China's Evolving Role in Asian Trade: A Network Approach

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Abstract

In this paper, network analysis is used to examine the changing role that China has played in the years 1995, 2005, and 2014. A network is constructed from a World Input-Output Matrix consisting of 43 countries and 56 industries. This matrix is transformed into a technology matrix where a filter is used to turn this matrix into a binary matrix. This matrix, in turn, is used to form a unweighted and directed network where each vertex represents a country and each edge represents a significant commercial relation that exceed the world average. Network centrality measures such as indegree, outdegree, betweeness centrality, hub index, and authority index are derived from this network and used to trace the role that China, Japan, South Korea, and Taiwan have played in World Trade, and see if there is evidence of interaction between these. Of the network measures used in this unweighted matrix, it is found that export-related measures show a strong positive correlation with GDP and import related measures have a negative correlation with GDP. It is observed that China has a large increase in all centrality measures across these years, while the centrality measures of the other East Asian nations remain largely unchanged. This, in conjunction with the increase in density and diameter of the World Trade Network as a whole, lead us to believe that even though China has made huge gains from trade through an export-led approach in the preceding decades with no evidence of displacement or "crowding out" of other developed economies in the East Asian region. This work presents that network analysis can present a viable and useful methodology to not only examine the structure of World Trade, but to examine the patterns of trade across time. Furthermore, it puts into context China's export-led approach to development and qualitatively demonstrates the huge impact this has had in China's place in World Trade and the world economy.

Dedication

To my mother and my father, who don't really understand what I do but they let me do it anyway.

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Contents

Chapter 1

Introduction

1.1 Motivation

Throughout the latter half of the twentieth century until today it has become increasingly clear that the rise of emerging economies constitutes the most important economic event of this generation and one of the most pressing issues of our time. The rise of emerging economies bring with them the prospect of lifting potentially billions of people from rural poverty and integrate them fully into the world economy. Furthermore, the way in which this process transpires will not only have a great impact on lives of billions, but on the environment and on the livelihood of generations to come. As such, conversation over the means as to how development is achieved, and the impact of these, is imperative. However, even though the progress made over the last half-century might present one of the greatest economic triumphs in human history, conversation around emerging economies have sometimes taken a more dire tone. In the latter half of the decade, some might argue that political discourse in the United States and elsewhere has revolved around the idea that there are "winners and losers" in the world economy. While political events of a magnitude such as the infamous "Brexit" might seem new, this type of anxiety has been present there long before. Such a preoccupation is perhaps infamously exemplified by the European Commission's white paper (1994), where said institution listed four reasons for the long upward trend in European unemployment, chief among them the "rise of nations that are competing with us - even in our own markets - at cost levels that we cannot match". In short, Europeans officials were worried that cheap labor abroad would permanently affect the standards of living at home. But concerns over trade and global economic forces are not limited to wealthy countries. Emerging countries on the other hand, have their own brand of skepticism. For example, after the onslaught of the 1997 Asian Financial Crisis, many questioned the merits of globalization and the role of global economic institutions such as the International Monetary Fund and The World Bank and their "rules of thumb" approach to many issues concerning emerging economies - now labeled the "Washington Consensus" (Williamson, 1989). In short, they question if greater economic integration of the brand that these institutions recommended and in many cases enforced, which in this case entailed opening up domestic economy, reducing all barriers to trade, balanced government budgets, and financial deregulation at all costs, can have the undeniable positive effect that these institutions claimed on their countries and lead them to a path of economic development and prosperity - regardless of context. In light of these issues, the topics of International Trade and Globalization, topics that perhaps had not seen much attention in recent last decade or so, have entered the spotlight both in the United States and abroad.

Today a similar question and attitude has developed with regards to the biggest developing economy of them all - China. China itself could perhaps be considered a microcosm of both the optimism and skepticism surrounding the story of economic development. On the one hand, China's rise is the cause for one of the biggest reductions in abject poverty in the world. Broadly speaking, around 800 million of the world's extreme poor (defined by the World Bank as those who live under a $1 a day, measured at purchasing power parity) lived in East Asia in the year 1981 (Chen & Ravallion, 2004). By 2001, this figure had decreased to around 250 million. No other region in the world has seen such a massive reduction of poverty of this type. In fact, in this same time frame, the number of extreme poor in many other regions such as Eastern Europe, Central Asian, Latin America, and Sub-Saharan Africa, this type of poverty increased. Told another way, in 1981 around 55% of the world's poor lived in East Asia; by 2001, this figure had reduced to around 15% (Chen & Ravallion, 2004). Seen yet another way, the Chinese economy continues to grow at an impressive rate - by a factor of 12 in between 1990 and 2007 (Giovanni et al., 2014). No region has seen such progress in such a short span. Of course, the story is not as simple as that. One could possibly see this as a move from "extreme poverty" to more "moderate poverty" (those living between $1 and $2 a day are considered to be among this category, as opposed to "extremely poor"). Furthermore, China's violent history during the Great Leap Forward from 1958-1960, made in the name of economic progress, resulted in the starvation of 30 million peasants (Studwell, 2014). Nevertheless, the progress made after reforms by Zhu Rongji has made China much more open, and in doing so, have lifted hundreds of millions out of extreme poverty. After said cultural revolution, in the period between 1978 and 1988, China's poverty headcount then declined by 154 million (Huang, 2012). This progress is undeniable. And in fact, the effect that these citizens have had on the global economy is well recognized by the international community. In fact, in some sense, many see this development rather darkly. As an economic force not allied with the west, many worry about the political implications of this economic transformation. But more to the matters of economics, many concern themselves with the possible effects that the rise of China's, especially in manufacturing, can have in labor markets abroad. Many of these effects are famously captured in D. H. Autor et al. (1990) paper, which has famously labeled the effect as the "China Shock". A great body of work, such as that by Giovanni et al. (2014), Mendez (2015), among others, examine this type of shock on labor markets around the world. In short, there is a natural interest in the effects that the effects that China can have on the world economy, especially as China continues to entrench itself into the world economy.

These variety of concerns and interest must be examined with great care, since for example, they stretch our limits of basics models of trade. For example, trade models such as the Ricardian and the Hecksheer-Ohlin models of trade suggest that trade liberalization is good for all of those involved, since everyone makes use of their corresponding comparative advantages in trade, and in doing so raise real wages and consumption possibilities (Krugman & Obstfeld, 2007). Such a doctrine has been so steadfastly held that it forms the ideological backbone behind the creation of the General Agreement of Tariffs and Trade (GATT), and later its successor, the World Trade Organization (WTO). Both of these being multinational attempts at making multilateral trade agreements the rule, and not the exception. Of course, trade is not a simple matter. Firstly, such as the body of work by David Autor suggests, there is a great policy questions that arise from this phenomenon. As D. Autor (2018) finds, for example, there are largely diffuse (but large) gains and concentrated costs from trade. As such, at least the questions of distribution are important. One can then surmise that a great number of other pertinent questions can arise from the phenomenon of trade, even if they do not contradict the implications of existing theoretical model. However, some like Rodrick (2018) point out that the great extent of economic theory concerns itself with the matter of tariff reduction and that, in actuality, Trade Agreements and the like concerns themselves with thousands of different topics. These include tariffs themselves, intellectual property protection, labor laws, etc. In this scenario, the issue of trade becomes very complex and must be approached in a holistic matter. It becomes hard to precisely evaluate at the outset the gains and losses that arise from real world trade. A critique of this type emerges from a long tradition, however. Notably, List (1885) emerged in the late 19th century to offer such a "holistic" and "historical" point of view than his British counterparts, Adam Smith and David Ricardo. In short, he accused this modern and theoretical movement as being hypocritical, claiming that the British were espousing views that benefited countries such as Britain itself, at its level of development, as absolute. In short, free trade would eventually harmful to un-industrialized economies since they could not compete with the manufactured products in Britain, and that opening up all barriers to trade in an early stage of development would eliminate infant industries and not afford these the opportunity to raise their level of manufacturing and technology. This view is summed up in the following words:

> "Any nation which by means of protective duties and restrictions on navigation has raised her manufacturing power and her navigation to such a degree of development that no other nation can sustain free competition with her can do nothing wise than to throw away these ladders of her greatness, to preach to other nations the benefits of free trade, and to declare in petinent tones that she has hitherto wandered in the paths of error, and has now for the first time succeeded in discovering the truths." (List as cited in Studwell, 2014, p. 84)

To be clear, List was firm in his view that free trade was the ultimate goal for any economy. However, this goal was referred until the "ladder of greatness" would be climbed - or in less grandiose terms, until a certain level of technological and industrial progress had been achieved. Until then, certain protective measures would be enacted to protect infant industries until they could compete effectively with British goods. To justify this, he in fact goes through a historic analysis of the development of German industry throughout the 19th century. This view was later shared by the rapidly developing economies of East Asia - mainly, Japan, South Korea, Taiwan, and China. In fact, the bureaucracies in charge of development policy in these countries, such as Japan's famous Ministry of International Trade and Industry (MITI). As Johnson (1982) explains in his famous book dedicated to explaining the "Japanese miracle", Japan exalted the educated generalist - its government bureaucracy distinguished between administrative officers and technical officers, and the former always outranked the latter. At the height of its power in the 1960's, MITI had just two employees with PhDs in economics among its senior staff. One could suppose that this might run somewhat contrary to the views espoused by the Washington Consensus. In fact, all of these countries were infamous for explicitly ignoring advice from the IMF and the World Bank n multiple occasions - ignoring pressure from these countries to opening up all barriers to trade and de-regularizing financial markets prematurely. Yet, it is precisely these countries the ones that succeeded, and can be said that they are the only countries who have climbed the ladder to development in such a short amount of time. On the other hand, as Stiglitz (2002) points out, every single country that followed the IMF's guidelines has had at least one financial or economic crisis in its history. And furthermore, few in the economic community look at any of these countries (among them, Chile and Argentina were seen as "IMF darlings") as a model of economic development - or at least not to the extent that South Korea, Taiwan, and Japan are.

None of this is to say, however, that orthodox trade or economic theory are mistaken. Quite the contrary, at each stage of development one can readily explain most of the economic forces at play. One could say that it this is rather an extension of our knowledge. This will hopefully become more evident as the history of economic development of these countries is summarized later in the paper. As List implies, it is an acknowledgement that the economic context of a country is different at different stages of development. Furthermore, as Stiglitz (2002) explains in his book, many of the failures associated with the IMF and Washington Consensus was a failure in administration, not in economic theory. That is, the main issue was associated with public officials in these institutions adopting a "rules of thumb" approach of economic theory. This included a confusion of policies directed towards macroeconomic stability rather than on structural issues, a "free-market" mentality even when it was evident that market failures were present, and an willing ignorance of local context. In short, the existence of a "consensus" when it could hardly be justified.

As the economic success becomes more and more apparent, it still becomes worthwhile to look at the history of development of these countries through various lens. That way, a fuller and more comprehensive picture of the economic forces at play in these country throughout their history may be achieved. This is essential, as these countries serve as the prime example economic development in recent history. And furthermore, as attitudes to China suggest, there is still space to improve our understanding of the economic history of these countries, and on the effects they can have on trade and the global economy. As such, many approaches and points of view could enhance our understanding of the processes and effects of trade, and it is with this intent in mind that we proceed forward to better understand the role that China and it development policy has played in world trade.

1.2 China's Changing Role in Trade and the Network Approach

The last half-century has seen China emerge as a manufacturing and economic giant. Of course, China is not the only country with this history. In fact, the entire region shares a similar history of rapid economic transformation. But of course, China is perhaps the most notable example due to its unorthodox nature. China is both unusually large and run by a Communist regime (although, the economic reality is much more complicated). Both of these features make it so that it draws the watchful eye of the west. Much like the latter half of the 20th century it seemed like it was going to be the "Japanese century", many think that going forward, the

21st century might be a Chinese one. While the future is uncertain (hardly anyone would claim that this is the "Japanese Century" now), it is still very worthwhile to observe what happens in China, and what is impact will be. This is for two important reasons. Firstly, the sheer size of China arguably remains its most important asset. For example, while China might still be one of the greatest development stories, it is still not as relatively competitive an economy as its East Asian neighbors are. China did not revolutionize manufacturing as Japan did, and its development has not been as swift and total as South Korea's (Studwell, 2014). Furthermore, long-run effects of its development policy is still unclear in many ways. As Naughton (2010) explains, there has been a heavy investment and capital acquisition drive in China and it is relatively unclear what the returns of these projects once this heavy investment drive is over. That is, how China can succeed as a *rich* country, if it gets to that level, is unclear. One could for example, point to Japan and its decades long recession and see that there are many challenges beyond development. Nevertheless, China's mere size makes it an extremely powerful economic force. China in a sense does not be as productive as Japan or South Korea to become a larger economic force, considering China is multiple times the size of any country besides India. In this way, China should of course become a subject of study and observation, as its relationships in trade is sure to have a footprint on regional and global trade. Of course, as in the rest of the field of economic development, things are not that simple. While China is in and of itself an important and fascinating topic, there is also a question of how generalizable the story of China is. And in this matter, things can get quite complicated. As Naughton (2010) points out, no country is quite like China, neither in size or government and economic structure. And in this sense many of its policy interventions cannot be easily replicated by other countries. Nevertheless, its most important policy objective *can* be, since it in fact a policy objective that Japan, South Korea, and Taiwan all embarked on their journeys from rural to advanced economies. And this is the concept of *export-led growth.*

The concept of export-led growth warrants some explanation as it is key to the story of Asian countries and their place in the regional and global trade, and will be discussed in more detail in future sections, but the overall concept can be explained succinctly as follows. Export-led growth is a development strategy where the state provides subsidies and temporary protection to domestic firms, but subjects them to "export discipline". That is, domestic firms must seek to export its products, and only firms with a track record of exports obtain these benefits. Firms that are not successful in exporting are culled or "weeded out", either by withdrawal of capital by a state directed financial system or by forced merger with a more successful company. This is all done in an effort to upgrade technological skills and being able to compete with foreign firms with vastly superior industrial skills, technological skills, and returns to scale. Domestic firms must be able to acquire the physical and human capital to be able to produce high value-added products and compete with foreign firms in both domestic and foreign markets in the long-run. This requires these countries to offer temporary protections to local firms, but also an "export discipline" to avoid rent-seeking behavior from local firms and encourage much needed competition. Of course, this strategy is not straightforward to implement neither economically nor politically. The short run costs are high, with poor consumers being unable to import cheaper foreign good as they would like too (that is, there exists a deadweight loss), and the opportunities for rent seeking behavior being ever present. Nevertheless, the countries that have been able to achieve to enforce strong export discipline, often with strong bureaucracies such as Japan's MITI or with (unfortunately) dictatorial regimes such as Park Chung-hee's South Korea and Chiang Kai-Sheks's Taiwan. The presence of strong export discipline in turn led to the creation of competitive firms that moved swaths of people from agriculture to manufacturing in high value added industries. Perhaps no firm exemplifies this approach so much as South Korea's Hyundai. The firm being the sole survivor of a brutally competitive process of the creation of a "national car", which was the end result a long journey of technological learning which involved the creation of a national steel industry, clever maneuvering with joint-ventures with foreign firms in order to obtain technology (in Hyundai's example, a partnership with Mitsubishi), competition with other domestic manufacturers, and government pressure to export cars to foreign markets. In a similar manner, many high value industries have evolved throughout all of Asia, with exports being both the benchmark and reason for success (Rodrick, 2010; Studwell, 2014) With this said, although China undoubtedly has many distinct features, its most likely driver to success is a similar drive to exports that begun in the 1960's. After the communist penchant for autarky was abandoned, after the disastrous Great Leap Forward revealed that a manufacturing drive in a closed economy is a foolish game, the approach was abandoned for a sudden drive to participate and compete in the world economy through exports, much like its neighbors in Asia had been doing. In this way, China is no different from its neighbors or any country with a successful track record towards development. It is with this in mind that the study of China in the region is approached.

In this study, China's evolving role in trade from 1995-2014 is observed. In particular, we qualitatively observe and describe what impact, if any, China's trade has had on its wealthier neighbors South Korea, Taiwan, and Japan. This is done in an effort to better understand the impacts of emerging economies in world trade, and to add a new perspective to the question of how emerging economies can impact more developed ones in terms of trade. This is especially important with regards to China, as it will likely be the largest emerging economy in history and its impact on the world economy will likely continue to grow. Furthermore, it serves as the largest case study for this phenomenon. In the words of David Autor and Hanson (2016), we live in a "China Shock", and thus it is unlikely that we might see another kind of shock of the same magnitude by a single emerging economy again. Likewise, exports are examined because "export-led growth" have represented an engine of growth not only for the country in question, but for the region as a whole. The effect that a surge of exports has in world trade is a relevant question for all types of countries, not only developed or undeveloped.

To achieve this, a network approach employed. Research by Benedicti et al. (2013) has already prompted the use of this approach to examine the structure of World Trade as a whole and begin to apply to a variety of economic questions. For example, other researchers such as Baldwin and Lopez-Gonzales (2015) and Ortiz (2017) used a network approach to construct a network of value-added trade and establish that world trade is "regionalized". That is, world trade can be divided into regional hubs that contain most aspects of the production chain, with certain countries in that network specializing in particular stages of the production sequence. They define three major regional hubs in the world, defined as: Factory Europe, Factory North America, and Factory Asia. Considering that East Asia is then a regional hub for trade, one can then use a network approach to observe what roles China, Japan, South Korea, and Taiwan occupy, and have occupied, in this region and others. In this study, measures derived from intermediate exports in the World Input-Output matrix will be used to form a network of World Trade and observe what role, China, Japan, Taiwan, and South Korea play in their region and in World Trade. And in particular, this approach will allow us to observe if centrality in the network correlated with measures such as GDP. Furthermore, we will attempt to observe if a more central position for a country necessarily displaces another. These are all questions that have been of interest to economists for more than two decades, and there have been various methodological attempts to examine what impact an increase in Chinese trade can have on particular countries such as the United States. This comes from an intent to use network analysis to both explore this topic in particular, but to also extend this methodology into more targeted uses. While network and graph analysis are widely used in other fields such as computer science and sociology, it is not as popular in economics to explore issues of trade. From Benedicti et al. (2013) forward it has begun to see more use in the area of international trade, but there are still topics in which this methodology can be extended. In particular, in questions that regard specific countries. For example, most studies such as those by Amador and Cabral (2016), Baldwin and Lopez-Gonzales (2015), and Ortiz (2017) have explored the overall structure of trade and Global Value Chains, but it has not seen much application in questions that pertain to more particular issues. It is our wish to both explore the use of this methodology to examine this issue qualitatively and demonstrate its use, and to explore the questions that arise with China and its role on World Trade.

To evaluate China's changing role in the region in particular, a variety of network measures will be employed that will describe the overall network and the countries within it. These include various centrality measures such as indegree, outdegree, betweeness centrality, and the Hub and Authority indices generated by the HITS (Hyper-Induced Topic Search) algorithm (Kleinberg, 1999), as well as network-wide metrics such as density and assortativity. This will help us determine how well connected these countries are to their neighbors in terms of trade, and to observe whether the region has a core-periphery structure. The data will be obtained from the World Input-Output Database (Wixted et al., 2006), which will allow the creation of a network in which countries can be represented as *vertices* in a network (nodes) and commercial relationships as *edges* (links). Using this network, we will be able to see how commercial relations in Asia have changed across time, and we will examine what place China, Japan, Taiwan and South Korea occupy in this network in the years 1995, 2005, 2014. It is the hope of this study to not only summarize the history of the economic development of this region, but also to establish what effect the growth of China has had on its developed neighbors. Specifically, to use network metrics to visually and qualitatively illustrate how China's growth has led it to become a dominant force in the region, and to determine whether has displaced or affected any of the other economies that will be under examination. Or, on the contrary, and as Moreira (2007) suggests, determine whether China's ascent has resulted in China gaining a more complementary status. East Asian commercial relations will thus be observed through through a network lens. This not only gives us information about individual countries, but also provides insight about the relations between said countries. Network analysis, then, will be used to observe the impact that China has had on the East Asian trading bloc during the last 20 years, and observe what effect this has had on Japan's, Taiwan's, and South Korea's place in the network. To do this, a network will be first constructed from the Input-Output table and the process discussed. Furthermore, a summary of of the industrial policies used by Japan, South Korea, Taiwan and other emerging economies in the region will be constructed so as to better understand how these policies could relate to international trade, and hence to these countries position in the network. In the end, it is our expectation to see a more connected and cohesive network in which economic relations become more important and abundant across time, which may be suggestive of cooperation between this economies. However, it is also expected that China will take a more central place in the network, possibly displacing Japan and South Korea as the most important trading partner in the

East. Even so, as Ortiz (2017) findings suggest, a core-periphery structure in regional trade is highly likely, which would mean that the other developing countries still remain highly relevant in world trade. Through this analysis we hope to provide a comprehensive picture of the evolving role of East Asian countries in World Trade, and use the network methodology to explore the role of exports in these countries. This will allow us to gain insight on the economic history of these economies, their role in the region, and an expansion of network methodology in answering questions related to international trade and economic analysis.

Chapter 2

Literature Review

2.1 Overview of East Asian Development

The discussion on the progress of China as an emerging economy and its possible further development must start with an overview on the economic history of the region. This is for several reasons. Firstly, it is obviously important to understand the context of whatever region is under study. But furthermore, China's development fits nicely into the story of the wider region. While China has various attributes that make it a rather unique economy, such as its size and government structure, the main drivers to economic development have been the same as they have been for entire region. China has closely followed the model of export-led growth set by South Korea and Taiwan, who in turn followed Japan's example. As explained by Studwell (2014), the distinct features that all of these economies share are threefold: firstly, they all undertook an aggressive land reform. Secondly, they engaged in a heavy export drive and had measures to ensure that "export-discipline" was enforced on leading firms. Thirdly, they resisted liberalization of financial markets until later stages of development. In this way, the Chinese economy is no different from that of its neighbors, and it is often argued that it is these practices that have led permitted the country to experience such sustained growth, nearly on par with its neighboring economies. Consistent with this analysis, countries which have not fully adopted these measures, such as those in South-East Asia, have seen rapid but unsustainable development. Many thought that these "tiger-cubs" would share in the success of the South Korea and Taiwan, for example, but an incomplete adoption of these measures led to unsustainable growth, which came to halt after the 1997 Asian crisis, which begun in precisely these economies (Stiglitz, 2002). While overall emphasis in this paper will be given on the role of exports, each of the stages of development will be briefly discussed since all of these measures serve a crucial role in the region, and are mostly complementary to each other.

Firstly comes to the discussion of land reform reform - historically the first step in the route towards economic development for all of the countries that experienced a growth miracle. This is often the most overlooked and least discussed of the three development measures, but it is equally important as it serves a jumping off point to industrial policy. China itself serves as the perfect example, as it managed to lift 154 million people out of poverty between 1978 and 1988. mainly through this type of intervention alone (Huang, 2012). This stands in immense contract to the atrocities committed under China's Great Leap Forward, which in a haste towards manufacturing under autarky managed to starve 30 million Chinese (Studwell, 2014). As such, agricultural reform and raising productivity in this sector can have an disproportionate effect on the economy. In fact, China might very well be the prime example of the importance of land reform, since private township and village enterprises put in place by reformists in the late 1970's after was the first big concession from the Communist Government, and initiated the hybrid economy that has led China towards a path to development. In this sense, at least in China, it was both a big economic and political step. However, the reason why land reform is economically vital for undeveloped economies is more broad in a sense, and warrants some discussion. As Studwell (2014) and Huang (2012) succinctly explain, at an early stage, a poor country with plenty of labor is better served by maximising its crop production until the return to labor falls to zero. With such a large pool of agricultural workers, you might as well use the labor you have since that is the only use you and increase the yield per worker. Land reform also gets rid of some troubling market failures. In short, since demand for land increases much faster than supply for land, landlords in these countries often prefer to lease out lands at very high rents. They also often serve as creditors for rural populations in poorer countries, with predatory high rates of interests. In such situations, tenants are unable to make the investments that will increase yields on the land they farm. Landlords themselves could make such investments, but often find it more profitable to exact the highest possible rents and take over plots that have been pledged as collateral when a tenant cannot pay down the debts they have taken. In this situation, the market fails to maximize output. This gives space for government intervention to restructure the market. Roughly speaking, land reform was similar in countries in East Asia, and it mainly consisted of appropriating land and dividing it up on an equal basis. This, supported by government support for agricultural credit, marketing institutions, agronomic training and other support services established a new kind of market in which small household farms to invest their labor and maximize production, hugely increasing yields. This had several benefits. First, it affects the vast majority of the population of these economies. For example, in Japan at the start of its development in the 1870's, three-quarters of its population was dedicated to farming. This was no different for the rest of these countries after the second-world war, including in many ways Japan itself, which essentially overwent to periods of development before and after the war. This population, via these reforms, then lives much closer to a competitive market scenario than was previously the case, with each household having its bit of capital along with the ability to access technical support, credit, and markets, on an equal basis with other similar household. This is a very different environment than the one where landlords exact high rents and engage in usury, which hurts the majority of the previously landless population and distorts incentives for everyone. Secondly, the increase agricultural surplus makes some amount of savings possible which can then fuel much needed investment. Thirdly, these countries did not need to spend foreign exchange in imported agricultural products, which freed some of the often scarce foreign-exchange to import technology and capital instead - which is essential to development and technological learning. A fourth way in which these reforms help is that household farming serves as a sorts of welfare role, which is much needed in poorer countries. When 200,000 factory workers were laid off after the oil-crisis in Taiwan, they were easily re-absorbed into the economy since they could return to their family owned farms. Finally, this increased surplus implies big increases in rural consumption. This is critical, since many firms that later became manufacturing giants emerges to serve these new types of domestic markets and learned huge lessons in manufacturing and marketing from such markets, with whom they shared a cultural affinity. Examples include Toyota and Nissan building robust cars for unpaved roads in Japan after the second world war (Studwell, 2014). All of this is important since it sets a friendly economic environment for the stage next step of development, the much acknowledged "export led-growth".

The next essential feature of economic development in these countries, and perhaps the most acknowledged, is the much lauded "export-led growth". While its execution is an enormous challenge, the reasoning is relatively straightforward and was in essence no different from that described by List (1885) in his historical description of Prussian (German) and American development in the 19th century. The idea is forcibly align the interests of national development and business through what is termed "export discipline". This means that the state protects domestic markets so as to protect its domestic firms, but also encourages firms (often, forcibly) to engage in exports so that they will engage in competition. Firms that do not meet a export benchmark are either acquired by more competitive firms, or its assets were acquired by the state. In short, successful firms were allowed to survive while weaker firms were weeded-out, of sorts. By engaging in exports, the leading firms were forced to acquire capital, reach scale, and engage in a technological learning process so as to be able to eventually compete with the leading firms in foreign markets. However, since domestic markets were protected in the short term, domestic firms had a market in which they could learn to sell, produce, and market their products. However, this domestic market was still subject to competition from other domestic manufacturers that were vying for state support, which could only be obtained by meeting export benchmarks and thus out competing their domestic rivals. Instead of the state backing one company in an industry, it simply let them compete in the domestic market and backed through various subsidies at the firms which also demonstrated that they could compete in foreign markets. This temporary protection of domestic markets (yet still subject to competition and discipline) was crucial to domestic firms since it allowed them the time and support necessary to effectively acquire technology and then develop and test their own technology in domestic markets. Some examples include Hyundai's technology licensing deal from Japan's weakest car manufacturer, Mitsubishi, as well as a hiring spree of industry leaders that allowed Hyundai to effectively scale such technology in the Korean market and then sell cars abroad. Likewise, Japan itself (via the Ministry of International Trade and Industry) had engaged in these sorts of practices, infamously blocking IBM's Big Blue business in the 1950's unless it licensed its technology to local firms at a maximum 5 percent royalty. Such maneuvers allowed domestic firms in these countries to acquire foreign technology and capital and then produce it for sale at their own markets, and once at scale, sell it abroad and compete with global leaders. (Johnson, 1982; Studwell, 2014).

The main worry for this type of approach is that it is susceptible to rent seeking behavior. This problem is a very real one, and has undermined development in many countries. South East Asia provides a perfect example, since although it tried to model itself like East Asian nations it did not enforce exports and thus entrepreneurs in those countries were often drawn to protect their rents and engage in more speculative industries such as real estate, instead of augmenting the country's manufacturing capacity. The difference between South East Asian countries and East Asian ones, in this instance, is that East Asian enforced export discipline. Exports are relatively easy to check on since they must pass through customs and provide a good benchmark as to which firms are actually competing in foreign markets. Subsidies themselves were tied to these benchmarks that were tied to actual firm performance. In Japan, this included the amount of depreciation firms were allowed to charge (essentially a tax break) was determined by exports. In Korea, export performance had to be reported on a monthly basis and such performance determined their access to credit. And in Taiwan, cash subsidies and preferential exchange rates was used to encourage exports (this is fairly in line with China's practices towards exports) (Studwell, 2014). Using such measures, these countries were able to provide protection and support in early stages of development, but to firms that were engaging in competition, technological learning, and had some chance of providing future returns. In South East Asians. The"rules of thumb" approach to policy professed by the Washington Consensus was at a loss to explain. It is true, that at a single point in time protection is expensive and inefficient because it adds costs, punishes consumers, and often invites retaliation. However, properly executed, protectionism allows domestic firms to acquire the vital knowledge needed to compete on a global scale. It allows for a re-structuring of the economy from lower value added activities to more value added ones. A great way to do this is through manufacturing, since technology and capital can be easily imported and it allows poor countries to mitigate their biggest constraint at an early stage of development, human skills, yet allows their productivity to increase and in the process aid technological learning with minimal training. The export-led approach provided a path to rapid industrialization at all levels for East Asian countries. Studwell (2014), Stiglitz (2002) and Rodick (2013) state that this export drive was the main reason for the rapid industrialization for these countries, and comes closest to explaining East Asian success, while simultaneously explaining the shortcomings of relatively similar economies such as those of the South-East Asian states. In this respect, China is no exception. In this sense, as Studwell (2014) and Naughton (2010) claim, the most important feature for success is that firms engage in export discipline, not so much the question of state versus private ownership. It is for these reasons that manufacturing is so important for countries, especially at early levels of development, and it is why it is the focus of this paper to look at how exports have evolved in world trade network. Nevertheless, to give a complete description of the history of East Asian development, the attitudes in these countries towards the subject of finance will be briefly discussed.

Finance in these countries took essentially was a resistance to the liberalization of financial markets until late stages of development, often even resisting IMF advice to open said markets (Stiglitz, 2002). This was mainly because these countries perceived that infant industry policy required that funds be directed to industrial projects that were often less immediately profitable than other more speculative investments, such as real estate, or consumer lending. Banks were therefore kept under close control and international inflows and outflows of capital kept under close watch so as to ensure that domestic capital remained under state control and unregulated flows of foreign funds did not disrupt developmental plans. In fact, banking returns were higher on South East Asian economies, where financial liberalisation led not to better allocation of capital, but to flows of cash to private banks, investors, and entrepreneurs that were not required to manufacture or be subject to export discipline, and who in the end preferred to short terms speculative investments. In short, for East Asian economies the goal was to have finance pointed at the right developmental targets, and to ensure that agricultural and industrial policy targets had been achieved first (D. Autor, 2018; Studwell, 2014). All and all, industrial policy came first, and finance second. This highlight the previous point, however, that at earlier stages of development exports and industrialization are the most important factors towards economic development, and as such should be observed carefully. It is with this in mind that we continue to look at the evolution of trade in Asia, as it has proven to be the key factor towards economic success throughout most of their industrialized history and can offer many clues about the future of these economies and of engaging in trade.

2.2 Theoretical Background and Justification

Any discussion on the evolution and impacts of trade by emerging economies, such as China, on the World Trade Network must at least take into account the possibilities established by theoretical frameworks. Firstly, the input provided by the Ricardian and Hecksherr-Ohlin model will be discussed, as these give a general idea of the economic forces at play, and which in essence provide the backbone for more complex models. The possibilities established by more recent trade models will later be examined, for example, such as Krugman (1980) New Trade Theory. Then, the wide empirical discussion surrounding China's "trade shock" effect on markets such as those in the United States will be explored.

The Ricardian and Hecksherr-Ohlin models are both theories of comparative advantage which have been historically been used to explain the competitiveness of certain economies in an international trade context, and can serve as a benchmark for such any such discussion. Ricardo's theory of comparative advantage focuses on a single factor of production, while the Hecksher-Ohlin model focuses on the comparative advantage that occurs on the basis of differences in the endowments of the factors of production. Both rely on the fact that most agents of trade have comparative advantage in *something*, particularly in the industries in which a country has a lower relative opportunity cost than its competitors. These two theories are often used to explain some of China's economic success since the country counts with vast amounts of relatively cheap labor. According to both models, and particularly in the Hecksher-Ohlin framework, China's endowment of cheap labor relative to its wealthier neighbors would encourage the country to specialize in the production of labor-intensive goods, while the economies of South Korea, Taiwan, and Japan would specialize in more capital-intensive goods. These economies would all then benefit from trade since it results in an increase in the real income of all consumers (Krugman & Obstfeld, 2007).

Reality is, of course, more complex than these two models suggest, and have been questioned on empirical grounds in the famous Leontief paradox, which pointed out that sometimes the labor/capital ratio in exports did not reflect the factor endowments of the country (Leontief, 1953). None of these models fully explains China's changing economic profile, one which has been slowly been shifting from Low Technology products to High Technology ones (Lall & Albaladejo, 2004). Furthermore, neither model accounts for movement of capital, differences in technology, or intra-industry trade. As Adams et al. (2016) point out, comparative advantage is mostly a microeconomic concept, since it is not meaningful to say that a country has an *aggregate* comparative advantage over another. Furthermore, it is also a static concept. Business decisions are taken over both the short and long terms and are dynamic processes that respond to changing economic conditions. Comparative advantage theories fail to explain these dynamics in their entirety.

To compensate for these shortcomings, various international trade theories and concepts have emerged. Among them, Krugman's New Trade Theory and the concept of Competitive Advantage, which merit some discussion. Krugman's New Trade Theory focuses on the role that economies of scale, monopolistic competition, and consumer preferences have to play when trade takes place and markets begin to merge. When said markets begin to integrate and barriers of trade break down, firms in both economies now compete with each other and firms which can take advantage of the new economies of scale available to them remain in the market, and the rest must exit the market. Within this framework, firms have the incentive to diversify. In the end, consumers will benefit from lower prices and a greater product diversity. However, the number of firms will be less than if we sum up the firms of the original isolated markets (Krugman, 1980, 1981). The possibility exists that while consumers in all countries benefit from trade with China, firms in competing countries might be harmed. This gives credence to some of the phenomenons observed in world trade, in particular to the shocks described by D. H. Autor et al. (1990), in which trade shocks are felt regionally and in industries which are more exposed to this type of competition (for example, labor intensive industries). Furthermore, even though the overall welfare gain from trade might be positive over the long run, regions and industries that are exposed adjust incredibly slowly, resulting in lower wages, lower labor participation, and high unemployment in such regions (David Autor & Hanson, 2016).

This framework might highlight some of the strengths of the Chinese economy and helps shed some light on China's growing share of exports and increasing clout in the region. Chinese export performance, after all, has been outstanding. Chinese manufactured exports grew by on average 16.9% per annum in the period of 1990-2000, compared to 10.3% for the rest of East Asia, and 6.4% (Lall & Albaladejo, 2004). Furthermore, according to the authors, this rise is likely to continue since China still has much "spare capacity". It's exports per capita is low compared to its neighbors, and the country still has a large reserve of cheap, disciplined labor. In addition to this, they point out that China's advantages are not confined to cheap labor. The governments efforts to increase tertiary education, lure foreign investment, and invest in R&D has made it so that its trading profile has upgraded and China now exports much more medium and high technology products than it did in the 1990's.

2.3 China's Effect on Other Countries

The empirical evidence shows that China has had some sort of effect on many countries, both developed and undeveloped. Needless to say, however, that it is far from a consensus and there are a different number of findings depending on the models of trade that are used and the parameters included in said models. As such, the has been much assessment and reassessment of these phenomena using a variety of models. A reason for this is that, as Rodrick (2018) explains, trade relationships now extend far beyond the question of tariffs. They involve a complex set of rules having to do not only with tariff reductions (or lack thereof), but worker's right, intellectual property agreements, etc. This wide set of changes makes the effects of trade more challenging to evaluate on the whole. As such, there is much discussion surrounding the effects of trade from a country like China. In this section then, various perspective from the literature surrounding China's trade and its effects on other countries will be explored.

However, whether China will directly compete in exports with its east Asian neighbors in the future remains a point of contention. Firstly, as seen in Giovanni et al. (2014), a modified Ricardian-Hecksher-Ohlin trade model involving 75 countries which finds that China has a negative welfare effect on countries that have a similar comparative advantages to it. In other words, China's growth has an adverse effect on economies that are similar to it. However, as China continues to develop, and if it develops on areas where it currently does not have the biggest comparative advantage, then the majority of countries experience a large welfare gain, since China will not have an economy that resembles that of most of the world. However, this then leaves us with the question that if China's economy continues to further resemble that of its East Asian neighbors, then they might be adversely affected by China's further growth. These results fits well with much of the empirical evidence that has been gathered on the subject.

For example, there have been multiple studies explaining how China affects different economies. Most famously, in the United States, D. H. Autor et al. (1990) finds that import competition between China and the United States has had a negative effect on US labor markets that are most exposed or have similar factor endowments as China. This paper uses a gravity model approach to model patterns of trade. They surmise that markets take much longer to adjust than anticipated, resulting in higher unemployment, lower labor participation, and reduced wages for these regions and industries. This trade shock he terms the "China Syndrome". They estimate that import competition explains one-quarter of the decline in US manufacturing employment. Likewise, in Mexico, Mendez (2015) concludes a similar analysis and finds that import competition has decreased the employment share in manufacturing for the average Mexican labor market. He finds, however, that workers' wages were largely unaffected due to the fact that labor mobility increased in Mexico, unlike in the United States. In this sense, the trade shock had a smaller effect on Mexico.

In East Asia there have been multiple findings, yet not concise agreement of consensus. Firstly, as to the efficacy of export led growth, Ricardo Hausmann and Rodick (2007) developed an "export index" termed "EXPY" that is used to compare the average basket of goods that countries export. Ricardo Hausmann and Rodick (2007) finds that countries who have a similar export basket as those as richer countries (that is, one who contains more high value products) tend to have much stronger performance. This model then gives a theoretical credence to East Asia's export led theory. The mechanism in which this acts is what they term "cost-discovery externalities". In short, they surmise entrepreneurs in an economy explore economic opportunities and survey the cost structure of the economy. This process itself has positive externalities for other entrepreneurs, as they can easily emulate the incumbent who incurred the original "cost of discovery". In summary, costs for discovery and innovation are privatized but the benefits are socialized. This knowledge externality implies that investment levels in an industry are sub-optimal unless the government can find a way to internalize this externality. They find that countries that are able to do this produce and export a more diverse and higher value added of goods. This is measured by the country's EXPY coefficient, which then correlates strongly with economic performance. The results suggest that the type of goods a country export have important implications for economic performance and that all else being equal an economy is better off producing goods that richer countries export. This is because a country's fundamentals generally allow it to actually produce more sophisticated and higher value added product than it currently produces, since countries can get stuck with lower-income goods due to the cost discovery externalities associated with innovation. Countries that can successfully overcome these externalities can then reap the benefits of higher economic growth. This framework well summarizes, in a theoretical basis, the logic of export led growth. In this framework, East Asian countries were able to internalize these externalities and become able to produce and export higher income goods.

Furthermore, they also find in the paper that China and India both have higher EXPY coefficients than their GDPs would suggest, possibly signaling that these countries could benefit from economic growth in the future.

Another body of work seeks to better understand the possible dynamics between the countries in the region, and possibly between emerging and developed economies. In this area, there is not concrete consensus on the issue. Firstly, there is Eichengreen et al. (2004)'s work, who models trade using a Gravity model approach and finds that China's growing exports positively affects its high-income neighbors, but negatively affects it's low-income ones. This is because China's trading profile resembles that of its low-income neighbors more than the high-income ones. In a consistent finding, (Lall & Albaladejo, 2004) find that although China is beginning to specialize more in High Technology products, but it is specializing in areas of the production chain that its neighbors do not, meaning that China complements its neighboring economies and does not directly compete with them. That is, China specializes more in certain parts of the production chain in a way that is beneficial to its developed neighbors. However, they postulate that this might change as China continues to climb the value chain and begins to take over activities that have driven East Asian growth. China's large influx of Foreign Direct Investment, at the expense of its low-income neighbors, might drive this development. In a similar manner, Athukorala (2008) again uses gravity models, albeit with altered parameters, and reaches a different conclusion than Eichengreen et al. (2004). Athukorala (2008) postulates that due to the emergence of cross-border production networks and China's emergence as an assembly center means that it does not crowd out low-income countries, but rather, that it fits well into these new and complex production chains. The author in fact points out that China's emergence has impacted the high-wage East Asian countries the most, as China's rapid penetration into labor-intensive manufactures goods which have been losing comparative advantages in these product lines.

As can be seen, even though the literature is abundant, it is still relatively unclear what the effect of China's rise is on the World Trade Network as a whole and how it affects other countries, whether rich or poor. It is with this in mind that a network approach can be employed to analyze this issue and add to this body of literature, so as to seek alternate perspectives that can help form a holistic understanding of China and its place in World Trade.

Chapter 3

Methodology

3.1 Data

The data used to construct the network originates from a harmonized World Input Output Matrix created by the World Input-Output Database project. This database contains inter-industry and inter-regional Input-Output data for 43 countries and 56 industrial sectors form the years 1995 to 2014. For this research, the World Input Output Matrix from the years 1995, 2005, and 2014 will be used (Timmer et al., 2015). In addition to this, information regarding other economic and development indicators can be obtained from the World Bank's *World Development Indicator* database, which contains relevant economic data for every country in this dataset from the year 1960 to the present[1].

3.2 Using Networks to Evaluate Economic Interactions

As detailed by multiple authors such as Amador and Cabral (2016) and Benedicti et al. (2013), among others, network and graph analysis can be employed to analyze interactions and relationships between industries and between countries. Essentially, it allows us to map and observe the relationships between these economic units, allowing us to both visualize the world economy and extract valuable information from it. In short, this kind of analysis allows us to both study economies individually and as a part of highly connected system. This is important because economies are not entities that exist in isolation, but rather, are highly interconnected. While network and graph analysis have long been employed in fields such a computer science, sociology and biology, it has never been a mainstream tool in the topic of trade,

[1]See *World Bank national accounts data, and OECD National Accounts data files*, n.d., for more information.

although its use has been expanding in the past few years (Benedicti et al., 2013), especially as the use of algorithms in data science and related disciplines continue to become more and more advanced. Using these tools, it becomes possible to use network metrics to not only study countries in particular, but to observe and interpret economic *relationships* (Benedicti et al., 2013). Even though the use and scope of this field has expanded in recent years, the foundation for network and graph analysis in economics has its foundations in Qualitative Input-Output Analysis, which naturally pairs the use of graph analysis with Input-Output Matrices to examine essential relationships between industries in a single economy. In defending the original Qualitative Input-Output methodology, Aroche-Reyes (2002) mentions the following,

> In general, Quantitative [Input-Output Analysis] has failed to describe the actual connection between sectors, so industry interaction remains unclear. In contrast, Qualitative Input-Output Analysis aims to reveal the basic features if the economic structure defined by the IO table and is capable of summarising results into a picture (a graph), along with a few numerical results. (p. 582)

All and all, a Qualitative Input-Output approach allows us to easily examine the "structure" of an economy. Network Analysis of International Trade is in essence the exact same exercise, except that instead of examining the structure of an single economy, the structure of International Trade can be examined. Similarly, the goal of this research is to form a similarly useful matrix which gives some insight into the dynamics of world trade.

To analyze a network or graph one can make use of the vast array of network measures that have been created to examine this type of mathematical structure. Some of these network metrics warrant mentioning. While there exist a wide array of measures, focus will be placed on the network metrics that will be used in this research. Firstly, there is the concept of *centrality.* This type of measure tries to address what the most important vertices (also known as nodes) are in a network. In this case, it will provide a measure that will allow us to gauge that importance of China, Japan, South Korea, and Taiwan have in world trade. There exist several extensions to these concepts, such as *indegree centrality, outdegree centrality, eigenvector centrality, betweeness centrality*, among others, several of which will be examined in this text. All these are variations on a theme, and each of them reveals unique and pertinent information, such as whether one vertex lies tends to lie on the path of other vertices, or whether they themselves are connected to other highly central nodes. This network information, in turn, can be used to get a glimpse at related economic phenomena.

Similarly, other network metrics can be used to examine the graph as a whole. This would be measures like *density*, which measures how many connections are in the overall network. These measures tell us more about the network, or the system, rather than one vertex or unit. These will be similarly useful in gaining some insight in how the world economy has changed in the last two decades.

However, before carrying out any type of analysis, a graph must be constructed. As in the rest of mathematics, a graph can be easily constructed from any matrix element, with the graph essentially acting as a visualization of said matrix. Thankfully, it is quite easy to construct a graph in economics due to the wide use of Input-Output Matrices. This means that the component of the matrix, and hence the graph, are the Input-Output transactions that for the Input-Output Matrix, or any measure derived from it. In this paper, the technical coefficient matrix will be used to form the graph and form the basis for the analysis of the World Trade Network.

3.3 Building a Network

A graph or network is most often constructed from a square matrix, often labeled the *Adjacency Matrix (W)* with the following form,

$$W = \begin{bmatrix} w_{11} & w_{12} & \dots \\ \vdots & \ddots & \\ w_{m1} & & w_{mm} \end{bmatrix}$$

In such a matrix, each term w_ij in the matrix represents an *edge* (also known as a *link*) between the *vertices* i and j. This in turn means that, in essence, each row is a list of all the *outgoing edges* of the vertex pertaining to that row, and each column is a list of all the *incoming edges* to that the vertex pertaining to that column. The elements w_{ij} can be any real number, but usually the elements w_{ij} are translated into binary numbers, with this *binary matrix* often forming the most basic element of network analysis and giving rise to an *unweighted network*. That is, each element of the matrix simply represents if there exists a connection or not, with no regard to the numerical value, or intensity, of the connection between vertices i and j. This does not mean that the alternative, a *weighted network*, is not used. On the contrary, weighted networks have become increasingly more popular; however, the network becomes much more noisy and it becomes harder to explore the essential structure of the network. Furthermore, for this research, the essential aspects of the network will be examined, to see if the fact that economic agents exist in a network structure itself has an impact on economic measures, instead of directly tying it that economic measure directly by way of the use of weights.

Whatever the case, one must choose what Matrix will stand as the Adjacency Matrix. Only then can a graph suitable for analysis be formed. As mentioned, in this study an unweighted graph will be used. As such, the adjacency matrix will be a binary matrix in which all entries consist of either 1 or 0. In this matrix, an entry w_{ij} is equal to 1 if there is an important commercial relationships between countries i and j, otherwise, w_{ij} will equal 0. A graph or network will then be drawn from this data, where columns and rows represent vertices and the individual values w_{ij} represent the edges. If w_{ij} is equal to 1, then there is a connection between vertices i and j, and if it is 0 then the edges will remain disconnected. Furthermore, since the Adjacency Matrix is a square symmetric matrix, it can be looked at in two different ways, from a column perspective and a row perspective. In essence, a single column of the matrix pertains to a vertex in the matrix, and each value w_{ij} in that column is a list of all the *incoming* edges connections that the vertex j has with the vertex i. From a row perspective, we get a complementary view. Like before, each row is a vertex, but each element w_{ij} now represents and *outgoing* edge. This idea can be naturally translated into an economics context via the use of Leontief Input-Output Matrices. In a Leontief Matrix, the idea remains the same. Each row or column is representative of an economic unit, such as an industry or in this case a country, and rows represent exports while columns represent imports. Each element of w_{ij}, then, is a transaction between industries i and j, which can be viewed as either an import or an export. The Leontief Matrix, then, is the ideal candidate for a graph analysis.

Creating a graph from a Leontief Matrix is not a trivial exercise, however, as several decisions must be made to transform the matrix into a network analysis, and each of these decisions can have a great impact on the observed structure of the matrix and its interpretability. Firstly, you could transform the Leontief Matrix so that it encapsulates other measures. For example, Amador and Cabral (2016) and Ortiz (2017) choose to transform the Leontief Matrix so that each term is proportional to the Foreign Value Added in Exports. Benedicti et al. (2013), on the other hand, uses raw imports and exports in his analysis. For this project, the standard procedure for Qualitative Input Output Analysis will be followed, in which the technical coefficient matrix (traditionally labeled $\mathbf{A}$) is transformed a Boolean Matrix (labeled , from which an unweighted, directed graph is constructed (Aroche-Reyes, 2002). This Boolean Matrix, then, becomes our Adjacency Matrix, the basis for the graph, and is representative of the overall structure of the economy that is under examination. This Boolean Array is formed by the following procedure: coefficients from the Leontief Matrix (a_{ij}) that are over a certain threshold f are labeled as 1 in the Adjacency Matrix ($\mathbf{W}$), while values below that threshold are labeled as 0. The second critical question then becomes, what value should f have? An f that is too low renders analysis to cumbersome - there is simply too much information and noise in the data. Too high a threshold, however, and valuable information could be lost. A useful threshold f must have a value so that it allows for a level of granularity in the analysis that is useful. In essence, the threshold must be high enough so that it reveals the "core" structure of the economy. Unfortunately, there has been much debate on the topic. Much of this debate is covered by de Mesnard (1998). Works like those of Aroche-Reyes (2002) utilize a filter where $f = \frac{1}{n}$, where n is the number of columns or rows in the adjacency matrix. Or in our case, the number of countries. This approach renders itself useful due to its simplicity and ease of use. There is a great body of literature that utilizes several other filters which incorporate endogenous information into the development of the filter. However, due there has been much debate about what methods or algorithms correctly incorporate such endogenous information and lead to filters, measures, or further matrices that capture useful economic information (Luciano, 2002). For this reason, the following approach will be used, Leontief's Technology Matrix will be extracted from the raw Input-Output Matrix, where each entry on the Technology Matrix is the corresponding entry in the raw Input-Output Matrix divided by the total output for each country. Given this, each entry in the Technology Matrix will be compared to the average value of the matrix. This value will serve as our filter, f. where $f = \frac{1}{a_{avg}}$. If a value exceeds f, in this case the average of all technical coefficients in the Technology Matrix, then it counts is labeled as a 1; otherwise, it is 0. Put simply,

$$\vec{w}_{ij} = 1 \quad \text{if} \quad a_{ij} \geq f \quad \text{for each country}$$

and

$$w_{ij} = 0 \quad \text{otherwise}$$

where f is the average value of all entries in the matrix.

It is worthwhile to note that the value of the f that was chosen is approximately equal to that of $\frac{1}{n}$, (both around the 0.015 mark) meaning that this value for the filter is around what is commonly used. Likewise, work such as those done by Amador and Cabral (2016) and Ortiz (2017) also use a filter that is around this value. Furthermore, is is important to note that the since each term a_{ij} in the Global Technology Matrix (A) is proportional to the percent that that country's i intermediate input's constitute in country's j's output, then the filter f makes it so that the edges present in the final network are those that constitute an above-average "commercial" relation. That is, an edge is present in the network between country's i and j is country's i input contribute more to country's j output than the average country. The edges present in our network then stand for "significant commercial relations".

3.4 Analyzing the Network

It is now time to explain the various metrics that will be employed in our network analysis. There are a plethora of network measures that one could use in any such analysis, with the number of metrics being created increasing by day as this type of analysis is used more and more in fields such as Computer Science. Nevertheless, the list has been kept relatively short in order to emphasize the most direct and valuable measures, and to keep it to a list that summarizes the dynamics of trade and is of economic relevance. Two kinds of measures will be utilized. Firstly, there are measures that describe the entire network itself. Chief among this are *density, diameter, and assortative mixing.* On the other hand, there are measures for the edges themselves. Chief among these are *centrality measures*, which measure how "central" or important edges are in a network. Each centrality measure gives us slightly different information, and so several measures will be used for this analysis. These are, chiefly, *indegree, outdegree, betweeness, authority index, and hub index.* These measures will be explained in detail in the sections below.

3.4.1 Diameter and Density

Two basic, albeit, important measures that tell us much about the structure of a network are diameter and density. Diameter is simply the minimum number of edges that need to be traversed to get from one end of the network to another (Newman, 2010). In essence, it tells us how "big" a network is. However, often times one also might want to know how tightly connected the network is. For this, the *density* of the structure can be measured (Newman, 2010). To obtain this, one can simply count the number of connections in our network and divide them by the maximum number of connections possible. Mathematically, this can be written in the following way,

$$\rho = \frac{m}{\binom{n}{2}} = \frac{2m}{n(n-1)}$$

where m is the number of edges. It is worth noting the the density, ρ, lies strictly in the range $0 \leq \rho \leq 1$, with 1 indicating a fully connected network with the maximum number of edges, and a 0 representing a network with no edges at all. These measures are straightforward but important, as they measure of economic activity in the network. Density is a measure of the amount of economic relationships in World Trade, and diameter of the size of the World Trade Network. A increase in density would be proportional to increases in trade in general, and an increase in diameter would indicate that more countries are participating in world trade at a meaningful volume.

3.4.2 Assortative Mixing

Assortative Mixing is a network metric that measures whether edges connect to other edges that are like themselves (Newman, 2002). For example, in our case, one can measure whether rich countries tend to have commercial relationships with other rich countries, or if countries tend to trade with those in their geographic region, etc. Often, high assortativity is evidence for a "core-periphery" structure, where the structure of the network is made up of a few high centrality edges surrounded by a less dense periphery of vertices of lower degree. Likewise, it is sometimes indicative of community presence in networks. Ortiz (2017) finds a core-periphery structure for the World Trade Network when based edges are based on Foreign Value Added in Exchange (FVAiX), which would lead to a high assortativity in the network since richer countries would belong to the "core" of the World Trade Network, while poorer countries would belong to the periphery. All and all, assortativity can give us some insights as to the underlying structure of world trade since it serves as a measure of non-randomness and interaction effects in the structure of trade, and would serve as a first indication of some of the forces shaping world trade. For this study, Assortative Mixing can be measured using the *assortativity coefficient*,

$$r = \frac{\sum_{ij}(A_{ij} - k_i k_j/2m)k_i k_j}{\sum_{ij}(k_i \delta_{ij} - k_i k_j/2m)k_i k_j}$$

where A_{ij} is the adjacency matrix that was used to build the network, k_i is the degree of the node we are measuring the centrality for, k_j is the degree of every other node that is connected to the *ith* node, m is the total number of nodes, and δ_{ij} is the kronecker delta. Notice that the numerator is the correlation between the *ith* and all the *jth* nodes, and that the denominator is the maximum value of that correlation, thus giving us a standardized measure. If $r = 1$ then that indicates that the network is perfectly assortative, meaning that every vertex is connected to one like itself and not other. Otherwise, if $r = -1$ then the network is disassortative, in which each vertex is connected to a distinct one. A core-periphery structure would indicate a positive assortativity coefficient since "like" countries would aggregate amongst themselves.

3.4.3 Indegree and Outdegree

After a directed network is formed using the Inverse Leontief Matrix, the nodes in the network can be first evaluated using two simple mathematical definitions. Since this network is directed; that is, the nodes point towards other nodes, then we have two different measures for measuring the degree. These are the *outdegree* and the *indegree* of a network. The outdegree is the number of outgoing edges, while the indegree is the number of incoming edges. An incoming edge represents the countries main supplier. Mathematically *outdegree* and *indegree* can be represented in the following manner,

$$d_i^{out} = \sum_{j=1}^{N} \vec{w}_{ij} \quad \text{and} \quad d_j^{in} = \sum_{i=1}^{N} \vec{w}_{ij}$$

It is important to note that, in this network, this serves as an abstraction for imports and exports. One edge is drawn for every "significant economic relation". In our network, this means that any intermediate import or export relationship in the technology matrix derived from the World Input-Output Matrix that exceeded that of the world average. As such, each indegree is a significant import relationship and each outdegree is an important export relationship.[2]

3.4.4 Betweenness Centrality

A different concept of centrality is *Betweenness Centrality.* This measures that extent to which a node lies on paths between other nodes. Betweenness centrality is simply defined as the following:

$$x_i = \sum_{st} \frac{n_{st}^i}{g_{st}}$$

where n_{st}^i is the number of geodesic paths between nodes s and t that pass through i. Geodesic path being the shortest route between two nodes. Then g_{st} is defined to be the total number of geodesic paths between s and i. In essence, betweeness tells us if the vertex under observation acts as a "bridge" in the networks. This measure could inform us whether a country is a common intermediary between two other ones in trade. Furthermore, it is used in the most widely used Community Detection Algorithm developed by Girvan and Newman (2002). Here, high betweeness vertices are removed to detect if by doing so two separate networks emerge. These are then labeled as communities. As such, measure can be used to detect

[2]See Sabidussi, 1966, for more information on the original formulation of these network measures.

communities in the World Trade Network and see how these change throughout the years.[3]

3.4.5 Hub and Authority Index

The final measures are the *hub* and *authority* indices. These were, like many modern network measures, developed in the context of the internet and was originally used to rank webpages to optimize search engines. Here, *hubs* are vertices that point to other important vertices, and *authorities* are vertices that have incoming edges from important vertices. This is done using the *HITS* algorithm, standing for *Hyperlink-Induced Topic Search*. The way these two scores are constructed is relatively simple. Firstly, a score of 1 is assigned to each vertex in the network. After that is done, the indegree and outdegree for each vertex is calculated. Afterwards, these measures are normalized by dividing by either the total indegree if calculating the authority index, or by outdegree if calculating the hub index. This is repeated k times until the scores converge. In the end, each vertex ends up with a score between 0 and 1, with 1 being the most connected network in the matrix and 0 the least connected one. What is important to note is that the authority and hub index are essentially weighted versions of the indegree and outdegree, respectively. They are important because they not only indicate if there are many incoming or outgoing edges, but the index depends also on the *quality* of the vertex at the other end of the connection. Edges between important vertices are much more important, according to the hub and authority indices. Likewise, in our network, edges between highly central countries are deemed more important when calculating the hub and authority index. As such, these measures provide information not only on the quantity of the connections a country has, but on the quality.[4]

[3]See Freeman, 1977, for more information on the original motives and formulation of betweeness centrality in networks.

[4]For more on the HITS algorithm see Kleinberg, 1999.

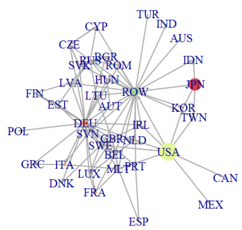
Chapter 4

Results

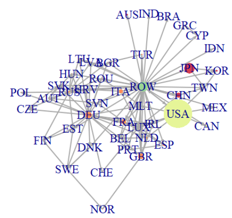
In this section, the overall results of the network analysis will be explored. Firstly, the various measures of the overall network such as density and assortativity will be discussed for the World Trade Network in the years 1995, 2005, and 2014. Afterwards, the network measures will be used to examine individual vertices in the network that correspond to China, Japan, Taiwan, and South Korea, and what their role in the network is. The role of the countries will be discussed for the year 1995 in order to form a firm picture of World Trade at one point in time. Afterwards, these measures will be regressed with GDP to see if these measures have any correlation with economic performance and can thus serve as an instrument through which can be used to talk about World Trade in any meaningful way. Finally, The evolution of these metrics and the value of these in the years 2005 and 2014 will then be discussed to observe if the role of the countries has changed over time.

Overall, we find that density and diameter have seen a very modest increase from 1995 to 2014, and assortativity by GDP and region has seen a modest decrease. These imply that there is higher overall trade activity. Likewise, the lower assortativities imply that a country is more likely to trade with one that is unlike itself in terms of income and geography. The increase in trade from very distinct countries could imply that, in a sense, trade is more inclusive than before. For the countries under observation, the following is observed: firstly, China has had a huge increase in all measures. These include indegree, outdegree, betweeness, hub index, and authority index. Taiwan, Japan, and South Korea, meanwhile, mostly retain their position. These measures are then correlated with GDP to see what these measures can tell us about economic performance. Of these, outdegree and hub index, export related measures, are observed to have a strong and positive correlation with GDP. On the other hand, import related measures such as indegree and the authority index are seen to have a significant and negative correlation with GDP. Betweeness is seen to have no significant correlation. No evidence of overt displacement is observed, as China's rise in the Network is seen to have little effect on the centrality measures of other countries. These findings are explained more detail in the sections below.

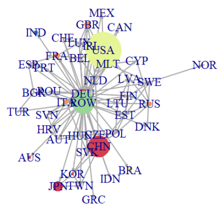
4.1 The World Trade Network



(a) World Trade Network in 1995.



(b) World Trade Network in 2005.



(c) World Trade Network in 2014.

Figure 4.1: The world trade network from the year 1995 to 2014. The vertices of the network represent individual countries, and the edges represent above average commercial relations with another country, as defined by an above average technical coefficient in the World Input-Output Matrix

Figure 4.1 above offers a quick glance of the structure of World Trade. This is done by using a qualitative input-out approach in conjunction with network analysis. Qualitative Input-Output Analysis allows us to summarize world trade data and simplify it in a way that allows us to see the structure of the system under analysis, and the relationship of individual elements in this system. Network analysis, on the other hand, uses this information and expands the analytical possibilities. It provides a means of visualizing the information, and adding further frameworks of analysis that further specify the role of each agent within the system. This gives us a means of performing a qualitative analysis to examine some aspects of the structure of world trade, as well as the role each country might play in it.

It can be observed in Figure 4.1 how the world trade network has changed from the year 1995 to 2014. This network is created from the World Input Output Matrix assembled by the OECD every year. Such a matrix is an inter regional matrix that details the flow of trade between industries and between countries. Over all, it includes data for over 40 countries (mostly OECD countries). Although the data is biased towards the European community, since most OECD countries are European and thus the likeliest to be present in the data. Nevertheless, two things can be immediately observed. Firstly, there appears to be a large degree of regionalization. And secondly, that richer countries appear to be more central in the network and interconnected to other rich countries. Over the years, on can observe that this trend has strengthened. At first glance, the 2014 network appears in Figure 4.1c appears even more interconnected and equally regionalized.

The overall structure of the world trade network can be examined using the measures that were previously discussed. Chiefly, *density*, *diameter*, and *assortativity*. Density refers to the proportion of edges versus the theoretical maximum amount of edges. This gives us a simple measure that describes the overall connectivity of the network, while diameter quantifies the minimum amount of vertices between two ends of the network. Assortativity, again, is a slightly more complex measure. Assortativity reflects the likelihood that a vertex is connected to vertex that shares a similar attribute. For the purposes of this study, assortativity with regards to GDP, region, and OECD membership will be observed. That is, how likely is it that a country has a significant commercial relationship with a country with a similar level of GDP, or with a country in the same geographic region? These measures are summarized in Table A.1.

Table 4.1: Network wide measure for the World Trade Network from the years 1995 to 2014.

Measure	1995	2005	2014
Density	0.065	0.064	0.069
Diameter	3	3	5
Assortativity by GDP	0.377	0.206	0.290
Assortativity by Region	0.242	0.220	0.204
GDP	$ 30.9 trillion	$47.5 trillion	$79.3 trillion

These measures allow for a concise summary of the main attributes of the network as a whole, and of the trade that is being represented by such a network. Firstly, one can discern a general increase in trade from these measures. For example, a higher network density and diameter are seen, indicating that there are more connections (edges) in the world trade network than before. Assortativity, on the other hand, has mainly lowered. This is indicative of greater connections or trading relationships between more distinct types of nations. While assortativity is still positive, indicating that countries would rather trade with countries that are geographically close and similar in income, it is indeed lower than in was in 1995. This indicates that countries are much more willing to trade with countries that are distant in geography and in the income ladder. It means that the average country is closer to being ambivalent when it comes to trade.

Beyond this, one can also observe an exciting development in world trade. Mainly, China has gone from having no significant commercial relationships with any country, to being one of the most central and connected nations in this very same network - all in the span of less than twenty years.

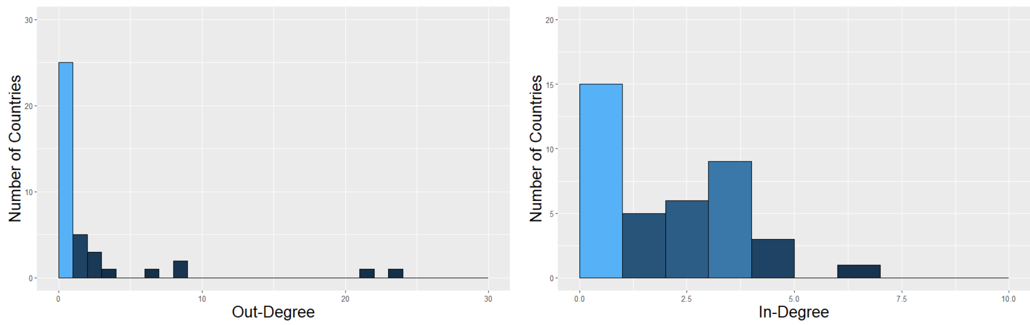
With this overview done, we move to a more exact discussion of these network metrics and economic performance.

4.2 Examining the World Trade Network in 1995

4.2.1 Outdegree and Indegree

(a) Outdegree (b) Indegree

Figure 4.2: The World Trade Network sized in proportion to indegree and outdegree in 1995.



(a) Outdegree (b) Indegree

Figure 4.3: Distribution of degree in the World Trade Network in 1995.

The outdegree of a vertex in a directed network is the number of nudges that emanate from it. Put more simply, how many arrows point out of it. In the context of world trade, an outgoing edge represents a significant export relation. It can easily be observed in the network diagram that there are basically vertices that are represented as being large exporters. This is confirmed by the histogram in Figure 4.3a, which reveals that there two vertices with higher outdegrees than the rest. By glancing at Figure 4.2a, one can see that the dominant vertices for this measure are Germany and the vertex deemed Rest of the World. Germany's dominance in this figure is due to its large status as an exporter. This is further accentuated by the fact that most vertices present on this dataset are of European countries. As such, one could argue that Germany is somewhat over represented in this network. Nevertheless, Germany dwarfs even other wealthy countries as an exporter. For example, France and the United Kingdom do not have high outdegrees. The "Rest of the World" vertex, on the other hand, represents every vertex that is not on the list, so its high outdegree is somewhat unwarranted. What is notable here, however, is China's absence from the network. While other East Asian countries relatively low outdegree can be somewhat accounted for by the fact that other Asian countries (likely trading partners) are relegated to the "Rest of the World" vertex; China's absence from the network indicates that it has no significant trading relationship with any country whatsoever. As far as trading go, China was an insular country in 1995.

Looking at the indegree network, however, presents a somewhat different picture. From Figure 4.3 one can glance that countries tend to have a lesser indegree than outdegree in general; that is, they have relatively few importing partners. They tend to trade, or have connections, with high centrality countries. In this case, most countries import from high exporters, such as Germany. It can be seen that indegree is fairly homogeneous across the network. There are no "high importers". Every vertex has more or less the same indegree.

4.2.2 Betweeness Centrality

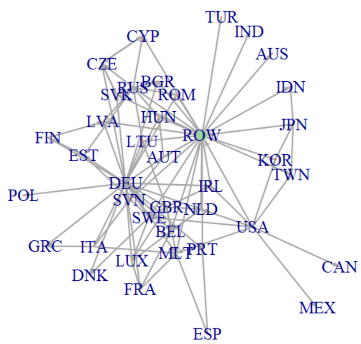


Figure 4.4: The World Trade Network sized in proportion to Betweeness Centrality.

Betweeness Centrality represents the number of shortest (or *geodesic*) paths that pass through any particular vertex. In most networks, it often represents how vital a network is in the flow of information or any such measure. As will be noted soon, Betweeness turns out to not have much correlation with economic measures such as GDP, so even if one could use it as a stand-in for some trade measure, such as whether any particular place is a port of entry or commercial hub where good flow through in large volumes, as of now it is hard to see if it could be meaningful. At least, that is the case with this particular dataset. To truly determine whether this particular measure could be useful, one would need to look at a more comprehensive dataset, perhaps even at a regional level, since cities such as Hong Kong and commercial hubs such as Singapore serve as commercial and transportation hubs with a high influx of good enter for later distribution. However, for this particular dataset, such an interpretation is speculative at best. From Figure 4.4, there is no particular country in the dataset has higher betweeness, except for "Rest of the World", which does not truly count since it is a fiction created by how the dataset is structured. Even though a clear relationship cannot be established between betweeness and measures such as GDP with this data, betweeness does have an interesting attribute. Mainly, betweeness is a useful measure in *Community Detection Algorithms*. That is, betweeness can help us detect whether there are communities, or tightly connected sub-networks, in our overall network. The way this is done is relatively simple. Mainly, high betweeness vertices are sequentially removed and sub-networks that results are considered communities. The result of running a community detection algorithm on the World Trade Network in 1995 would the graph present in Figure 4.5. What is interesting to note from this graph is not only that the network can be segmented into various internally coherent communities which correspond nicely with geographic regions or international communities that one might recognize in a real world context. This goes in accordance to the relatively high assortativity that was observed in the network as a whole. For example, it can be seen that the community algorithms Mediterranean countries such as Greece and Italy as a separate community, separates Western European countries from Central European countries, and even recognizes the Iberian countries as a separate entity. And more importantly, it recognizes East Asian countries such as Japan, South Korea, and Taiwan as members of their own community. This will help us track these countries (and China's) role in both a regional and worldwide context. These communities all correspond well to our own notion of international and economic communities, and further shows that network measures such as betweeness can have some use in an economics context.

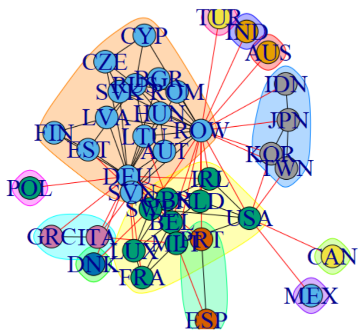


Figure 4.5: Communities in the World Trade Network in 1995. Community Detection Based on Edge Betweeness Algorithm (Girvan & Newman, 2002)

4.2.3 Hub and Authority Index

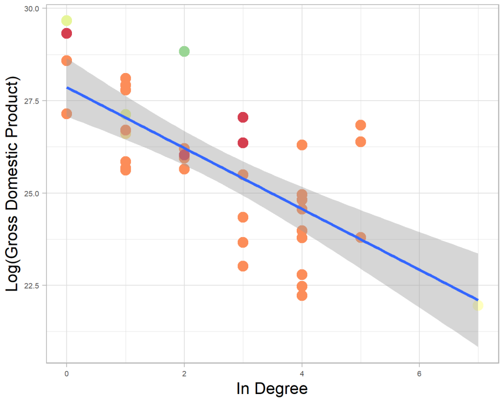
(a) World Trade Network Authorities in 1995.

(b) World Trade Network Hubs in 1995.

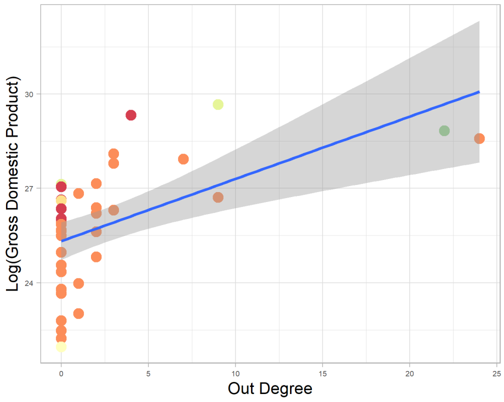
Figure 4.6: The World Trade Network sized in proportion to indegree and outdegree in 1995.

Another important and useful measure for network analysis is the Hub and Authority indices. As was previously mentioned, this measures actually arise from Computer Science, and are a popular and essential tool for search engine algorithm. In their original context, these two measures were developed in order to rank webpages. Web pages (or other repositories) with high authorities were meant to be pages that withheld useful information, and hubs are pages that point to these important sources of information. Nevertheless, these measure could easily be used in other contexts, as they are weighted versions of outdegree and indegree. What is particularly useful about these two measures is that they have the important property that the quality of the connections matter. For example, hubs that point to important authorities are more important that ones who point to vertices with low authorities. This way, can get a measure of how good the connections are, not just how many. In this way, these measures can transcend the original use and become important in other contexts. In the 1995 World Trade Network, some important feature can quickly be glanced. Firstly, as can be seen in Figure 4.6a, many countries seems to have a similar level of authority. This implies that these countries are tightly connected in terms of indegree. In the commercial context, that these countries are mainly importers, and that they import from a similar array of countries. On the other hand, hubs present an opposite picture. Very few countries are heavy exporters. As can be seen in Figure 4.6b, only Germany is a big exporter. Germany is a specially important in this network considering that most vertices are European. Perhaps if more data were available, other important regional exporters could be observed. Nevertheless, this does not diminish the importance of Germany in this network. As it dominant hub index reveals, it is by far the leading exporter at a regional and a global level.

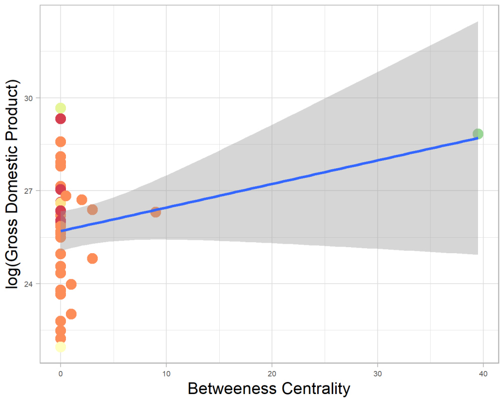
4.3 Examining the validity of network measures



(a) Indegree vs GDP in 1995.

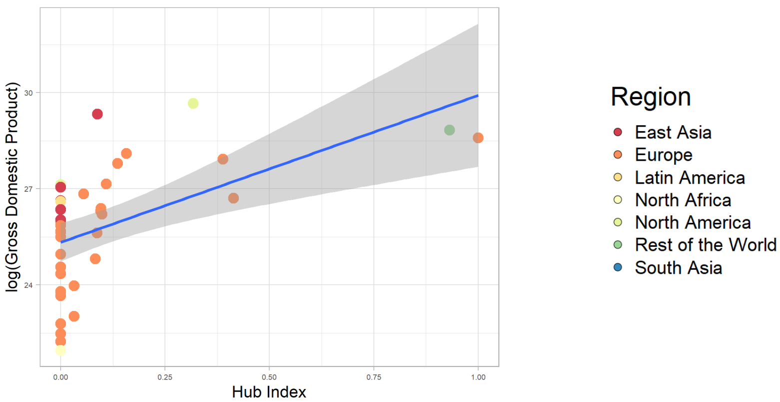


(b) Outdegree vs GDP in 1995.



(c) Betweeness vs GDP in 1995.

(d) Authority vs GDP in 1995.



(e) Hub vs GDP in 1995.

Figure 4.7: Regression between network measures and Gross Domestic Product in the World Trade Network in 1995.

Table 4.2: Gross Domestic Product versus network measures regression results for the World Trade Network in the year 1995.

	Dependent variable:				
	Log(Gross Domestic Product)				
	(1)	(2)	(3)	(4)	(5)
Outdegree	0.198***				
	(0.050)				
Indegree		−0.824***			
		(0.129)			
Betweeness Centrality			0.076		
			(0.048)		
Hub Centrality				4.588***	
				(1.194)	
Authority Centrality					−4.754***
					(0.770)
Constant	25.323***	27.864***	25.700***	25.331***	28.076***
	(0.294)	(0.389)	(0.316)	(0.296)	(0.428)
Observations	39	39	39	39	39
R^2	0.296	0.523	0.063	0.285	0.507
Adjusted R^2	0.277	0.510	0.037	0.266	0.494
Residual Std. Error (df = 37)	1.661	1.368	1.917	1.674	1.390
F Statistic (df = 1; 37)	15.577***	40.490***	2.480	14.758***	38.125***
Note:	*p<0.1; **p<0.05; ***p<0.01				

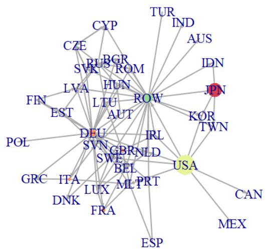
Now that the World Trade Network has been properly characterized using a variety of network measures, it is time to talk about how these might to GDP. In this way, by tying network measures to economic measure, one can better understand the uses and limitations of network analysis and better understand the insights that this method of analysis can offer us.

From Figure 4.7 and Table 4.2 it can readily be seen how these measures may or may not tell us about a vertex's position in world trade and how this may affect it economically. Looking at these figures and table in conjunction, it is possible to gather some insights. Mainly, it is possible to confirm from Table 4.2 that there are statistically significant relationships between all of these variables and the GDP, with exception of betweeness, which does not seem to correlate with GDP at any level of statistical significance. As can be observed from Table 4.2, a relationship can be established between all of these measures and the logarithm of GDP. Now, these measures are not directly comparable. Outdegree is not directly comparable with the Hub index since the Hub index is normalized. That is, it's range of values lies between 0 and 1. Nevertheless, the following can be seen in our network model of world trade: An increase of outdegree of one unit correlates with an approximately 22% increase in GDP, while an increase of indegree of 1 unit correlates with a 56% decrease in GDP. Likewise, with Hub and Authority centrality, a vertex with a maximum Hub Index of 1 is estimated to have 4.5 times the logarithm of GDP of a disconnected vertex, and vertex with a maximum Authority index of one is estimated to have a a logarithm of GDP that is 4.7 times lower than a disconnected vertex. These values are enormous, however, they largely stem from the fact that the Hub and Authority index are normalized values with a maximum of 1, which in this network happens to be Germany. Meaning that a one unit increase would be representative of a country having the same level of exports as Germany (the vertex with a Hub value of 1 in this network). More reasonably, we can also say that a 0.1 unit increase in the Hub Index corresponds roughly to a doubling of GDP, and a 0.1 unit increase in the Authority Index corresponds to a halving of GDP. Overall then, one can observe that there exists a statistically significant indicated that this measure correlates well with economic performance in an overall sense, and is a useful measure for gauging the size of a country's trade. The high R-squared values suggest that these measures are in essence stand-ins or representations for GDP in the network model, which makes sense considering these were formed from export data. In a sense, then, these measures serve well as stand-in for trade data and in observing the effect of relationships.

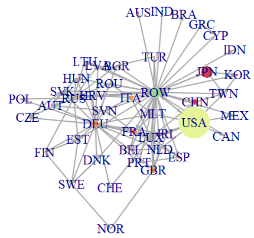
There are several things to note about these estimates, however. As can be seen from both the figures and the table, there is evidence of heteroskedasticity, in part because these measures do not seem to have to much granularity. That is, most vertices have close to zero while other ones have very high centrality measures. Nowhere is this clearer than with the betweeness measure, where most vertices had a value of zero, with two vertices having high values. Beyond this, as one can see in the regression diagnostics in Appendix B, this pattern results in having high leverage points. In this network, these often being Germany and the Rest of the World Vertex. A case could be made for removing these vertices, in particular Rest of the World, since the latter vertex is in a sense a statistical anomaly - an agglomeration of all the countries not included in the dataset, and as such will exhibit different behavior from the rest of the vertices. However, the case is more difficult to make with Germany, since there is no legitimate reason from removing it from the regression. It most be noted, however, is that regression results could improve and a more exact relationship could be established between network and economic measures if the network were more complete and more data were available for more countries. In this case, vertices such as the United States and Japan would appear more central, since they are likely to have many connections to Latin American and Asian countries that are largely unrepresented in this sample. The high centrality of these countries would raise the representation of high centrality vertices and would present a more complete picture of the relationship between network measures and GDP. For the purposes of this analysis, then, we will simply rely on the overarching trends, which are unlikely to be changed by more data and give us at least a general idea of the utility of network analysis.

The overarching insights can be summarized as follows: for this subset of data countries with higher outdegree have higher GDP, and countries with big indegree have lower GDP. In the context of trade, this means that countries with many exporting relationships have high GDP while a high number of import relationships correlates with a low GDP. This can be observed not only with indegree and outdegree measures, but with the Hub and Authority indices. Of course, the Hub and Authority indices are derived from indegree and outdegree, but they also provide the additional information. Mainly, that the quality of the connections also matter. Vertices that "export" to other important vertices get a huge economics boost, and vertices that simply "import" from big exporters are punished economically. These general results give at least some credence to the notion that an export oriented economy could be the driver for development. Of course, the reverse could also be true. Good economies lend themselves to exporting. Furthermore, it can be observed that other strong economies such as France and the United Kingdom are not strong exporters in this network, but they still have robust economies. For this work, however, a strong correlation between export behavior and economic gain exists, and this will help us visually observe the behavior of famously export oriented economies such as Taiwan, South Korea, and China.

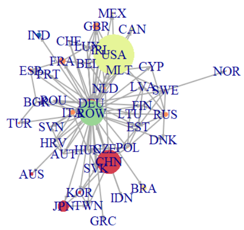
4.4 The evolution of Asian countries in the world trade network



(a) World Trade Network in 1995.



(b) World Trade Network in 2005.



(c) World Trade Network in 2014.

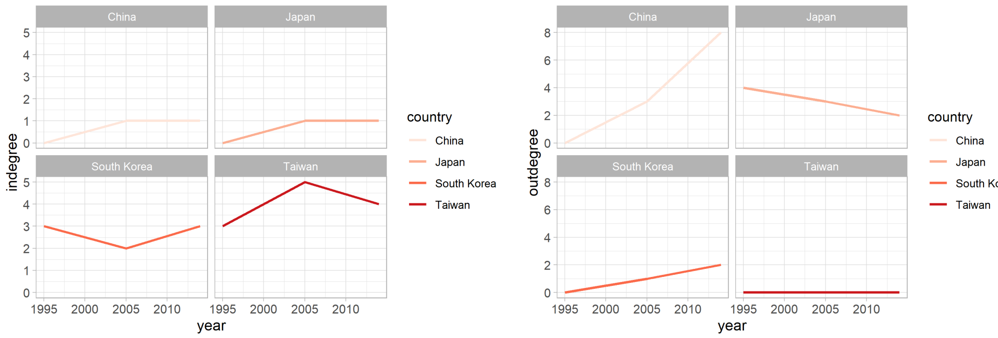
Figure 4.8: The world trade network from the year 1995 to 2014, where each vertex is sized according to GDP.

While it is important to observe the place of a country within a network, it is equally important to observe how the country's place in the network changes through time. Figure 4.1 once again shows how the world trade network has changed in the span of two decades, from 1995 to 2014. The role of each country in East Asia present in the World Trade Network throughout the years is now then discussed.

As can be seen in Table 4.1, and in the preceding sections, there is evidence of a denser, bigger, and more connected network. But, more importantly, there is evidence of a very important development. Mainly, that China starts to appear in the network by the year 2000. In 1995, only two countries in the dataset did not have any above average commercial relationship that could be represented in the network, these being China and Brazil. By 2014, China has a prominent place in the network.

It can be seen that it is tightly integrated to the World Trade Network, even more so than the rest of its Asian counterparts, as it has a more central position and a higher number of connections. Equally impressive is that it is the only developing country has assumed such a position so quickly. Other developing countries in the dataset, like India and Brazil, either continue to have a periphery position or do not have a commercial relationship that can be represented in the network. With these things in mind, it could be said that China has experienced a near economic miracle. To better observe this change, let us look at the network measures and see how these have changed for East Asian countries present in the network.

4.4.1 Indegree and Outdegree



(a) indegree (b) Outdegree

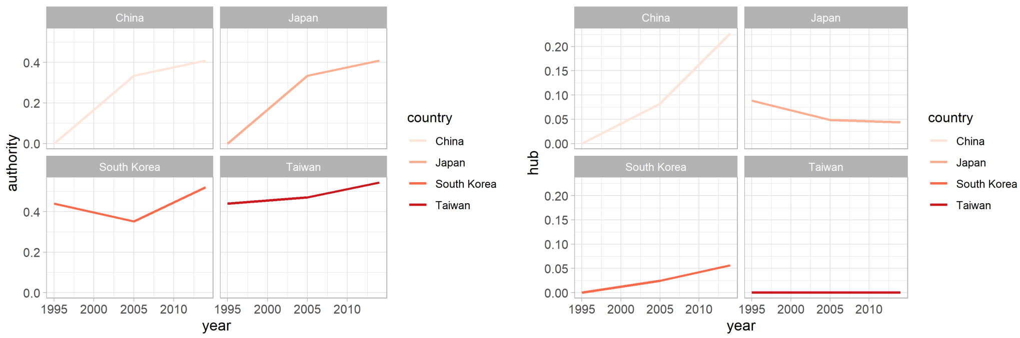
Figure 4.9: Indegree and outdegree for each of the East Asian countries in the world trade network for the years 1994, 2005, and 2014.

It can be discerned from Figure 4.9 that indegree has in general increased for all the East Asian countries under analysis. This is not too surprising, as the overall density of the network has increased throughout the years. It stands to reason, then, that it is likely that the degrees of each vertex in the network is likely to increase over time. What stands out here, however, is the vast increase in outdegree for China from zero to eight, as can be seen in Figure 4.9b. It can be clearly seen that the China has had a dramatic increase in outdegree among these countries and among the World Trade Network. This large increase in outdegree goes in accordance with the export growth model that these countries have followed throughout the latter half of the 20th century, and which China has perfected in more recent times. According to our regression estimates, this increase in outdegree would account for a five-fold increase in GDP. This is within the order of magnitude of growth experienced by China throughout this time, where the Chinese economy has increased ten-fold[1]. The only other economy to see an increase has been South Korea, with an increase

[1]See *World Bank national accounts data, and OECD National Accounts data files*, n.d., for more information.

of 2 outdegree. It remarkable that Japan's and Taiwan's outdegree, in turn, has not seen much increase in outdegree, and Japan's has actually lowered. This indicates less exporting activity, in relative terms. As was seen from Table 4.2, this decrease in export performance could translate to lower economic performance. These figure paint the overall picture that over the last 20 years, China has started to become a regional and world powerhouse in terms of both imports and exports. And, as of 2015, vastly outperforms its neighbors in terms of how many export relation it has with other countries around the world. None of the countries experienced very large changes in indegree, with indegree being within similar ranges between 1995 and 2014.

4.4.2 Hub and Authority Index

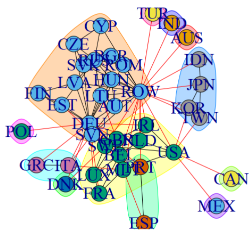


(a) Authority Index (b) Hub Index

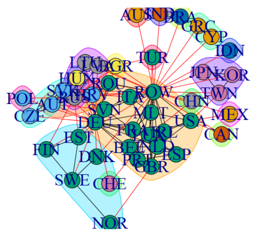
Figure 4.10: Hub and Authority Indices for each of the East Asian countries in the world trade network for the years 1994, 2005, and 2014.

The overall trend in the hub and authority index remain the same as they did for indegree and outdegree. This is not at all too surprising, since the hub and authority indices are derived from the indegree and outdegree, and are in essence weighted versions of these. However, since "meaningful" connections carry more weight, it is a useful measure of how important these vertices (or countries) are to the overall network. Nevertheless, a similar pattern is seen. All Asian countries see an increase in Authority Index, indicating more import relations. Meanwhile, only China sees a large increase in the Hub Index, South Korea having a modest increase, Taiwan having no increase, and Japan having a slight decrease. The scale of these changes also correspond well to the ones seen with outdegree and indegree. For example, our regression estimates indicate that a 0.2 increase in the Hub Index would correspond to a four-fold increase in GDP, which is a similar estimate as that offered by the outdegree. This is consistent with what was seen before. Mainly, that China's export oriented economy has given it a prominent place in the World Trade Network, far outweighing their neighbors in this metric. However, it remains important to remark that China's increase in its hub index far outweighs the decrease of, for example, Japan. Likewise, Taiwan and South Korea do not a decrease in their Hub Index, indicating that there is little to no displacement. Nevertheless, it can be seen that there are large gains from a central position in trade.

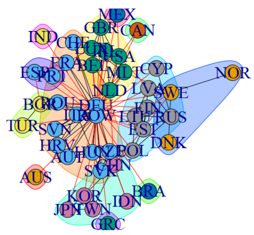
4.4.3 Betweeness and Community



(a) Authority Index



(b) Hub Index



(c) Hub Index

Figure 4.11: Communities in the World Trade Network, as determine by the Givan-Newman Community Detection Algorithm (Girvan & Newman, 2002).

While it was shown that betweeness was the one centrality measure that did not correlate well with GDP, it is still worth noting that the communities drawn correspond well to well-known economic blocs, and in particular, that by 2014 (as seen in Figure 4.11c) China is at the intersection of many more communities than any of its Asian counterparts. It is worth noting that East Asian countries constitute their own community in each of the years. Each country does have a connection to another community and is not completely isolated, nevertheless, by 2014 it is evident that China is much more well connected to distinct communities than either Japan, South Korea, or Taiwan. It might not be immediately indicative of economic performance as other centrality measures, but it does tell us something distinct about China's trade structure, and the wide array of significant trading partners that it possesses.

Chapter 5

Conclusions and Recommendations

5.1 Overview

In this study we have used network analysis to help answer some important questions on the role of China in World Trade and its impact on other countries. In particular, we have used network analysis to observe how's China's role has changed in World Trade from 1995 to 2014, and whether its rise has had any visible effect on other countries, in particular Japan, Taiwan, and South Korea. This countries have been chosen because China has in many ways emulated the developmental paths that these countries established, and so as China's trade profile evolves and develops the first economies to be affected would be these very same countries. In a sense, they serve as a useful example of how the "China Shock" would affect developed economies. With this in mind, we have used network theory as a tool to observe China's evolving role in World Trade, to observe if China's evolving role has affected any of the East Asian countries in the network, and to test how network measures correlated with GDP and see what information can be gathered from trade from a network approach. It was also shown that the export-led theory of growth is credible from a network approached, as it was observed that export related measures showed a very strong correlation with economic performance and placement in the World Trade Network.

The results section showed that, overall, China has vastly increased its presence in a binary and directed World Trade Network constructed using the technical coefficients of the World Input-Output Matrix (Timmer et al., 2015). The rise in China is clearly observed within said network, as shown by a general and sustained increase in every centrality measure that was used to measure the importance of the vertices (countries) in the network. These indegree, outdegree, betweeness centrality, authority index, and hub index. All of these measures, except for betweeness centrality, showed a correlation with GDP. Among these, indegree and authority index, which correspond to imports, showed a negative correlation with GDP across all the years studied (1995, 2005, and 2014). On the other hand, outdegree and hub index, which correspond to exports, showed a strong and positive correlation with GDP. Betweeness centrality, which essentially tells us if a vertex links different communities together, showed no statistically significant correlation with GDP, it did allow us to map the distinct communities that exist within the World Trade Network. For the network as a whole, it was found that it has grown slightly more dense, its diameter has increased, and its assortativity by region and income has very slightly decreased, meaning that wealthy countries are a slightly more likely to engage in significant trade relations with lower income countries. These are all signals of a more tightly connected web of commercial relations across the years.

An analysis of China throughout time shows a remarkable pattern. In 1995, none of China's trade relations were significant enough, meaning that when the Input-Output Matrix was converted a binary matrix using our criteria (that the technology coefficient between one country and another is higher than the average trade coefficient for the world), none of China's relations stood out as significant. As such, China did not appear in the World Trade Network. However, already in the year 2005 China begins to appear in the network and have a more prominent role. This trend continued to take place until 2014, where our analysis ends. In fact, China had the most striking rise out of all the Asian countries examined. While the rest of the Asian countries held their place in the network and saw a slight increase in all network measures, the only exception being Japan which saw a very slight decrease in export related measures. Furthermore, with exception to India and Brazil in 2014, China is in essence the only developing country to enter the network. Moreover, by 2014, it is an incredibly important vertex in the network with high marks in all network measures. It saw an incredibly rise in indegree, outdegree, hub index, and authority index. In short, it saw an incredible rise in both intermediate imports and exports and as a result it has managed to become more central in this World Trade Network. In fact, as of 2014, China has a higher centrality than all the Asian nations. This rise in centrality is important, since it was shown that export related network measures correlated strongly with GDP even in this binary matrix. It can be seen from a network approach that this rise in exports has given the country a more central position in World Trade, and that this correlated heavily with its overall economic performance. This goes in line with the export-led theory. In this network, China's incredible rise in manufacturing and export are clearly observed, and in turn, it was seen that exports in particular correlate well with economic performance. Network analysis, then, presents a useful tool to analyze the evolution and patters of trade in a country, and this in part can be related to economic performance. Not only it was shown that this is possible, but we have also seen a plain picture of how a country with an export led approach to development has taken a huge central role in the World Trade Network.

Another important observation is that this network approach has allowed to in part observe the economic relations between countries. In this regard, the relative role of all East Asian countries present in the network was observed in the years 1995, 2005, and 2014. While it becomes the hard to carefully explore the role of countries' in the entire world network, due to the fact that 70% of the countries in the database are European. Even so, these Asian countries are likely to have an even greater economic role in Asian countries not included in this database, such as Thailand, Malaysia, and other South-East Asian and Pacific countries. Their impact in this network is actually likely to be understated.

Overall, the incredible rise of China via export-led growth was observed in the network. We observe not only a huge increase in intermediate exports, but in intermediate imports as well. However, it was found that the export related network measures in particular showed a positive correlation with GDP, while import related measures showed a negative correlation with GDP. This held in this binary and directed network, where a global Input-Output matrix consisting of at least 43 countries and 56 industries was used to derive an technological matrix, and this in turn was used to derive a binary matrix by utilizing a filter. In such a network, China's role corresponds to that dictated by the export led theory of growth. In fact, China was the only country with such a rapid rise, having gone from no significant commercial relations in the network to having eight, with only Germany having such a high number. Furthermore, from a network perspective, it can largely be observed that China taking a more central place in the network has not resulted in an outright displacement of Japan, South Korea, and Taiwan. While Japan did have slightly lower centrality measures in 2014 than in 1995, these were not in proportion to the huge increase the China saw. Furthermore, South Korea and Taiwan also saw slight increases in their centrality measures (both import and export). As such, there is no observed evidence for displacement in this network. On the contrary, the increased density and diameter of the network is evidence of a more cohesive and interconnected network, and these countries have largely shared the gains from increased trade and connectivity in the network.

This study has found much evidence for a more interconnected and cohesive network, which has allowed many countries to simultaneously benefit from added connectivity in the network, and hence from the gains of trade. These findings reflect interesting patterns in world trade and in the role that individuals countries fill in said trade. It is in observing these mechanisms that network analysis proves itself to be most useful. While this is only one tool in many, it has been demonstrated that network analysis can be further used in an economic context to attempt to explain economic phenomena. While Benedicti et al. (2013) started to introduce its use in a trade context, it has not seen wide use in exploring issues regarding countries *themselves* or relations between countries. It is with this in mind that this study was done. To demonstrate the capability of this methodology to give insight to these types of questions. It is not the tool to answer such questions, nor should it be, but it can be used to get further insight into countries and their relations, and to attack longstanding questions from a new angle. It is with this in mind that we advocate for this method. However, the method does present some limitations. Among these perhaps the most important is the limited availability of data. In this case, the presence of mostly European data presented some limitations when it came to fully witnessing the role of Asian countries in World Trade, as it is likely that these countries would have had even greater roles in a network where more countries from more places were present. Nevertheless, important patters and consistent patters were observed. As Amador and Cabral (2016) and Ortiz (2017) postulated in their networks, trade was seen to be regionalized. And furthermore, the countries position and centrality positions were seen to be consistent with our notions of World Trade. Countries such as the United States and Germany were seen to be highly central, and across the years, China achieved similar centrality and managed to further connect the Asian community to other regions. In short, we managed to observe the "skeletal structure" of World Trade, just as Qualitative Input-Output Analysis has historically done in intra-regional and inter-industry trade.

5.2 Implications and Further Recommendations

With the utility of the network approach well established, we would like to provide additional recommendations for further research. Firstly, this approach should be become even more useful when more data from more countries is gathered, and should serve as a reminder of the urgency and utility of such high quality data. Another point we would like to remark is the adaptability of this method. This method can be used to observe trade in many situations, be it inter-industry or intra-regional such as is commonly done in Qualitative Input-Output Analysis, or at a global level such as it was done here. Furthermore, a variety of networks can be formed. It is possible to do weighted networks, undirected networks, or any combination of these. And at an even more fundamental level, Input-Output matrices can be transformed and different matrices can be used to form the basis for the network. For example, in this work a technology matrix was used to form the basis of the network, but any matrix derived from the Input-Output matrix can be used as long as it provides useful economic information. With this in mind, further research in this area could focus on more value-added measures, such as in the work done by Ortiz (2017) and Amador and Cabral (2016). Such measures would give insights not only utilizing the volume of trade, but in ways more telling measures such as value-added. This could be highly relevant for the region as it would reveal information about China's role in the Global Value Chain, what kind of activities it specializes in, and how this activity compares to those of the wealthier East Asian nations and the world in general. These questions are highly relevant, and can continue to be tackled using the network approach. Furthermore, it would also be interesting to explore the quantitative capabilities of weighted networks. Unweighted networks such as the ones used in this study are able to show the patterns and the "skeletal structure" of World Trade, but is very difficult to interpret centrality measures in a concrete way. As such, their use is limited and likely not to be to helpful in shaping concrete policy. However, since weighted networks do not filter data and instead incorporate raw economic data into the various measurements, weighted network metrics could have more concrete economic meaning. Testing the capability of these as quantitative models could provide yet another tool in exploring the utility of networks to examine World Trade. Furthermore, they allow for a more granular level of data, which could lead to more accurate and numerical meaningful estimates and could lead to a robust modeling of trade data, which could then be used to explore a variety of other questions. This presents a further opportunity for study. Likewise, network theory should only be one tool in the arsenal. For example, as David Autor and Hanson (2016) shows, the effects of China's trade could very much be heterogeneous, and affect different people in different ways. While networks could continued to be used to observe the general patters and obtain a sense of scale, it cannot provide the whole picture. Nevertheless, the world of network theory is very advanced and has been developed to be of great use in multiple areas of study, as such, it remains relevant to further expand its use in economic analysis and we hope that this study provides one such step.

Finally, we must remark on one of the main findings of this study, which is the importance of exports in economic trade. Network measures associated to exports in this study were found to have a strong positive correlation to Gross Domestic Product. This reflects the importance of the export led growth that all East Asian countries underwent in their road to development. The utility of such approach is visible in this network. This approach provides a good way of visualizing and quantifying the importance of exports in economic development, and can be used to track how countries engage in these practices. In a sense, many institutions in the practice of making economic policy historically overrated the beliefs that were part of the Washington Consensus and undermined the benefits of using state resources to accelerate and engage in trade. In particular, to use industrial policy to increase the state's industrial capacity and engage meaningfully in trade, utilizing exports as a measure of industrial capacity and a vehicle for development. No country in our network showed such a rapid change in roles, and most of this change can be attributed to export-led growth. It is hard to know exactly if other countries will follow a similar model for growth, but we surmise that a manufacturing drive along with the export led approach will continue to be a key in economic development. As Rodick (2013) postulates, the development landscape is sure to be different in the future, with trade agreements and the evolution of global value chains across national borders making the development recipe from East Asia harder to emulate, not to mention the various political challenges associated with it. Nevertheless, as he himself remarks China remains an example of such an approach, demonstrating the effects of a huge export drive and of a successful example of the economics of agglomerations even in a world where global value and manufacturing chains have expanded across borders. In that sense, China remains an example to the rest of the world, and the responds of East Asian countries will themselves show another example of how to respond to this trade. It would be beneficial to explore this same response with added-value measures and bigger database, but the overall trend remains clear. That is, that the gains of trade remains evident even as the world changes and evolves.

Appendix A

The World Trade Network in the years 1995, 2005, and 2014

A.1 World Trade Network

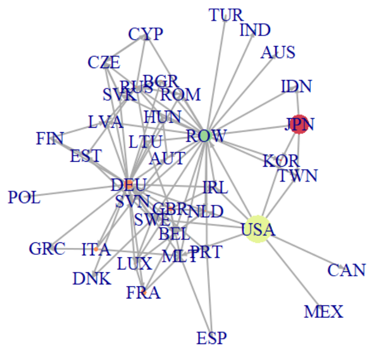


Figure A.1: The World Trade Network in 1995. Vertices in the network are sized in proportion to their Gross Domestic Product and colored by region. Each edge indicates a a technical coefficient in the Input-Output Matrix that is greater than the average.

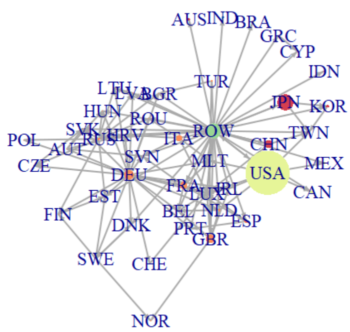


Figure A.2: The World Trade Network in 2005. Vertices in the network are sized in proportion to their Gross Domestic Product and colored by region. Each edge indicates a a technical coefficient in the Input-Output Matrix that is greater than the average.

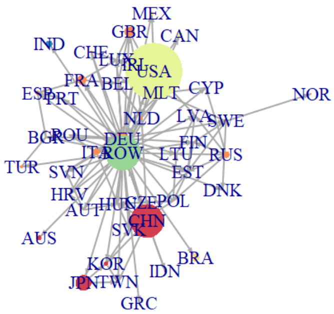


Figure A.3: The World Trade Network in 2014. Vertices in the network are sized in proportion to their Gross Domestic Product and colored by region. Each edge indicates a a technical coefficient in the Input-Output Matrix that is greater than the average.

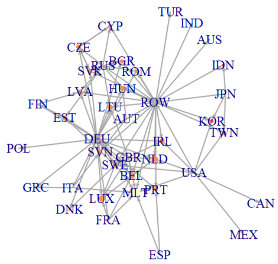
A.1.1 Network Wide Measures of the World Trade Network

Table A.1: Network wide measure for the World Trade Network from the years 1995 to 2014.

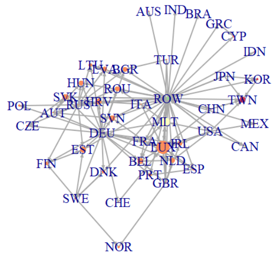
Measure	1995	2005	2014
Density	0.065	0.064	0.069
Diameter	3	3	5
Assortativity by GDP	0.377	0.206	0.290
Assortativity by Region	0.242	0.220	0.204
GDP	$ 30.9 trillion	$47.5 trillion	$79.3 trillion

A.2 Network Measures

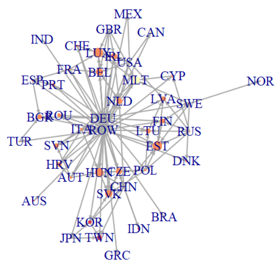
A.2.1 Indegree of the World Trade Network for the years 1995, 2005 and 2014



(a) 1995



(b) 2005



(c) 2014

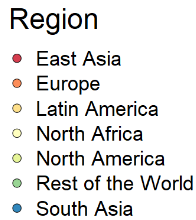
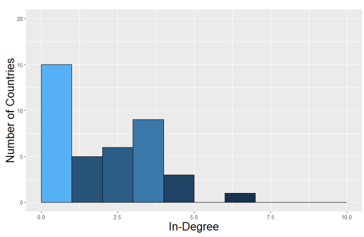
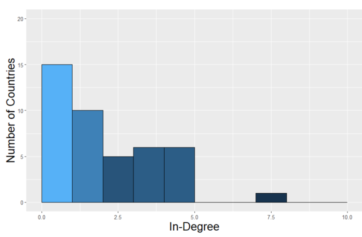


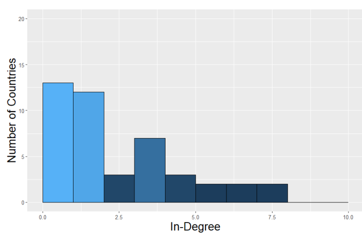
Figure A.4: The World Trade Network with each vertex sized in proportion to Indegree for the years 1995, 2005, and 2014.



(a) 1995



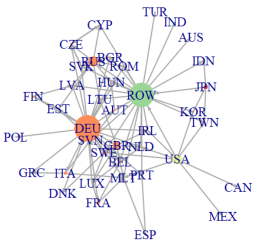
(b) 2005



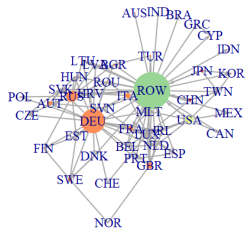
(c) 2014

Figure A.5: Distribution of Indegree in the World Trade Network for the years 1995, 2005, and 2014.

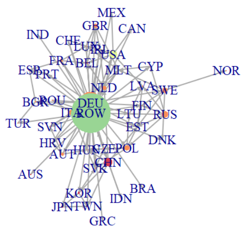
A.2.2 Outdegree of the World Trade Network for the years 1995, 2005 and 2014



(a) 1995



(b) 2005



(c) 2014

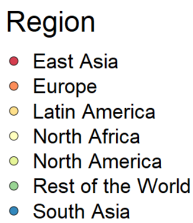
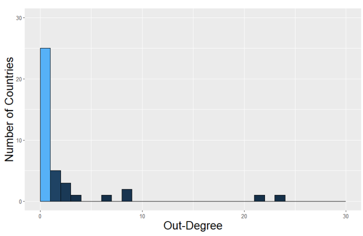
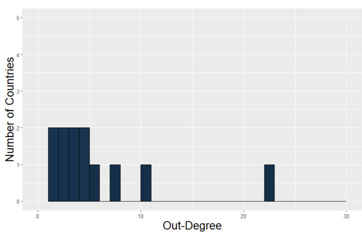


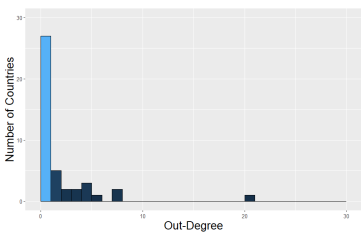
Figure A.6: The World Trade Network with each vertex sized in proportion to Outdegree for the years 1995, 2005, and 2014.



(a) 1995



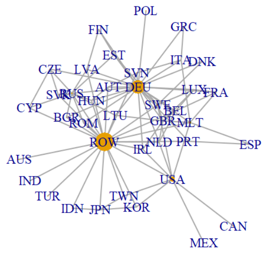
(b) 2005



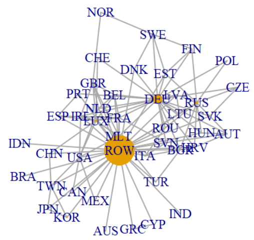
(c) 2014

Figure A.7: Distribution of Outdegree in the World Trade Network for the years 1995, 2005, and 2014.

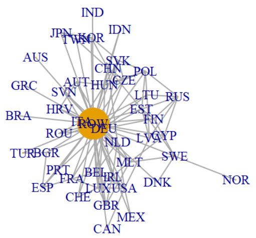
A.2.3 Betweeness Centrality in the World Trade Network for the years 1995, 2005, and 2014.



(a) 1995

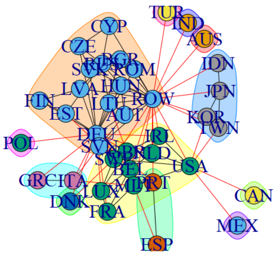


(b) 2005

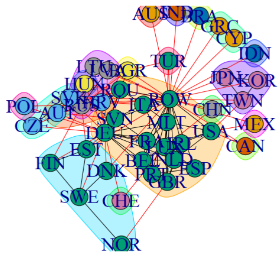


(c) 2014

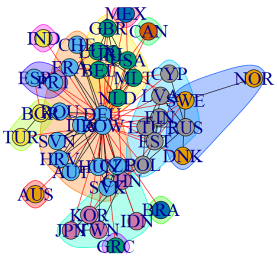
Figure A.8: The World Trade Network with each vertex sized in proportion to their Betweeness Centrality for the years 1995, 2005, and 2014.



(a) 1995



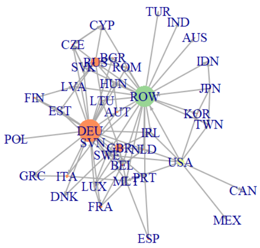
(b) 2005



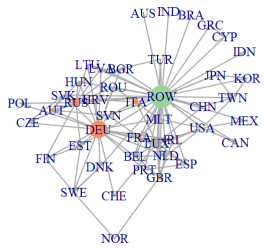
(c) 2014

Figure A.9: Communities present in the World Trade Network as calculated by the Girvan-Newman Algorithm (Girvan & Newman, 2002)

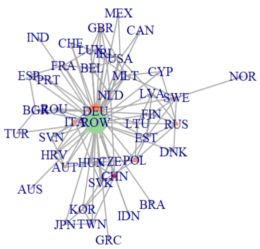
A.2.4 Hub Index in the World Trade Network for the years 1995, 2004 and 2014.



(a) 1995



(b) 2005



(c) 2014

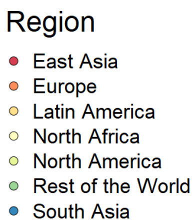
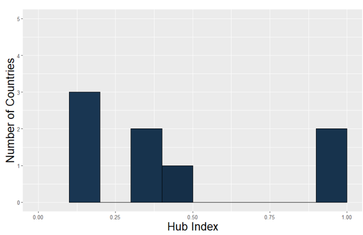
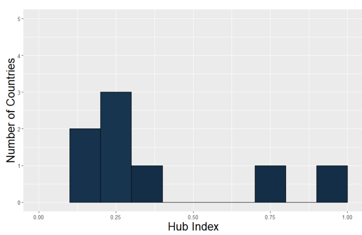


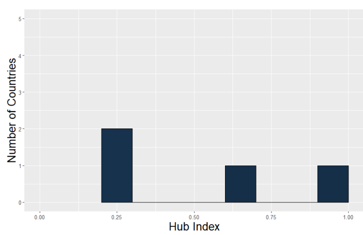
Figure A.10: The World Trade Network with each vertex sized in proportion to their Hub Index for the years 1995, 2005, and 2014.



(a) 1995



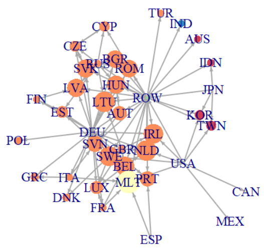
(b) 2005



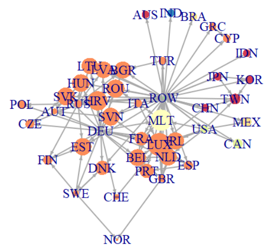
(c) 2014

Figure A.11: Distribution of countries' Hub Index in the World Trade Network for the years 1995, 2005, and 2014.

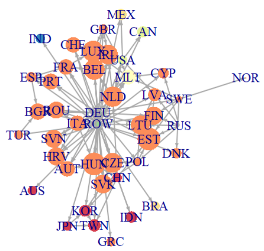
A.2.5 Authority Index in the World Trade Network for the years 1995, 2004 and 2014.



(a) 1995



(b) 2005



(c) 2014

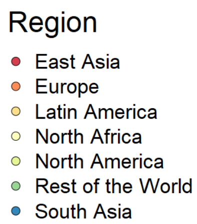
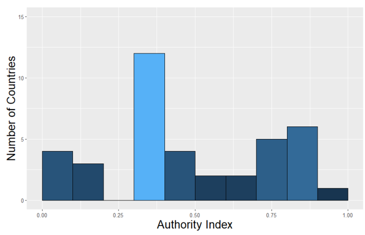
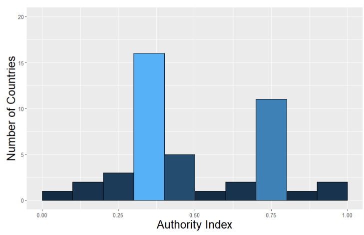


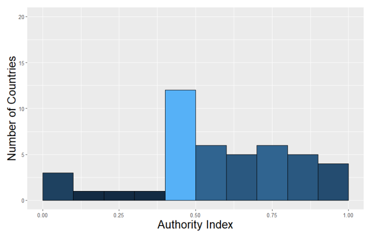
Figure A.12: The World Trade Network with each vertex sized in proportion to their Authority Index for the years 1995, 2005, and 2014.



(a) 1995



(b) 2005



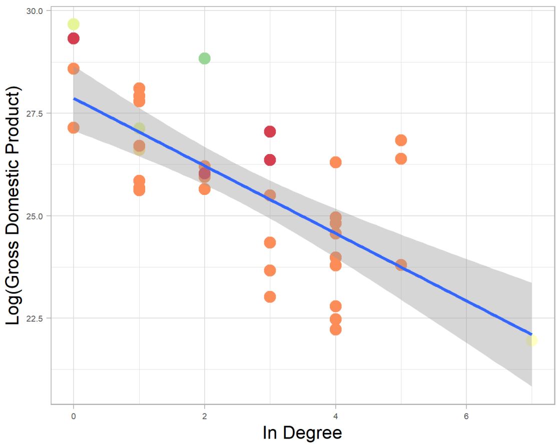
(c) 2014

Figure A.13: Distribution of countries' Authority Index in the World Trade Network for the years 1995, 2005, and 2014.

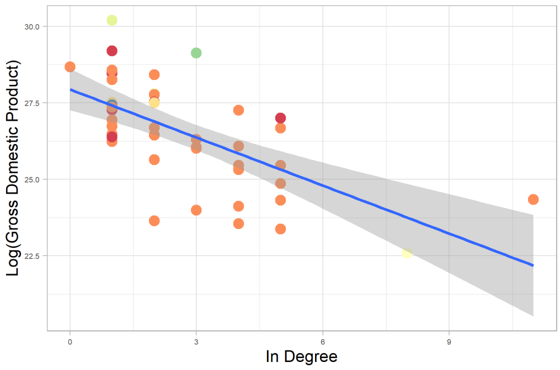
Appendix B

Regression and Regression Diagnostics

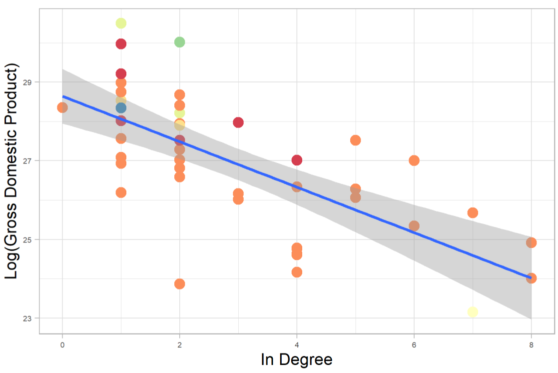
B.1 Indegree and Gross Domestic Product Correlation for the years 1995, 2005, and 2014.



(a) 1995

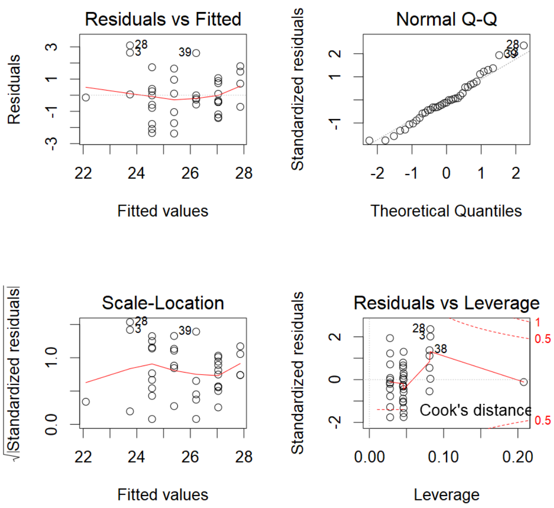


(b) 2005

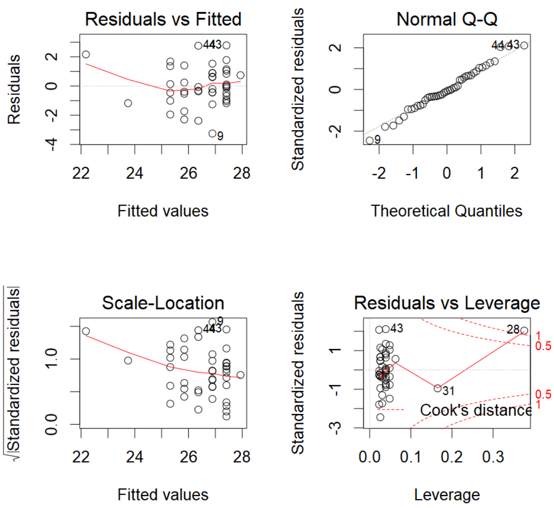


(c) 2014

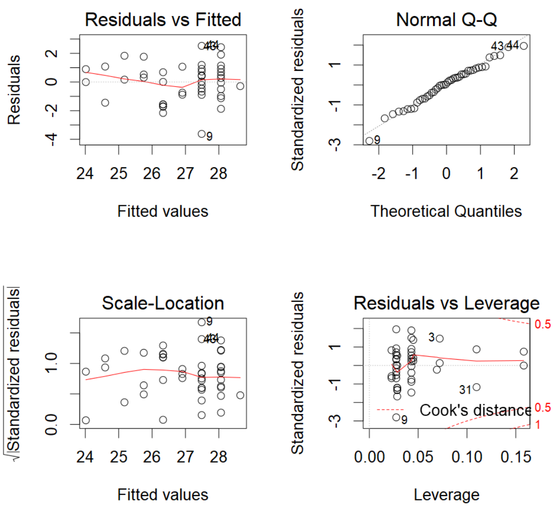
Figure B.1: Correlation between Indegree in the World Trade Network and Gross Domestic Product for the years 1995, 2005, and 2014.



(a) 1995



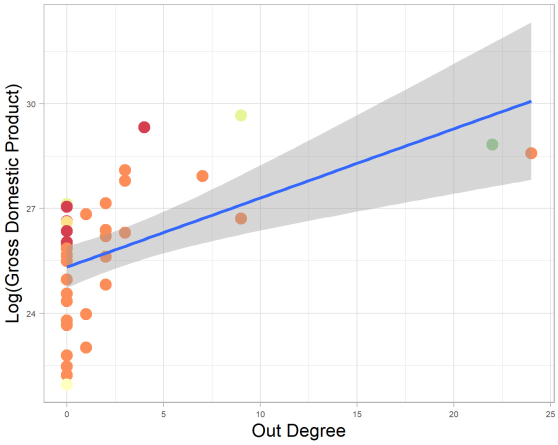
(b) 2005



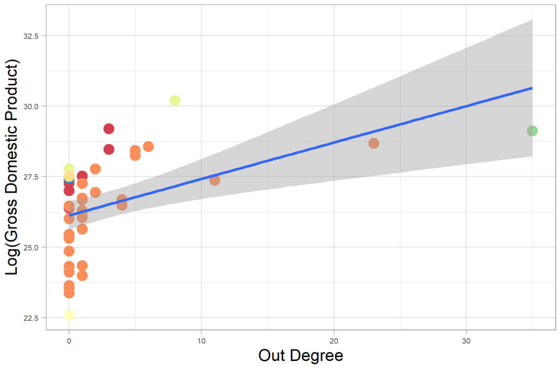
(c) 2014

Figure B.2: Regression diagnostics for Indegree and Gross Domestic Product regression for the years 1995, 2005, and 2014.

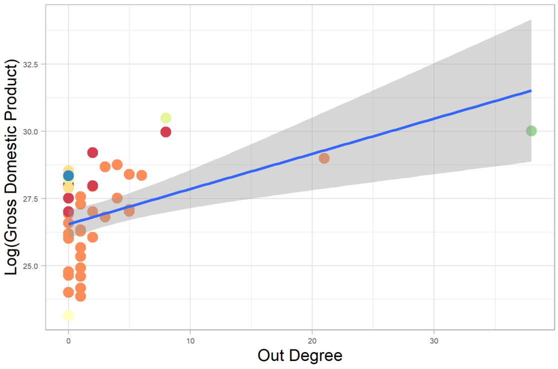
B.2 Outdegree and Gross Domestic Product Correlation for the years 1995, 2005, and 2014.



(a) 1995

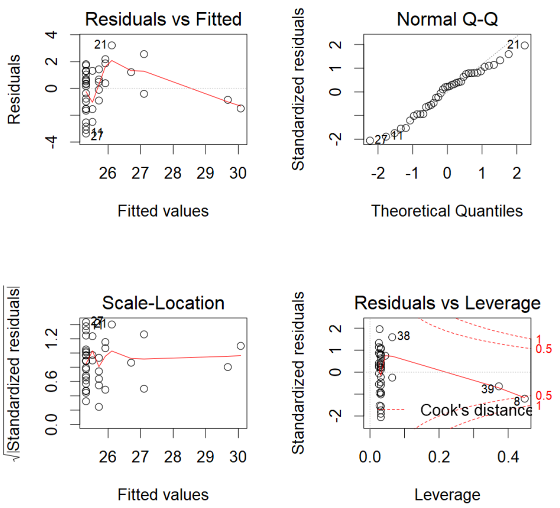


(b) 2005

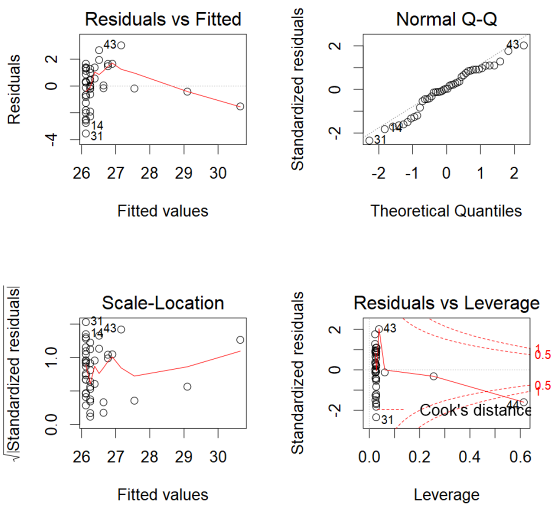


(c) 2014

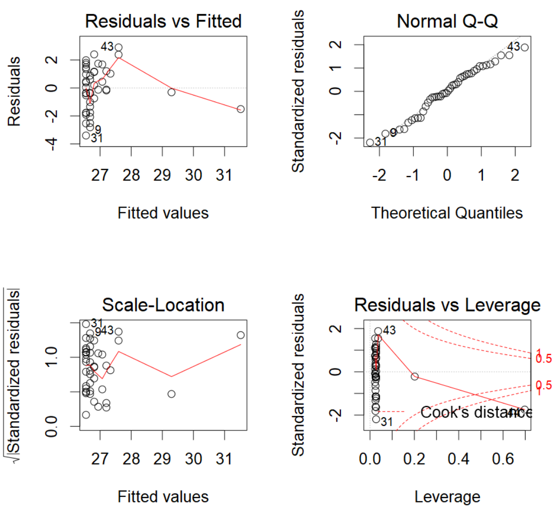
Figure B.3: Correlation between Outdegree in the World Trade Network and Gross Domestic Product for the years 1995, 2005, and 2014.



(a) 1995



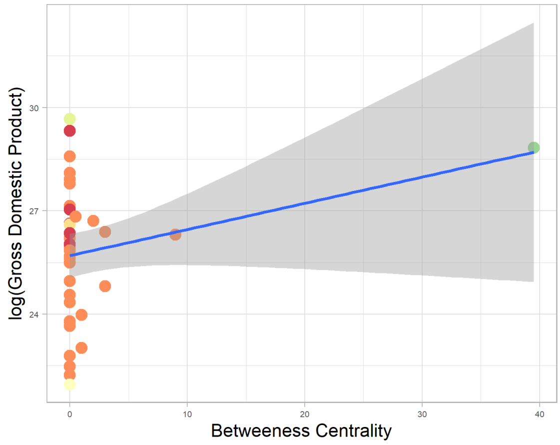
(b) 2005



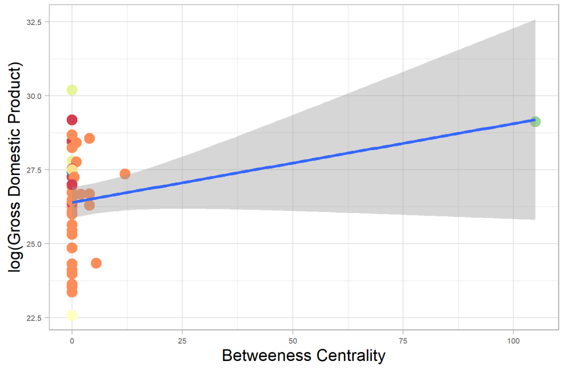
(c) 2014

Figure B.4: Regression diagnostics for Outdegree and Gross Domestic Product regression for the years 1995, 2005, and 2014.

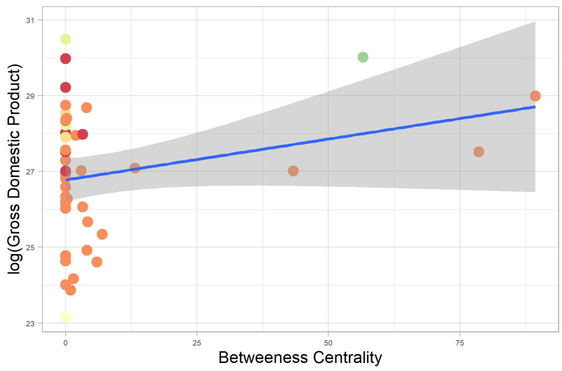
B.3 Betweeness and Gross Domestic Product Correlation for the years 1995, 2005, and 2014.



(a) 1995

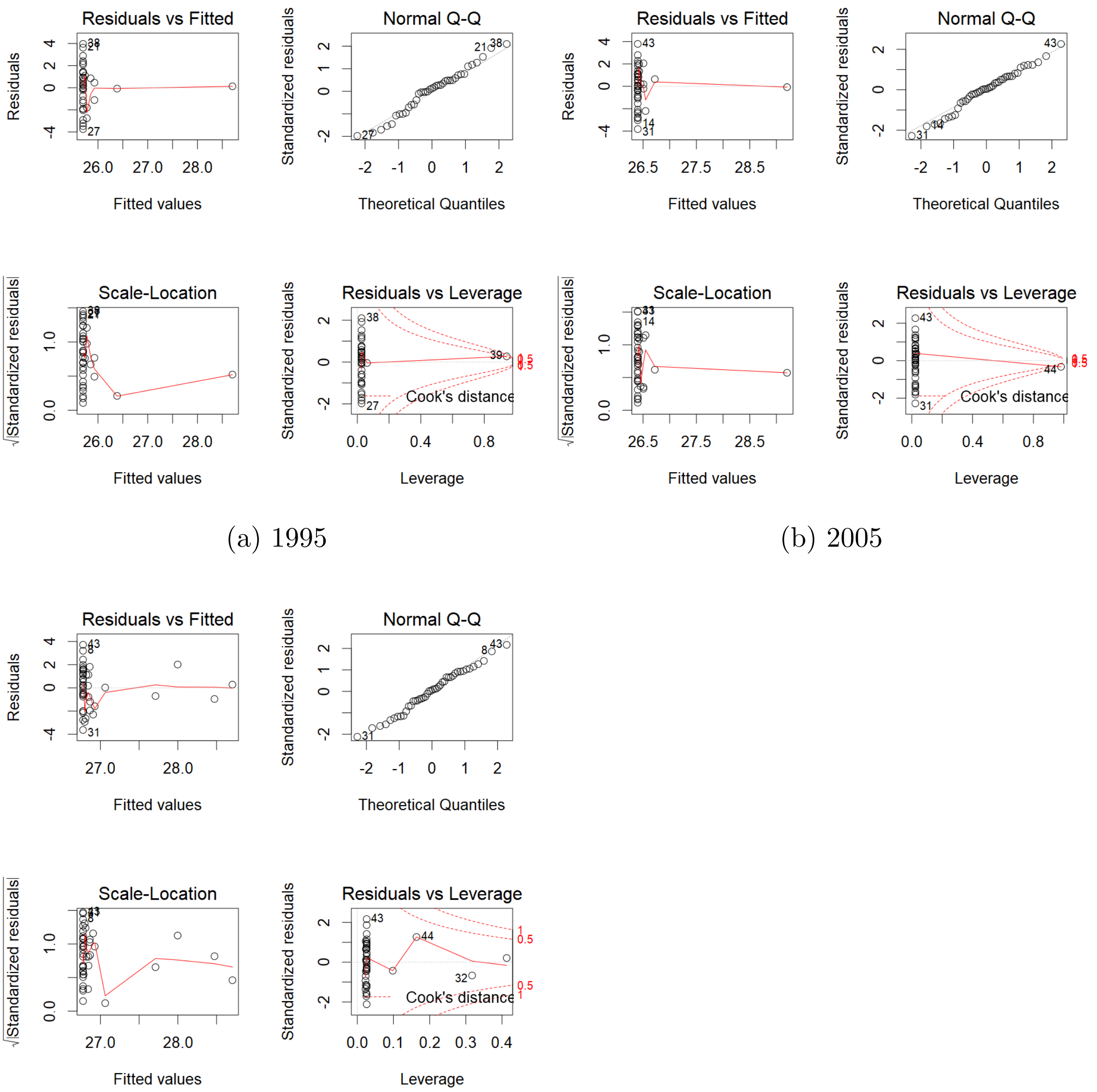


(b) 2005



(c) 2014

Figure B.5: Correlation between Betweeness in the World Trade Network and Gross Domestic Product for the years 1995, 2005, and 2014.



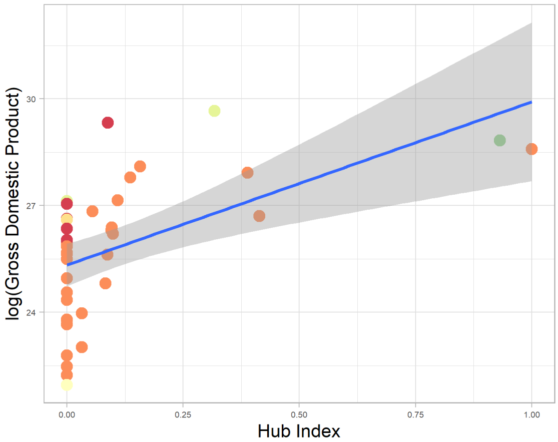
(a) 1995

(b) 2005

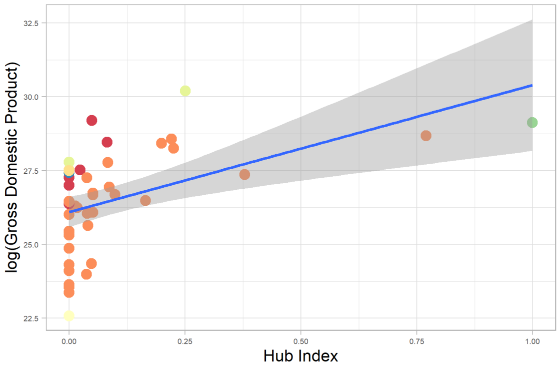
(c) 2014

Figure B.6: Regression diagnostics for Betweeness and Gross Domestic Product regression for the years 1995, 2005, and 2014.

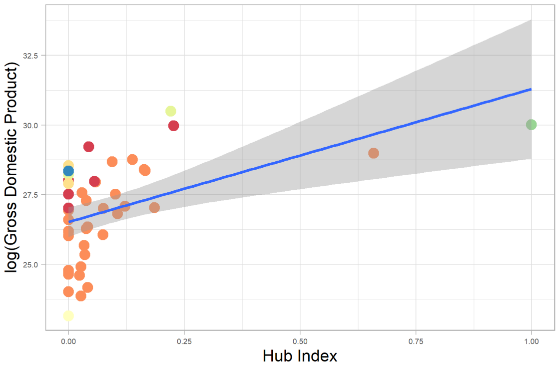
B.4 Hub Index and Gross Domestic Product Correlation for the years 1995, 2005, and 2014.



(a) 1995

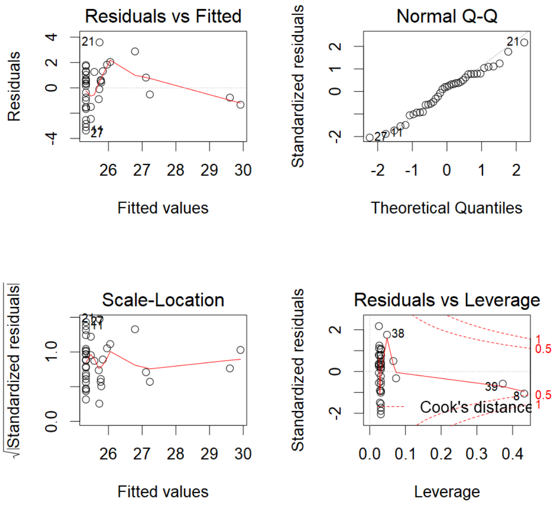


(b) 2005

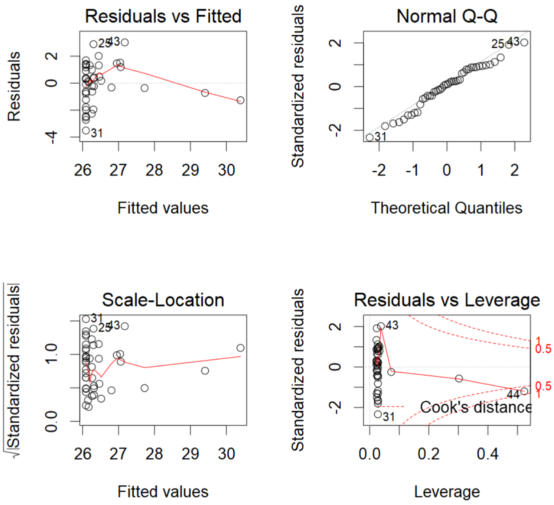


(c) 2014

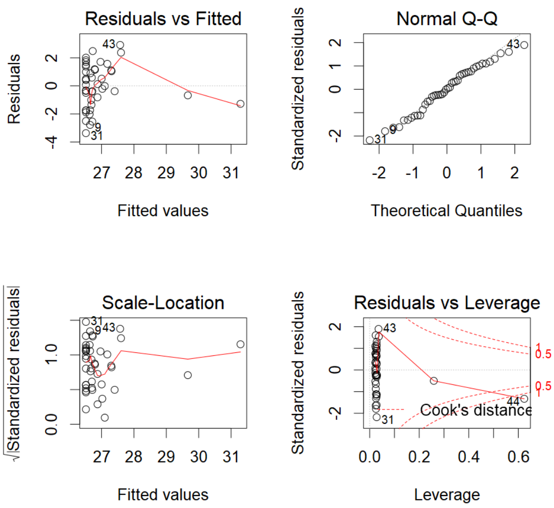
Figure B.7: Correlation between Hub Index in the World Trade Network and Gross Domestic Product for the years 1995, 2005, and 2014.



(a) 1995



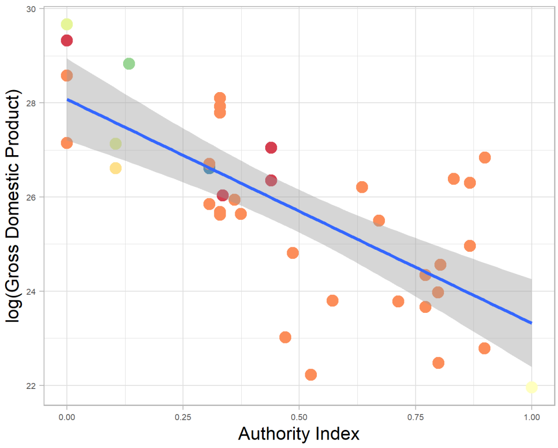
(b) 2005



(c) 2014

Figure B.8: Regression diagnostics for Hub Index and Gross Domestic Product regression for the years 1995, 2005, and 2014.

B.5 Authority Index and Gross Domestic Product Correlation for the years 1995, 2005, and 2014.

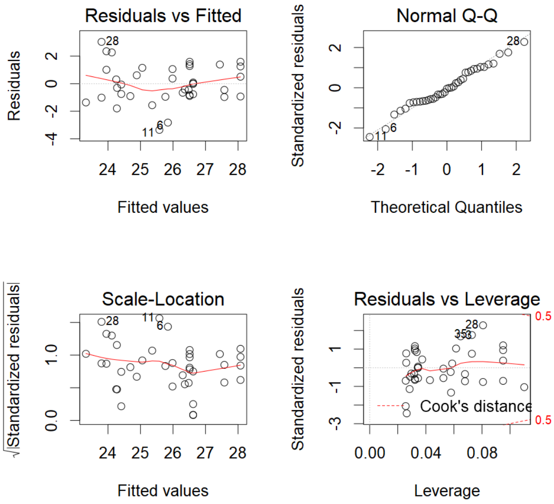


(a) 1995

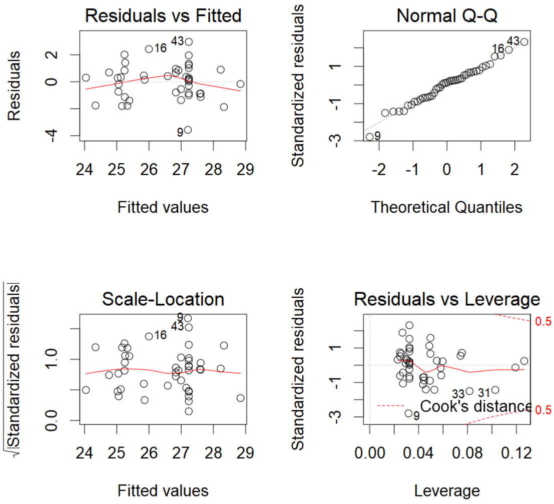
(b) 2005

(c) 2014

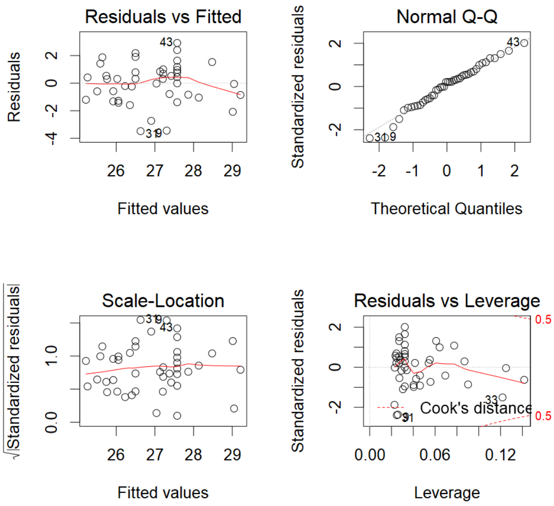
Figure B.9: Correlation between Authority Index in the World Trade Network and Gross Domestic Product for the years 1995, 2005, and 2014.



(a) 1995



(b) 2005



(c) 2014

Figure B.10: Regression diagnostics for Authority Index and Gross Domestic Product regression for the years 1995, 2005, and 2014.

Appendix C

Regression Tables

C.1 Regression results for 1995.

Table C.1: Regression results between network measures and Gross Domestic Product in the year 1995.

	Dependent variable:				
	Log(Gross Domestic Product)				
	(1)	(2)	(3)	(4)	(5)
Outdegree	0.198***				
	(0.050)				
Indegree		−0.824***			
		(0.129)			
Betweeness Centrality			0.076		
			(0.048)		
Hub Centrality				4.588***	
				(1.194)	
Authority Centrality					−4.754***
					(0.770)
Constant	25.323***	27.864***	25.700***	25.331***	28.076***
	(0.294)	(0.389)	(0.316)	(0.296)	(0.428)
Observations	39	39	39	39	39
R^2	0.296	0.523	0.063	0.285	0.507
Adjusted R^2	0.277	0.510	0.037	0.266	0.494
Residual Std. Error (df = 37)	1.661	1.368	1.917	1.674	1.390
F Statistic (df = 1; 37)	15.577***	40.490***	2.480	14.758***	38.125***
Note:			*p<0.1; **p<0.05; ***p<0.01		

C.2 Regression results for 2005.

Table C.2: Regression results between network measures and Gross Domestic Product in the year 2005.

	Dependent variable:				
	Log(Gross Domestic Product)				
	(1)	(2)	(3)	(4)	(5)
Outdegree	0.129^{***}				
	(0.037)				
Indegree		-0.523^{***}			
		(0.097)			
Betweeness Centrality			0.027		
			(0.016)		
Hub Centrality				4.301^{***}	
				(1.188)	
Authority Centrality					-4.798^{***}
					(0.822)
Constant	26.127^{***}	27.936^{***}	26.402^{***}	26.092^{***}	28.841^{***}
	(0.253)	(0.337)	(0.261)	(0.255)	(0.448)
Observations	44	44	44	44	44
R^2	0.228	0.409	0.060	0.238	0.448
Adjusted R^2	0.210	0.395	0.037	0.220	0.435
Residual Std. Error (df = 42)	1.536	1.344	1.695	1.526	1.299
F Statistic (df = 1; 42)	12.424^{***}	29.050^{***}	2.671	13.104^{***}	34.099^{***}
Note:					$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

C.3 Regression results for 2014.

Table C.3: Regression results between network measures and Gross Domestic Product in the year 2014.

	Dependent variable:				
	Log(Gross Domestic Product)				
	(1)	(2)	(3)	(4)	(5)
Outdegree	0.131^{***}				
	(0.037)				
Indegree		-0.578^{***}			
		(0.096)			
Betweeness Centrality			0.022		
			(0.013)		
Hub Centrality				4.772^{***}	
				(1.332)	
Authority Centrality					-3.995^{***}
					(0.891)
Constant	26.547^{***}	28.642^{***}	26.776^{***}	26.518^{***}	29.212^{***}
	(0.261)	(0.344)	(0.279)	(0.263)	(0.555)
Observations	44	44	44	44	44
R^2	0.231	0.466	0.060	0.234	0.324
Adjusted R^2	0.213	0.453	0.037	0.216	0.308
Residual Std. Error (df = 42)	1.571	1.309	1.737	1.568	1.473
F Statistic (df = 1; 42)	12.623^{***}	36.660^{***}	2.665	12.843^{***}	20.110^{***}
Note:					*p<0.1; **p<0.05; ***p<0.01

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