\) to be one of the six countries under investigation and let variable \(s\) vary over all Eurozone countries one by one. The resulting list of pairs, i.e. \(\mathbf{b}_{va}^{r,s}\) values with associated sector decompositions \(\mathbf{b}_{va}^{r,s}\), were subsequently sorted in descending order along their \(\mathbf{b}_{va}^{r,s}\) values.

We now turn our attention to the analysis of the graphs presented in figures 6.16 and 6.17. As always we start with analyzing the result for Germany. As a first general observation...
we note that Germany’s overall intra-Eurozone trade balance surplus more than tripled over the period from 2000 to 2007, from 1.1% of its GDP in 2000 to 3.4% of its GDP in 2007 – calculated, of course as almost always in this report, in constant prices of 2001. Secondly, for the year 2000 we notice that Germany’s overall intra-Eurozone trade surplus is established by five countries, of which three are peripheral countries. Its largest positive contributors for that year are Italy and Spain (both peripheral countries) followed by Austria and France. Germany had only two Eurozone countries which negatively contributed to its trade balance: primarily The Netherlands, followed by Ireland to a lesser extent. The other Eurozone members barely influenced Germany’s trade balance in that year with all exhibiting nearly zero trade balances. For the year 2007, we first of all notice that Germany’s trade surplus is still determined by the same five top-contributors from the year 2000, but only now these countries contribute significantly higher amounts to Germany’s trade balance (which consequently implies that these countries are running large bilateral deficits against Germany). Next, we also notice that over this seven year period Germany created small bilateral trade surpluses with several new Eurozone members who were previously running zero balances with this country, these include: Belgium, Latvia, Lithuania and Luxembourg. On the deficit side, we see that no new deficits were created over the period. The trade deficit with The Netherlands even significantly reduced. We can summarize the second general conclusion by stating that over the period 2000-2007 Italy and Spain (two peripheral countries) evolved to become by far the two most important Eurozone members contributing to Germany’s overall trade surplus accumulation. Thirdly, when inspecting the sector decompositions in the year 2000 we clearly notice that Germany’s high tech and medium-high tech manufacturing industries are by far the biggest sectors contributing to Germany’s trade surplus, especially when considering the bilateral trade balances of Italy, Spain, and France. For the year 2007 we notice that the services sectors of Italy and Spain gained some significance in their contribution to Germany’s trade surplus, even though the high tech and medium-high tech industries remained by far the two most important trade surplus contributors in the majority of Germany’s positive bilateral trade balances of 2007.

The two graphs of Greece first of all reveal that over the period 2000-2007 Greece had virtually only trade deficits (or zero balances at best) with every of its Eurozone trading partners. It even had large trade deficits with almost half of the Eurozone countries. Secondly, the observed increase in its intra-Eurozone trade balance from -11.9 billion US$ to -17.8 billion US$ ‘fortunately’ did stay more or less in proportion the development of its GDP. However, its overall trade deficit has taken on extraordinary proportions over the period 2000-2007 reaching an overall trade deficit of 22% of the country’s total GDP! Thirdly, inspecting the largest negative contributors to Greece’s trade balance in the year 2000 reveals that back then the country was mainly running large trade deficits with all its five largest Eurozone trading partners: Italy, Germany, France, The Netherlands, and Spain. Of these five countries, Germany and Italy were by far the two biggest negative contributors. Moving to the year 2007, the situation has remained mostly the same, apart from the observation that the bilateral trade deficits with Greece’s three largest contributors from the year 2000 have been substantially further increased over the period 2000-2007, with the contribution of France and Germany both having increased by over one-third of their contribution in the year 2000. Furthermore, most of the already existing smaller bilateral trade deficits from the year 2000 further deteriorated to larger values in the year 2007. Finally, when inspecting the sector decompositions we observe that the negative trade balance contributions are spread out
roughly equally over the various main industry categories and that these proportions stay reasonably the same for most contributing countries when moving from 2000 to 2007.

The case of Italy firstly reveals that its negative trade balance evolution is much less dramatic compared to for example the case of Greece described in the previous paragraph: the country’s intra-Eurozone trade balance (in constant prices of 2001) deteriorated from -0.8% of its GDP in 2000 to only -2.4% of its GDP in 2007 (a fourfold decrease, but still ‘only’ -2.4% of its GDP compared to for example -11.6% for Greece in that same year). Secondly, interestingly Italy’s largest trade deficit contributors in the year 2000 are Germany, The Netherlands, and Belgium (listed from most to least important), i.e. three Eurozone core countries. On the surplus side, Italy exhibits two small, but significantly enough to mention, bilateral trade surpluses: with Greece and Spain. The other Eurozone members barely influenced Italy’s trade balance in that year with all exhibiting nearly zero trade balances. Moving to the year 2007, we observe that there is one country who’s negative impact on Italy’s trade balance drastically increased: Germany. In other words, over the period 2000-2007 Germany by far became Italy’s largest trade deficit contributor: the bilateral trade deficit between Italy and Germany increase more than threefold over that period. In comparison, the other positive contributors identified in the year 2000 only marginally increased their impact on Italy’s overall trade balance over this period. Also remarkable is that over this period the majority other Eurozone core countries (The Netherlands, Belgium, and Austria) all moved to the top of the Italy’s negative trade balance contributors. Thirdly, when inspecting the sector decompositions we notice that the Germany’s negative contribution to Italy’s trade balance mainly proceeds via the high-tech and medium-high tech industries (both in the years 2000 and 2007).

The the two bilateral trade balances graphs of Ireland firstly show that over the period 2000-2007 Ireland’s intra-Eurozone overall trade balance remained roughly stable in real terms as a percentage of the country’s GDP: the country exhibited an intra-Eurozone trade balance of 7.5% of its GDP in 2000, which only slightly declined to 7% in 2007. Secondly, the two graphs show that Ireland had virtually no trade deficits with any of its Eurozone trading partners in the year 2000, whereas it did several have trade surpluses, mainly with four Eurozone members: Germany, France, Italy, and Spain (listed from most to least important). Apart from very small surpluses with Belgium, Greece, Portugal and Austria, the other Eurozone members barely influenced Italy’s trade balance in that year with all exhibiting nearly zero trade balances. Moving to the year 2007, we observe that two of the country’s four large trade surpluses identified in the year 2000 further increased over the period 2000-2007: Germany and Italy. Ireland’s trade surplus with Belgium also doubled. Ireland’s trade surplus with France slightly declined (but still remained substantially positive) and the surplus with Spain more or less stayed the same. On the deficit side, we notice that moving from 2000 to 2007 Ireland established only one small trade deficit with The Netherlands. Thirdly, when inspecting the sector decompositions we notice that all the trade surpluses are strongly dominated by Ireland’s high tech industry in both the years 2000 and 2007. The positive contribution of Ireland’s low tech manufacturing industry also rose substantially over the period 2000-2007, especially with respect to Ireland’s trade surpluses with Germany, Spain, and France.

Portugal’s graphs firstly reveals that the country has mainly no Eurozone partner countries who contribute positively to Portugal’s overall intra-Eurozone trade balance: the country was running trade deficits (or zero balances at best) with virtually all its Eurozone partners, both
Empirical analysis A: Evolution of industry and trade structures within the Eurozone (1995-2009) in the years 2000 and 2007. In the year 2000, the country’s largest bilateral trade deficits occurred via trade with Spain, Germany, Italy, France, and The Netherlands (listed from most to least important). In that year, Spain was by far Portugal’s largest negative trade balance contributor with a bilateral trade deficit being more than a threefold of the trade deficit with Portugal’s second largest contributor Germany. Moving to the year 2007, we can see that Germany developed to become Portugal’s largest trade deficit contributor: Germany’s negative influence increase by around a threefold. And while Portugal’s trade deficit with Spain is still very high and ranked just under the trade deficit with Germany, in comparison to the year 2000 this trade deficit already seriously declined. Portugal’s trade deficit with France stayed around the same absolute value, while the deficit with Italy seriously declined. When we inspect the sector decompositions we notice that in the year 2000 the contributions of the four manufacturing industries were roughly evenly distributed for most of the deficit contributors and that Portugal’s large trade deficit with Spain is significantly determined by a large bilateral trade deficit in Spain’s services industry category. The sector decompositions for the year 2007 reveal that the trade deficit contribution via the high tech industry gained substantial importance, especially in the trade deficits with Germany and Spain. This industry category is by far the biggest responsible for Portugal’s growing bilateral trade deficits with France, Spain, and Germany.

Finally, we discuss the two intra-Eurozone trade balances graphs of Spain. We first make the observation that expressed as a percentage of Spain’s GDP (and calculated in constant prices) Spain’s trade deficit more than doubled over the period 2000-2007, from -2.2% of its GDP in the year 2000 to -5.5% of its GDP in 2007. Secondly, for the year 2000 we notice that Spain was running one single trade surplus: with Portugal. On the deficit side Spain was running bilateral trade deficits with mainly Germany, Italy, and France (and The Netherlands, Belgium, and Ireland to a lesser extent). Already in this year to we observe that Germany is Spain’s largest negative trade balance contributor of all the Eurozone members. Moving to the year 2007, Germany’s contributors positions only further increases: the country became by far the largest trade deficit contributor, with the bilateral trade deficit between Spain and Germany being over two times the amount of the second largest bilateral trade deficit in that year. Over the period 2000-2007 Gemany’s impact increase more than threefold! Furthermore, the smaller bilateral trade deficits with France, Italy, and The Netherlands also grew substantially over this period. On the surplus side no new bilateral trade surpluses were established, while the only trade surplus the country had in the year 2000 even gradually declined over the period. When inspecting the sector decompositions for both years we notice that in both years the sector contributions are fairly balanced: there is not one industry category that seriously dominates the bilateral trade balances (in contrast to for example the graphs of Ireland). We do observe, however, the Spain’s largest bilateral trade deficit in both these years (i.e. with Germany), gives most weight to mainly the high tech and medium-high tech manufacturing industries (apart from the service industry category), while the medium-low and low tech manufacturing industries only exhibit marginal contributions to Spain’s bilateral trade deficit (this last observation is also true for the other large trade deficit contributors).
Figure 6.16: Intra-Eurozone bilateral trade balance in value added terms, decomposed by its major sector contributions for the years 2000 and 2007, covering the period 1995-2009. (Source: WIOD, author’s calculations)

Figure 6.17: Intra-Eurozone bilateral trade balance in value added terms, decomposed by its major sector contributions for the years 2000 and 2007, covering the period 1995-2009. (Source: WIOD, author’s calculations)
Empirical analysis B: Intra-Eurozone trade spillovers in 2011

This chapter is the second of two empirical analysis chapters. While the previous chapter’s main result is the undeniable observation of a growing structural asymmetry between Germany and the peripheral countries in terms of both their industrial capacities as well as their trade specialization, this chapter turns to the question on how to deal with this structural problem. To be more specific, this section helps to empirically determine if one particular scenario suggested by some economists could be considered feasible in any way: exploiting the intra-Eurozone trade spillovers in terms of value added by a coordinated simultaneous Eurozone growth-stimulus program. The crucial point behind this scenario is that in an open economy – which each of the Eurozone economies are – a possibly significant amount of any external injection aimed at boosting the domestic aggregate demand might ‘leak’ away to foreign Eurozone countries via the existence of global value chains caused by product fragmentation. In line with this thesis’ research design this chapter basically addresses research questions two and three.

This chapter analyzes the data for the year 2011, the most recent year in the World Input-Output Database, and we assume that this data more or less describes the world’s current economic structure. The first two sections consecutively investigate two types of intra-Eurozone trade spillovers: (1) industry stimulation spillovers of value added, and (2) final consumer stimulation spillovers of value added (which essentially is the same is a country’s value added exports). The industry stimulation spillovers quantify the additional value added (i.e. income, or GDP) that is created in an industry of a foreign country by demanding one additional unit of output from a particular domestic industry. Hence, these spillovers describe the intra-Eurozone industry interdependencies. The final consumer stimulation spillovers, on the other hand, quantify the impact of countries’ final consumers on the creation of value added on foreign countries. Hence, these spillovers describes the ‘true’ trade spillovers created by the current buying behavior of the various final demand consumer groups. The final consumer stimulation spillovers of course partially come about via the industry interdependencies, but in addition they also include the direct importing and exporting decisions of the various final consumers. It is this difference which mainly distinguishes the two spillovers from one another. Moreover, it should be noted that the final consumer stimulation spillovers are lying outside the immediate influence of the domestic governments to a substantial degree: households and firms are two of the other final demand groups influencing the aggregate final...
demand. The third and final section of this chapter analyses two concrete Eurozone-level coordinated final demand stimulus scenario’s.

7.1. Industry stimulation spillovers of value added
This section aims at gaining insights into the impacts of a final demand stimulus in a particular Eurozone country on the creation of value added in industries of other Eurozone countries. We will use the term industry stimulation spillover of value added to refer to the extra value added that is created in an industry of a foreign country by stimulation of a particular industry of the domestic country by one extra unit of final demand. In other words, an industry stimulation spillover of value added expresses how much value added is created in a foreign industry by demanding one additional output from a particular domestic industry. As an increase in an industry’s value added is equivalent to an increase in its country’s GDP, these trade spillovers quantify the benefits that foreign industries and their countries receive by a unit increase in the demand for the output of a domestic industry.

These spillovers effects can arise via several routes. To see this, consider what happens when a particular domestic industry is demanded to produce one additional unit of its output, could be a good or service. Remember that in our input-output model an industry is fully characterized by a production function which translates inputs from its processing industries (i.e. other industries) and payments sectors into output which can be used both as intermediate input for other processing industries as well as for final demand consumption purposes. A unit increase in the final demand for one particular industry is propagated or ‘multiplied’ through the entire economy by the domestic and foreign production linkages that exist between the various domestic and foreign industries. All the extra output generated by a particular industry because of this unit-size stimulation (triggered via both direct and indirect channels) is neatly captured by the Leontief output multipliers recorded in matrix $L$ (or $M_o$, which is simply a renaming of $L$). The extra value added, or income, generated by a particular industry because of a unit-size stimulation is captured by the Leontief value added multipliers recorded in matrix $M_v$. Matrix $M_v$ is obtained by premultiplying matrix $L$ by matrix $V_c$, i.e. $M_v = V_cL$, where $V_c$ is a diagonal matrix with all the domestic value added coefficients of each industry in each country listed along its diagonal.

As this section aims to analyze the value added interdependencies that exist between the various Eurozone core and peripheral countries, our interest lies in investigating the values of matrix $M_v$ in an efficient manner. To this end, a circular visualization has been developed to graphically illustrate the mutual spillovers between the industries of two or more countries. Using a circular layout is beneficial to show relationships between any type of objects, be them places, people, genes, industries, etc.. Rectilinear layouts and ordinary graphs are much less capable to depict relationships because these designs cannot prevent relationships lines to cross other structures in the graph (Circos, 2015). Circular graphs have been applied successfully in a variety of scientific domains, ranging from biology in understanding genome sequences to the study of networks in mapping complex network information. Before turning attention to the case of analyzing the value added interdependencies between the Eurozone countries, in the next two subsections a discussion and an example are provided on the general components and interpretation of the circled spillover graphs.
Main design of the circled layout for industry stimulation spillovers

Figure 7.1 below illustrates the circular layout that has been designed to visualize the value added spillovers between countries and their industries. These circles illustrate two parts of the same data. Before we turn our focus on interpreting the results visualized by both graphs and the differences between them, we first discuss the main structure and components of the general circled layout.

![Figure 7.1: Two examples of the general circled layout adopted to visualize the value added spillovers.](image)

Both graphs in Figure 7.1 visualize the industry spillovers between four countries: Germany (DEU), Spain (ESP), China (CHN), and Portugal (PORT). Each country is assigned one quadrant of the circle. The industries of each country are listed around the circle on the perimeter. The circular layout adopts the industry aggregation that was set forth during the discussion of the country and industry aggregations: the original 35 industries listed in the WIOTs are aggregated to a set of thirteen higher-level industries. These industries are still characterized by the same unique color as the ones put forward in the previous chapter.

Each country-industry combination on the circles’ perimeter is marked by either a ○ or × symbol. When a country’s industry is marked by a ○ symbol then this means that the industry is being activated: it is stimulated to produce one additional unit of its output. When a country’s industry is marked by a × symbol then this means that the industry is not being activated and instead just acts as a ‘receiver’ of other countries’ spillovers, i.e. the industry might be triggered by industries of other countries to produce extra output and hence extra value added.

The colored lines in the graphs indicate a spillover from one industry to another. The direction of a colored line is always: from an industry marked by a ○ symbol to an industry marked by a × symbol. The color of the line corresponds to the color of the activating industry, i.e. the industry marked by the ○ symbol. The thickness of the line corresponds to the relative size of the spillover effect. The lines shaded in light gray indicate the other significant spillovers that exist between the industries of the selected countries. These lines are not colored because their stimulating industry has not been activated in the graph, i.e.
has been marked by a × symbol.

Lines are only drawn when the value of the spillover exceeds a particular predefined threshold, or critical value. All spillovers which are smaller than this critical value are omitted from the circular graph. In theory this threshold could be set at any chosen value. For this research, however, it has been decided to normalize the spillover effects by determining an average value for the entire Eurozone and setting this value as the threshold for any of the presented circular graphs. The threshold value is determined by taking the average of only the intra-country value added multipliers among the 19 Eurozone countries. In other words, an average is taken of the domestic value added multipliers in the Eurozone. The argumentation behind this is that when inter-country value added spillover values exceed this threshold then the spillover is definitely large enough to be considered significant for the analysis, as it is larger than the average domestic spillover in the Eurozone. Figure 7.2 below illustrates the threshold determination. The threshold is calculated as the average of all the elements of the intra-country value added multiplier matrices \( M_i^{r,r} \), with \( r \in \text{Eurozone} \). The intra-Eurozone normalized threshold for the year 2011 is determined, using this procedure, to be 0.0243 (as a comparison, the global threshold is very similar with a value of 0.0255). Hence, the value 0.0243 is used as the critical value in all circled spillover graphs to determine which lines to draw.

\[
M_v = \begin{bmatrix}
M_v^{1,1} & M_v^{1,2} & \ldots & M_v^{1,k} \\
M_v^{2,1} & M_v^{2,2} & \ldots & M_v^{2,k} \\
\vdots & \vdots & \ddots & \vdots \\
M_v^{k,1} & M_v^{k,2} & \ldots & M_v^{k,k}
\end{bmatrix}
\]

**Figure 7.2:** Illustration on the determination of the spillover threshold value, calculated as the average of all the elements of the intra-country value added multiplier matrices, \( M_i^{r,r} \), surrounded by a red rectangle. Only the Eurozone countries are considered in the calculation of the average threshold value, i.e. only submatrices \( M_i^{r,r} \) with \( r \in \text{Eurozone} \). Hence \( k = 19 \).

It should be understood that when it is stated that one of the thirteen industries is stimulated to produce one more unit of its output, then the underlying assumption is that the lower-level industries which belong to this high-level industry are demanded to together produce one more unit (i.e. a dollar’s worth) of their output. This implies that each of the low-level industries belonging to the high-level industry is demanded to produce a fraction of (i.e. less than) a dollar’s worth of their output. Because all industries are assumed to be equally important, each industry’s fraction should be equal in size, under the condition that the sum of the fractions totals one. For example, because the FIRE industry is compromised of three lower-level industries – ‘Financial intermediation’ (ISIC Rev. 3, 65-67), ‘Real estate activities’ (ISIC Rev. 3, 70), and ‘Renting and other business activities’ (ISIC Rev. 3, 71-74) – this implies that to stimulate the FIRE industry by one dollar’s worth of extra output each of its three lower-level industries is demanded to produce one-third of a dollar’s worth of their output. In line with the reasoning above, when we measure the amount of value added produced by one of the thirteen higher-level industries as the result of a particular stimulation, then we basically calculate the average of the associated value added multipliers of each of the lower-level industries that belong to this high-level industry. In other words, we sum up all the associated value added multipliers for each of the lower-level industries belonging to this high-level industry and divide the total by the number of lower-level industries that
7.1. Industry stimulation spillovers of value added

belong to the stimulating industry. The paragraph below explains the exact steps that are taken to calculate these spillover values.

As already mentioned, the basic information required to calculate any of the value added spillover graphs is stored in matrix \( \mathbf{M}_s \). More specifically, the value added created in the industries of country \( r \) because of unitary final demand stimulations of the industries in country \( s \) are captured by the submatrix \( \mathbf{M}_{r,s}^{v,aggr} \). Any particular element \( m_{r,s}^{v,aggr} \) describes the extra value added that is created in sector \( i \) of country \( r \) because of a unit increase in the final demand for the output of sector \( j \) in country \( s \). Because matrix \( \mathbf{M}_{r,s}^{v,aggr} \) is of dimension \( n \times n_s \) with \( n \) the number of original, low-level industries, the first step required is to reduce the dimensions of this matrix to distinguish only the thirteen high-level industries. This is done by aggregating (summing together) the rows and columns of the lower-level industries belonging to the same high-level industry. The result is a matrix of lower dimensions capturing the aggregate value added spillover values between the thirteen high-level industries (from country \( s \) to country \( r \)). We call this matrix \( \mathbf{M}_{r,s}^{d,aggr} \), as is shown in Figure 7.3. Each of its values describes the total extra value added that would be created in a particular high-level sector if all the low-level industries belonging to the high-level stimulating industry would be demanded to produce one unit more of their output.

\[
\mathbf{M}_r^{r,s} = \begin{bmatrix}
    m_{r,s}^{1,1} & m_{r,s}^{1,2} & \cdots & m_{r,s}^{1,n_s} \\
    m_{r,s}^{2,1} & m_{r,s}^{2,2} & \cdots & m_{r,s}^{2,n_s} \\
    \vdots & \vdots & \ddots & \vdots \\
    m_{r,s}^{n,1} & m_{r,s}^{n,2} & \cdots & m_{r,s}^{n,n_s}
\end{bmatrix}
\]

**aggregation**

\[
\mathbf{M}_{r,s}^{v,aggr} = \begin{bmatrix}
    m_{v,aggr,1}^{r,s} & \cdots & m_{v,aggr,13}^{r,s} \\
    \cdots & \cdots & \cdots \\
    m_{v,aggr,13}^{r,s} & \cdots & m_{v,aggr,13}^{r,s}
\end{bmatrix}
\]

**normalization**

\[
\mathbf{M}_{r,s}^{d,aggr} = \frac{\mathbf{M}_{r,s}^{v,aggr}}{\sum_{i=1}^{13} m_{v,aggr,i}^{r,s}}
\]

**Figure 7.3:** Explanation of the mathematics involved in calculating standardized value added spillover values used in the circled spillover graphs.

Because each high-level industry might be compromised of a different number of low-level industries and we want to be able to compare the multiplier values of the various high-level industries in a fair manner, these values should be normalized. Therefore, the next step downscales the multiplier values by the number of low-level industries that belong to the high-level industry that provides the demand stimulation. Figure 7.3 explains this standardization operation in more detail and shows that the standardization operation can be summarized by the following formula:

\[
\mathbf{M}_{r,s}^{d,aggr} = \mathbf{M}_{r,s}^{v,aggr} \times \text{diag}([nrInd_1, nrInd_2, \ldots, nrInd_{13}])^{-1}
\]

where the function ‘diag’ creates a diagonal matrix containing the inputed vector on its diagonal and zeros everywhere else, and \((\cdot \cdot \cdot)^{-1}\) denotes the matrix inverse operator. Essentially the formula above divides all the elements in each column of \( \mathbf{M}_{r,s}^{v,aggr} \) by the number of low-level industries captured by that column, denoted by values nrInd1, nrInd2, ..., nrInd13.
Interpreting the industry stimulation value added spillover graph example

Having extensively explained the main components and creation of the general value added spillover graph, we now turn our attention to the interpretation of the two example graphs presented earlier in Figure 7.1. Both graphs essentially highlight a different part of the same data: the major value added industry stimulation spillovers between Germany, Spain, China, and Portugal in 2011 – where a spillover is considered significant when its value exceeds the threshold of 0.0243 calculated earlier. By looking at the symbols, we can see that the left graph in Figure 7.1 shows the spillovers that occur when the Portuguese industries are stimulated, whereas the right graph shows the spillovers that occur when the Spanish industries are stimulated. The shaded gray lines visualize the spillovers that would occur should the non-stimulated (but simply receiving) industries be stimulated.

Immediately several important observations catch the eye. Firstly, by far the largest part of all the spillovers between these four countries are the spillovers flowing from Portugal to Spain. Stimulating the industries of Germany or China triggers practically no significant spillover effects among any of the other three countries. A related observation is the strong spillover asymmetry between Portugal and Spain: whereas stimulating Portugal’s industries is beneficial for various industries in Spain, stimulating Spain’s industries creates no significant advantages for any of Portugal’s industries. Secondly, the majority of the spillovers occur within the same industry category. For example, stimulating Portugal’s medium-low tech industry mainly triggers the creation of value added in the medium-low tech industry of Spain, stimulating Spain’s utilities industry creates extra value added in Spain’s utilities sector, etc. Thirdly, the left graph shows that the spillovers from Portugal to Spain are unevenly distributed over the thirteen industries. The largest spillover effects arise from stimulating the high tech and medium-low tech industries (i.e. these show the thickest lines), followed by low tech, medium-low tech, transport and FIRE industries. Finally, the few significant spillover effects created by stimulating Spain’s industries end up creating value added in Germany (its medium-low tech and FIRE industries) and China (its high tech industry), whereas none of the Portuguese industries receives any significant spillover of Spain. In a way this is rather remarkable because Spain and Portugal are neighboring countries while Germany and China are geographically much less proximate to Spain.

Value added industry stimulation spillovers: the case of the Eurozone

Having explained in detail the construction and interpretation of the general circular spillover graph, we are finally in the position to start investigating the industry stimulation spillovers of value added for the case of the Eurozone. Figures 7.4, 7.5, 7.6, and 7.7 on the next few pages show these spillovers between the core and peripheral countries and France, for the year 2011. Each individual circle graph illustrates the value added (i.e. income, or GDP) that is created in the selected set of Eurozone countries if the industries of one of these countries would be stimulated to increase their output by one extra unit, i.e. a dollar’s worth. Let us now investigate the results presented by these graphs.

The top graph of Figure 7.4 provides an overview of all the significant (i.e. above-average) spillovers between any of the selected Eurozone countries. In other words, this graph summarizes all the subsequent graphs presented in Figures 7.4, 7.5, 7.6, and 7.7. A general observation is that the significant spillovers are reasonably concentrated: the
Industry stimulation spillovers of value added

Four manufacturing industries complemented by the transport and travel, FIRE and utilities services industries clearly dominate the graph. Because in this graph the industries of each country are stimulated, it is not possible to distinguish the direction of the spillover flows, i.e. from which country to which other country. Nevertheless, this graph clearly shows some first signs of one or more asymmetries in the spillover structure between the core and peripheral countries of the Eurozone. First, it can be clearly observed that a large part of the spillover lines go to or leave from German industries. Secondly, the majority of the lines linked to German industries are connected to other core countries. Finally, barely any lines connect core with peripheral countries, leaving aside Germany. To further investigate this apparent structural asymmetry we will now factually walk through the other graphs (which show the stimulation spillovers for a single country).

We first discuss the situation in which the industries of one of the core countries is stimulated, shown in the bottom two graphs of Figure 7.4 and the three graphs of Figure 7.5.

**Finland** exhibits only a few significant spillovers and these are all directed towards Germany (i.e. Germany is the beneficial). All these spillovers arise from stimulating the manufacturing industries – each of the four manufacturing industries has one or more associated spillovers – and the majority of these spillovers occur between the same category of industries (e.g. high tech to high tech). It is somewhat remarkable that considering the relatively large set of selected Eurozone countries only Germany is significantly stimulated by Finland to create value added.

The spillover graph for **Belgium** shows much more significant spillovers in comparison to Finland’s graph. The graph shows a strong concentration towards a relative small selection of beneficial countries. Furthermore, the beneficial countries are two core countries (The Netherlands and Germany) and France. In other words, not a single peripheral country benefits significantly of any industry stimulation actions in Belgium (except for the transport and travel industry in Spain). It should come as no surprise that Belgium is strongly linked to (i.e. creates significant value added in) precisely its direct geographical neighboring countries, leaving aside the economic negligible Luxembourg. The main significant value added spillovers occur within the four main manufacturing categories as well as between the utilities and transport and travel service industries. Belgium’s three most influential spillover sectors are clearly the high tech and medium-high tech manufacturing industries and the transport and travel service industry. The final noteworthy observation is the strong link between Belgian’s high tech industry and the primary sector of the The Netherlands.

**Austria**’s spillover graph is highly skewed and concentrated towards one beneficial country: Germany. Hence, in line with the other core countries analyzed so far this country creates virtually no above-average value added benefits for any of the peripheral countries. The vast majority of its industries (10 out of the 13 high-level industries) exhibit above-average spillover effects: the only industries which don’t trigger significant value added creation in Germany are Austria’s hotels and restaurants, FIRE and public sector service industries. While the majority of these industry stimulation spillovers trigger the creation of value added within the same industry category, several important cross-industry spillovers can also be observed: (1) Germany’s FIRE industry is stimulated by a number of Austrian industries: the primary sector, all four manufacturing categories, the utilities industry and the transport and travel industry, (2) Austria’s transport and travel industry stimulates the German high tech, medium-high tech, hotels and restaurants, transport and travel, and FIRE industries, and (3) Austria’s high tech industry stimulates the German primary, high tech,
hotels and restaurants, and FIRE industries.

The spillover graph of The Netherlands confirms the trend which started to emerge from the analysis of the previous core countries above: all of the country’s significant value added spillover effects benefit other core countries – mainly Germany – and sometimes France, while none of the peripheral countries receive any above-average spillover incentives to create extra value added in their industries. In case of The Netherlands, the only countries significantly benefiting from stimulating the Dutch industries are mainly Germany, and to a lesser extent France and Belgium. The most influential industry categories coincide to a large extent with the main industries emphasized by the previous spillover graphs: the four main manufacturing industries (and here mainly high and medium-low tech), the utilities industry, and the transport and travel industry. Another observation worth mentioning is that the Dutch transport and travel industry stimulates the same two industries in each of the three countries: the transport and travel industry (an obvious relation) as well as the FIRE industry (a little less obvious relation). Finally, similar to the previous observation, the Dutch high tech industry has the same cross-industry spillover for each of the three countries: stimulating the Dutch high tech industry provides significant value added benefits for the FIRE industries of both Germany, Belgium and France.

Analyzing the spillover graph of Germany – our final and most important Eurozone core country – shows perhaps the most remarkable and interesting result of all: stimulating any of the German industries creates not a single above-average spillover of value added in any of the other core or peripheral countries or even France! Together with the trend that emerged from analyzing the previous spillover graphs, this rather remarkable result strongly confirms the existence of a structural spillover asymmetry between the members of the Eurozone core and periphery, as was suggested at the beginning of this section. The essence behind this asymmetry – and hence the core message from the preceding analysis – can be summarized as follows. None of the Eurozone core countries provides significant (i.e. above-average) value added creation incentives to any of the peripheral countries while they do significantly stimulate other core countries and primarily Germany. Germany is by far reaping the most value added spillover benefits among all the Eurozone core countries, while the country does not ‘return’ any significant incentive to any of its Eurozone partner countries (neither core or peripheral) to create value added in their country.

We now turn our attention to the analysis of the spillover graphs of the peripheral countries, presented in Figures 7.6 and 7.7. Greece exhibits nearly none (only two) significant above-average value added spillovers: the only two significant spillovers occur within the transport and travel industry between Germany and Italy. Hence, combining this result with the results from the previous analysis, we can conclude that Greece’s industries do not significantly stimulate the industries of Greece’s partnering Eurozone countries to create value added in their countries, nor do Greece’s industries receive any significant spillover incentives from these partners’ industries to create any value added. In other words, based on solely analyzing a country’s value added interrelatedness, Greece’s industries are greatly isolated from the industries of the other Eurozone core and peripheral countries.

The spillover graph of Italy has a strong resemblance with Finland’s spillover graph: the country exhibits only a few significant spillovers and these are all directed towards Germany. Similar to Finland’s case, all these spillovers arise from stimulating the four manufacturing industries. In conclusion, and in line with the observations from our previous analysis, Germany is again the important beneficiary while non of the peripheral countries receive any
significant incentive to create value added in their country.

Ireland’s spillover graph shows a few relatively concentrated sets of above-average industry stimulation spillovers and many of these are cross-industry spillovers. Firstly, the country’s high tech manufacturing industry has strong spillover linkages with the FIRE industries of Italy, The Netherlands, Germany, and France. Secondly, its transport and travel industry creates significant value added in the FIRE industries of both Italy and Germany. Thirdly, its FIRE industry has a strong spillover link with Germany’s FIRE industry. Finally, as already became partially clear from the previous points, Germany’s FIRE industry is one of the two German industries which is significantly stimulated to create value added, but it is done via a variety of Italian industries: the FIRE, transport and travel, medium-low tech, medium-high tech, and high tech industries.

The spillover graph of Portugal is greatly skewed towards two countries: Spain and Germany. Spain is by far the biggest receiver of significant industry stimulation spillovers of value added originating from Portuguese industries. Its four manufacturing industries (and especially high tech and medium-low tech) stimulate the creation of above-average value added in a range of Spanish industries, including among others the primary, high tech, medium-high tech, medium-low tech, and FIRE industries. Especially the Spanish medium-low tech manufacturing industry and the FIRE industry are significantly stimulated by a large variety of Portuguese industries to create value added. Germany has three industries significantly benefiting from Portuguese stimulation activities: the medium-high, medium-low, and utilities industries, and these benefits mainly arise via spillovers within the same industry category. We must again conclude that, apart from the Portuguese dependence on Spain, Germany is the only above-average spillover beneficiary among all the selected Eurozone countries.

Analyzing Spain’s spillover graph reveals two important observations. Firstly, while we concluded in the previous paragraph that Portuguese industries strongly incentivize a variety of Spanish industries to create value added, the opposite is not the case at all: Spain does not stimulate any of Portugal’s industries in an above-average manner to create significant amounts of value added. This makes us conclude that, based on solely analyzing a country’s value added interrelatedness, the trade relationship structure between Portugal and Spain is seriously skewed, with Spain being the large beneficiary or favorable party and Portugal the large provider of benefits and much stronger dependent on the other. Secondly – and this observation is in line with the preceding analysis – Germany is again by far the largest spillover beneficiary among any of the selected Eurozone countries (leaving Portugal aside). Its medium-high tech, medium-low tech, utilities, and FIRE industries all receive significant spillover benefits. The majority of these spillovers originates from within the same industry category. As a final observation we note that the FIRE industry of both Germany and France is significantly stimulated by Spain’s high tech and medium-low tech industries to create value added.

The last country in our analysis is France. It is the only non core or peripheral country in our analysis but an important country nevertheless, given the fact that it contributes around 21% to the Eurozone’s total GDP. France’s spillover graph fully confirms the pattern that emerged in the preceding analyzes: among all the selected Eurozone countries by far the largest beneficiary of industry stimulation activities in France is Germany (its only non-German significant spillover is the one linking the medium-low tech industry of France and Italy). Furthermore, a strong resemblance can be noticed between the German industries significantly
activated by French industry stimulations and the German industries significantly activated by Spanish industry stimulations: almost exactly the same German industries are significantly activated by almost exactly the same industries when comparing France with Spain. In both countries, the high tech, medium-high tech, medium-low tech, and utilities industries trigger the creation of above-average value added in Germany’s medium-high tech, medium-low tech, utilities, and FIRE industries, with the majority of these spillovers originating within the same industry category. This lets us conclude that the value added interrelatedness between France and Germany versus Spain and Germany exhibits a very similar spillover structure.

What can be concluded from all the preceding spillover analyses? In essence, the structural asymmetry in value added industry stimulation spillovers between the core and peripheral Eurozone countries that was identified after the analysis of the five core spillover graphs is further confirmed and strengthened by our subsequent analysis of the industry spillover graphs of the five peripheral countries. We already concluded that none of the Eurozone core countries’ industries provides significant value added creation incentives to any of the peripheral countries while they do significantly stimulate other core countries’ industries and primarily German ones. We can now extend this conclusion by noticing that from the opposite perspective none of the industries from the peripheral countries of the Eurozone provide significant value added creation incentives to any industry of the core countries except to German ones. Neither do any of the peripheral countries’ industries significantly stimulate the value added creation of other peripheral countries’ industries (apart from Portugal’s strong influence on Spain). The data clearly shows that Germany is the central country and biggest ‘winner’ among all selected Eurozone countries with respect to these industry stimulation value added spillover linkages. Because of its central position in the spillover ‘network’, Germany collects by far the greatest amount of value added (or ‘rent’) from the industry stimulation activities of other countries. And what makes this even more interesting is the clear observation that the German industries themselves don’t return any significant value added spillover ‘favors’ to any industry of any of these Eurozone trade partners! In other words, the industry stimulation spillover relationship between Germany and the rest of the Eurozone core and peripheral countries is seriously skewed with Germany being the single large beneficiary and the other Eurozone countries being the large providers of above-average spillover benefits directed towards Germany.
Figure 7.4: Industry stimulation spillovers of value added between the Eurozone core and peripheral countries and France, for the year 2011. From top to bottom the circled graphs illustrate the GDP that is created in a selected set of Eurozone countries if the industries of respectively all countries, Finland, and Belgium would be stimulated to increase their output by one extra unit, i.e. a dollar’s worth, in current prices of 2011.
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Figure 7.5: Industry stimulation spillovers of value added between the Eurozone core and peripheral countries and France, for the year 2011. From top to bottom the circled graphs illustrate the GDP that is created in a selected set of Eurozone countries if the industries of respectively Austria, The Netherlands, and Germany would be stimulated to increase their output by one extra unit, i.e. a dollar’s worth, in current prices of 2011.
Figure 7.6: Industry stimulation spillovers of value added between the Eurozone core and peripheral countries and France, for the year 2011. From top to bottom the circled graphs illustrate the GDP that is created in a selected set of Eurozone countries if the industries of respectively Greece, Italy, and Ireland would be stimulated to increase their output by one extra unit, i.e. a dollar’s worth, in current prices of 2011.
Figure 7.7: Industry stimulation spillovers of value added between the Eurozone core and peripheral countries and France, for the year 2011. From top to bottom the circled graphs illustrate the GDP that is created in a selected set of Eurozone countries if the industries of respectively Portugal, Spain, and France would be stimulated to increase their output by one extra unit, i.e. a dollar’s worth, in current prices of 2011.
7.2. Final consumer stimulation spillovers

In the previous section we focused on analyzing the value added that is created in an industry of a foreign country by stimulation of a particular domestic industry of another country – termed industry stimulation spillovers of value added – for the case of the Eurozone. In this section we shift our focus and investigate the impact of countries’ final consumers on the creation of value added in foreign countries world-wide, which we will term final consumer stimulation spillover of value added. To this end, we have decided to aggregate the value added created in each of the individual industries into one overall number for each country and hence analyze the value added interrelatedness on a country-level. Before turning attention to the case of analyzing these final consumer stimulation spillovers between the Eurozone countries, the next subsection first discusses the modified circle graph that has been developed to analyze these spillovers.

Main design of the circled layout for final consumer stimulation spillovers

Because of the shift in focus and aggregation-level we had to modify the circular layout graph to deal with country-level spillovers on a world-wide scale. Figure 7.8 below illustrates the adopted circular visualization. All 40 countries distinguished in the world input-output tables have been included in the graph and are listed on the circle’s perimeter. The countries are grouped according to the multi-country aggregation which was discussed earlier. All countries are still characterized by the same unique color as the ones defined in the previous chapter.

The example graph above shows the amount of value added created in foreign countries as a result of the buying decisions of Spanish, Belgian, and Turkish final demand consumers in the year 2011. To understand how this works, we have to realize that whenever a group of final consumers in our input-output model demands output from domestic and/or foreign
industries, this activates a set of domestic and foreign production activities – defined by the global input-output relationships – along a global value chain in order to produce the output demanded. These activities, in turn, create value added (or income) in the various countries involved in this global value chain.

In order to be able to perform a fair comparison of the amounts of value added created in each foreign country, the values have been normalized to percentages of the total value added (i.e., GDP) created in the foreign country over that year. Similar to the graphs of the previous section, spillover lines are only drawn when the value of the spillover exceeds a particular predefined threshold, or critical value. The threshold for the graphs in this section have been chosen by the author to be 1%. In other words, whenever the final demand consumers of a particular home country are responsible for creating more than 1% of a foreign country’s GDP, a spillover line is drawn from the home country to that foreign country.

The precise mathematics involved in calculating this spillover metric were extensively discussed in the research methodology section. To summarize, in essence this section visualizes and interprets the foreign value added absorbed (or ‘activated’) by domestic final demand. More specific, it focuses on the bilateral value-added definition of this indicator, which we defined by:

\[ v_{s,r} = B_s' p_r = q = \sum_{q=1}^{k} s,q v_{s,q} r \quad (7.2) \]

or, equivalently, in its decomposed form:

\[ v_{s,r} = m_{s,s'} f_{s,r} + m_{s,r'} f_{r,r} + \sum_{q \neq s,r} m_{s,q} f_{q,r} \quad (7.3) \]

where \( r \) denotes the home country (or activating country), \( s \) denotes the foreign country (or activated country), vector \( m_{s,r} \) captures the sector-demand-to-economy-wide-value-added-created multipliers from activating country \( r \) to activated country \( s \), and vector \( f_{s,r} \) captures country \( r \)’s demand for final goods produced by country \( s \). As a little refresher, the first component of the decomposition formula captures the value added created in foreign country \( s \) that is activated directly by home country \( r \) via the import of final products. The second component captures the value added of country \( s \) that is embodied in intermediate products that are imported from country \( s \) to industries of home country \( r \) to be used to create final products that are demanded by final consumers of country \( r \). Finally, the third component captures the value added of foreign country \( s \) that is embodied in intermediate products produced that are imported from country \( s \) to industries of a third country \( q \) to be eventually used to create final products that are demanded by final consumers of home country \( r \). As an example, the spillovers originating from Spain in Figure 7.8 above – the lines in dark red – essentially illustrate the following values:

\[ \frac{v_{s,r}}{\text{GDP}_s} \quad (7.4) \]

where \( r = \text{Spain} \) and \( s \in \text{any other country} \neq r \), and a line is only drawn if \( \frac{v_{s,r}}{\text{GDP}_s} > 1\% \). The thickness of the lines is determined by the value: the higher the value, the thicker the line.
Final consumer stimulation spillovers: the case of the Eurozone

Having explained the main design and interpretation of the circled layout for final consumer stimulation spillovers, we are now in the position to start analyzing these spillovers for the case of the Eurozone. Figures 7.9 and 7.10 on the next two pages show these spillovers on a country-level for the year 2011 for respectively the Eurozone core and peripheral countries. Figure 7.9 visualizes the amounts of value added created in the various foreign countries as a result of the buying decisions of the final consumer groups from the five core countries (the spillover threshold is set at 1%, as mentioned earlier). Figure 7.9 shows the same metric for the consumer groups of the five peripheral countries. The top left graph in each of the two figures shows an overview of all the significant final consumer stimulation spillovers of value added created by all member countries of respectively the core and peripheral regions. This is done to provide a regional overview on the various spillover effects. The five subsequent graphs in succession show the spillovers of each individual member of the region. As can be observed these single-country graphs have percentage values listed on the outside of their circle’s perimeter next to each country receiving a significant spillover. Each of these values represent the spillover value ‘received’ by that particular country, expressed as a percentage of the total value added created in that country over that year.

We start by analyzing the case of the Eurozone core countries, shown in Figure 7.9. The first observation is that among all five core countries, Germany is by far the country creating the most significant final consumer stimulation spillovers. The country’s final consumers are responsible for at least 1.5% of each Eurozone’s country GDP (except for Greece and Cyprus), and in many of these countries this value is even much higher than this lower limit with several countries reaching values above 5%. The countries most dependent on German final demand include among others Czech Republic (8.3% of GDP), Hungary (6.5% of GDP), Austria (5.8% of GDP), Slovak Republic (5.7% of GDP), and The Netherlands (5.6% of GDP). Among the core and peripheral countries we observe that the non-German core countries are stimulated significantly more – over twice the percentage – by German consumers compared to the peripheral countries: the average significant spillover value for the core is 4.5%, whereas for the periphery this value amounts to only 1.7%. In addition to the observation that Germany is strongly embedded in European value chains because its consumers create significant amounts of value added in the majority of its European partner countries, we can further observe that Germany is also strongly integrated with other parts of the world: the country’s consumers are responsible for creating GDP in countries like Russia (1.9% of GDP), China (1.2% of GDP), Taiwan (1.5% of GDP) and South Korea (1.4% of GDP). This observation is somewhat remarkable because these countries lie geographically much further removed from Germany.

The other four Eurozone core countries exhibit much less significant final consumer stimulation spillovers in comparison to Germany. Dutch consumers, as a start, only stimulate a significant amount of value added in Belgium (2.6% of Belgium’s GDP). Belgian consumers, on the other hand, are responsible for around the same percentage of Dutch value added (2.1% of GDP), while in addition they also stimulate 3.2% of Luxembourg’s GDP. This mutual interrelatedness is most likely due to the trade integration associated with the long established politico-economic Benelux union. Next, Austria and Finland also both significantly stimulate only a few countries in their immediate neighborhood. Austrian consumers are responsible for 1% of Germany’s GDP, while with respect to Hungary, Czech Republic,
Slovenia, and Slovak Republic, Austrian consumers account for a little under 2% of their GDP. Finnish consumers only account for the creation of significant amounts of value added in Estonia (4.8% of GDP) and Sweden (1.2% of GDP).

We now turn our attention to the analysis of the spillover graphs of the peripheral countries, presented in Figure 7.10. Two countries clearly dominate these spillover graphs: Italy and Spain. Italian final consumers are responsible for the creation of significant amounts of value added in the majority of the members of the European Union. Most of these spillovers fluctuate around a value of 2% of the foreign country’s GDP. Also noteworthy is the observation that Italian consumers account for the creation of 2% value added in most Eurozone core countries, whereas most of the other peripheral countries are stimulated significantly less. Furthermore, compared to Germany – the core country creating by far the most final consumer stimulation spillovers – Italian consumers have much less significant influence on countries outside of the European Union: apart from Russia and Turkey, Italian consumers account for no other significant amounts of value added in any of those countries.

Spain’s spillover graph reveals that the buying behavior of the Spanish consumers significantly stimulates several core and several peripheral countries in addition to a small handful of other EU members, and no countries outside of the EU. Spain’s largest beneficiary is Portugal with 3.1% of Portugal’s GDP being activated by Spanish consumers. Ireland is the only other peripheral country being activated by Spanish consumers to a reasonable extent, with a spillover value of 1.7%. Among the Eurozone core countries, three members receive significant Spanish spillovers: Germany (1.0% of GDP), The Netherlands (1.6% of GDP), and Belgium (1.5%).

The spillover graphs of Greece, Ireland, and Portugal reveal that the buying behavior of the final consumers of these three countries barely have an impact on the creation of significant amounts value added in any of the foreign trade partners around the world. Ireland exhibits not a single significant spillover, Portugal only one (1.1% of Spain’s GDP), and Greece just two: Bulgaria (1.6% of GDP) and Cyprus (1.7% of GDP).

In order to further investigate the final consumer stimulation spillovers specifically associated with to the Eurozone core and periphery countries, figures 7.12 and 7.11 provide slightly modified spillover graphs for respectively these two regions. To be more specific, Figure 7.12 shows all the significant spillovers received by any of the five core countries from any of their world-wide foreign trading partners. Figure 7.11 shows the same data for the five peripheral countries. Hence, instead of analyzing how the buying decisions of final consumers from the core or periphery affect the creation of value added in any other country around the world, we now switch the roles and analyze how the buying decisions of final consumers from any country around the world affect the creation of value added in the core or periphery.

To provide a regional overview on these spillovers, the top left graph in each of the two figures shows a summary of all the significant final consumer stimulation spillovers of value added received by the members of the region and created by the buying decisions of final consumers from around the world. The five subsequent graphs in each of the two figures in succession show the significant spillovers received by each individual member of the region. The percentage values listed on the outside of the circle’s perimeter next to the foreign countries indicate the spillover value activated by the foreign country as a percentage of the GDP created in the particular member country over that year.
Figure 7.9: Final consumption stimulation spillovers of value added created by final consumers from the Eurozone core countries, for the year 2011.
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All periphery countries
Greece
Italy
Ireland
Portugal
Spain

Figure 7.10: Final consumption stimulation spillovers of value added created by final consumers from the Eurozone peripheral countries, for the year 2011.
7.2. Final consumer stimulation spillovers

Figure 7.11: Final consumption stimulation spillovers of value added received by the Eurozone periphery and created by the buying decisions of final consumers from around the world, for the year 2011.

Figure 7.12: Final consumption stimulation spillovers of value added received by the Eurozone core and created by the buying decisions of final consumers from around the world, for the year 2011.
Let us start by analyzing Figure 7.11, showing the case of the Eurozone periphery. What immediately catches the eye is that all the significant foreign sources of value added creation for the various peripheral countries can be counted on less than two hands: Germany, France, UK, USA, China, Japan, and the rest of the world region. In other words, the foreignly activated value added in the Eurozone peripheral countries mostly originates from the buying decisions of the final consumers of a relatively small group of countries. Secondly, Greece is the one peripheral country with virtually no significant sources of value added. This implies that Greece is mostly dependent on the buying decisions of its domestic final consumers to create value added. An immediate consequence of this is that Greece is poorly able to capitalize on the dynamics of the global final demand. The other four peripheral countries are much stronger integrated into the global value chains and especially are all significantly dependent on the following three foreign sources: Germany, France, and the USA. Thirdly, Germany and France are the only two European countries significantly contributing to the creation of value added in the peripheral countries.

Shifting our focus to the case of the Eurozone core, depicted in Figure 7.11, shows a somewhat different picture. Similar to the case of the Eurozone periphery the majority of the significant foreigny activated value added in the Eurozone core countries originates from the buying decisions of the final consumers of a relatively small group of countries, in particular: France, Italy, UK, USA, China, and the rest of the world region. However, in comparison to the graphs of the Eurozone periphery, the graphs in Figure 7.11 clearly show that all core countries are activated much more strongly by these foreign countries. To be more specific, final consumers of France, Italy, UK, USA, China, and the rest of the world region are each responsible for creating significant amounts of value added in each of the five Eurozone core countries. In addition, around 1% of German and Belgian value added even originates from the buying decisions of Russian final consumers.

While we do not discuss the spillovers of the single-country graphs in figures 7.11 and 7.12, we encourage the interested reader to closely inspect the other five graphs of each of these figures to find the detailed significant foreign consumer stimulation spillovers for each of the individual core and peripheral countries, which are accompanied by the exact percentage spillover values. For completeness, we decided to also mention the total percentage of a country’s value added created by foreign final consumers, commonly abbreviated as a country’s total ‘foreign value added’. These values indicate the extent to which a country is dependent on the final demand of foreign residents and hence also to which extent a country is able to capitalize on the global final demand dynamics. The foreign value added percentages for all 40 countries for the year 2011 are presented in Figure 7.13.

This figure show a clear discrepancy between the Eurozone core and periphery regions. Apart from Ireland – which obtains the second highest value – all peripheral countries exhibit considerably lower percentages of foreigny activated value added in comparison to the five core countries: GR (11%), IT (20%), PORT (18%), and ESP (18%), versus DEU (32%), NL (39%), FIN (28%), AT (34%), and BE (40%). In other words, the Eurozone core countries are all significantly stronger embedded into global trade networks and are better able to capitalize on the trends in foreign final demands in comparison to the peripheral countries. Consequently, the peripheral countries are much more dependent on the demand created by their domestic final consumers in order to create value added and hence produce welfare.
The key conclusions that should be remembered from the preceding spillover analyses can be summarized as follows. Among all the Eurozone core and peripheral countries only German, Italian, and Spanish final consumers create significant contributions to the GDP of foreign EU countries. Furthermore, practically only the German consumers have significant impacts on several non-European countries (such as China, Russia, South Korea, and Taiwan). With respect to the structural asymmetry in industry stimulation spillovers of value added that was observed in the previous section, this section shows that the symmetry is not fully reflected when investigating the countries’ final consumer stimulation spillovers. Still a small
asymmetry can be noticed: the final consumers of the two biggest peripheral countries (Italy and Spain) create several significant value added contributions towards the core countries while conversely, and apart from Germany, the final consumers of the core countries do not create any significant value added contributions towards any of the peripheral countries. Perhaps the most important overall conclusion is that the two types of spillover graphs analyzed so far each investigate a different part of the inter-Eurozone trade structure and present different information pieces that should be put together rather than played off against one another. On the one hand, the industry stimulation spillover analysis reveals an important structural asymmetry between the industry relationships of the various Eurozone members and portrays Germany as the single important beneficiary returning no significant spillovers to any of its Eurozone trade partners. The final consumer stimulation spillover analysis, on the other hand, reveals that Germany is by far the greatest embedded in European (and global) value chains as this country’s final consumers are responsible for creating the most value added in various Eurozone and non-Eurozone countries.

### 7.3. Effects of a coordinated Eurozone-level manufacturing final demand stimulus

We now turn our attention to the final empirical investigation presented by this research project. This section analyzes the effects of a Eurozone-level coordinated final demand stimulus in 2011. To be more precise, we analyze the scenario in which each Eurozone country increases its public spending on its manufacturing sectors with 2 per cent of its GDP-level in 2011, and determine how much the GDP-levels in each country eventually rise. Our goal is to determine the contribution of the value-added spillover effects on the GDP growth in each country under this scenario. Of course, each country’s GDP will minimally increase with 2 per cent, but we are interested in the additional percentage points which are created by the global spillover effects. The results of this analysis provide important insights into each country’s dependence on global value chains, as well as on the feasibility of a coordinated Eurozone stimulus scenario aimed at reducing the Eurozone imbalances. Before we present the results of this analysis, we first explain the scenario in a little more detail and provide a translation of the scenario into the mathematical formulas required to calculate the solution.

**Mathematical transition: from scenario outline to its model implementation**

In essence we are dealing with an ‘impact analysis’ scenario because we are aiming at estimating the effects of an exogenous initial change in economic activity on the world-wide economy. Before we explain the mathematical details required to implement this scenario, we first briefly list the major assumptions that are implicitly made when using an input-output model to perform such impact analyses (these are discussed in more detail in the research methodology chapter). Furthermore, we also provide a justification of why these assumptions are reasonable with regards to the current economic situation of the Eurozone.

Firstly, our input-output model is a demand-pull model. In this model all sources of final demand are assumed to be exogenous to the economic system as part of the model’s initial conditions. Quantities are the changing variables in this model. Secondly, another assumption is the absence of any supply-side constraints (i.e. the absence of resource scarcity). Hence, the economies are not running at full capacity. Furthermore, because no competition will
occur over any resources, prices (and wages) do not have to perform their traditional signaling role as a mechanism to allocate scarce resources and hence are fixed. Lastly, under the aforementioned conditions our model implicitly assumes that no crowding-out of the fiscal stimuli will occur (by a decrease in private investment). These assumptions can be justified by the observation that because of the Eurozone crisis and the associated economic recession, all Eurozone economies are suffering from a general over-capacity in their productive systems, and hence can be assumed to not be running at full capacity. The high unemployment rates in many Eurozone countries clearly illustrate this issue of over-capacity and underutilization. Furthermore, interest rates are extraordinarily low in the Eurozone. The benchmark Euro area interest rate, set by the European Central Bank, was last recorded at 0.05 per cent (ECB, 2015a) (it has gradually been declining to this record-low value in the period following the start of the financial crisis), and the general threat of inflation in the Eurozone is also low (ECB, 2015b). Under these clear conditions of economic recession the use of our input-output model to perform impact analyses on the Eurozone economy seems to be very reasonable and defensible. Moreover, our assumptions are largely backed by the International Monetary Fund (IMF). In providing estimations and growth forecasts of fiscal multipliers, the IMF has made roughly the same assumptions (Blanchard and Leigh, 2013).

One additional assumption deserves a special treatment. An important assumption which we have to make in order to perform these impact analyses is that the Leontief technologies (i.e. fixed coefficients technologies) which characterize each industry in our model stay unchanged over the short term, when moving from 2011 to 2012. As we similarly saw at the beginning of the research methodology chapter, this assumption can be mathematically expressed by saying: $L^{2011} = L^{2012} = L$. As we also assume the value added coefficients to be unchanged, the following condition also holds: $V_c^{2011} = V_c^{2012} = V_c$. By making this assumption it becomes very easy to determine the economy-wide changes in industries’ output and generation of value added created by a change in the exogenously given final demand levels: we simply have to replace the $F$ matrices or $f$ vectors in each formula listed in the research methodology chapter, with corresponding $\Delta f$ vectors representing the absolute changes in these final demand levels. To illustrate this operation, several of the resulting formulas are listed below:

$$\Delta x = L \Delta f$$
$$\Delta X = L \Delta F$$
$$\Delta v = V_c L \Delta f$$
$$\Delta V = V_c L \Delta F$$
$$\Delta V^{r,s} = \hat{v}_c \sum_{q=1}^{k} (L^{r,q} \Delta F^{q,s})$$
$$\Delta v^{r,s} = \hat{v}_c \sum_{q=1}^{K} (L^{r,q} \Delta f^{q,s})$$

Having explained this important assumption, let us now focus on the policy scenario analyzed in this chapter. As already explained, we want to analyze the scenario in which each Eurozone country increases its spending on its manufacturing sectors with 2 per cent of its GDP-level in 2011, and determine by how much the GDP-levels in each country eventually rise. To implement this scenario we first have to determine exactly by how much each manufacturing industry of each Eurozone country is stimulated. To this end we have to make an assumption
on how much weight (i.e. importance) a country gives to each of these industries. We know that the objective is for each country to demand more output of its manufacturing industries so that the total amount of value added directly created in this country equals 2 per cent its GDP, but the question is how much extra output does that country have to demand of each particular domestic manufacturing industry in order to reach this overall GDP level? On this matter, we decided to make the following assumption:

**Assumption about stimulation distribution:** In our scenario we assume that both the country’s governments expenses as well as investments, i.e. gross capital formation (which include public investments), are being stimulated and that the weights given to each domestic manufacturing industry follow the same proportions as the ones which can be derived from the country’s actual (i.e. 2011) final demand expenditure levels for these two final demand consumer groups.

To translate this assumption into a mathematical condition, remember that all the final demand levels for the year 2011 are stored in that year’s $F$ matrix and its sub-matrices $F^{r,s}$.

The final demand levels we are interested in are essentially stored in the second and third columns of matrix $F^{r,r}$:

$$F_{(n\times 3)}^{r,r} = \begin{bmatrix} f_{cr}^{r} & f_{cg}^{r} & f_{gcf}^{r} \end{bmatrix}$$  \hspace{1cm} (7.5)

The second column $f_{cr}^{r}$ captures the final demand levels imposed by country $r$’s government on each of this country’s domestic industries, whereas the third column $f_{gcf}^{r}$ captures the final demand levels imposed by country $r$’s gross capital formation (i.e. investments). In order to focus on the final demand values of only the manufacturing industries, we introduce the notation $\hat{f}_{m}$ to express that the non-manufacturing entries of vector $\hat{f}_{m}$ have all been changed to zero. Using this notation the assumption stated above can now be mathematically formulated as follows:

$$\Delta f_{cr}^{r} = c \times \left( \frac{1}{I^{r}(f_{cr}^{r}, f_{gcf}^{r})} \right) (f_{cr}^{r} + f_{gcf}^{r}) \hspace{1cm} (7.6)$$

where $c$ is a scaling constant that we still need to determine.

Figure 7.14 below illustrates, in an abstracted way, how the exogenous part of this coordinated stimulus scenario would look like in a mathematical way. All the white rectangles in this depicted matrix are zero vectors of length $n$ (where $n$ denotes the number of industries). The red rectangles symbolize the $\Delta f_{cr}^{r}$ and $\Delta f_{gcf}^{r}$ vectors of each Eurozone country, which capture the eventual demand stimuli. The inner blue parts of these red rectangles represent the manufacturing entries, while the remaining inner white parts represent zero values.

To determine the value $c$ for each Eurozone country we will use the scenario agreement that each country’s increases its spending with 2 per cent of its GDP-level. Before we can use this value, we need a mathematical equation describing this scenario agreement. To this end, we must recognize that the extra value added directly created in each industry can be calculated using the value-added coefficients as follows:

$$i^{r}((\hat{v}_{m} \Delta f^{r,r})) \hspace{1cm} (7.7)$$

Note, that this formula captures only the direct effect of the demand stimulus and not the indirect effect (which would create additional value added via the global input-output multiplier effects). The equation stating that each Eurozone country will increase the spending
on its manufacturing industries with 2 per cent of its GDP in total can now be stated as follows:

$$\mathbf{i}^r \hat{\mathbf{v}}^c \times \mathbf{c} \times \left( \frac{1}{\mathbf{i}^r \left( \mathbf{r}^c_{g,m} + \mathbf{r}^c_{gcf,m} \right)} \left( \mathbf{r}^c_{g,m} + \mathbf{r}^c_{gcf,m} \right) \right) = 2 \% \text{ GDP country } r \quad (7.8)$$

And hence $c$ can be determined as follows:

$$c = \frac{2 \% \text{ GDP country } r}{\mathbf{i}^r \hat{\mathbf{v}}^c \left( \frac{1}{\mathbf{i}^r \left( \mathbf{r}^c_{g,m} + \mathbf{r}^c_{gcf,m} \right)} \left( \mathbf{r}^c_{g,m} + \mathbf{r}^c_{gcf,m} \right) \right)} \quad (7.9)$$

Now that we know the value of each scaling constant $c$, we can fully determine the vector $\Delta \mathbf{r}^c$ for each Eurozone country and thereby complete the stimulation matrix $\Delta \mathbf{F}$. And knowing matrix $\Delta \mathbf{F}$ and all its sub-matrices we are finally in a position to start focusing on the effects of the coordinated demand stimulus in terms of the creation of additional value added world-wide. All these effects are essentially captured in the following formula:

$$\Delta \mathbf{V} = \mathbf{V}_r \mathbf{L} \Delta \mathbf{F} \quad (7.10)$$

or in sub-matrix definition:

$$\Delta \mathbf{V}^{r,s} = \hat{\mathbf{v}}^r \sum_{q=1}^{q=k} \left( \mathbf{L}^{r,q} \Delta \mathbf{F}^{q,s} \right) \quad (7.11)$$

Having provided the mathematical transition layer between the scenario description and its implementation in our input-output model, we now turn our attention to the presentation and discussion of the results.
Presentation and discussion of the results

The results of our scenario of a coordinated Eurozone stimulus of the manufacturing industries are presented in figures 7.15 and 7.16. Figure 7.15 presents the results for the Eurozone countries, whereas Figure 7.16 shows the results for the other (i.e. non-Eurozone) countries.

We start by discussing the results for the Eurozone countries. The portions of each bar exceeding the base line of 2% – the minimum increase in GDP of each country, which is created by the direct effect of the stimulation – indicate the additional value added created by the indirect input-output multiplier effects (also called global spillover effects or global backward linkages). Each global spillover effect can be separated into two parts: a domestic part and a foreign part.

- The red portion exceeding the base line indicates the additional value added created in that particular country, via the indirect multiplier effects, as a reaction on the initial stimulus of this country. In short: the multiplier due to domestic spillover effects (without considering the 2% created by the direct effect).

- The blue portion exceeding the base line indicates the additional value added created in that particular country, via the indirect multiplier effects, as a reaction on the initial stimuli of the other Eurozone countries. In short: the multiplier due to international spillover effects.

The value in each blue and red bar indicates the numerical value of respectively the foreign and domestic multiplier effects. For example, France’s domestic multiplier value of 2.6 is calculated by dividing the total size of its red bar by the initial stimulus of 2% (i.e. 2.6 = 5.28%/2%). Its multiplier due to international spillover effects is calculated by dividing the total size of its blue bar by the same 2% (i.e. 0.2 = 0.0048/0.02). Several observations can be made from this graph.

Firstly, it can be easily observed that a large majority of the Eurozone countries significantly benefit from a coordinated manufacturing stimulus via the existing indirect input-output multiplier effects. Under our stimulation scenario ten out of the nineteen Eurozone countries would generate around 3% additional GDP (or sometimes even more) on top of the original 2%. Five countries would create over 2% additional GDP, and the remaining four countries would all still generate over 1% additional GDP.

Secondly, the figure clearly shows that the core countries – especially Belgium, The Netherlands, and Austria – all benefit significantly more from the manufacturing stimuli of their European partners in comparison to the peripheral countries. To be more specific, the multipliers due to international spillover effects for the core countries amount to the following values: BE: 0.8, NL: 0.8, AT: 0.6, DEU: 0.5, and FIN: 0.4, which averages 0.6. The same multipliers for the peripheral countries, on the other hand, amount to the following values: PT: 0.4, IR: 0.4, ESP: 0.3, IT: 0.3, GR: 0.1, which averages 0.3. Hence, on average the core countries benefit twice as much from the foreign Eurozone stimuli actions compared to the peripheral countries, which consequently are more dependent on the domestic stimulation of these industries.

Thirdly, it can be noticed that Greece and Cyprus are both practically entirely dependent on the manufacturing stimulus of their home country and barely benefit from the stimulus actions of their Eurozone partners: the multipliers due to international spillover effects
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Figure 7.15: Results of a Eurozone-level coordinated demand stimulus of the manufacturing industries: the Eurozone countries.

Figure 7.16: Results of a Eurozone-level coordinated demand stimulus of the manufacturing industries: the non-Eurozone countries.

amount to barely 0.1 for both these countries. This clearly suggests that these two countries are badly embedded into global value chains and hence are incapable of responding to the overall dynamics and trends in the foreign intra-Eurozone demand structures.

Fourthly, by generating almost 4% additional GDP, France clearly benefits the most of the coordinated demand stimulus. Interestingly moreover, is that by far the largest part of France’s spillover originates from the manufacturing stimulus in its home country. The stimulation actions of its Eurozone partners are responsible for only a small additional increase in its GDP. To be more specific, France’s multiplier due to its domestic manufacturing stimulus amounts to 2.6, whereas its multiplier due to the stimuli of its Eurozone partners is only 0.2.

We now turn our attention to the results for the non-Eurozone countries, shown in Figure 7.16. The figure clearly shows that among all non-Eurozone countries mainly the European countries benefit the most of the coordinated stimulus. The top nine most beneficial coun-
tries include the eight non-Eurozone European countries and is complemented by Russia, which is ranked fifth by generating 1.1% additional GDP. Czech Republic and Hungary are in the most beneficial position by generating 1.8% and 1.6% additional GDP respectively. The UK and Denmark are the least beneficial countries among these European countries by generating both a mere 0.6% additional GDP. The non-European countries all generate between 0.5% and 0.1% additional GDP. Two of these countries are worth mentioning: the U.S. and China (Europe’s two biggest competing economies). In response to the initial Eurozone coordinated manufacturing demand stimulus, both these two countries generate only a small amount of additional value added expressed as a percentage of their GDP. This does not imply, however, that there are no significant spillover effects towards these two economies. On the contrary, because the GDP of these two countries is very large, the results of Figure 7.16 partly mask the fact that the absolute amounts of stimulation spillovers towards these two countries are relatively large.

In addition to the scenario discussed above, we decided to consider a second stimulation scenario. This time we investigate the situation in which each Eurozone country increases its spending on all its sectors with 2 per cent of its GDP-level in 2011, and compare the results to the previous scenario in which each country only stimulated its manufacturing industries. In other words, in this scenario we remove each Eurozone country’s constraint of only stimulating its manufacturing industries and allow these countries to also stimulate their primary and tertiary (i.e. services) sectors. We still apply the same assumption about the industry distribution: the weights given to each domestic industry follow the same proportions as the ones which can be derived from the country’s actual final demand expenditure levels of the government and gross capital formation final demand consumer groups. In essence, all the formulas presented in the previous mathematics section still apply. The only adaptation required to deal with this new scenario is the removal of the $f_{\cdots,m}$ notation.

![Figure 7.17: Results of a Eurozone-level coordinated demand stimulus of the all industries: the Eurozone countries.](image)

The results of this second scenario are presented in figures 7.17 and 7.18. Figure 7.17 presents the results for the Eurozone countries, whereas Figure 7.18 shows the results for the non-Eurozone countries. The results under this scenario look surprisingly different from the
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Figure 7.18: Results of a Eurozone-level coordinated demand stimulus of the all industries: the non-Eurozone countries.

results of the previous scenario – both for the Eurozone and non-Eurozone countries: under this scenario we notice that much less additional value added is generated in each country. Hence, a first important conclusion is that a scenario in which only the manufacturing industries are being stimulated creates much more additional value added in each country compared to the scenario in which all the industries are involved in the stimulation. Secondly, we can clearly see that under this second scenario the differences between the various countries are only marginal: the percentages of additional GDP generated in each Eurozone country are all located in the range between 0.5% and 1.5%. Thirdly, for each of the Eurozone countries the amount of value added generated by the stimulus of their Eurozone partners is very small. For each of these countries the multiplier due to international spillover effects lies between 0.01 and 0.19. Consequently, the value added created in each home country in response to the initial stimulation of that country occupies by far the largest part of the total stimulus effect. The results for the non-Eurozone countries confirm the conclusions from the previous paragraph. A coordinated stimulus in which all industries are involved also creates much less additional GDP in the non-Eurozone countries. All values in Figure 7.18 are located within the range of 0.02% to 0.37%. The general observation that under this scenario much less value added is generated in each country in comparison to the previous scenario, sounds somehow understandable if we take into account that in this second scenario importance is given to the stimulation of several non-tradeable services industries.

Overall the results of these analyzes seem to suggest that if the coordinated stimulation is targeted towards the manufacturing industries only, then several significant multiplier effects can be exploited to generate additional amounts of value added in the Eurozone countries – with several inevitable spillover ‘leaks’ to other parts of the world. This general conclusion is also empirically confirmed by similar research. Garbellini et al. (2014b) also used to World Input-Output Database to analyze the domestic demand and global production in the context of the Eurozone crisis. They conclude that “a strategy of coordinated fiscal austerity cannot be sustained by empirical evidence” (Garbellini et al., 2014b, p. 335). Their main policy implication, and also an important conclusion of our analysis, is formulated very clearly as follows: “The Eurozone countries should reconsider the prominent role of domestic sources
of final demand in determining activity levels, acknowledging that spillovers may significantly amplify potential gains from coordinated action. Such a 'coordinated domestic demand-led policy', in which fiscal expansion, together with targeted industrial and income policies, are tipping points for a sustained recovery, remains essential.” (Garbellini et al., 2014b, p. 355)

Our analysis strongly confirms this conclusion and even makes it a little more concrete and specific by pointing out that stimulation of the manufacturing industries yields significant more benefits for each Eurozone country, in comparison to scenarios in which all the industries are stimulated. To be more specific, in our scenario where each Eurozone country stimulated its manufacturing industries by 2% of its GDP in total, a large majority of these countries generated at least 2% additional GDP, whereas several countries even reached values of 3% or higher. With regards to reducing the macro-economic imbalances between the core and peripheral countries, our analysis seems to suggest that the intra-Eurozone spillover effects generate much smaller impacts on the peripheral countries while contributing much more to the core countries. Hence, our analysis suggest that exploiting possible spillover effects to reduce the imbalances via a coordinated stimulus scenario is not very plausible. This last observation is in line with the structural asymmetry between the core and peripheral countries which emerged as one of the important observation from the previous two analysis chapters.
Research conclusions and policy discussion

This chapter brings together the main findings of the previous two analysis chapters and assembles these empirical results into a storyline on the evolution of the Eurozone’s structural imbalances and its deeper origins. The presented story essentially constitutes the result of the research process documented in all the previous chapters. It is primarily directed towards the policy and decision makers at the European level as it conveys several important policy messages with respect to the internal structural dynamics to which the Eurozone economy is undoubtedly subjected.

8.1. The empirical observation of a growing structural asymmetry within the Eurozone

The main result from the analysis on the historical evolution of the Eurozone’s productive and trade structure – chapter 6 – is the undeniable observation of a growing structural asymmetry between Germany (the protagonist of the core region) and the GIPS, or peripheral countries (Greece, Italy, Portugal, and Spain): a substantial structural heterogeneity between Germany and the periphery in terms of both their industrial capacities as well as their trade specialization has been gradually developing over the last two decades. Moreover, the empirical evidence clearly suggests that these structural differences have widened after the monetary unification and the introduction of the common currency. In essence, the asymmetry entails that Germany has gradually been building up a strong comparative advantage in the production and export of high and medium-high technology manufacturing goods, while the periphery got locked-up in specializing in low and medium-low technology manufacturing industries as well as several non-traded industries including construction and tourism. To substantiate this hypothesis, we now summarize the empirical findings for both sides of the asymmetry successively. We start by looking at Germany.

8.1.1. The benefiting party

Over the last two decades, Germany has managed to develop substantial high technological productive capabilities both in terms of its domestic industry structure as well as in term of its trade structure. Let us first summarize the findings on its industry structure. In chapter 6 the graphs on the total industry output evolution reveal that Germany’s share of high technology and medium-high technology manufacturing industries has always been significantly
higher compared to any of the GIPS countries. To be more precise, the country’s manufacturing output originating from high and medium-high technology sectors as a percentage of the total manufacturing output has always been significantly over 50%, while in comparison the share of low and medium-low technology sectors of any of the GIPS countries has always been well above 50% of the total manufacturing output. The country’s graph on the sector distribution in terms of the domestic value added created in each industry strongly reinforces this observation: the value added created by high and medium-high technology sectors as a percentage of the total value added created by all the manufacturing industries has always been significantly over 50%, while for any the GIPS countries this value has always been far below 50%. Germany’s global revealed comparative advantage graph, in terms of total production, partially reinforces the asymmetry hypothesis by showing that the country has retained a strong comparative advantage in its medium-high technology manufacturing industry throughout the whole period following the monetary unification.

Next, we move to the main findings on Germany’s trade structure. We start with the exports and imports structure. Please bear in mind that all the trade structure analyses in chapter 6 measure trade in value added terms (compared to the traditional gross terms) to circumvent the double counting problem that occurs when trade is measured in gross terms – because of intermediate goods potentially crossing borders multiple times. Firstly, the export dependence graphs show that Germany is much more dependent on exports compared to any of the peripheral countries – its dependence gradually grew from 20% to over 30% in value added terms (i.e. this is the percentage of GDP created by foreign final demand). Moreover, the gap between Germany’s and the periphery’s dependence on exports increases significantly in the years following the introduction of the Euro – from 5% difference in 2001 to 10% in 2007. Secondly, the sector decomposition of Germany’s exports reveals that its high technology productive capabilities are also reflected in its trade structure. Germany’s concentration in medium-high and high technology manufacturing exports was already high in the middle of the 1990’s and its exports developed even further towards those two segments between 2003 and 2007 – roughly the period between the monetary unification and the onset of the financial crisis – reaching coverage levels of around two-thirds of the total manufacturing exports (measured in real terms). Furthermore, Germany’s specialization in low technology manufacturing exports has always been significantly smaller compared to the low technology exports shares of any of the peripheral countries. Thirdly, Germany’s global revealed comparative advantage graph, in terms of value added exports, again reinforces the asymmetry hypothesis by revealing that Germany has a strong comparative advantage in terms of value added exports in mainly the medium-high technology manufacturing industry. It also had a relatively strong comparative advantage in its high technology manufacturing, but this position slightly deteriorated over the period even though the advantage did not disappear. Fourthly, with respect to the dependence on value added imports, among the analyzed countries Germany is the least dependent on imports together with France and Italy. Its dependence has roughly been 20% of its total GDP over the entire period and has always been roughly 10% less dependent on imports compared to Greece, Portugal, or Spain.

We continue the summary on Germany’s trade structure with a discussion of its trade balance evolution. A first general observation reveals that Germany’s overall intra-Eurozone trade balance surplus more than tripled over the period from 2000 to 2007, from 1.1% of its GDP in 2000 to 3.4% of its GDP in 2007 – calculated in constant prices of 2001. Secondly, the graph showing the relative contributions of imports and exports to the year-on-year changes
in Germany’s overall trade balance reveals that Germany’s interrupted trade balance surplus accumulation is for the largest part due to a strong growth of its exports – instead of a decline in its imports, which even rose slightly as well. Especially during the period 2004-2007 did Germany’s export rose substantially. Thirdly, a decomposition of Germany’s overall trade balance in the contributions of each of its main trading partners reveals that in the years following the introduction of the Euro the two most important peripheral countries, Spain and Italy, both significantly increased their bilateral trade deficit with Germany, creating an equally large surplus for Germany, and accounted for a substantial share of Germany’s overall trade surplus accumulation during that period. Fourthly, a sector decomposition of Germany’s overall trade balance reveals that the trade balance accumulation mainly occurred because of increases in Germany’s net value added exports of its medium-high technology and services industries: especially after the monetary unification do we observe that the Germany’s trade surplus in these two industry categories significantly increased as a percentage of the country’s GDP. Finally, the intra-Eurozone bilateral trade balances and their sector decomposition reinforce the asymmetry hypothesis by conforming that Germany’s high tech and medium-high tech manufacturing industries are by far the biggest sectors contributing to Germany’s trade surplus and that this is especially true when considering the bilateral trade balances of Italy, Spain, and France.

To summarize, all the empirical evidence mentioned in the previous paragraphs strongly reinforces the general observation that Germany has experienced that a very high pace of technological upgrading over the last 15 years, building up a dominant position in the production and export of technological intensive goods within the Eurozone which is reflected by a strong comparative advantage in these industries. The evidence, moreover, suggests that the monetary unification and economic integration at the turn of the century have, at least partially, helped to reinforce this structural divergence and associated accumulation of Germany’s substantial trade surplus.

8.1.2. The weakening party

In this section we shift our focus to inspecting the other side of the asymmetry by summarizing the most significant empirical results for the GIPS countries. As a start, the graphs on the total industry output evolution reveal that over the whole period in all the GIPS countries the manufacturing sector has been dominated by low tech and medium-low tech industries, bearing well above 50% of the total manufacturing output in these countries (measured in real terms adjusted for inflation). Furthermore, these graph also clearly point out that in each of these four peripheral countries the construction industry has been much more prevalent in comparison to Germany’s construction sector. This is especially true for Spain and Portugal. Mainly Spain experienced a significant increase in the real output of its construction industry in the years following the introduction of the Euro. Furthermore, the FIRE (Finance, Insurance, and Real Estate) industry has gained significant importance in especially Italy, Portugal, and Spain, and most of this growth occurred after the Euro introduction. Overall, these graphs seem to point out that the GIPS countries have been specializing in lower technology manufacturing as well as several non-traded industries including construction, tourism, and wholesale, retail, and repair services. As a final note, remember that one could also analyze the specialization patterns by looking at the domestically created value added in each industry, because as was shown these graphs show very much the same specialization patterns.
This first indication on a possible asymmetry is strongly confirmed when looking at the results presented by the revealed comparative advantage graphs in terms of total production. Let us start by looking at the evolution on the comparative disadvantages first. Greece deepened its comparative disadvantage in the high technology (and FIRE) industry in the years following the Euro introduction. A similar observation characterizes Italy which saw both its high and medium-high technology manufacturing industries gradually both significantly deteriorate throughout the decade after the unification, creating a strong disadvantage in this industry categories. No difference for Portugal which experienced a large deterioration of its high technology industry after the unification. Spain, finally, creates no exception to this observation: after the introduction of the Euro it demonstrates significant decreases in its high technology and medium high technology manufacturing industries. In summary, we can conclude that all the four peripheral countries experienced a substantial deterioration of their technological productive capabilities, without a single exception. The evolution of their comparative advantages also shows a relative broad consensus. Greece shows a strong comparative advantage in the hotels and restaurants sectors (i.e. read: tourism), followed by the construction industry, over the whole period. Moreover, in the years following the monetary unification it gains significant advantages in the wholesale, retail, and repair as well as the transport and travel industries. Italy does not strongly excel in any industry, but it does demonstrate smaller comparative advantages in the medium-low and low technology, transport and travel, and hotels and restaurants industries. The unification did not change much in relation to these advantages. Portugal reveals relatively strong comparative advantages in low technology manufacturing, construction, hotels and restaurants, and utilities sector over the whole period. Spain, finally, demonstrates strong comparative advantages in its construction and hotels and restaurants industries. It furthermore has weaker comparative advantages in the low and medium-low technology manufacturing, and transport and travel industries. After the monetary unification, the country demonstrates a strong increase in the comparative advantage of its construction industry. In summary, we conclude that the four peripheral countries gradually got locked-up – especially in the years following the Euro introduction – in low and medium-low technology manufacturing activities and/or several non-traded sectors including construction, hotels and restaurants, and wholesale, retail and repair services. Each country shows some differences in the precise emphasis, but the overall trend is really clear. Put differently, the peripheral countries became technologically stagnant and started concentrating more on several non-traded activities.

We now move focus to summarizing the main empirical findings on the trade structures of the peripheral countries. As in the German case, we start with inspecting the exports structures. Firstly, we observe that throughout the whole period and both in gross and value added terms the peripheral countries are significantly less dependent on exports in comparison to the core countries. The average graph for the GIPS countries indicates that in each year the peripheral countries are roughly 18% less dependent on value added exports in terms of contribution made to their GDP. Secondly, the sector decomposition of the exports of the peripheral countries confirms a strong asymmetry in comparison to Germany. Greece has a low share of manufacturing exports and a severe dependence on services exports. After the monetary unification its manufacturing sector barely grew in real terms, while the service industry experienced an enormous boom that nearly doubled its total exports between 2000 and 2007 (in value added terms). If we do nonetheless inspect its relatively small manufacturing exports, Greece shows a strong specialization in low and medium-low technology exports.
The empirical observation of a growing structural asymmetry within the Eurozone shows that the manufacturing sector in Italy has a similar specialization trend. Compared to Germany, Italy’s share of low technology manufacturing exports has always been significantly higher, compromising on average around 40% of its total manufacturing exports, versus around one-sixth on average for Germany. No difference for Portugal. Inspecting the manufacturing exports reveals that Portugal shows a strong specialization in low technology manufacturing exports and that after the monetary unification a gradual increase occurred in its medium-low technology exports. Its manufacturing and services both account for roughly 50% of the country’s total exports. Spain’s value added exports structure, finally, reveals no significant specialization. All four manufacturing industries each cover around one-fourth of the total manufacturing exports. Overall, we can conclude by stating that there is a strong asymmetry in the export structure between Germany and the periphery in that Germany’s share of low and medium-low technology manufacturing exports comprises between 30 and 40% maximum, while this value is higher than 50% for each peripheral country throughout the whole period.

Focusing on the revealed comparative advantage graphs, in terms of value added exports, the peripheral countries’ exports asymmetry is once more strongly reinforced. We start by summarizing the evolution of their comparative disadvantages. Greece’s high and medium-high technology sectors are characterized by strong comparative disadvantages over the complete period. A similar observation for Italy: after the monetary unification the country experienced a strong deterioration of its high technology manufacturing industry creating a substantial comparative disadvantage for this sector. In line with the previous two peripheral countries, also Portugal exhibits a strong comparative disadvantage in its high technology manufacturing industry throughout the whole period. Especially after the monetary unification did the country experience a strong decrease in its revealed comparative advantage values of its high technology industry. The observations of Spain’s graph, finally, reveal that the country is completely in line with the analysis of the comparative disadvantages of the other peripheral countries: the country demonstrates a strong comparative disadvantage in its high technology industry with a strong deterioration in the years following the Euro introduction. The evolution of their comparative advantages in their value added exports also shows a relative broad consensus. For Greece, a sharp increase can be noticed in the revealed comparative advantage of its construction, WRR, and hotels and restaurants industries. Italy exhibits the strongest comparative advantages in its construction, and medium-low and low technology manufacturing industries. Especially the comparative advantage of its construction industry has experienced an immense increase after the unification. Portugal shows a strong comparative advantage in its low technology industry over the whole period. Moreover, in the years after the Euro introduction a strong increase can be observed in the comparative advantage of its medium-low, construction, and transport and travel industries. Spain, finally, demonstrates a strong comparative advantage in mainly the construction sector and medium-low technology sector over the whole period.

We now move to the analysis of the trade balances of the peripheral countries. Firstly, the graph showing the relative contributions of imports and exports to the year-on-year changes in the peripheral countries’ overall trade balance reveals a very similar pattern for all these countries which sharply contrasts Germany’s image. In both Greece, Italy, Portugal, and Spain the overall trade balance with the rest of the world seriously deteriorates from year to year during most of the period — or at best only slightly increases or does not change as occasionally happens in Portugal — and this decline is by far mostly due to continuous strong
year-on-year growth in their imports – rather than a decline in their exports. Particularly in
the years following the monetary unification (2001 to 2006) do the value added imports of
these countries rise significantly. Secondly, the trade balance decomposition by contribution
of the main trading partners reveals that the Eurozone is for many of the peripheral countries
one of the key deficit contributing partners. Greece’s growth of its trade balance deficit in the
years following the Euro introduction was primarily the result of an increase in the negative
contribution of the Eurozone core and the growing trade deficit with China. A similar
observation for Portugal: the Eurozone core region is by far the most dominant negative
contributor to Portugal’s trade deficit and the country experienced a strong increase in this
bilateral trade deficit with the core in the years following the monetary unification. No
difference for Spain: similar to the graphs of the other GIIPS countries the Eurozone core
is one of the most dominant negative contributors to Spain’s overall trade balance. Thirdly,
a sector decomposition of the peripheral countries’ overall trade balance further confirm the
asymmetry. Greece’s graph reveals that the deterioration of Greece’s overall trade balance
after the monetary unification is mainly the result of an increase in the overall trade deficits
in its high tech manufacturing industries. Italy’s graph similarly shows that the decline in the
country’s overall trade balance after the monetary unification is mainly the result of a gradual
increase in the overall trade deficit of its high tech industry category and a simultaneous
gradual decrease in the trade surplus of its low tech industry category. No large difference
for Portugal: the gradual decline in its trade balance after the Euro introduction is mainly the
result of an increase in the trade balance of its high tech industry. Spain’s deterioration of
its trade balance after the Euro introduction, finally, is again mainly the result of an increase
in the value added trade balance of its high technology manufacturing industry.

8.1.3. Conclusion
All the empirical findings summarized above – and described in much more detail and ac-
companied by many graphs in chapter 6 – basically all support the overall message that
a substantial economic restructuring among the main Eurozone countries has been taking
place over the last two decades. We collected various structural insights which all to a
greater or lesser extent point out that the monetary unification in 2001 reinforced a process
of structural divergence between mainly Germany and the peripheral or Southern European
economies both in terms of their productive and trade structures and reflected on the sur-
face by a growing divergence between their overall current account balances. Germany has
gradually been intensifying its technological capabilities by building up a strong comparative
advantage in the production and export of high and medium-high technology manufacturing
goods, while the periphery has been technologically stagnant and got locked-up in special-
izing in low and medium-low tech manufacturing industries as well as several non-traded
industries including construction and tourism to name just a few. This undeniable growth in
asymmetry between the core and periphery is one of the main conclusions of the first analysis
chapter.

8.2. The story behind the Eurozone’s economic restructuring
The following discussion presents an attempt to link back the observed structural divergence
conclusion outlined in the previous section to the theoretical exposition that was presented
in the literature review chapter. It essentially sketches a story on how the Eurozone is
being subjected to a natural process of economic restructuring which is causing Europe to be gradually redrawn economically in many ways. It should be emphasized that this story did not emerge out of nowhere but was carefully derived from the economic theories from chapter ?? and is being backed up by the empirical findings of chapter 6.

The empirical analysis of chapter 6 has clearly pointed out that the macro-economic problems in the Eurozone are largely structural in nature. Put in simple terms, over the many years leading up to and following the monetary unification several of the Eurozone members, strongly led by Germany, have gradually strengthened their high technology intensive capabilities and associated technological competitiveness which is reflected in their industry specialization structure as well as their related export structure. These medium-high to high technological capabilities makes these countries internationally more competitive and more dynamic because it allows them to more easily tap into emerging markets who are experiencing strong growths in demand but don’t have a strong technological edge over these technological superior countries. Evidence shows that this ‘tapping in’ indeed happened. When analyzing how each of Germany’s trading partners yearly contributed to the country’s overall trade balance, it becomes very clear that Germany developed large growing trade surpluses with many of its trading partners over the period following the monetary unification – and indeed during that period most of these partners were experiencing booming times with rising levels of domestic aggregate final demand. Hence, Schumpeter’s long-ago emphasis on technology-led (or innovation-based) growth, with technological competition being the key driver, appears to hold-up quite well (Schumpeter, 1943).

On the other side, during the same period other members of the Eurozone, and mainly the Southern European or peripheral economies, have gradually been diverging towards specializing into medium-low and low technology activities as well as several non-trade activities which often include construction, hotels and restaurants, and wholesale, retail and repair services activities. In other words, the economic structure of these economies gradually got locked-up in a technologically stagnant, less productive state both in terms of industry specialization and in terms of trade structure. Moreover, these peripheral economies became increasingly dependent on imports to satisfy the demand of its domestic consumers and as empirical evidence showed a substantial part of that demand is increasingly being satisfied by German and other Northern European countries. This creates a reinforcing cycle which further widens the structural divergence between these opposing Eurozone groups.

Before these member countries joined the monetary union, each of them walked along a different path of economical, social and political development, steered by a variety of driving factors including, among others, competitive advantages, historical and geographical factors, increasing returns and transportation costs. Consequently, this gave rise to a strong variety of economic structures which developed in a path dependent manner and which uniquely characterized each of the acceding members when they entered the monetary union. The empirical evidence from this research project clearly suggests that the monetary unification, at least partially, must be hold responsible for reinforcing the structural heterogeneity among these Eurozone members which encouraged a strong uneven regional development of the Eurozone (i.e. on a country-level) and diverging industrial concentrations.

Let us assume that Paul Krugman’s model of centripetal and centrifugal forces steering economic development holds and that consequently these forces operate on the Eurozone economy. Then the evidence leads us to conclude that the Eurozone economy has strongly been steered by centrifugal forces which are responsible for fostering divergence and regional
specialization among the Eurozone members. Moreover, the evidence also suggests that the monetary unification and European integration have reinforced these centrifugal forces which accelerated the observed restructuring process. A plausible general explanation for this causal link between the establishment of the monetary union and the reinforcement of the regional divergence process goes as follows. If you sufficiently integrate economies, which happened during the creation of the Eurozone, then you logically become a unity in many ways: the Eurozone members experienced more or less the same interest rate, the same exchange rate, more or less the same fiscal policies or at least a very constrained fiscal policy space, one monetary policy, etc. As argued by Paul Krugman, among others, in this united economy the increase in market integration and trade liberalization associated with the creation of a monetary union leads to regional concentrations of certain industrial activities and hence regional specialization on a European level. Similar specializations occurred in, two give just two examples, the U.S. economy and the Dutch economy, where specific states respectively provinces started to more and more specialize in particular economic activities. For instance, in the U.S. Florida specialized mainly towards tourism, California towards technological start-ups (i.e. Silicon Valley) among others, etc. while in The Netherlands Drente started attracting tourism, Friesland’s main strength is water technology, etc. Hence, coming back to Europe’s situation, the empirical data confirms that over the last fifteen years – and especially after the monetary unification – the Eurozone has been subjected to such a similar restructuring but this time on a country-level (instead of a state or a province).

This process of structural divergence is a macro-economic process that arises from the rational behavior and decisions of the millions of individual actors in the economy who are all behaving according to their own interests. In short, households earn, spend and safe income in accordance to their individual preferences and how much they earn. Investors are continuously seeking investments which will give the highest possible returns under a particular risk level. Companies decide to expand or constrain their production activities, and on where to best locate new factories, etc. Governments are mitigating market imperfections, provide social safety, education, health insurance, make public investments, etc. And so on. In a sense it is very fascinating to see that the combination of all these individual decisions over the last two decades has yielded this Eurozone-aggregate process of structural divergence and asymmetries. Hence, in a way it could well be argued that this process and the associated centrifugal forces was perhaps largely inevitable or at least mostly a natural occurring process, outside the immediate influence of any of these individual actors.

What is more, this gradual restructuring of the Eurozone’s economy has also a significant impact on the international division of labour and the role played in this division by each Eurozone member. To be more specific, the uneven regional development among the Eurozone members will cause an associated restructuring of the internal division of labour. As an example, Spanish or Greek engineers will find more job opportunities in regions (i.e. countries) where there exists a larger supply of technical jobs, read Germany. Gradually an under-supply of technical jobs is expected to rise in some of the peripheral because of the observed process of de-industrialization. Attracted by more and better job prospects more and more engineers trained and raised in the periphery might decide to move from the periphery to Germany. Other labour migration flows could similarly develop between members of the Eurozone. The point is that the increasing regional specialization among the Eurozone members is expected to pull in motion a rising amount of labour migration flows between these various economies which are steered by the supply and demand of jobs in these regions.
8.3. How to deal with this growing economic divergence?

Now that we set out the storyline on the evolution of the Eurozone’s structural imbalances and its deeper origins, we turn to the important question on how to deal with this structural problem. Several scenario’s can be distinguished, some being more plausible than others. In regards to this scenario analysis, the aim of the second empirical analysis chapter in this research report – chapter 7 – has been to help empirically determine if some of these scenario’s could be considered feasible in any way – particularly in regards to the second scenario (see below). We provide an outline for each of these scenarios one by one. It should be noted that this enumeration is not meant to be exhaustive, but instead is aimed at offering outlines on several general policy paths to the European decision-makers concerning the stabilization of the Eurozone economy.

8.3.1. Scenario 1: Laissez-faire

The first scenario to deal with the structural divergence problem in the Eurozone is to just let it happen. Theoretically doing nothing is always one of the options. This scenario essentially entails to let the process happen without strongly interfering. In line with the conclusion from the previous section stating that the observed process of structural divergence is largely a natural occurring process steered by forces which are to a certain extent outside the immediate influence of any of the individual economic actors, this scenario could at first sight make good sense. It would at least be consistent and fit the ideology of an economic system characterized by a “laissez-faire” attitude as described by the economist John Stuart Mill or the related metaphor of Adam Smith’s invisible hand to describe the societal benefits
that arise when the individual economic actors in the economy are driven by self-interests and establish a natural force which self-regulates the overall market economy and theoretically could make everyone better off (Mill, 1848; Smith, 1776). In many ways this scenario would entail a liberal Anglo-Saxon view on society in which a free market orientation with limited government intervention is central. This is what we see in, two give two examples, the United States and the United Kingdom. So in a sense, one could expect it to be a feasible scenario in light of the evidence provided by two other large economies which have implemented such a system in practice. However, this scenario is not all rosy as one might be tempted to expect. Without elaborating on the ideological arguments for or against such a societal system we highlight one important barrier, or constraint, which could seriously hinder the practical feasibility of this scenario. It is the argument which we also made at the end of the previous section. The Eurozone economy differs with both the Anglo-Saxon economy of the U.S. as well of the U.K. on, among other factors, one important and undeniable characteristic: its regions (i.e. countries) are characterized by severe differences in both language and cultural traditions. This seriously hampers the overall degree of labour mobility within the Eurozone which could otherwise help in accommodating the situation by allowing the population (or more formally the labour production factors) to move to places where the ‘action’ is happening. Hence, the fact that the Eurozone populations have strong ties with their home regions because of linguistic and cultural barriers implies that they will get partially shielded from job opportunities (and hence welfare opportunities) that are created by the bigger internal dynamics in the ‘united’ Eurozone economy of which all these populations are part of. Put differently, whereas each Eurozone member plays its part in the regional specialization process and associated intra-Eurozone division of labour, the Eurozone populations cannot fully enjoy all the associated welfare opportunities because of an unavoidable absence of a flexible and open attitude towards working and living within the global Eurozone economy created by strong linguistic and cultural barriers. We are convinced that at least a part of the currently observed frictions among the Eurozone populations and the rising degree of political polarization among the Eurozone’s electorate – measured by the amount of extreme votes the Eurozone area – can be linked to the aforementioned inherent barrier.

8.3.2. Scenario 2: Exploit intra-Eurozone trade spillovers

The second scenario we discuss is the idea to exploit the intra-Eurozone trade spillovers, in terms of value added created, by a coordinated Eurozone growth-stimulus program composed of targeted public investments. To this end, we suppose that the Eurozone members could reach an agreement to join hands and implement a coordinated industry stimulation program whereby each country would stimulate each of its domestic industries by a particular, predetermined, country-specific amount of final demand. The underlying hope behind this scenario is that a targeted and simultaneous set of domestic public investments is capable of creating a stronger, multiplier-reinforced impact on the overall structure of the European economy, and could perhaps help to reduce the structural asymmetry between the Eurozone economies. The crucial point behind this scenario is that in an open economy – which each of the Eurozone economies are – a possibly significant amount of any external injection aimed at boosting the domestic aggregate demand might ‘leak’ away to foreign countries via the phenomenon of product fragmentation and the associated global value chains. We are aware that this scenario could be received as being partially unrealistic on the following
two grounds: (1) It could be seriously questioned whether a general consensus on such a
coordinated industry stimulation program could ever be easily achieved among the various
Eurozone members without the existence of a true democratic ‘Eurozone government’ with
its own budget and parliament – after all, each Eurozone government is primarily defend-
ing the interests of its own electorate; (2) The scenario is implicitly formulated under the
assumptions of a demand-pull input-output economy in which the final demand is assumed
to be an exogenous factor which is partly under control of the domestic governments since
they are part of the final demand consumer groups. Nevertheless, it certainly remains an
important scenario worth inspecting more closely.

As was mentioned earlier, the empirical analysis of chapter 7 was aimed at helping to
determine the feasibility and possible degree of success of this scenario, together with offering
suggestions for each country on which sectors to stimulate should the analysis reveal that such
a coordinated growth-stimulus could be feasible at all. The chapter analyzed the data for the
year 2011, the most recent year in the World Input-Output Database, and we assumed that
this data more or less describes the world’s current economic structure. The chapter started
with consecutively investigating two types of intra-Eurozone trade spillovers: (1) industry
stimulation spillovers of value added, and (2) final consumer stimulation spillovers of value
added (which essentially is the same is a country’s value added exports). The industry
stimulation spillovers quantify the additional value added (i.e. income, or GDP) that is
created in an industry of a foreign country by demanding one additional unit of output from
a particular domestic industry. Hence, these spillovers describe the intra-Eurozone industry
interdependencies. The final consumer stimulation spillovers, on the other hand, quantify
the impact of countries’ final consumers on the creation of value added on foreign countries.
Hence, these spillovers describes the ‘true’ trade spillovers created by the current buying
behavior of the various final demand consumer groups. The final consumer stimulation
spillovers of course partially come about via the industry interdependencies, but in addition
they also include the direct importing and exporting decisions of the various final consumers.
It is this difference which mainly distinguishes the two spillovers from one another.

The results of the first two sections of chapter 7 can be summarized as follows. As a
start, the average size of the intra-Eurozone trade industry stimulation spillovers in terms of
value added creation is very modest. The threshold in all the industry stimulation spillover
graphs was determined to be set at 0.02. If this value would be set at 0.05 many of the
spillover lines would already have disappeared. A spillover value of 0.02 implies that for each
additional unit (i.e. a dollars worth) of output demanded of a particular domestic industry,
only 2% (i.e. a fraction) of one additional (i.e a dollars worth) unit of output of the foreign
industry will be created. In other words, the impact of these intra-Eurozone value added
trade spillovers via industry stimulation seems to be relatively small.

Secondly, the industry stimulation spillover graphs again reveal an asymmetry between
the core and peripheral countries. None of the Eurozone core countries’ industries provides
significant value added creation incentives to any of the peripheral countries, while they do
significantly stimulate other core countries and primarily German ones. Furthermore, from the
opposite perspective none of the industries from the peripheral countries provide significant
value added creation incentives to any of the core countries expect to German ones. Neither
do any of the peripheral countries’ industries significantly stimulate the value added creation
of other peripheral countries’ industries. In short, Germany is again the biggest ‘winner’
among all these Eurozone countries: its industry interdependence structure reveals that it
collects by far the greatest amount of value added from the industry stimulation activities of other countries. And even more interesting is the clear observation that the German industries themselves don’t return any above-average value added spillover ‘favors’ to any industry of any of these Eurozone trade partners, the relation is hence seriously skewed.

Thirdly, the final consumption stimulation spillover graphs (which are essentially value added exports figures) reveal some signs of hope. The graphs show that among all the Eurozone core and peripheral countries German, French, Italian and Spanish final consumer groups create significant contributions to the GDP of foreign EU countries. German consumers create the most GDP in the other Eurozone countries. The other core countries’ consumers do not significantly influence the GDP creation in these peripheral countries. Overall the core countries have a much higher percentage of their GDP created by foreign sources of final demand in comparison to the peripheral countries which consequently are more dependent on domestic sources of final demand. With regards to the situation of the periphery the graphs show that Germany and France are the two Eurozone countries whose final consumers significantly impact the creation of value added in most of the peripheral countries. For example the following percentages highlight the amount of the country’s GDP activated by German consumers: Italy (2%), Ireland (3.4%), Portugal (1.5%), and Spain (1.7%). For France the following values apply: Italy (1.7%), Ireland (2.1%), Portugal (1.8%), and Spain (2.2%). The other major contributors are all non-Eurozone countries.

The third section of chapter 7 addressed the feasibility of a coordinated Eurozone stimulus scenario aimed at reducing the Eurozone imbalances. To be more specific we analyzed two concrete scenarios. The first scenario simulated the situation in which each Eurozone country increases its public spending on its manufacturing sectors with 2 per cent of its GDP-level in 2011, to determine how much the GDP-levels in each country would eventually rise. The second scenario is similar to the first and only differs from it in that it stimulates all industries instead of only the manufacturing industries. Of course, in both scenarios each country’s GDP will minimally increase with 2 per cent, but we are interested in the additional percentage points which are created by the global spillover effects. Overall the results of these two stimulation scenarios suggest that if the coordinated stimulation is targeted towards the manufacturing industries only, then several significant multiplier effects can be exploited to generate additional amounts of value added in the Eurozone countries – with several inevitable spillover ‘leaks’ to other parts of the world. To be more specific, in our scenario where each Eurozone country stimulated its manufacturing industries by 2% of its GDP in total, a large majority of these countries generated at least 2% additional GDP, whereas several countries even reached values of 3% or higher. With regards to reducing the macro-economic imbalances between the core and peripheral countries, our analysis seems to suggest that the intra-Eurozone spillover effects generate much smaller impacts on the peripheral countries while contributing much more to the core countries. Hence, our analysis suggest that exploiting possible spillover effects to reduce the imbalances via a coordinated stimulus scenario is not very plausible. This last observation is in line with the structural asymmetry between the core and peripheral countries which emerged as one of the important observation from the previous two analysis chapters.

In light of the aforementioned observations we end this section by stating two main conclusions. Firstly, a coordinated Eurozone-level domestic demand-led strategy (by targeted industrial and income policies) could potentially be beneficial in supporting a sustained recovery of the recession in the Eurozone, because the empirical results reveal that the intra-Eurozone
8.3. How to deal with this growing economic divergence?

Spillovers can significantly be exploited to increase the overall gains from coordinated action. This general conclusion is also empirically confirmed by similar research. Garbellini et al. (2014b) also used to World Input-Output Database to analyze the domestic demand and global production in the context of the Eurozone crisis, and they conclude that “a strategy of coordinated fiscal austerity cannot be sustained by empirical evidence” (Garbellini et al., 2014b, p. 335). Their main policy implication, and also an important conclusion of our analysis, is formulated very clearly as follows: “The Eurozone countries should reconsider the prominent role of domestic sources of final demand in determining activity levels, acknowledging that spillovers may significantly amplify potential gains from coordinated action. Such a 'coordinated domestic demand-led policy', in which fiscal expansion, together with targeted industrial and income policies, are tipping points for a sustained recovery, remains essential.” (Garbellini et al., 2014b, p. 355) Our analysis strongly confirms this conclusion and even makes it a little more concrete and specific by pointing out that stimulation of the manufacturing industries yields significant more benefits for each Eurozone country, in comparison to scenarios in which all the industries are stimulated. Secondly, it is not feasible to help re-balancing the Eurozone industrial structure by a spillover generating coordinated program of domestic public investments. The results of our stimulus scenarios clearly suggest that the intra-Eurozone spillover effects generate much smaller impacts on the peripheral countries while contributing much more to the core countries. This is further confirmed by the industry stimulation spillover graphs which identified Germany as the big winner receiving significant amounts of value added and not returning any above-average favors to the industries of the other Eurozone partners.

8.3.3. Scenario 3: Introduce central fiscal stabilization mechanism

The third scenario which we will briefly discuss is the proposal advocated by many economists to create some sort if automatic fiscal stabilizers at the center of the Eurozone whose main purpose would be to transfer money from the core to the periphery in order to help in restructuring the economy and gradually restore the structural balance. To be more specific, this scenario essentially proposes to create a substantial Eurozone central budget with the purpose for it to be used as a fiscal stabilization instrument to reverse the diverging industrial trends and associated region-specific recessions. This implies that the Eurozone monetary union eventually needs to get embedded in a fiscal union. This has been argued by many economist to be an essential next step after the monetary unification because without it the Eurozone would have no single real policy instrument to stabilize country-specific downturns, such as the ones experienced in the peripheral countries. This might sound like the most logical scenario and most promising scenario, but unfortunately this proposal receives strong opposition by many member states. In the words of economist Paul De Grauwe: “This is probably the hardest part of the process to make the Eurozone sustainable in the long run, as the willingness to transfer significant spending and taxing powers to European institutions is very limited. It remains a necessary part, though. Without significant steps towards fiscal union there is no future for the Euro.” (De Grauwe, 2013).
8.4. Reflections

In this section I reflect on my overall research process and I evaluate the final product. I start with a discussion on the scientific contribution of my work, after which I briefly argue its societal relevance. Next, I focus on several of my thesis’s strongest points. Lastly, I turn attention to my thesis’s main shortcomings and opportunities for further research.

Scientific contribution

This graduation project has been relevant from a scientific perspective for several reasons. Firstly, because the World Input-Output Database was released relatively recently, we were able to distill many new empirical insights which were not yet extensively discussed in the literature, especially on the productive structure of the Eurozone economies as well as the international interrelatedness in productive and demand structures. Secondly, this research project helped in closing an important gap in the current literature body: linking insights on the sectoral production linkages to the current Eurozone crisis and the persistent macroeconomic imbalances between the Northern and Southern European countries. Thirdly, the detailed mathematical elaboration presented in our research methodology chapter in itself already created substantial value to the academic literature on input-output models and trade in value added. The authors of the few articles we were able to find on measuring trade in value added terms, all adopted their own notation throughout the mathematical derivation of their framework and trade metrics. These notations surprisingly varied substantially with the standard notation adopted in Miller and Blair’s classical textbook (an essential reference on input-output research). Because we believed a clear and consistent mathematical basis was crucial for the derivation of structural indicators and for our empirical analyses, we developed a consistent notation from scratch aimed at being a logical and coherent extension of the input-output notation used by Miller and Blair. Fourthly, the integration of our theoretical input-output model with the individual World Input-Output Tables into one comprehensive and operable framework in Matlab (see appendix C for a detailed discussion), proved to be of great use for quickly calculating any of the structural indicators and spillover graphs. This Matlab model could be a useful tool for future researchers to analyze related research questions, because it would enable them to quickly calculate new indicators without having to implement the entire model and its mathematical equations from scratch.

Societal relevance

As already mentioned during the introduction of this research report, this graduation project has also been relevant from a societal perspective. The Eurozone debt crisis has been the most severe crisis in long the history of the European Union. There rests no doubt that in future history textbooks this crisis will be described as an important milestone in the history of Europe. Most signs today indicate that the decisions made by the European political decision-makers so far have failed in greatly improving Europe's economical conditions after the outbreak of the global financial crisis. To this day, the question of what can and should be done remains highly relevant. By providing new insights and testing alternative policy scenarios this research made a valuable contribution to this question. In the end, we must not forget that all these theoretical and empirical observations could help to impact the lives of millions of businesses and ordinary people. I’m therefore confident that this research project
is characterized by a high societal relevance.

**Thesis’s strengths**

I’m confident that my thesis exhibits several strong points and interesting findings. Firstly, my story has focused on both the underlying causes of the macroeconomic imbalances as well as on concrete policy suggestions on how to deal with these problems, and has furthermore been backed up by substantial empirical findings. Secondly, the empirical findings in my thesis have been presented as much as possible in a visual manner. Compared to the traditional and often difficult to interpret numeric tables, the figures in my thesis have been attempting to make the structural insights relatively easy to understand. In particular the visualization of the spillover graphs by means of a circular layout has never been done before in the literature (as far as I know) and offers many interesting and easy to interpret insights. Thirdly, as already mentioned above, the comprehensive Matlab implementation developed during this research project proved to be of vital importance to efficiently collect the right empirical insights.

**Thesis’s shortcomings and further research**

Inevitably my graduation project is also characterized by several weaknesses and shortcomings. Firstly, a lot of time was spent on developing the mathematics required to measure trade in value added and to decompose gross exports into its domestic and foreign parts. Some of these mathematical derivations were eventually not used during the empirical analysis chapters. I’m convinced that it would have been better if I had first determined a list of the indicators relevant for my research questions before diving into some unnecessary mathematical details. Secondly, in line with this observation, I also believe that it would have been more efficient if I had first determined a rough sequence of graphs to discuss in my first empirical analysis chapter. The strategy I applied with regards to writing this chapter was to first generate a broad variety of puzzle pieces (i.e. graphs) revealing many insights on the evolution of the Eurozone’s industry and trade structure evolution and to subsequently order a selection of these pieces into a coherent storyline. I’m convinced that based on previous literature articles it could have been more efficient to build further on their conclusions and storylines by trying to fill in their shortcomings with additional empirical extensions, instead of building up a complete story from scratch. Thirdly, I limited my research to only analyzing total output and value added values. The World Input-Output Database also contains data to determine the evolution of several types of employment indicators and to determine detailed spillover impacts in terms of employment. If I had more time it would have been very interesting to include an analysis of these indicators and effects in my analysis. Hence, this is an important area for further research. Fourthly, in the first empirical analysis chapter I often limited my discussion to a comparison between Germany and the five peripheral countries. In future research it could be interesting to include the other four core countries as well as the continental Eurozone countries into these analyses. Fifthly, my first empirical analysis chapter mainly analyzes and compares the production and trade structure of these six countries in a *graphical* way, but does not summarize the discovered asymmetry into quantifiable indicators. For future research it could be useful to find ways to summarize and encapsulate the differences in industry and trade structures into single-value indicators, like
for example ‘structural uniformity’ which would numerically describe these differences and make it more easy to compare the various Eurozone countries. Lastly, I did not present any statistical conclusions in my research project. While my visual representations clearly show the existence of a strong structural asymmetry in the Eurozone, we are still unable to state how significant this asymmetry is. The same observation applies to the conceptual research model presented in chapter 4. While this model illustrated the context of our research questions and highlighted our literature gap, we did not empirically test any of the causal and/or moderating relations of this model. I believe that this could be another interesting research area with many research opportunities.
# A. WIOD country labeling and industry classification

The 35 industries and 41 countries distinguished by the World Input-Output Database (WIOD) are listed in the Figure 1.

<table>
<thead>
<tr>
<th>WIOD industry classification</th>
<th>WIOD countries</th>
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</thead>
<tbody>
<tr>
<td>Industry code</td>
<td>Industry name</td>
</tr>
<tr>
<td>1 Agriculture, Hunting, Forestry and Fishing</td>
<td>AUS Australia</td>
</tr>
<tr>
<td>2 Mining and Quarrying</td>
<td>AUT Austria</td>
</tr>
<tr>
<td>3 Food, Beverages and Tobacco</td>
<td>BEL Belgium</td>
</tr>
<tr>
<td>4 Textiles and Textile Products</td>
<td>BGR Bulgaria</td>
</tr>
<tr>
<td>5 Leather, Leather and Footwear</td>
<td>BRA Brazil</td>
</tr>
<tr>
<td>6 Wood and Products of Wood and Cork</td>
<td>CAN Canada</td>
</tr>
<tr>
<td>7 Pulp, Paper, Printing and Publishing</td>
<td>CHN China</td>
</tr>
<tr>
<td>8 Coke, Refined Petroleum and Nuclear Fuel</td>
<td>CYP Cyprus</td>
</tr>
<tr>
<td>9 Chemicals and Chemical Products</td>
<td>CZE Czech Republic</td>
</tr>
<tr>
<td>10 Rubber and Plastics</td>
<td>DEU Germany</td>
</tr>
<tr>
<td>11 Other Non-Metallic Mineral</td>
<td>DNK Denmark</td>
</tr>
<tr>
<td>12 Basic Metals and Fabricated Metal</td>
<td>ESP Spain</td>
</tr>
<tr>
<td>13 Machinery and Equipment, Nec</td>
<td>EST Estonia</td>
</tr>
<tr>
<td>14 Electrical and Optical Equipment</td>
<td>FIN Finland</td>
</tr>
<tr>
<td>15 Transport Equipment</td>
<td>FRA France</td>
</tr>
<tr>
<td>16 Manufacturing, Nec; Recycling</td>
<td>GBR United Kingdom</td>
</tr>
<tr>
<td>17 Electricity, Gas and Water Supply</td>
<td>GRC Greece</td>
</tr>
<tr>
<td>18 Construction</td>
<td>HUN Hungary</td>
</tr>
<tr>
<td>19 Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles</td>
<td>IDN Indonesia</td>
</tr>
<tr>
<td>20 Repair of Household Goods</td>
<td>IND India</td>
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<tr>
<td>21 Repair of Household Goods</td>
<td>IRL Ireland</td>
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<tr>
<td>22 Hotels and Restaurants</td>
<td>ITA Italy</td>
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<tr>
<td>23 Inland Transport</td>
<td>JPN Japan</td>
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<tr>
<td>24 Water Transport</td>
<td>KOR Korea</td>
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<tr>
<td>25 Air Transport</td>
<td>LUX Luxembourg</td>
</tr>
<tr>
<td>26 Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies</td>
<td>LVA Latvia</td>
</tr>
<tr>
<td>27 Real Estate Activities</td>
<td>MEX Mexico</td>
</tr>
<tr>
<td>28 Public Admin and Defence; Compulsory Social Security</td>
<td>MLT Malta</td>
</tr>
<tr>
<td>29 Renting of M&amp;Eq and Other Business Activities</td>
<td>NLD The Netherlands</td>
</tr>
<tr>
<td>30 Education</td>
<td>POL Poland</td>
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<tr>
<td>31 Health and Social Work</td>
<td>PRT Portugal</td>
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<tr>
<td>32 Other Community, Social and Personal Services</td>
<td>ROU Romania</td>
</tr>
<tr>
<td>33 Private Households with Employed Persons</td>
<td>RUS Russia</td>
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<td>34 USA United States</td>
<td>SVK Slovak Republic</td>
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<td>35 Taiwan</td>
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<td>37 Turkey</td>
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<td>38 Rest of the World</td>
<td>TWN Taiwan</td>
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<tr>
<td>39 United States</td>
<td>USA United States</td>
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<tr>
<td>40 RoW Rest of the World</td>
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B. Aggregation of industries and countries

The World Input-Output Database (WIOD) captures trade data for 35 industries and 41 countries, of which an overview was provided in appendix A. This appendix focuses on aggregating the industries into a smaller set of higher-level categories, and similarly on aggregating the countries into a smaller amount of multi-country groups. The main reason behind these aggregation steps is to be able to better focus on the variables that are expected to be partly explanatory in the context of both the Eurozone crisis as well as the general economic developments within and between the Eurozone countries and their trade partners. Having to search for (and interpret) trends in an disaggregated dataset containing over two million trade interdependencies (i.e. \((35 \times 41)^2 > 2 \times 10^6\)) per year for a period of 17 years, would be an elaborate process and could allow for broader trends be more easily overlooked. Smartly aggregating the industries and countries into smaller but meaningful groups allows us to better focus on the developments that are relevant for this graduate project.

It is important to note that the aggregation steps will only be applied after the multiplier matrices and all structural indicators have been calculated using the original disaggregated data. The aggregation steps do not aim at (nor achieve) any reduction in the number of calculations required to calculate the indicators. The main motivation behind the aggregation, on the contrary, is achieving a clearer view on the relevant developments in the context of the Eurozone. Put differently, the econometric part of the analysis will use all the disaggregated data to capture the various trade interdependencies on their most detailed level. The descriptive part of the analysis, which succeeds the econometric part, will use the smaller set of broader aggregate industries and countries in order to focus on the key trends and dependencies in the data. The first subsection of this section deals with the aggregation of the industries. The second subsection discusses the country aggregation.

B.1. Industry aggregation

The industries in the WIOD are classified according to Revision 2.0 of the International Standard Industrial Classification (ISIC) of all economic activities, in short ISIC Rev. 2 (Timmer et al., 2012). This industry classification scheme is developed by the statistics division of the United Nations and includes both goods and services industries. The ISIC Rev. 2 classification corresponds to Revision 1 of the NACE code, developed by the European Union. The WIOD uses an industry disaggregation at the two-digit level for most industries (e.g. industry 25, representing ‘Rubber and Plastics’), even though some industries are disaggregated only at the one-digit level (e.g. industry F, representing ‘Construction’).

The sectoral breakdown in ISIC (and hence in the WIOD) essentially conforms to the three-sector theory developed by A. Fisher, C. Clark and J. Fourastié, according to which economies can be divided into three main sectors of activity: primary, secondary, and tertiary sectors (Fisher, 1939). In ISIC Rev. 2, industries A to C (01 to 14) together constitute the primary industries, representing the industries that directly process natural resources and other raw materials. The secondary industries are all posted under label D and represent the industries that manufacture finished goods, including the construction industry. The remaining industries E to Q represent the tertiary industries producing services instead of finished goods.

For the descriptive part of the analysis, the original industries in the WIOD are aggregated and re-labeled into a smaller set of broader industries. The resulting industry grouping is
shown in Table 1, and adheres to the overall three-sector breakdown. The numbers to the left in each cell of the table denote the associated WIOD sector numbers, the numbers to the right denote the corresponding NACE Rev 1 Codes. Let us now walk through this table.

To start with the primary industries, the two industries of this type distinguished by the WIOD are renamed to ‘Agriculture’ and ‘Mining’ respectively. Next, only four secondary (or manufacturing) industries are distinguished: ‘Low-technology’, ‘Medium-low-technology’, ‘Medium-high-technology’, and ‘High-technology’. The manufacturing industries are classified according to a technological criterion, because the technological effort required to produce certain products is broadly considered to be a key determinant of an economy’s productivity growth as well as international competitiveness (OECD, 2007, p. 219). Because of this relation between technology and growth and the fact that technological effort is well known to be distributed unevenly throughout the various sectors in the economy, technological aspects are considered to be important for economic analyses of structural change and industry performance. The four-fold classification listed above conforms to the technology intensity definition as formally defined by the OECD Directorate for Science, Technology and Industry (OECD, 2011a). This widely accepted classification distinguishes manufacturing industries according to their technology intensity by looking at their direct research and development (R&D) intensity. This measure is based on the original paper by Hatzichronoglou (1997) in which he formally defines the four manufacturing categories listed above. To be more precise, the four categories are determined by looking at two technology intensity indicators for each industry (for a selected set of 12 OECD countries and covering the period 1991-1999):

1. R&D expenditures divided by value added, and
2. R&D expenditures divided by production

Based on this technology intensity definition we classify the manufacturing industries in the WIOD into the four technology intensity groups as shown in Figure 1. It should be noted, however, that three slight adaptations have been made to the OECD’s original technology intensity classification in order to deal with the absence of separate disaggregated data for several sub-industries in the WIOD. Firstly, according to the technology intensity definition sub-sector 2423 (Pharmaceutical industry) is considered high-technology, while the rest of sector 24 is classified as medium-high-technology. Since the Pharmaceuticals industry is by many considered to be an important high-technology industry, we decided to classify sector 24 as high-technology manufacturing. Secondly, according to the technology intensity definition, sub-sector 353 (Aircraft and spacecraft) is a high-technology industry, sub-sector 352 and 359 (Railroad and transport equipment) are medium-high-technology industries, and sub-sector 351 (Building and repairing of ships and boats) is a medium-to-low-technology industry. Because the WIOD considers sectors 34 and 35 to be one aggregate industry, disaggregated data for these separate sub-sectors is not available. Hence, since sector 34 is classified by the definition as a medium-high-technology industry, we decided to classify the aggregate industry 34 to 35 as medium-high-technology manufacturing. Thirdly, because sectors 30, 32, and 33 are considered to be high-technology industries and sectors 30 to 33 are grouped as one aggregate sector in the WIOD, we decided to classify this aggregate industry as high-technology, even though sector 31 is considered to be only medium-high-technology manufacturing.
### Primary industries

<table>
<thead>
<tr>
<th>Industry</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture, Hunting, Forestry and Fishing</td>
<td>01-05</td>
</tr>
<tr>
<td>Mining</td>
<td>10-14</td>
</tr>
</tbody>
</table>

### Secondary industries

<table>
<thead>
<tr>
<th>Industry</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture, Hunting, Forestry and Fishing</td>
<td></td>
</tr>
<tr>
<td>Mining</td>
<td></td>
</tr>
<tr>
<td>High-technology manufacturing</td>
<td></td>
</tr>
<tr>
<td>Secondary industries</td>
<td></td>
</tr>
<tr>
<td>Medium-high-technology manufacturing</td>
<td></td>
</tr>
<tr>
<td>Primary industries</td>
<td></td>
</tr>
<tr>
<td>High-technology manufacturing</td>
<td></td>
</tr>
<tr>
<td>Medium-high-technology manufacturing</td>
<td></td>
</tr>
<tr>
<td>Low-technology industries</td>
<td></td>
</tr>
<tr>
<td>Primary industries</td>
<td></td>
</tr>
<tr>
<td>Medium-high-technology manufacturing</td>
<td></td>
</tr>
<tr>
<td>Low-technology industries</td>
<td></td>
</tr>
<tr>
<td>Medium-low-technology industries</td>
<td></td>
</tr>
<tr>
<td>Tertiary industries</td>
<td></td>
</tr>
<tr>
<td>Utilities</td>
<td></td>
</tr>
<tr>
<td>Construction</td>
<td></td>
</tr>
<tr>
<td>Wholesale, Retail and Repair</td>
<td></td>
</tr>
<tr>
<td>Hospitality</td>
<td></td>
</tr>
<tr>
<td>Transport and Travel</td>
<td></td>
</tr>
<tr>
<td>Post and Telecommunications</td>
<td></td>
</tr>
<tr>
<td>Financing, Insurance and Pension Funding</td>
<td></td>
</tr>
<tr>
<td>Renting and Business Activities</td>
<td></td>
</tr>
<tr>
<td>Public sector services</td>
<td></td>
</tr>
<tr>
<td>Renting of Machines and Equipment and Other Business Activities</td>
<td>71-74</td>
</tr>
</tbody>
</table>
Finally, we make a distinction between eight tertiary industries. The aggregation and labeling of the categories ‘Wholesale, Retail and Repair’ and ‘Transport and Travel’ is based on our own understanding without reference to any formal definition. The definition of the category ‘Public sector services’ is based on the classification presented in the OECDs Science, Technology and Industry Scoreboard of 2011 (OECD, 2011b, p. 194). The other categories simply constitute a re-labeling of the original industries.

To summarize, the resulting aggregated industries are listed in Table 2. The number of industries to be analyzed has thus been reduced to 15, compared to the 35 original industries distinguished by the database.

<table>
<thead>
<tr>
<th>Nr</th>
<th>Code</th>
<th>Industry name</th>
<th>WIOD sector number</th>
<th>NACE 1 (= ISIC Rev. 2) code</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PRIM</td>
<td>Primary sector (agriculture and mining)</td>
<td>1,2</td>
<td>AtC</td>
</tr>
<tr>
<td>2</td>
<td>LT</td>
<td>Low tech manufacturing</td>
<td>3-7, 16</td>
<td>15-22, 36-37</td>
</tr>
<tr>
<td>3</td>
<td>MLT</td>
<td>Medium-low tech manufacturing</td>
<td>7, 10-12</td>
<td>23, 25-28</td>
</tr>
<tr>
<td>4</td>
<td>MHT</td>
<td>Medium-high tech manufacturing</td>
<td>13, 15</td>
<td>29, 34-35</td>
</tr>
<tr>
<td>5</td>
<td>HTM</td>
<td>High tech manufacturing</td>
<td>9, 14</td>
<td>24, 30-33</td>
</tr>
<tr>
<td>6</td>
<td>UTI</td>
<td>Utilities</td>
<td>17</td>
<td>E</td>
</tr>
<tr>
<td>7</td>
<td>CON</td>
<td>Construction</td>
<td>18</td>
<td>F</td>
</tr>
<tr>
<td>8</td>
<td>WRR</td>
<td>Wholesale, retail, and repair</td>
<td>19-21</td>
<td>50-52</td>
</tr>
<tr>
<td>9</td>
<td>HOS</td>
<td>Hotels and restaurants</td>
<td>22</td>
<td>H</td>
</tr>
<tr>
<td>10</td>
<td>TT</td>
<td>Transport and travel</td>
<td>23-26</td>
<td>60-63</td>
</tr>
<tr>
<td>11</td>
<td>ICT</td>
<td>Post and telecommunications</td>
<td>27</td>
<td>64</td>
</tr>
<tr>
<td>12</td>
<td>FIRE</td>
<td>Financial intermediation, insurance, and real estate</td>
<td>28, 29</td>
<td>J, 70</td>
</tr>
<tr>
<td>13</td>
<td>PSS</td>
<td>Public sector services</td>
<td>30-35</td>
<td>L-P</td>
</tr>
</tbody>
</table>

Table 2: Resulting industry grouping after aggregation and re-labeling.

B.2. Country aggregation

In this subsection the original 41 countries in the WIOD are grouped into smaller multi-country groups. The discussion of this regrouping can be separated into two subsections. The first part of this subsection deals with grouping of the countries within the Eurozone. The second part focuses on defining several major non-European trading blocks.

Aggregation of Euro area countries

In the context of the macro-economic developments that occurred within the Euro area during the 1990’s and 2000’s, it is our aim to classify the EU member states according to a measure that captures the essence of the growing observed divergence between the core and periphery countries in the Euro area. Because many authors in the literature emphasize that the observed ‘core-periphery dualism’ – a term used by Cesaroni and De Santis (2014) – is manifested and caused by the growing current account differences between the various members of the Euro area since the middle of the 1990’s, we decide to classify the Euro area countries according to how this indicator has evolved over the last two decades.

Figure 2 shows the evolution of the current account balance for 14 of the 19 Euro area members, covering the period from 1994 to 2013. With respect to the five missing countries – Estonia, Cyprus, Latvia, Lithuania, and Malta – it should be noted that the OECD.stat
database used to compile this graph did not provide current account data for these countries. However, the expenditure weights of these five missing countries (i.e. the share of expenditure components in GDP) compared to the rest of the Euro area for 2015 sum to a total of merely 1.1%, which basically indicates that these five countries only account for a small part all the economic activity in the Euro area.

By analyzing this graph we can clearly see that just after the monetary unification a strong divergence in current account balances among the Eurozone members started to arise. Based on this observation we can classify each Euro area member into one of three groups:

1. The first group collects those countries that have had a consistent current account surplus (i.e. a positive balance) after the turn of century. This group consist of the following members: Germany, The Netherlands, Austria, Finland and Belgium. In line with the literature, we refer to this group as the core countries of the Euro area, or alternatively the Northern European countries.

2. The second group corresponds to the countries that have had a consistent current account deficit (i.e. a negative balance) after the turn of the century. This group consists of the following members: Greece, Italy, Ireland, Portugal and Spain. These countries are often commonly described as the ‘GIIPS’ countries. In line with the literature, we refer to this group as the periphery countries of the Euro area, or alternatively the Southern European countries.

3. The third group captures the remaining countries, whose current account balance has been fluctuating around zero to varying degrees and with varying frequencies. This group includes the following countries: Cyprus, Estonia, France, Latvia, Lithuania,
B. Aggregation of industries and countries

Luxembourg, Malta, Slovak Republic and Slovenia. We refer to this group has the **Continental European** countries.

The core-periphery classification provided above accords to the prevailing classification used by many authors in the literature (see for example Cesaroni and De Santis (2014), Angelini and Farina (2012), or Gros (2012)). Furthermore, these country groups do not only share a similar evolution of their current account balance. These groups also share common developments in several other aggregate indicators such as productivity and employment, as is shown by an analysis of the McKinsey Global Institute (Roxburgh, 2010). According to the findings presented in this report, the core countries generally experienced above-average productivity (compared to the rest of the EU) while their labour utilisation rates were generally significantly below the average. The peripheral countries lagged substantially behind the average levels on productivity as well as on measures related to innovation and the development of the service sectors (Roxburgh, 2010, p. 9).

The evolution of the total current account balance for the core and periphery countries, as well as for the complete Euro area, is depicted in Figure 3.

![Current account developments in the Eurozone, Eurozone regions](image)

**Figure 3:** Evolution of the total current account balance for the core (Northern European) and periphery (Southern European) countries, as well as for the overall Euro area. The group of core countries includes: Germany, The Netherlands, Austria, Finland and Belgium. The group of periphery countries includes: Greece, Italy, Ireland, Portugal and Spain. (Source: OECD.Stat)

Both Figure 2 and 3 highlight the observation that after completion of the European Monetary Union (EMU) and the associated introduction of the Euro in 2000, a substantial and persistent divergence between the core and peripheral countries has progressively emerged, especially from 2004 until to advent of the financial crisis in 2007.

Now that the Euro area members have been classified into three groups, we classify the remaining members of the European Union into one group, and refer to this group as the
Non-Euro EU countries. This group comprises the following countries: Bulgaria, Czech Republic, Denmark, Hungary, Poland, Romania, Sweden and the United Kingdom (Croatia would also be classified in this group, but this country is not listed in the WIOD). To summarize, the resulting aggregation of the various EU countries described above is geographically visualized in Figure 4.

![Figure 4: Visualization of the resulting aggregation of the EU countries.](image)

**Aggregation of Non-European countries**

This part focuses on aggregating the remaining countries listed in the World Input-Output Database (i.e. other than the European countries) into several ‘supranational’ regions or trade blocs, in order to be able to analyze the trade patterns and developments between these multi-country regions. The definition of these trade blocs is chosen to be in accordance with the regional aggregation proposed by the creators of the WIOD in their user guide (Timmer et al., 2012). They distinguish the following five non-European trade blocs:

2. **East Asia**: Japan, Korea and Taiwan.
3. **China**
4. **BRIIAT**: Brazil, Russia, India, Indonesia, Australia and Turkey
5. **RoW**: Remaining non-European countries in the WIOD not classified in one of the first four categories above.
To summarize, the resulting aggregated countries are listed in Table 3.

<table>
<thead>
<tr>
<th>Resulting aggregated countries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nr</td>
</tr>
<tr>
<td>-----</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
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<tr>
<td>3</td>
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<tr>
<td>4</td>
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<td>6</td>
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<td>7</td>
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<tr>
<td>8</td>
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<tr>
<td>9</td>
</tr>
</tbody>
</table>

Table 3: Resulting country grouping after aggregation.
C. Model implementation in Matlab

This section describes how the mathematical input-output model introduced in the previous section has been implemented in Matlab. Focus is put on describing the main data structures and the overall framework as well as the general workflow that has to be adopted by the user in order to retrieve data for a particular metric of his choice.

C.1. Combining the Excel input-output tables into one comprehensive Matlab database

This subsection provides an outline on how the original world input-output tables (WIOTs) for each year over the period 1995-2011 have been converted and combined into one comprehensive data structure in Matlab. The input-output tables are publicly available in Excel format and are part of the World Input-Output Database (WIOD) project which is funded by the European Commission as part of the 7th Framework Programme. Each of the WIOTs contains world input-output data expressed in current prices and denoted in millions of US dollars for a particular year. A detailed discussion on the construction of the WIOTs can be found in Dietzenbacher et al. (2013).

I have chosen to implement the input-output model in Matlab because this programming language offers several key advantages over Excel in relation to the required modeling tasks. Firstly, the basis data element in Matlab is the matrix and the language has built-in mathematical operations for nearly all standard matrix operations. As the input-output model is based entirely on linear operations this creates a natural fit between the modeling exercise and the adopted programming language. Secondly, Matlab offers a complete programming environment (not only a programming language) which allows for the definition of programs and functions to encapsulate separate tasks, perform repetitive tasks, etc. Thirdly, Matlab allows for the definition of so-called multidimensional matrices which are defined as matrices having more than two dimensions. This is a useful property that allows for all the input-output tables (i.e. for all years) to be stored into one overall data structure which can be easily modified and adjusted. This is especially advantageous for analyzing the evolution of any indicator over two or more years.

Before focusing on restructuring the separate Excel WIOTs into one comprehensive data structure in Matlab, we first provide a discussion on converting the input-output tables from current to constant prices. Although this discussion might seem a little technical it does emphasize an essential step that should not simply be overlooked. Indeed, without this step the year-on-year comparisons of any derived structural indicator would only be possible in nominal terms and not in real terms which could potentially create a significant bias in any of the results.

Converting the data from current to constant prices

As mentioned earlier, the world input-output tables are expressed in (million US dollar) current prices, or nominal terms, for each particular year. This means that the data values in each table are expressed in the value of the US dollar currency for that particular year. In order to allow for volume comparisons over two or more years and hence measure the true growth of the data series it is necessary for the input-output tables to be expressed into constant prices, or real terms. Representing data in constant prices involves expressing the
data for each year in the value of a chosen base year (i.e. in the prices of that year) and hence correcting all values for the inflation that occurred over the whole period. This implies revaluing every data point into the chosen year’s prices. The idea behind this is that when the constant price values change from one year to the next then that change will fully capture the change in volume, because the effect of a change in prices has already been controlled for (i.e. the effects of price inflation have been adjusted for).

Generally, constant price data series are derived from current price series using so-called price deflators (or price indices) to deflate the current price data series. Hence, price deflators for each industry and for each year are required in order to convert the current price input-output tables to constant price equivalents expressed in a particular base year. Fortunately, a set of world input-output tables in previous year’s prices is made publicly available by the WIOD project for the years 1996 to 2009.\(^1\) Details on these WIOTs in previous year’s prices and the adopted construction method can be found in Los et al. (2014). By combining the current price and previous year’s price input-output tables we can calculate the price deflators for each industry for each year over the period 1996-2009. Using these deflators we can then convert the current price WIOTs in constant prices of any chosen base year. We now turn our attention to the details of this conversion process from current to constant prices.

The constant price construction method adopted for this research project corresponds to what is called the double deflation method (Los et al., 2014). This method adopts the principle of uniform row valuation. This principle basically states that the price of a good or service produced by any particular industry is applicable to all supplies (or ‘deliveries’) of that good or service. In other words, each particular industry row in any of the input-output tables has a uniform industry price which is the same for all the cells in that row – both cells related to intermediate deliveries as well as those related to deliveries to final demand purchasers. Hence, each cell in any particular row can be deflated by the same gross industry output deflator. These gross industry output deflators can be calculated by dividing the current price gross output values (the values in the last column of the original input-output tables) by their corresponding previous year’s price output values (the values in the last column of the input-output tables in previous year’s prices), or in short:

\[
p_r^i(t) = \frac{x_r^i(t)}{\tilde{x}_r^i(t)}
\]

where \(p_r^i\) denotes the price deflator of industry \(i\) in country \(r\), the \(\tilde{\text{\scriptsize{\text{\textregistered}}}\text{\scriptsize{\text{\textregistered}}}}\) notation indicates a value in previous year’s prices, and the \(\text{(t)}\) notation indicates that the value originates from the input-output table of year \(t\). To summarize, all cells in the row corresponding to industry \(i\) in country \(r\) for year \(t\) are deflated by the same price deflator \(p_r^i(t)\). For clarity and illustration purposes the general format of the world input-output table in previous year’s prices for any particular year is shown in Figure 5.

Because for each industry the monetary value of its total output equals the monetary value of its total inputs (a basic property of the input-output model that arises from the underlying accounting conventions), the gross industry output deflator \(p_r^i(t)\) can also be used to deflate the gross output values in the last row of each current price WIOT.

Using the industry output deflators we can now express the current price intermediate flows \(z_{i,j}^{r,s}(t)\), final demand flows \(f_{r,u}^{i,a}(t)\) and total industry output values \(x_r^i(t)\) in the prices

\(^1\)The WIOTs of 2010 and 2011 could not be deflated and expressed in previous year’s prices because price information in the Socio-Economic accounts have not yet been updated to include these years.
of any other base year. To express the current price values in a lower base year we simply have to divide the value by the associated industry output price deflator(s), which can be formulated as follows:

$$a(t) \div p_i^k(t) \cdot p_i^l(t-1) \cdots \cdot p_i^l(t-n)$$

where $a$ has to be substituted by $z_{i,j}^{r,s}$, $f_{i,u}^{r,s}$ or $x_i^r$, and $n$ denotes the number of years separating the current price year from the base year (in other words, $t-n$ is the base year in which we want to express the current price value $a(t)$). Conversely, if we want to express a current price value in a higher base year we have to multiply by the associated industry output price deflator(s), which can be formulated as follows:

$$a(t) \cdot p_i^k(t+1) \cdot p_i^l(t+2) \cdots \cdot p_i^l(t+n)$$

where again $a$ has to be substituted by $z_{i,j}^{r,s}$, $f_{i,u}^{r,s}$ or $x_i^r$, and $n$ denotes the number of years separating the current price year from the base year.

Now that we know how to express the intermediate, final demand, and total industry output flows in constant prices of any particular base year we can easily derive the overall value added values in constant prices because these values implicitly follow as the residual. This residual relation is formally expressed as follows:

$$v_i^s(t) = x_i^s(t) - \sum_{r=1}^{k} \sum_{i=1}^{n} z_{i,j}^{r,s}(t)$$

Constant price value added values can be calculated by using the formula above with constant price values for $x_i^s(t)$ and $z_{i,j}^{r,s}(t)$. The whole idea is that if all intermediate cells of a particular column are properly converted to a particular base year and the same is done for the total industry output value of that column, then properly converted value added values follow as the residual (Los et al., 2014). This is the essence behind the double deflation method.

All charts presented in this thesis dealing with the evolution of a particular structural indicator over time have their data expressed in constant prices of the 2001, the year in which
the Euro currency was introduced. The base year was chosen to be that year because many authors and studies have highlighted the introduction of the Euro and the creation of the European monetary union as an important milestone in the widening of the macro-economic imbalances between the various Eurozone countries. Even though the choice of base year does not affect any of the percentage change calculations it will influence the absolute change figures which makes it important to mention the base year. In other words, analyses which look at how a volume changes percentage-wise over time won’t be affected by the choice of base year, the choice only influences the absolute values in which the volumes are expressed.

Constructing one comprehensive world input-output database in Matlab

This part describes how all the world input-output tables, which are captured in a separate Excel file for each year, can be combined into one single database by using Matlab’s multi-dimensional matrix data structure. This conceptualization is essential in understanding how the input-output model has been implemented in Matlab.

Figure 6 illustrates the concept of a three-dimensional matrix in Matlab and how data from this data structure can be accessed.

Suppose the matrix above is called $A$. To access or modify any particular element of $A$ the following notation is used: $A(r,c,p)$, where subscript $r$ indexes the row (the matrix’s first dimension), subscript $c$ indexes the column (the matrix’s second dimension), and subscript $p$ indexes the page (the matrix’s third dimension). To index more than one single element of the matrix (i.e. more rows, columns, and/or pages) we can use the colon operator (:). For example, $A(:,:,1)$ accesses the complete first page of $A$.

Having explained the basic workings of a three-dimensional array in Matlab we now discuss how this functionality has been used to aggregate the separate WIOTs into a single data structure. For each year we essentially perform the following steps. First, we import the WIOT Excel file into Matlab using the built-in `xlsread` function. This results into one large matrix. Secondly, we convert this matrix from current to constant prices using the method described in the previous subsection. Assume that the name of the resulting matrix is `IO_table_const_price`. Thirdly, we add this matrix to a three-dimensional matrix, `all_IO_tables`, as follows:

$$
all_IO_tables(:,:,year) = IO_table_const_price
$$

where `year` is a number indicating the particular year (1 = 1995, 2 = 1996,...). The idea is that after having gone through all years, the variable `all_IO_tables` will contain the
input-output tables for every year. The result of all these operations is that retrieving input-output data for any selection of years, countries, and industries, has been made very easy because it simply requires using the right subscripts. For illustration purposes the general structure of matrix all_IO_tables is shown in Figure 7.

![General structure of the three-dimensional matrix all_IO_tables for an economy with three countries and three industries. This data structure conveniently stores the input-output tables for every year into one single variable.](image)

**Figure 7:** General structure of the three-dimensional matrix all_IO_tables for an economy with three countries and three industries. This data structure conveniently stores the input-output tables for every year into one single variable.

### C.2. Implementing the model equations

As should have become clear throughout the mathematical discussion of the input-output model in the first six sections of this chapter, any of the equations and structural indicators introduced in that chapter are defined in linear algebra notation using sub-matrices or vectors which all originate from the input-output tables. In other words, any of the derived structural indicators can be calculated using only data that is stored in the three-dimensional matrix all_IO_tables. For example, the \( kn \times kn \) matrix \( Z \) for a particular year can be defined as follows:

```
1 % define total number of unique industries in the table:
2 totalNrUniqueIndustries = nrCountries*nrIndustries;
3 % global inter-industry matrix (= transactions table): 
4 Z(:,:,year) = subindex(all_IO_tables(:, :, year), ..., 
5 1:totalNrUniqueIndustries, 1:totalNrUniqueIndustries)
6 % the three dots ... used above indicate a new line in Matlab 
7 % subindex(A, range1, range2) returns the result of A(range1, range2)
```

**Matlab code** 1: Definition of matrix \( Z \) for a particular year, stored in the multi-year variable \( Z \).

Notice that we decided to store the resulting matrix in a separate multi-year variable \( Z \). We chose to do this because having the matrices \( Z \) stored in a separate multi-year variable allows for their values to be easily accessed for future calculations.

We can repeat the method used above to define the \( n \times n \) sub-matrices \( Z_{rs}^{\text{rs}} \) as follows (notice that the variable \( Z_{rs} \) is a five-dimensional matrix):
C. Model implementation in Matlab

Matlab code 2: Definition of matrices $Z_{r,s}^{y}$ for a particular year, stored in the multi-dimensional variable $Z_{rs}$. This variable captures all sub-matrices $Z_{r,s}^{y}$ (for all $r$ and $s$, and for any year).

Any of the other sub-matrices or vectors defined in the research methodology chapter are calculated in a manner similar to the two code fragments presented above. For example, the matrices $F$, $F_{r,s}$, $A$, $A_{r,s}$, $L$, $L_{r,s}$, $X$, and $V$ are stored in the multi-year variables $F$, ..., $F_{rs}$, $A_{rs}$, $L_{rs}$, $L_{rs}$, $X$, and $V$ respectively. The same holds for any of the vectors. For example, the vectors $x$, $x_r$, $v$, $v_c$ and $v_r$ are stored in the multi-year variables $x$, ..., $x_r$, $v$, $v_c$, and $v_r$ respectively.

C.3. Calculating a particular metric

In order to easily and quickly calculate a structural indicator for any selection of industries, countries, multi-country regions, and/or years, one single function has been created to deal with any data request. This function is called `calculate_metric`. This function uses a specific, well-defined syntax for its input arguments and encapsulates all details and underlying calculations that are required to obtain the results. This greatly streamlines the process for retrieving any of the structural indicators. The rest of this subsection provides a brief outline on this syntax and on the procedure to calculate any particular structural indicator using `calculate_metric`.

The general input-structure of `calculate_metric` is as follows:

```
calculate_metric(metric_name, varargin)
```

The first input argument, `metric_name`, is a string indicating the structural indicator to be calculated. Examples of structural indicators that can be calculated by the function include: gross exports and imports, value added exports and imports, gross and bilateral trade balances, domestic value added absorbed by foreign final demand, GDP, revealed comparative advantage indexes, etc. Each particular indicator has its own unique string. In addition, each string starts with the prefix ‘val_’ or ‘vec_’:

- The prefix ‘val_’ indicates that one single aggregate value will be calculated for the particular indicator. This value aggregates the indicator over all industries (all industry values are summed together).
- The prefix ‘vec_’ on the other hand indicates that a column vector will be calculated for the particular indicator. The elements of this vector capture the indicator’s value for each of the industries.

To summarize the discussion above we provide two examples. The metric string ‘val_bva_bil’ indicates that we want to calculate a bilateral trade balance in value added terms as a single
value, summing over all industries. The metric string ‘vec_fddom_FVA’ indicates that we want to calculate the foreign value added embodied in the domestic final demand for each individual industry.

The second input argument, varargin, is Matlab’s notation for a variable-length input argument list. This allows the function to accept any number of input arguments, which depends on the particular indicator that has to be calculated. The first element of varargin will always be the home region. This can be a single country or any group of countries. A group of countries is represented by a list containing the corresponding country numbers\(^2\), e.g. \([3, 30, 26]\) means: consider Belgium, The Netherlands, and Luxembourg as one aggregate region (i.e. the Benelux). The last element of varargin will always be the period over which we want to calculate the indicator. This can be a single year or any combination of years. A multi-year period is represented by a list containing the corresponding year numbers\(^3\), e.g. \([1, 6, 11]\) means: calculate the data for years 1995, 2000 and 2005. The varargin variable might contain other variables. This is completely dependent on the indicator to be calculated. For example, to calculate a country’s GDP the only input argument that is required is the country or multi-country region from which one wants to calculate the GDP. On the other hand, calculating the bilateral gross exports between two countries requires two input arguments: the home region as well as the foreign partner region.

To close this section we present an example on how a structural indicator can be calculated using the function calculate_metric. To this end, suppose we are interested in calculating the bilateral gross exports from The Netherlands to Belgium on a sectoral level for the years 1995, 2000 and 2007. The following line of code retrieves exactly this information:

```matlab
>> calculate_metric('vec_e_bil',c2n('The Netherlands'), ... c2n('Belgium'), [y2n('1995'), y2n('2000'), y2n('2007')])
ans =
    1.0e+03 *
     0.9736   0.8439   1.2653
     1.7653   3.1770   4.4189
     2.5658   2.3860   2.8223
     0.8819   0.5540   0.4233
     .
     .
     0.0002   0.0003   0.0009
     0.1437   0.0956   0.0947
```

The function call above returns a \(n \times 3\) matrix, where \(n\) is the number of industries distinct-

\(^2\)Each country has been assigned a unique integer number ranging from 1 to 41 in our Matlab model. To avoid having to remember or look-up each country number, the function c2n has been created. This function accepts a country name in string format and returns its associated number. For example, c2n('Belgium') returns the value 3, and c2n('The Netherlands') returns 30.

\(^3\)Each year has been assigned a unique integer number in our Matlab model. To avoid having to remember or look-up each year number, the function y2n has been created. This function accepts a year in string format and returns its associated number. For example, y2n('1995') returns the value 1, and y2n('2005') returns 11.
guished in the input-output model (35 in the original WIOTs). Each of the three columns captures the bilateral gross exports from The Netherlands to Belgium for each of the Netherlands’ individual industries in a particular year. The first column contains values for the year 1995, the second column for 2000, and the third column for 2007. Remember that the bilateral gross exports metric captures a home country’s exports of both intermediate and final products to both industries and final demand consumers of the receiving country (see the definition of $e^{r,s}$ in the mathematical discussion of the research methodology in the previous chapter). In other words, each column from the resulting matrix above exactly represents $e^{r,s}$ for each of the specified years, with $r$ equaling 30 (country number of The Netherlands) and $s$ equaling 3 (country number of Belgium). For example, the value on the second row and third column, 4.4189, states that the mining industry (industry 2 in our model$^4$) of The Netherlands exported 4418.9 million US dollar$^5$ worth of products to all industries and final demand purchasers in Belgium in the year 2007.

By now it should have become clear that the function `calculate_metric` has been developed to encapsulate all the underlying mathematics required to obtain any of the structural indicators. Hence, any user basically only needs to learn how to use this one single function in order to retrieve any information or structural indicator from the input-output database. To further illustrate the function’s workings we briefly explain how the result from the example above was determined by the function. Basically `calculate_metric` looks at the specified metric name string, ‘vec_e_bil’, to determine which mathematical formula it should use. To this end, it uses a series of conditional if-else statements with regular expressions to match the metric name with the part of its code that is responsible for calculating the required metric. The part that is executed in order to calculate the required metric for one single year is summarized in the code fragment below:

```plaintext
% declare the variable that will hold the calculated indicator
result = zeros(nrIndustries,1);
% calculate the bilateral gross exports from the home region to the ...
% foreign receiving region
for r=homeRegion
    for s=receivingRegion
        result = result + Ars(:,:,r,s,yn)*xr(:,:,s,yn) + ...
                  frs(:,:,r,s,yn)
    end
end
```

The variable `result` is a $n \times 1$ matrix, with $n$ the number of industries distinguished in the model. Note that the variables `homeRegion` and `receivingRegion` are lists that have to be specified as the inputs to the function. In our case `homeRegion` equals the one-element list defined by `c2n('The Netherlands')` and `receivingRegion` is the one-element list defined by `c2n('Belgium')`. The function `calculate_metric` will basically repeat the code fragment above for each of the specified years (1995, 2000 and 2007 in this case) and store the overall result in a matrix called `multi_year_result` which at the end is returned.

$^4$Each industry has been assigned a unique integer number in our Matlab model. To avoid having to remember or look-up each country number, the function `n2i` has been created. This function accepts an industry number and returns a string with the name of the associated industry. For example, `n2i(2)` returns ‘Mining’.

$^5$All values are expressed in constant prices of 2001.
as final output to the user.

Calculation of any of the other indicators by `calculate_metric` essentially follows the same procedure as the one outlined for the bilateral gross exports metric in the discussion above. All the necessary information with regards to the exact metric names and input arguments to be used to calculate any particular metric is listed in the comments section at the top of the `calculate_metric.m` code file.
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