Forecasting balanced international trade flows

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Master thesis in Operations Research and Quantitative Logistics

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1 Introduction

In a world as chaotic and eventful as ours, there is always a need to explain and predict, no matter how difficult it may be. One of the most interesting and most difficult things to analyze and predict is the global economy. As mankind progresses into the future, new technologies, new ways of life and an ever increasing population all affect the total amount of products we produce and consume. While environmentalists worry about how much more the planet can handle, others are more interested in simply studying the intricate web of globalization that we have created. What is produced where, where does it go, how is it moved? What about twenty years from now?

Each year millions of euros and dollars are spent by governments and independent institutions worldwide on the development of new models and tools that help us achieve a better understanding of global freight flows. NEA Transport Research and Training has been one of the many entities that have contributed to this field of modelling. Their NEAC system (NEA transport system for the Community), consisting of several databases and models that together describe national (Dutch) and international freight flows, has long been used by European policy makers. The methodology within it has also been used within TRANSTOOLS, an EU-commissioned transport network model that serves as the main tool for policy analysis.

However, innovation is key in this knowledge-driven society. The shortcomings of the NEAC system, such as the limited geographical scope, the lack of adaptability, and its limited capabilities to take into account newly available data, have led to the birth of a new project that aims to develop a system worthy of replacing NEAC. This project is called Worldnet.

Much like the NEAC system, Worldnet aims to describe and forecast national and international freight flows. Unlike NEAC, it is global in scope. It is designed to handle all the latest developments in the reporting of trade data. Another major component of Worldnet is its ability to easily visualise any of the outputs that it produces.

One of the more innovative aspects of Worldnet, in the sense that it has rarely been applied to the forecasting of freight flows, is a macro-economic one. For example, when forecasting the amount of food transported by road from country A to country B, the impact of these countries' economies as a whole is rarely considered. Instead, only factors such as the current trend, GDP growth in country A's agricultural industry, and infrastructural developments are taken into account. While that makes sense, and the state of the economy as a whole might not affect food transport at all, it is important to include these macro-economic elements in the freight forecasting system, particularly as a means to stabilise the forecasts that are being produced.

The objective of this thesis is to develop the macro-economic module of the Worldnet project and to assess its predictive power. This module is meant to produce forecasts of the value of trade between all countries in the world. By taking various factors into account that should logically affect the long-term trade potential of these countries, the forecasts should be more realistic than ones that are only based on trend.

The output of the macro-economic module, hereafter called the world trade model, then works as a constraint on the other Worldnet models that determine present and future freight flows at a more detailed level.

The outline of the thesis is as follows.

In chapter two a brief description of NEA Transport Research and Training is presented, along with the Worldnet project which serves as the driving force behind the trade forecast model described in this thesis. The central ideas behind Worldnet are explained, and also the role of this trade forecast model within it.

Chapter three provides some insight into the main economic theories that attempt to explain global trade and its growth. Additionally, some existing models are examined and an explanation is given why they are not suitable for the Worldnet project.

Models are driven by data. In chapter four the available databases are described as well as the problems that are usually encountered in such databases. It is shown how the raw trade data that comes directly from the databases is processed and prepared for the trade forecast model.

Chapter five describes the development of the actual forecast model. Potential explanatory variables for changes in import and export growth are chosen, analyzed and kept or discarded. The outputs of the different models are presented and compared.

Chapter six features a more in depth analysis of the model output.

A summary and some conclusions follow in chapter seven.

2 The Worldnet project

2.1 Introduction

In this chapter NEA is introduced, as well as its Worldnet project. The history of Worldnet is explained, its basic methodology, and the role of the world trade model developed in this thesis. Additionally, some applications are discussed in which Worldnet outputs have been or can be useful.

2.2 NEA Transport Research and Training

NEA Transport research and training is an independent and leading international institute, working in the fields of transport, traffic, infrastructure and logistics. Its activities are focused on research and research-based consultancy and training in the Netherlands and abroad. The institute in its current state was founded in 1986 as a result of a merger between three Dutch companies that were active in the field of transport research.

NEA employs circa 70 professionals who work in different fields of knowledge, encompassing all the economic and social aspects of both passenger and freight transport, for all modes of transport and the corresponding infrastructure.

Domestic as well as foreign clients have commissioned NEA to perform feasibility studies, economic effect studies on infrastructure, research on logistics and physical distribution. NEA is able to provide reliable and objective analyses of the economic, legal, organizational and institutional aspects of traffic, transport, infrastructure and logistics. NEA aims at contributing to the innovative and structural improvement of transport worldwide by providing a well-founded vision based on the principle of sustainable mobility.

NEA is based in the Netherlands and over the years has built up a vast network of national, as well as international contacts which have led to joint ventures in China, Turkey, Kazakhstan and the Netherlands.

2.3 Overview of Worldnet

The primary purpose of Worldnet is to extend and refine the European Commission's freight transport policy knowledge base, focusing on improving the representation of medium and long distance flows, the multi-modal aspects and the relationships between trade and the development of transnational transport corridors.

Specific objectives include:

- Attain a precise representation of freight flows between European countries and the rest of the world;
- Create a road/rail/sea/air network model on a global scale;
- Implement a graphical communication tool using internet based GIS technology, allowing users worldwide to interact with and benefit of the knowledge of Worldnet.

2.3.1 History of Worldnet

NEA has studied freights flows for a long time. Their NEAC system has long served as a valuable tool for describing and predicting national (Dutch) and international freight flows. It was also the basis of one of the modules in TRANSTOOLS, which is an EU-sponsored project that aims to model transport flows of both freight and passengers, along with externalities such as pollution and accidents.

The NEAC model works with a specific base year (2002) and can forecast future freight flows by using trends (GDP growth rates) and a gravity model. Unfortunately, the base year is not easily updated, and for that reason NEAC has slowly become outdated. Rather than once again arduously updating the required data to a new base year, it was decided that something new needed to be developed that could replace and improve upon the existing system. From that necessity the Worldnet project was born, a collaboration between several European companies with NEA as the coordinator. It aims to describe, forecast and visualise freight flows, not just in the Netherlands and the rest of Europe, but in the entire world.

2.3.2 Role of world trade model within Worldnet

The Worldnet project is innovative in scope, detail and methodology. Existing methodology was thoroughly reviewed and new ideas explored to come up with a new way to model freight flows. The main issue with older methodology was that it allowed for major trade imbalances to be forecasted. Zones would attract imports or exports of a certain product, regardless of the supply or demand of that product in neighbouring zones. A country’s total import and export growth forecasts were the result of an aggregation of many different region-to-region forecasts for a particular commodity.

This bottom-up approach would often lead to strange forecasts, especially in the long run. It was unreasonable to assume that the situation and trend as they were in 2002 would continue for decades. The difference between a country’s imports and exports would often become unrealistically high. While it is true that some countries have been able to maintain growing trade deficits, it can be assumed that they cannot grow indefinitely.

Figure 1: Current account balance as a percentage of GDP in 2008 (WTO)

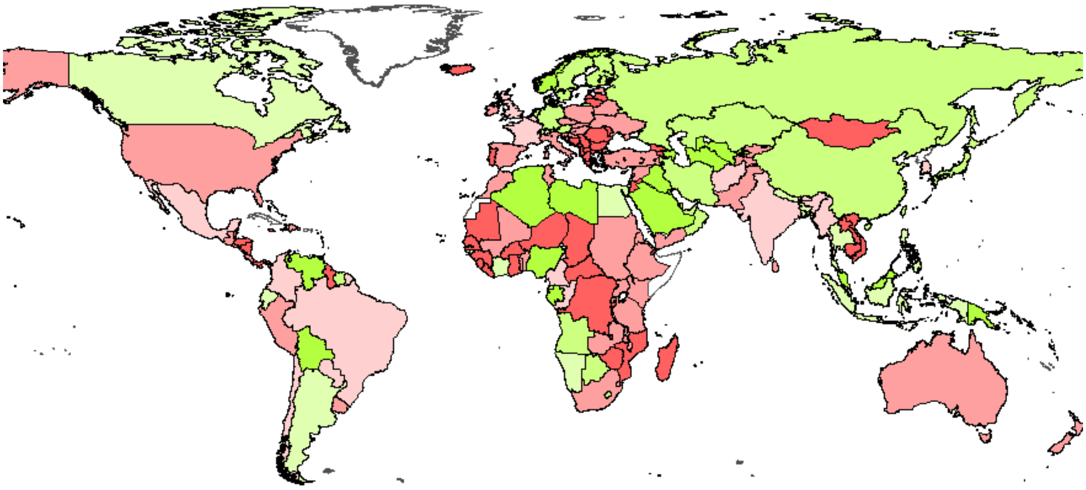


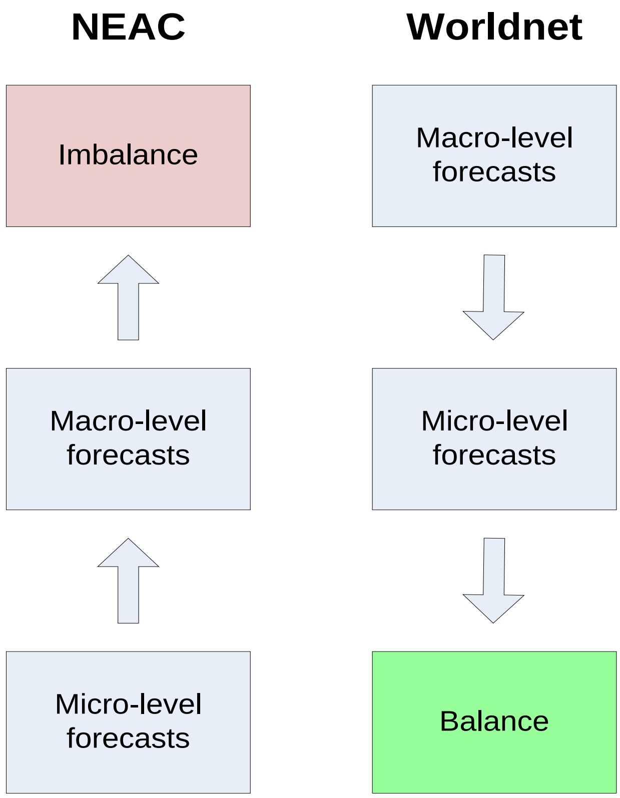
Figure 1 shows the nature of the trade imbalances in the current global economy. For example, the US runs an annual trade deficit of nearly $3000 per capita. Many European and African countries also run high trade deficits.

The main issue here is to determine how long these deficits (and surpluses) are sustainable and how large they can become without affecting the country's economy and trade flows. The "balancing of the trade balance" is something Worldnet has taken into account, through the development of the model described in this thesis. The main assumption of the model is that in general, these large gaps are unsustainable, and something has to happen to correct them.

Worldnet utilises a top-down approach where constraints on a national level prevent the "big picture" from becoming too imbalanced. The upper layer of Worldnet is a macro-economic model that forecasts the state of each country's economy, and subsequent micro-level forecasts (from commodities and zones to links on road and rail networks) are constrained by these upper-level forecasts. In figure 2 the difference with the NEAC approach is highlighted.

Of crucial importance is the robustness of the model; the output it produces should be sensible. The model should also be able to easily incorporate newly available data into its forecasts. To that end, the inputs it requires should be sufficiently simple.

Figure 2: NEAC approach vs. Worldnet approach

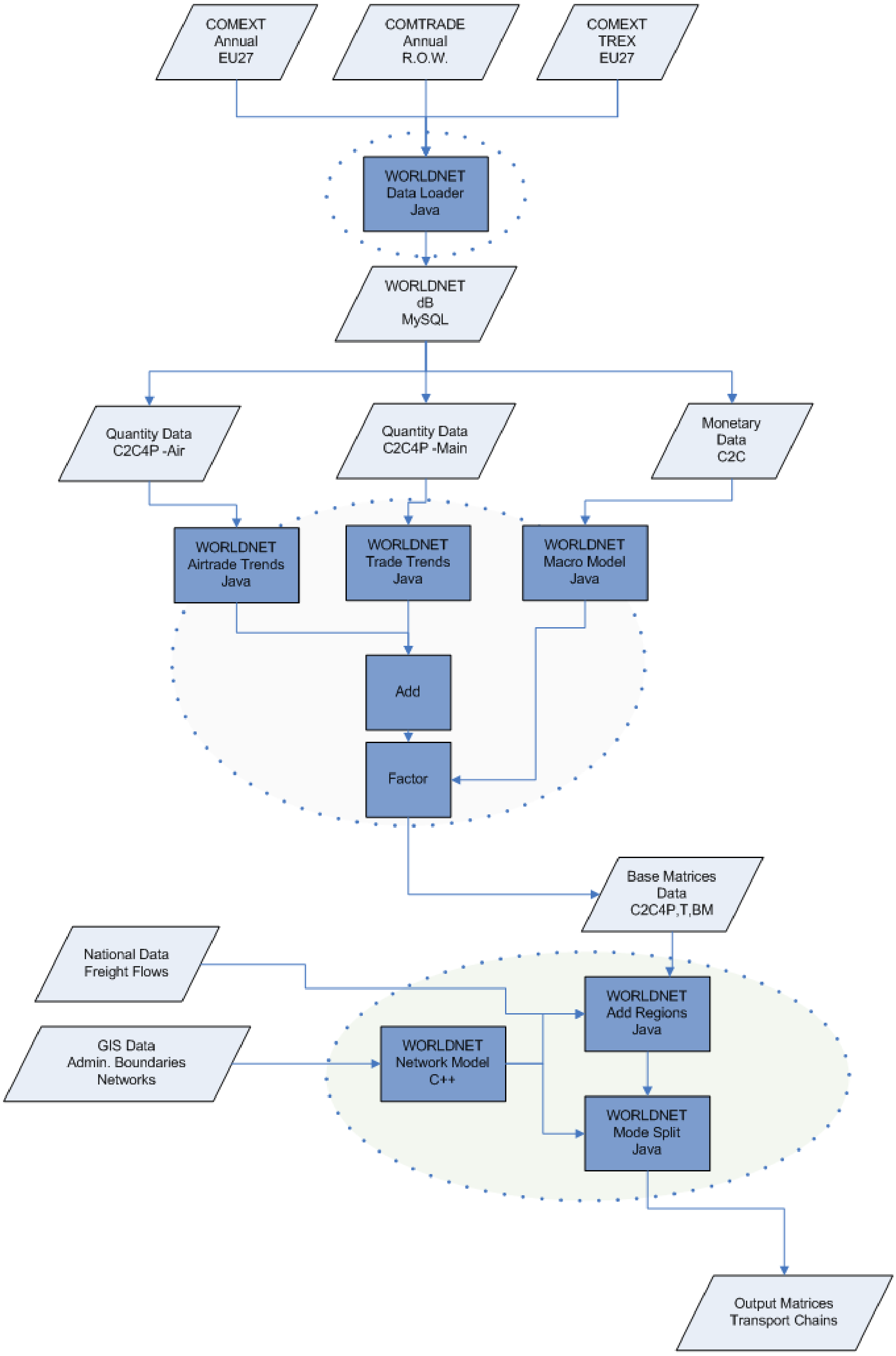


In figure 3 the design of the complete Worldnet system is displayed in a diagram. The "macro model", or world trade model, is part of the process that produces country-to-country trade forecasts in tonnes, for a given commodity. These "base matrices" are then further split by dividing the countries into regions. By using road, rail, sea and air networks, and national trade data, the regional flows are assigned to the different modes, and from that complete transport chains are created.

The flexibility of the system is one of its greatest strengths. If more detailed transport flows are wanted for a certain country, or group of countries, it suffices to expand the regionalization only for those target areas. Because each module can run on its own, other external inputs can be used if desired.

Since the quantity of input data is relatively low, it is also simple to update the base year as soon as the data for it is available. This is especially helpful if there are dramatic turns in the current world trade situation which should be taken into account when producing new long-term forecasts.

Figure 3: Worldnet database and modules



2.3.3 Applications of Worldnet

The Worldnet output can be used for various projects. Knowing what kind of freight traffic can be expected across the world is a valuable tool when making infrastructural decisions. The following are several example problems for which Worldnet can be useful.

- Deciding whether an additional port should be constructed on Turkey's northern shore. How much freight will enter Turkey from the Black Sea? Which commodities can be expected to be handled most?

- Research into rail traffic on certain European rail corridors. Is the capacity of the existing rail network enough? If trade volumes grow, does the amount of rail traffic grow faster or slower than the other modes?

- The construction of national freight flow models for countries that are generally new to this kind of research, like Serbia and Bulgaria. How would expanding the road or rail network affect the existing freight flows?

- Research into maritime greenhouse gas emissions. How much maritime freight traffic is there now and how much will there be in the future? Where is it? Which countries are driving this traffic? Who is responsible for the emissions?

Essentially, the possibilities are endless. The top-down approach means that for a specific research area a higher detail level can be incorporated as long as the necessary data is available. Ideally, Worldnet should be the go-to tool for every project that requires some information about current and future freight flows, in any of its manifestations.

3 Global trade imbalances and models

3.1 Introduction

To provide some theoretical background for this thesis, the relevant macro-economic ideas and theories will be reviewed in the literature.

One crucial assumption that is intended to “drive” the world trade model is that a trade deficit or trade surplus will eventually correct itself. In this chapter the economic theory behind this assumption will be briefly discussed.

The second important aspect is the actual forecasting of global trade. Which models already exist for this very purpose and how reliable are they? Some standard ways of modelling global trade are discussed, along with their pros and cons.

3.2 The effects of a trade deficit

If the monetary value of a country’s imports is higher than the monetary value of its exports, then that country is essentially indebted to its foreign trading partners. The past century there have been exponential increases in the value of trade, and with it the trade deficits and trade surpluses have also increased. Presently, many countries consume much more than they produce. Economists have different views regarding the dangers and the effects of such trade deficits.

3.2.1 Trade deficits in theory

Whether running a trade deficit is detrimental to a country’s economy or not is an ongoing and heated debate, especially in recent years. The trade gaps are larger than ever and governments and economists tend to find cause and effect between trade gaps and other economic factors such as the value of a currency, unemployment and GDP growth.

Unfortunately, there are as many opinions as there are people involved in the debate. There are those who think the trade deficit is the source of all of their country’s problems, and that reducing it should be the number one priority. And there are those who think a trade deficit is a sign of a strong economy, and that a deficit alone is absolutely no reason for concern, and can be sustained indefinitely. And finally, there are many who find themselves somewhere in the middle.

For example, Blecker (2011) argues that the US trade deficit has contributed to causing the recent recession, and is also the reason for the slow recovery. He warns that the deficit is not sustainable, and that the situation could end abruptly and unexpectedly, with often dire consequences.

On the other hand, Cooper (2008) argues that the US trade deficit is a natural outcome of the globalisation of financial markets and demographic change, and that it would be wrong to explicitly focus economic policy on reducing the deficit as that could also have a disastrous effect.

Generally, there is some agreement on *when* a trade deficit is a problem, and also on what *can* be done to combat the deficit. Policy makers find themselves at odds with each other when they have to assess how pressing of a problem it actually is, and what *should* be done to combat it, if at all.

In broad terms, a trade deficit is a problem when one or more of the following apply:

- It is persistent and shows no signs of self-correcting
- The deficit forms a large share of GDP
- There are no inflows of investment income or capital account income to compensate for the deficit
- The central bank has low reserves
- The economy has a poor record of repaying debt.

These are the main instruments available to reduce a trade deficit:

- Deliberate reduction of consumer spending
- Devaluation of the currency
- Measures that directly affect trade, such as import tariffs and quotas, and subsidies for firms that contribute to exports
- Policies that improve the country's productive potential.

3.2.2 Trade deficits in reality

In the real world, each country views and deals with its trade deficit or surplus differently. Due to lack of empirical evidence, and the mixed results when applying the same policy to two different economies, it is always a guess as to what policy delivers the best results. What makes it more complicated is that there are always other factors present that also have an influence on the economy and on trade.

Some countries suffer less from their trade deficit better than others. The US trade deficit is ever increasing and persistent, but it is hard to say if it is affecting their economy negatively. China is simply hoarding a lot of US dollars.

In Europe however there is some evidence that a trade deficit can hurt the economy. Countries like Greece, Italy, Spain and Ireland have traditionally run large trade deficits, and they are the countries that now need help from the rest of the EU to be able to stay afloat.

3.3 Global trade forecasting

There are already many models that forecast global trade. There are static and dynamic equilibrium models, gravity models, trend models, and models that combine the different approaches. Some require large databases of input, while others are much simpler.

3.3.1 Existing models

One of the most prominent existing models is the GTAP model, which is the work of the Global Trade Analysis Project (Hertel, 1999). This network of researchers maintains a computable general equilibrium model to forecast trade and calculate scenarios. There are also many variants of the model that focus on specific applications. Behind the model is a large database with all kinds of inputs taken from sources around the world.

NEA itself has also previously developed models to forecast trade. For example, there is the NEAC model that was already mentioned in section 2.3.1.

3.3.2 Comparison with world trade model approach

The existing models usually have common downsides. The input data is not easily updated, the forecast covers only one year at a time, and many assumptions are required for the models to even work. The new world trade model aims to tackle all of these weaknesses.

- Input data should be easy to obtain and incorporate.
- Forecast should be quick, dynamic and transparent.
- Number of assumptions should be kept to a minimum.

4 Trade databases

4.1 Introduction

The world trade model should be flexible and based on the most recent numerical data concerning trade flows between countries. The data available to NEA comes in the form of two databases, the Comtrade database provided by the UN Statistics Division, and the Comext database provided by Eurostat, which is the statistical arm of the European Commission. In this chapter the two databases will be described, along with the problems encountered within them and how they are dealt with.

4.2 Comtrade and Comext

The United Nations Commodity Trade Statistics Database (UN Comtrade) contains detailed import and export statistics reported by statistical authorities of close to 200 countries. Customs records are the most prevalent source of data for these institutions, but other sources such as foreign shipping manifests and records of monetary authorities are used to supplement the customs data (UN, 2004).

One major example where customs records are unavailable is for trade between EU members. Customs control has been abolished for intra-EU trade, so intra-EU data is mostly collected from trade operators who are obligated to report all shipped goods that are valued above a certain threshold. This threshold is in place to exempt smaller trade operators from statistical formalities. Any trade omitted from the records because of these thresholds is subsequently estimated by the Member States (Eurostat, 2006).

The database consists of over 1.1 billion data records. An example of such a record would be the export of apples from the UK to the Netherlands in 2004 in terms of value (current US dollars), weight, and supplementary quantity, as reported by the UK. For most records an equivalent record exists; in this case the imports of apples from the UK in 2004 as reported by the Netherlands. The database covers only merchandise trade between countries, so trade in services is excluded.

Data will be used from 1995 and onward and updated continuously.

Raw Comtrade data is first processed by NEA so that the Worldnet country codes, among other things, are included within each record. This updated database is then used to compile the input data for the world trade model.

For each record, the following data is available:

- Flow: 1 = import, 2 = export
- Worldnet and UN country codes for the reporting and partner country
- NST commodity code (Standard Goods Classification by EU)
- SITC commodity code (Standard International Trade Classification by UN)
- Hazardous (binary variable)
- Chilled (binary variable)
- Manifestation (liquid, bulk, etc.)
- Value in thousands of current US dollars
- Value in thousands of euros (derived from the value in dollars)
- Tonnes (weight)
- Unitised Tonnes
- TEU (twenty-foot equivalent unit)
- FEU (forty-foot equivalent unit)

The data is stored on an SQL server, which means retrieving the data and performing operations such as determining the sum or average of a certain variable for a certain aggregation of records becomes a lot faster and easier.

The Comext (Commerce Exterieur) database is similar to the Comtrade one. The major difference is that while the Comtrade database consists of trade records of nearly 200 reporting countries, the Comext database only has trade reported by Member States of the European Union. Also, Comext trade values are originally published in euros and then converted to the US dollar, rather than the other way around.

The raw Comext data has been processed by NEA so that the updated database is very similar to the Comtrade one. The only differences are that instead of the UN country codes, EU country codes are used, and there is an additional goods classification, CN8 (Combined Nomenclature). Just like the Comtrade data, Comext data is stored on an SQL server for easy retrieval and processing.

Comext and Comtrade data often do not coincide. The main reason is that trade figures published by Eurostat (known as Community figures) can differ from those published by the EU Member States themselves (Eurostat, 2006). Other reasons for discrepancies between the two databases, and other more general problems with trade statistics, are summarised in section 4.4.1.

4.3 Data analysis

The data in the trade databases is very detailed. This level of detail is unnecessary for the world trade model, which operates on a macro-economic level and is only concerned with the total monetary value of trade between countries. The Worldnet project utilises a top-down approach, which means that the total trade flow in dollars between countries (the “top” level) constrains the lower level trade flows, and not the other way around. Variables such as the commodity classifications, the volume of trade (in tonnes), and the different types of transport (whether it’s chilled, its manifestation, etc.) can therefore be disregarded.

The value of a transaction as stored in a trade data record is expressed in current US dollars. Any currency conversions are done according to the exchange rates as they were in that year. A large part of international trade already is reported in US dollars, even when the US is not involved. The international oil markets, for example, use the US dollar as the preferred transaction currency.

Because trade is in current US dollars, fluctuations in the value of the dollar affect the year-to-year values in the database. If the value of the dollar were to drop by 10% in relation to most of the other major currencies, some countries could overestimate their monetary trade growth. The problem here is that it is impossible to tell how much of the growth in value was caused by the dollar depreciation. The monetary value of trade cannot reliably be converted to a currency that shows the “real” monetary trade growth. Therefore the input data for the world trade model should simply be expressed in current US dollars. Whether these values are taken at face value or are adjusted for inflation or dollar fluctuations is a choice that should be made during development of the world trade model and not while preparing its input data.

Every month new trade data becomes available. In principle, all of the currently available data can be used as input for the world trade model. On the other hand, the most recent data could be problematic or incomplete. For a given trade flow in a given year there could be less data available than for the same flow in a previous year. One of the countries might still need to report the trade, or data for some commodity groups might be unavailable. This could cause some irregularities to appear in the input data. Therefore the world trade model will work with a base year, up to which all available data will be gathered and from which future data will be projected. This base year will typically have a lag of one to two years. For example, at the beginning of 2012, the base year could be updated from 2009 to 2010, and forecasts would be made for 2011 and on.

During development of the world trade model, a base year of 2009 will be used.

4.4 Data processing

The trade data needs to be processed so that it can be used as input for the world trade model. In this section some of the problems encountered in the data will be discussed, along with proposed solutions and/or workarounds.

4.4.1 Problems with the data

The Worldnet project works with a newly developed regional coding system. Every country ever defined by the UN or EU has a separate country code. A lot of the problems encountered in the data are related to conflicting country codes. For example, France has two Worldnet country codes, one for France alone and one including Monaco. The Comtrade database uses the country code that includes Monaco, while the Comext database doesn’t. But the model still has to know that they are for all intents and purposes the same country.

Another example is the splitting or merging of countries. Belgium and Luxembourg had combined trade data up until a few years ago, while countries such as Serbia and Montenegro used to form one nation. These changes also need to be dealt with so that a complete time series from 1995 to 2009 can be constructed for each country in the model.

Besides conflicting country codes, the values themselves can also be conflicting. One flow of trade can be reported up to four times. For instance, Dutch exports to Germany are reported as:

- $99.5 billion by the Netherlands in the Comext database
- $74.4 billion by the Netherlands in the Comtrade database
- $89.1 billion by Germany in the Comext database
- $64.4 billion by Germany in the Comtrade database

There are many reasons why there are differences between these values. Values for imports are usually recorded as a CIF-type value (Cost, Insurance and Freight) which includes not only the transaction value of the goods but also the value of services performed to deliver the goods to the border of the importing country. On the other hand, exports are usually recorded as a FOB-type value (Free On Board) which, besides the transaction value of the goods, includes only the value of services to deliver the goods to the border of the exporting country. This means that imports are often valued higher than exports.

Another reason is time lag. Goods that leave the country in one year could arrive at their destination in the next, which can cause a discrepancy. Sometimes goods enter customs warehousing for several months.

Some goods are transported via intermediate third countries, which can cause mix-ups regarding the origin and final destination of these goods. This can also happen when the country of consignment is used instead of the actual origin or destination.

Currency conversion is another source of discrepancy. Exchange rates vary constantly, so if the same flow is converted to different currencies at different times, the values can end up differing. Also, the Comext database uses monthly exchange rates to convert the data to the same currency, while the Comtrade database uses an annual average exchange rate.

Countries also use different trade systems. There are two main trade systems. Under the general trade system, goods are recorded as they enter or leave the country. Under the special trade system, goods are recorded only when they enter into free circulation. For example, if goods exported from country A are placed in a customs warehouse in country B and then subsequently re-exported to country C, these goods would appear in the general trade statistics for country B, but not in its special trade statistics. So the total value of trade recorded under the special trade system is lower than its corresponding general trade figure. The EU uses the special trade system for extra-EU trade.

The differences can become quite large. For example, trade from Denmark to Portugal is reported as:

- $406.6 million by Portugal in the Comtrade database
- $406.1 million by Portugal in the Comext database
- $1017.3 million by Denmark in the Comtrade database
- $1117.2 million by Denmark in the Comext database

Even when looking at a specific case such as this one, going down to the commodity level, the disaggregated data alone is not enough to determine where the discrepancy comes from and which reported value is correct. Some method is needed to decide which value to use as input.

Besides the conflicting country codes and conflicting values, there can also be spikes and gaps in the data. If trade between a pair of countries grows by 500% in one year, one could assume that a mistake was made that should be corrected. Data can also be missing for certain years. There should be a consistent time series for each trade flow that does not exhibit any strange behaviour.

4.4.2 Country codes

Each of the data records are processed to remove conflicting or duplicate Worldnet country codes, so that data from 1995 to 2006 is available for each of the countries in the world trade model. For the years when only aggregated data is available (such as Belgium + Luxembourg up until 1998), estimates for the separate countries are determined by looking at the averages of the ratios in the years that the countries do have separate data. An example is given in the table below. For both Belgium and Luxembourg their total imports and exports are taken and with that their share of the total is calculated.

Table 1: Belgium and Luxembourg as a percentage of their total trade

	1999	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	***Average***
Belgium	0.947	0.949	0.944	0.948	0.943	0.942	0.941	**0.945**
Luxembourg	0.053	0.051	0.056	0.052	0.057	0.058	0.059	**0.055**

One problem is that when countries separate, the trade between them (like the trade from Belgium to Luxembourg) is recorded in the database, whereas before it was not. However, this trade is in most cases relatively insignificant compared to the total trade and does not need to be taken into account when determining separate import and export values for these aggregated countries.

4.4.3 Conflicting sources

After making sure the codes are all the same, the other problem can be tackled, which is that there are multiple values for each trade flow. Factors that could be taken into account when determining the final value are:

- Reliability of the specific table in the database

  Some countries may report figures that are more reliable than others. Customs regimes and practices are different in every country, which contributes to the amount of data available in such a country (UN, 2004). Some regions might also be more fraudulent regarding their customs declarations as a way to avoid tariffs and duties. One way to get a general idea of the completeness of a table is to compare the reporting country's total imports and exports in that year to a data source with fairly reliable import and export totals, such as the statistical department of the World Trade Organization.

- The direction of trade

  One could say that trade reported by the importing country tends to be more accurate because they are reported in sufficient detail to allow customs to apply taxes, duties and other regulatory controls. On the other hand, the invoice prices reported to customs (often used to obtain the statistical value of imports) may be inaccurate, with the aim of affecting the duties that are applied.

- The values in previous and future years

  This has more to do with the problem of spikes and gaps as was explained earlier. For example, if the annual trade flow between a country pair in the years 1995 to 2004 was determined to be around $200 million, then that same trade flow should be close to that value in 2005 as well. If a source would report this trade to be $1 billion, that source could safely be dismissed.

4.4.4 Determining the final values

Because there is no simple way to decide whether a country's export figures should be dismissed altogether or whether they are less accurate than the corresponding import figures, there is no compelling reason to generally prefer imports over exports. Therefore, no immediate handicap is given to reported exports.

The tables within the database are ranked according to their reliability. There are separate tables for each combination of year and reporting country. The import and export data within each table is ranked separately. To determine a table's reliability, the total reported trade within it is compared to the trade totals as reported by the World Trade Organization.

This method of ranking gives some interesting results. For 2005, Azerbaijani import figures (from Comtrade) are considered to be the most reliable, followed by Croatian and Kazakh exports (from Comtrade). The reason that these totals coincide with the WTO figures is probably because the WTO and Comtrade use the exact same data source for them. This means that a comparison to the WTO might not always be the best way to judge a table's completeness or accuracy.

Rather than determining which database to use beforehand, one could also take all the available data at face value and run it through a simple smoothing algorithm to determine the final series. The algorithm used can be found in Appendix 2.

A third method would be to derive a single time series for the trade according to the first method, and then smooth it according to the second method (limiting growth in consecutive years).

The three methods can be compared. Trade from Denmark to Portugal showed a large difference between Comext and Comtrade in 2005. Application of the three methods results in the following series. For the smoothing, the parameters c = 0.1, n = 5, and g = 3 were chosen.

Table 2: Trade from Denmark to Portugal in millions of USD (Comtrade/Comext)

DK to PT	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Comtrade PT	282.1	277.7	231.0	248.0	247.7	278.4	229.9	259.3	262.6	345.9	406.6
Comtrade DK	301.5	260.0	189.1	219.8	232.4	228.9	211.0	235.1	239.5	630.9	1017.3
Comext PT	265.5	287.0	233.8	248.9	248.7	277.9	230.0	259.3	262.6	345.7	406.1
Comext DK	298.5	316.9	235.1	245.3	298.9	265.0	272.9	321.3	304.0	732.9	1117.2
Smoothing	290.7	286.9	222.9	241.5	258.0	262.7	236.0	269.4	267.0	513.6	736.8
Data ranking	265.5	287.0	233.8	248.9	248.7	278.4	230.0	259.3	262.6	345.9	406.6
Smoothed ranking	265.5	287.0	233.8	248.9	248.7	278.4	230.0	259.3	262.6	345.9	406.6

Clearly when database ranking is used, the higher values reported by Denmark are completely disregarded, while with the general smoothing algorithm an average of the four series is taken. The smoothing algorithm has no effect on the fairly stable result of the database ranking method. It's unclear which method is better.

Sometimes there is not enough data available, leaving too many gaps in the time series. For example, trade from the US to Iran looks like this:

Table 3: Trade from US to Iran in millions of USD (Comtrade/Comext)

US to IR	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Comtrade IR	0.0	0.0	37.8	60.3	62.3	88.3	73.8	57.2	66.8	71.3	95.2
Comtrade US	277.3	0.3	1.1	0.0	48.1	16.6	8.3	27.2	98.8	85.3	95.8
Smoothing	53.5	40.1	21.5	38.1	55.1	52.2	42.2	44.9	82.6	78.3	95.5
Data ranking	277.3	0.3	37.8	0.0	48.1	16.6	8.3	27.2	66.8	85.3	95.8
Smoothed ranking	41.4	13.8	37.8	16.0	48.1	16.6	9.1	27.2	66.8	85.3	95.8

Here it is obvious that the smoothing algorithm produces the most stable time series. With database ranking some of the Iranian data is dismissed outright, even though it looks more stable than the American data. It does not seem sensible to dismiss any of the data before looking at the total picture. That is why the smoothing method will be used to generate all of the input data for the world trade model.

Now an input trade matrix can be constructed with trade in US dollars between all pairs of countries for each year from 1995 to 2009.

5 Development of the world trade model

5.1 Introduction

In the previous chapters the Worldnet project has been outlined. It was made clear that this project requires a model for international trade that will act as a constraining upper layer for the other models in the project. This chapter describes the development of the new world trade model.

First the framework of the model will be described in detail. Next the different factors that possibly influence trade growth will be discussed, including the ways they can be incorporated in the model. Afterwards, the different models will be tested and a definitive selection will be made. Then the results will be tested for real world applicability, and a few tweaks to the model will be discussed that might not be in line with economic theory, but could produce more realistic forecasts.

5.2 Model framework

The goal of the world trade model is to provide financial trade forecasts on a country-to-country level, for a certain forecast year and all years in between. Aside from the existing trade time series already discussed in the previous chapter, the model will use simple inputs such as GDP and population. The main drivers of the forecast should be the overall economic growth of the country, and the effect of the (cumulative) trade imbalances.

This section describes the framework of the model.

5.2.1 Countries as objects

In the world trade model, each country in the system is an object with its own constants and variables. Constants are those values that are known when the object is created; they do not ever change. Variables are the values that change from year to year.

Most constants help the system identify the object, like its name, its Worldnet code and the currency it uses. Other constants can be added if an object's rule set requires them.

Variables make up the bulk of the data. There are four primary variables:

- GDP in US dollars (GDP_Y)
- Imports in US dollars (IM_Y), made up of merchandise (IM_M_Y) and services (IM_S_Y)
- Exports in US dollars (EX_Y), made up of merchandise (EX_M_Y) and services (EX_S_Y)
- Population (POP_Y)

These can be used to construct additional variables:

- Annual growth (ΔGDP_Y, ΔIM_Y, ΔEX_Y, ΔPOP_Y)
- Annual trade gap ($TG_Y = EX_Y - IM_Y$)
- Annual trade gap ratio to GDP ($TGR_Y = TG_Y / GDP_Y$)
- Cumulative trade gap ($CTG_Y = CTG_{Y-1} + TG_Y$)
- Cumulative trade gap ratio to GDP ($CTGR_Y = CTG_Y / GDP_Y$)
- GDP per capita ($GDPC_Y = GDP_Y / POP_Y$)
- Exports ratio to GDP ($EXR_Y = EX_Y / GDP_Y$)
- Imports ratio to GDP ($IMR_Y = IM_Y / GDP_Y$)
- Trade ratio to GDP ($TR_Y = EXR_Y + IMR_Y$)

The world trade model will provide forecasts for the 186 countries that have been deemed "economically significant" within the Worldnet project. The list of countries can be found in appendix A.

As described in chapter four, the country-to-country merchandise trade matrices for the years 1995 to 2009 are available as input. The row and column totals of these matrices correspond with IM_M_Y and EX_M_Y.

5.2.2 Trade in services

The input trade data (available from the databases as described in the previous chapter) is only made up of merchandise trade. However, merchandise trade is only part of the balance of trade; trade in services should also be taken into account. In the model, total imports and exports are defined as follows:

- $IM_Y = IM\_M_Y + IM\_S_Y$
- $EX_Y = EX\_M_Y + EX\_S_Y$

Only IM_M_Y and EX_M_Y are known from the input data. A great imbalance between those two could be interpreted by the model as a large trade gap, while the trade in services could actually compensate for that imbalance. So it is important that trade in services is also a part of the model somehow.

The main problem here is that when both merchandise and services trade are endogenously modelled with different growth rates, the model becomes far more complicated. It would have to calculate changes in both merchandise and services trade simultaneously, the constraints and rules of the model affecting them differently. Another problem is that country-to-country data regarding trade in services is unavailable for a majority of the countries in the model, so it would be difficult to construct a country-to-country matrix for these trade flows. Also, the purpose of the model is to produce country-to-country forecasts of merchandise trade only. For services trade, country aggregates are sufficient, as they are only used to calculate the total trade and the trade gap more accurately.

If trade in services were a fixed percentage of total trade, the model would need to come up with only one growth rate, calculating the new value of trade in services afterwards. To check whether this is a viable approach, the ratios of services to total trade for some of the largest countries were analyzed for the past 10 years. The data comes from the online statistics database of the World Trade Organization (WTO).

Table 4: Services trade as a percentage of total trade (WTO, 2008)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Average
US Imports	14%	14%	14%	15%	15%	14%	15%	15%	15%	14%	14%	**15%**
US Exports	25%	26%	25%	26%	27%	26%	27%	28%	28%	28%	28%	**27%**
JP Imports	27%	27%	26%	28%	27%	23%	23%	24%	22%	22%	20%	**24%**
JP Exports	13%	15%	15%	15%	14%	13%	15%	14%	14%	14%	15%	**14%**
DE Imports	22%	22%	22%	22%	23%	21%	22%	23%	22%	21%	21%	**22%**
DE Exports	12%	13%	13%	13%	13%	13%	13%	14%	13%	13%	13%	**13%**

Clearly, for some trade flows this ratio is quite stable. For others, like Japanese imports, the ratio shows trend-like behaviour.

Despite these occasional trends, assuming that the ratios are constant greatly simplifies the workings of the model, and the model aims to be relatively simple and transparent.

With that in mind, two constant ratios (sr_{IM} and sr_{EX}) are introduced for each country that indicate how much of a country's imports and exports consists of services. They are determined by taking the average in the years 1995 to 2009. With these ratios, the total imports (IM_Y) and total exports (EX_Y) can be split up into trade in merchandise and services. IM_Y and EX_Y are then calculated as follows:

- $IM_Y = IM\_M_Y / (1 - sr_{IM})$
- $EX_Y = EX\_M_Y / (1 - sr_{EX})$

So if US merchandise exports in 2006 equal 900 billion USD, total US exports as calculated by the model are 900 / (1 – 0.27) = 1233 billion USD.

5.2.3 The rest of the world

Even with 186 countries in the model, some significant trade flows are reported to come from or go to regions that were deemed too insignificant, such as New Caledonia, Andorra and regions that are unspecified in the database. These trade flows could still be incorporated into the model by adding a so-called dummy object that represents all of them. When building the original country-to-country trade matrices, any trade to or from an undefined country or region instead goes to or comes from this "rest of the world" region.

Looking at the input data gathered from the Comext and Comtrade databases, the flows to and from the dummy object appear to be negligible for most countries, constituting less than 1% of the total value. There are some exceptions where this trade is fairly significant, such as Spanish exports (1.05%), Kazakh exports (2.65%) and Iraqi imports (7.85%). In all likelihood the inclusion of a dummy object would not affect the forecasts much, but for completeness' sake it is done anyway.

Within the model the dummy object should not behave like a regular country, as its trade flows do not react to trade imbalances or other factors. It is simply a way to model external trade flows. To determine future trade flows to and from this dummy object, the ratio of "rest of the world" trade to total trade is assumed to be constant (per country). This constant is the average of the ratio in the years 1995 to 2009.

5.2.4 The forecasting process

A forecast is needed for all future years up to a certain point, which means the model should be dynamic and produce a forecast one year at a time. This year-by-year forecast can be described succinctly in three steps.

Step 1. New levels of GDP_Y, POP_Y, IM_Y and EX_Y are determined for all objects in the system.

This first step is also the most crucial. Most of the model adjustments will relate to this step. For GDP, the question is whether the annual or cumulative trade imbalance will influence GDP growth or if a GDP series can be derived before running the model. The same holds for population; should readily available population prospects be used or should the model decide population growth some other way?

Most attention should be paid to deciding new import and export levels, as that is the model's main purpose. Various variables need to be analyzed to see if and to what extent they influence import and export growth.

For a more in depth analysis of this step, refer to section 5.3.

Step 2. Total imports equal total exports

The system should be closed, which means that the total imports of all countries in the system are equal to the total exports of all countries in the system. This step would not have been necessary if import and export growth were determined on a country-to-country level. A 10% increase in the trade from Netherlands to Germany would not cause an imbalance in the system, as both Dutch exports and German imports would grow by the same amount. But since forecasts are done on a country level, total import growth might exceed total export growth, or the other way around. Then the system would be imbalanced.
The easiest way to fix this is to simply let imports and exports meet each other halfway. To illustrate this, suppose that the world has three countries: A, B and C. After calculating their import and export growth rates of the current year,

their total imports equal $300 billion and their total exports equal $320 billion. This is impossible, because the countries can only trade with each other. As a compromise, the total value of trade is set to be $310 billion. Each of their import figures are multiplied by the factor (310/300) while each of their export figures are multiplied by the factor (310/320) (see table 5).

Table 5: Total imports and total exports are equalised

From / to:	A	B	C	Total EX
A	0	...	...	60
B	...	0	...	100
C	...	...	0	160
Total IM	50	110	140	300/320

→

From / to:	A	B	C	Total EX
A	0	...	...	58.1
B	...	0	...	96.9
C	...	...	0	155
Total IM	51.7	113.7	144.7	310

Step 3. Determine new country-to-country trade matrix

To determine the new matrix, a biproportional matrix balancing procedure is needed so that for each row and column the cells add up to the total imports and exports as forecast by the model. One such procedure is the well-established Furness method (Furness, 1970). Rows (exports) and columns (imports) are factored up or down iteratively so that they agree with the already known row and column totals. The matrix quickly converges to a solution.

Consider the example given in the previous step. The row and column totals for the forecast year are taken together with the trade values from the previous year. Using the Furness method, new country-to-country values are calculated.

Table 6: Furness method is used to determine new origin-destination trade values

From / to:	A	B	C	Total EX
A	0	6.3	50.6	58.1
B	5.2	0	88.8	96.9
C	44.1	105.2	0	155
Total IM	51.7	113.7	144.7	310

→

From / to:	A	B	C	Total EX
A	0	5.6	52.5	58.1
B	4.8	0	92.2	96.9
C	46.9	108.1	0	155
Total IM	51.7	113.7	144.7	310

The Furness method is ideal because zeroes in the matrix (a country trading with itself, or having no trade relations at all with some other country) remain zeroes. It converges to a solution quickly, and there is a feasible solution as long as there are enough non-zero values, which in the case of the world trade model is never a problem.

5.2.5 Currencies, exchange rates and inflation

Another important aspect of the model framework is the way in which monetary values in the model are expressed. The trade databases available use current US dollar values, so it would seem logical to do the same for the world trade model. However, for the sake of consistency, GDP values should then also be expressed in current US dollars, which could pose a problem. To clarify, even when a particular currency has been chosen, GDP can still be expressed in a variety of ways:

- Nominal GDP (value of currency changes in different years)
- Real GDP (value of currency is based on a constant base year, removing inflationary effects)
- Nominal or real GDP by purchasing power parity (currencies are converted according to their purchasing power)

The latter is not useful, because in essence world trade means buying foreign currency to buy foreign goods, which means market exchange rates are used rather than PPP exchange rates. Purchasing power parity is useful for comparing standards of living between countries, but not for measuring countries' economic strength (Krugman, 2006).

This leaves the choice whether to use nominal or real GDP values. Because the trade data is expressed in current US dollars, changes in the value of total traded goods from year to year are a result of:

- A change in the actual value of the goods, meaning a change in the amount of goods or a (non-inflationary) change in their average price
- US dollar appreciation or depreciation
- Inflation rates in the importing and/or exporting country

Aside from a change in the actual "size" of the economy, nominal GDP also depends on the latter two factors. Real GDP eliminates the effect of inflation.

In an ideal situation, either all real or all nominal values would be used. However, this is problematic because of the following:

- Nominal past GDP growth is not available for all important countries and can be very unstable if the reporting country has had major currency revaluations in the past.
- Trade data cannot be easily adjusted for inflation and/or US dollar appreciation/depreciation, because there are many different currencies and inflation levels throughout the world.

Since real GDP growth (as derived from GDP figures in the countries' own currencies) is available, the nominal GDP value in US dollars in some base year could be taken, and the real GDP growth rates could then be used to calculate real GDP values is US dollars in the other years. This eliminates the effect of a change in the value of the dollar. The resulting GDP series are stable and can be compared to one another to judge which economy is stronger. That is why the model will use these GDP series as input.

That leaves the problem of the trade data, and the fact that inflation and currency dynamics play a role.

In some cases the effect might be negligible. It could be assumed that a country's price levels and the value of its currency are directly linked. Suppose that Egypt imports €100 worth of goods from Germany, which would convert to 150 US dollars or 50 Egyptian pounds. If hyperinflation would cause the price of those goods to increase to €200 while exchange rates stayed the same, Egypt would now have to pay 100 Egyptian pounds which would convert to 300 US dollars. In the trade data this would appear to be a 100% increase. However, if the inflation were accompanied by a depreciation of the euro, the dollar value (and value in Egyptian pounds) would stay the same and the data would report no growth instead of 100% growth. In the real world, a country's inflation and the value of its currency do seem to be negatively correlated in the long run (Krugman, 2006), but it is a weak correlation, making the assumption weak in turn.

Suppose the US dollar itself depreciates. Assuming this depreciation is accompanied by US inflation, converting the trade data using an index that measures inflation (such as the American consumer price index) could eliminate the effects of that depreciation. In theory such a conversion would result in a good estimation of the "real" value of trade which could then be better compared to real GDP.

However, it's not practical to do this. It is difficult to accurately measure US dollar depreciation, or to determine how it affects the trade values as reported in the databases. Converting the data using the consumer price index would only add another element of uncertainty that could throw off some of the time series.

For the world trade model real GDP values and nominal trade values, will be used, keeping in mind that inflation and US dollar appreciation/depreciation disrupt the correlation between the two. It will also affect the model's output in unclear ways.

5.3 Trade determinants

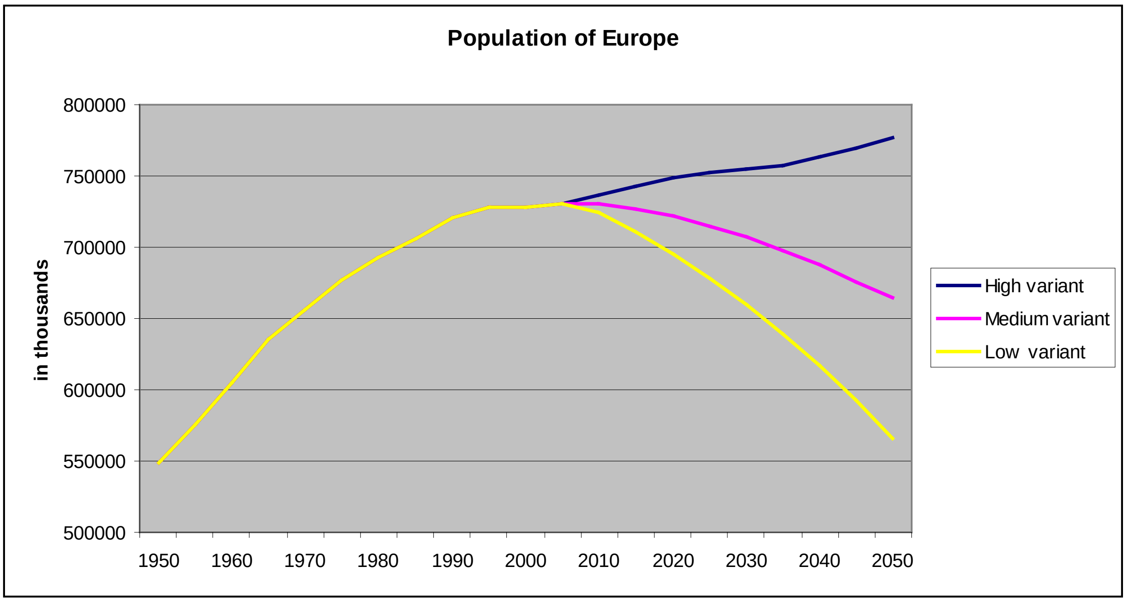
In this section the various rules and constraints that can possibly be added to the framework are discussed. Analysing historical data will give an idea of whether certain cause-and-effect relations have existed in the past and whether they should be added to the model.

First long-term GDP and population prospects are discussed. Finally, the various factors that could influence imports and exports are covered, such as the existing trade imbalance.

5.3.1 Long-term population and GDP growth

First we look at population growth. For each country the current population and prospects for the next fifty years are available, released by the United Nations' Department of Economic and Social Affairs. These prospects are given as input to the model. There are three different variants (as the growth of the world's population is subject to a lot of uncertainty), a low, a medium and a high variant. Figure 4 shows the European population prospects.

Figure 4: Forecasted population of Europe (UN, 2005)



There are five-year gaps between each of the forecasted population figures; the years in between are added by assuming a linear trend between the points. For population figures after 2050, the model assumes the last known growth rate to remain constant.

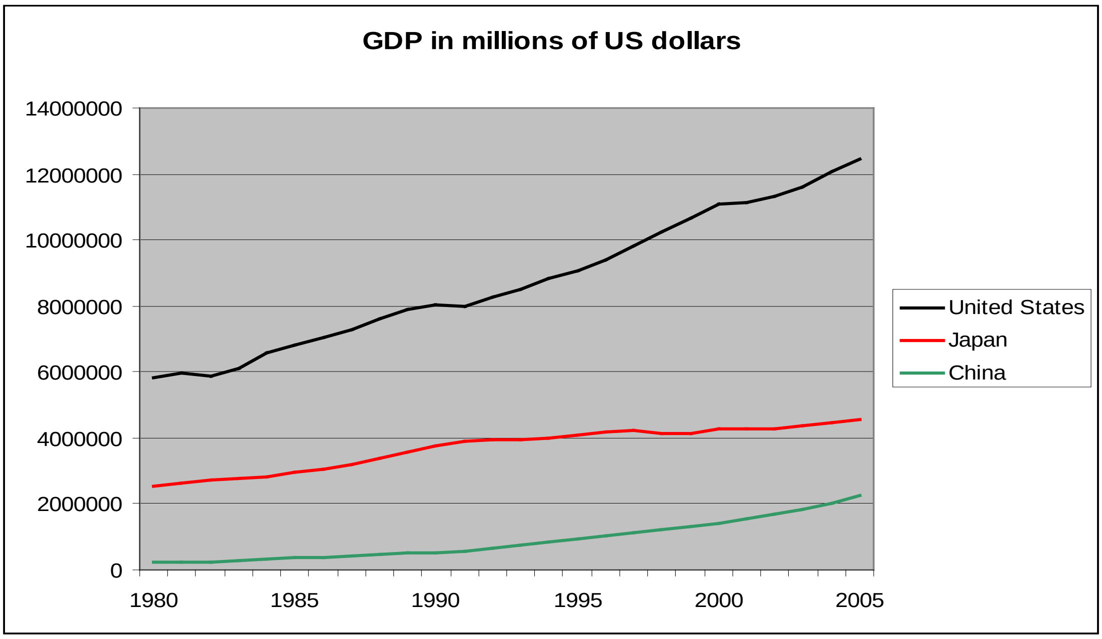
When running the model the user can choose between the three different variants. In this thesis the medium variant is used.

There is no compelling reason to use population prospects different from the UN's. Population therefore becomes an exogenous variable.

GDP is more complicated. There are many factors that affect its growth, and no one has yet succeeded in accurately forecasting it. Even short-term forecasts are unreliable. Some economists have shown that simple methods such as taking the linear trend or assuming a constant growth rate result in better forecasts than those calculated by advanced macroeconomic models (Marcellino, 2007).

Looking at the GDP levels of large economies such as the United States, Japan and China in the past 25 years, the trends are not exactly linear. From 1990 and on, China has been growing faster while Japan's growth has slowed down.

Figure 5: Real GDP of three large economies (IMF, 2007)



The problem is that these changes in the trend are unpredictable, even with extensive qualitative and quantitative analysis. In the model it will be assumed that these changes will not happen in the future.

On the other hand, countries that are very poor can be expected to sustain high growth rates for many years as their industries develop. Their growth could be more exponential than linear. GDP growth is usually also related to population growth, so trends in GDP/capita should also be studied. So to summarise, the following regression models will be used:

$$(1) \quad GDP_Y = \beta_1 + \beta_2 \cdot Y$$
$$(2) \quad GDP_Y = \beta_1 + \beta_2 \cdot Y + \beta_3 \cdot Y^2$$
$$(3) \quad GDPC_Y = \beta_1 + \beta_2 \cdot Y$$
$$(4) \quad GDPC_Y = \beta_1 + \beta_2 \cdot Y + \beta_3 \cdot Y^2$$

One could also propose a model where GDP depends on both time and population:

$$(5) \quad GDP_Y = \beta_1 + \beta_2 \cdot Y + \beta_3 \cdot POP_Y$$

But because population almost always depends on time, their separate effect on GDP would be impossible to estimate.

For each country, the regression models will be run with a starting year from 1980 to 1990 (and end year 2009). Any drastic changes in the trend in the 1980s can then be avoided. The trend will always be based on a period of at least fifteen years. Ordinary least squares (OLS) is used to estimate the parameters.

One problem is how to compare the outcomes of the models. The coefficient of determination, R^2, measures the proportion of response variation explained by the regressors in the model. However, this is not an appropriate statistic to use here. A fairly constant GDP_Y or $GDPC_Y$ would often result in a low value of R^2, even if the regression line would closely match the actual data. Also, the models with dependent variable GDP_Y would usually have a higher R^2 because the slope would be relatively high compared to the models with dependent variable $GDPC_Y$. Lastly, adding regressors to a multiple regression model always results in an equal or higher value of R^2, so the models with a second-order polynomial fit, (2) and (4), would always give better results than their first-order counterparts.

Another way to compare the models is to use the Akaike information criterion (AIC) or the Bayesian information criterion (BIC). These take into account the number of parameters *k*, the model fit, and the number of observations *n*. When $n \geq 8$, the BIC imposes a stronger penalty on extra variables than AIC, which is a desirable property in this case. With an exponential trend the forecast can "explode" in future years, and this could throw off the entire model. The GDP forecasts should be fairly robust. However, AIC or BIC can only be used when the dependent variable of the models is the same. In this case, we also want to choose between estimating GDP itself or GDP per capita.

Therefore, a proposed statistic to measure the goodness of fit is the mean relative error:

$$mre = \frac{1}{N} \sum_{i}^{N} \frac{|\hat{y}_i - y_i|}{y_i}$$

The most important aspect of this statistic is that it does not depend on the mean value of the dependent variable (GDP_Y is in most cases much higher than $GDPC_Y$).

In the table below, the best *mre* found for the different regression models are listed for the world's ten largest economies. It should be noted that OLS does not minimise *mre*, but it is used because it can be implemented analytically and has a unique solution.

Table 7: Comparison of *mre* of different GDP regression models

Country	(1) GDP-1	(2) GDP-2	(3) GDPC-1	(4) GDPC-2
United States	1.22%	1.17%	1.17%	1.18%
Japan	1.01%	1.02%	1.04%	1.03%
Germany	1.01%	0.91%	1.00%	0.97%
United Kingdom	1.38%	0.90%	1.18%	0.95%
China	5.35%	2.34%	4.21%	2.27%
France	1.42%	1.13%	1.40%	1.25%
Italy	1.01%	0.96%	1.02%	1.03%
Canada	2.03%	1.53%	1.90%	1.65%
Spain	2.86%	1.40%	1.95%	1.74%
Brazil	1.61%	1.61%	1.62%	1.63%

When deciding which regression model is best to forecast GDP, the following should be kept in mind:

- If the estimated parameter β_3 in the second-order polynomial fit models (2) and (4) is negative, then high values of *Y* result in negative values of the dependent variable. This is not acceptable, as GDP can not be negative.
- A linear trend is generally favourable because it will never show extreme growth rates. An exponential trend can "explode" as the years go by (if no countermeasures are taken), and the model should be robust enough so that it can handle very long-term forecasts.
- Having $GDPC_Y$ as the dependent variable is favourable because ideally population prospects affect GDP prospects.

To that end, the following algorithm is used to arrive at the final choice. First, it is checked whether β_3 in the second-order models (2) and (4) is positive; those with negative β_3 are effectively dismissed. Then, the minimum *mre* of the second-order models is compared to the minimum *mre* of the first-order models (1) and (3). If the second-order models show a significant improvement then the exponential trend will be used, if not, the linear trend will be used. Finally, the trend based on GDP per capita is compared to the one based on GDP alone. GDP per capita is used unless the GDP trend performs significantly better.

Input: mre_1, mre_2, mre_3, mre_4, corresponding with models 1 to 4, along with β_{ij}, the estimated parameters β_j for model *i*

If $\beta_{23} < 0$, set $mre_2 = 1$
If $\beta_{43} < 0$, set $mre_4 = 1$
If $\min(mre_1, mre_3) / \min(mre_2, mre_4) > d_1$ then
    If $mre_4 / mre_2 > d_2$ then use model 2
    Else use model 4
Else
    If $mre_3 / mre_1 > d_2$ then use model 1
    Else use model 3

Output: the model that should be used

The problem here is the choice of parameters d_1 and d_2. When is one model "significantly" better than the other? There is no analytical way to calculate them, since they are merely a tool to facilitate the choice for the preferred model, which is the first-order model based on GDP/capita (3). Therefore, they are arbitrarily chosen: $d_1 = 1.5$ and $d_2 = 1.25$. As can be seen in table 7 on the previous page, the decision process often leads to a linear relation in $GDPC_Y$. For the ten largest economies, the exception is China, which shows an exponential trend in $GDPC_Y$.

Looking at all 186 countries in the system, the distribution is as follows:

Table 8: Distribution of models for forecasting future GDP levels

Model	# Countries	Largest countries
(1) GDP-1	10	Taiwan, Malaysia, Singapore
(2) GDP-2	8	Iraq, Cuba, North Korea
(3) GDPC-1	107	United States, Japan, Germany
(4) GDPC-2	61	China, India, Russia

Some countries like Brunei Darussalam, Gabon and Venezuela exhibit a downward linear trend in $GDPC_Y$. For these countries, β_2 is set to 0, so that they will never see negative GDP levels.

Figure 6 shows prospected GDP levels for the three largest economies.

United States $GDPC_Y$ is constantly growing, along with its population, which means its GDP rises a little bit faster than it would with a linear trend in GDP. Clearly, China grows faster, but because Chinese population will stall and American population will keep growing, China will never have a higher GDP than the US. Meanwhile, Japan's drop in population causes its GDP to stop growing.

Figure 6: Prospected real GDP of three large economies

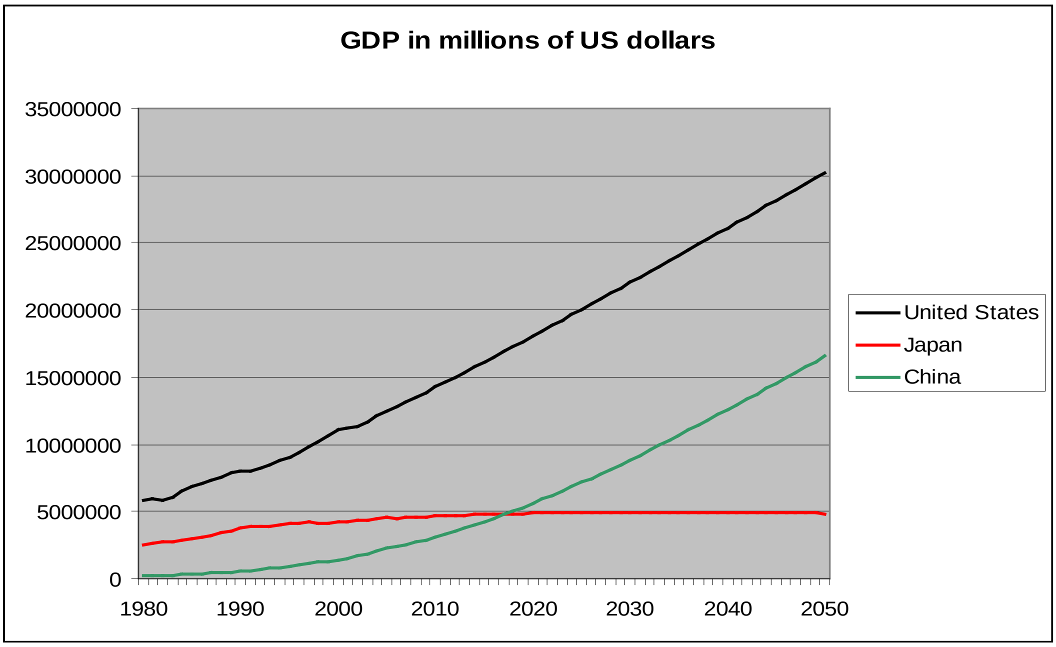


Table 9: GDP prospects (in millions of dollars) of ten largest economies

Country	GDP_{2005}	Rank	GDP_{2025}	Rank	Annual growth 2005-2025	Annual growth 1985-2005
United States	12455825	1	20044598	1	2.41%	3.05%
China	2243688	4	7152841	2	5.97%	9.57%
Japan	4557116	2	4929453	3	0.39%	2.15%
United Kingdom	2230608	5	3385760	4	2.11%	2.63%
Germany	2791737	3	3377103	5	0.96%	2.03%
Russia	763878	14	3327163	6	7.63%	0.84%
France	2127168	6	2899929	7	1.56%	2.06%
Italy	1772769	7	2195912	8	1.08%	1.75%
India	780784	12	1947846	9	4.68%	5.97%

Country	GDP_{2005}	Rank	GDP_{2025}	Rank	Annual growth	
					2005-2025	1985-2005
Canada	1132436	8	1821162	10	2.40%	2.81%
Spain	1127975	9	1715419	11	2.12%	3.40%
Brazil	882043	10	1277527	13	1.87%	2.46%

The system is not perfect. Some countries' prospects could be regarded as unrealistic, especially those for which an exponential trend was found in GDP or GDP per capita. Equatorial Guinea is the most prominent example, rising from the 31st highest GDP per capita in 2006 to the 4th highest in 2025. By 2100, its GDP per capita is the highest in the world at more than $1 million.

Although it's true that Equatorial Guinea has shown remarkable growth the past couple of years while becoming a major exporter of oil, it is doubtful this trend will continue. Most of the population lives in extreme poverty, with no signs of improvement. Regardless, such qualitative analysis is better used to adjust the output of the model rather than the model itself, which should be based on data alone. It should also be kept in mind that the economy of a country like Equatorial Guinea would still only be about 2% of the size of the United States' economy at the start of the 22nd century, so its extreme growth has a fairly insignificant impact on the model output, aside from its own trade statistics.

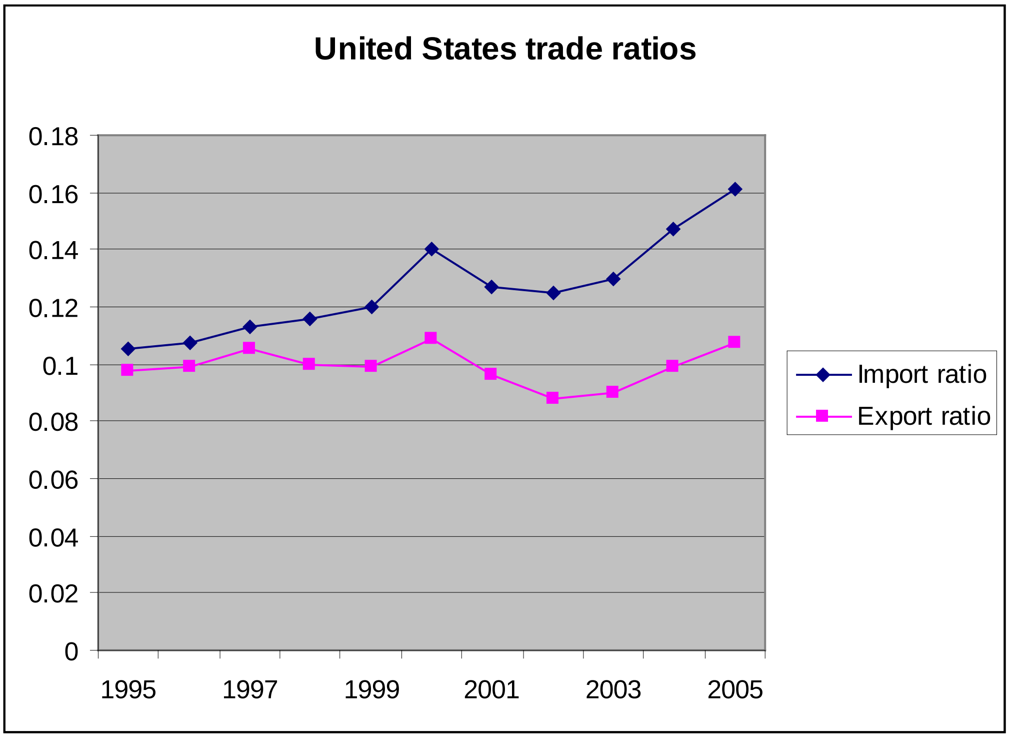
As can be seen in table 9, the largest economies will experience slower growth in the next 20 years when compared to the past 20 years. The exception is Russia, which suffered from contracting GDP until 1999, when GDP growth started booming. This trend is expected to continue in the future and is not completely unrealistic, as Russia has many natural resources that are yet to be exploited.

5.3.2 Long-term import and export prospects

Similar to GDP, long-term import and export figures are difficult to forecast. They are highly dependent on the state of the world's economy as a whole. Also, total import and export data in years prior to 1995 is not available for all countries, so determining long-term trends can be difficult in those cases.

As explanatory variable one can consider either imports or exports themselves (IM_Y and EX_Y) or their ratios to GDP (IMR_Y and EXR_Y) or total trade to GDP (TR_Y). Since GDP is a good indicator of the size of a country's economy, and GDP projections have already been made, this variable should not be disregarded in the analysis of long-term trade volumes. However, looking at trends in IMR_Y and EXR_Y separately is a bad idea, because their linear trends would in almost all cases be different and so in the long run their forecasts would be diverging (see figure 7). This contradicts the most important assumption within the model that countries can't sustain a growing trade deficit (or surplus) indefinitely.

Figure 7: United States import and export ratios to GDP (WTO, 2006)



Therefore, the best thing to do is to analyse historical levels of the total trade ratio TR_Y to see if there is a trend. Before these series can be determined, it is necessary to revisit the discussion of section 5.2.5 regarding the fluctuation in the value of the dollar. Naturally, trends change dramatically if historical import and export values are adjusted up or down.

Figures 8 and 9 shows the historical total trade ratios for some of the largest economies, one where the raw data is used and another where this data has been adjusted for inflation with the help of the US consumer price index.

The figures show that the upward trend of the ratio as exhibited in the raw total trade ratios is caused primarily by the effects of inflation, which have mostly been removed in the second panel (using the US consumer price index). The total trade ratios seem to be more constant for the adjusted time series.

In both cases, projecting the series into the future means that some assumption has to be made regarding the level of inflation in future years. If the adjusted, deflated data were used, the forecasts of the world trade model would have to be adjusted up (or down) corresponding with externally forecasted inflation levels. If the raw data were used, the forecasts would already include endogenously determined inflation levels, in the sense that past inflation affects the future trend.

Figure 8: Total trade ratio to GDP of largest economies (raw value)

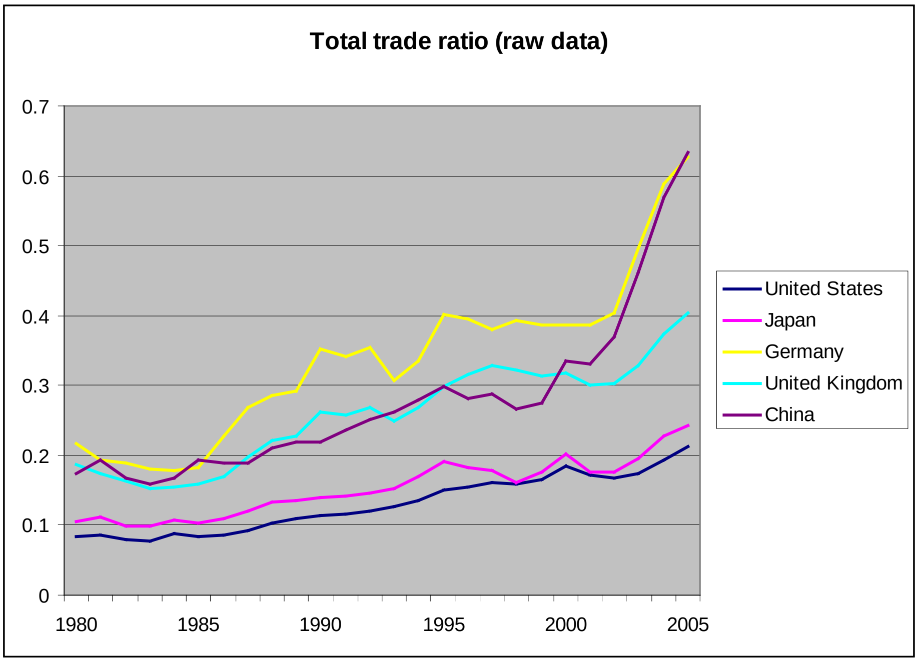
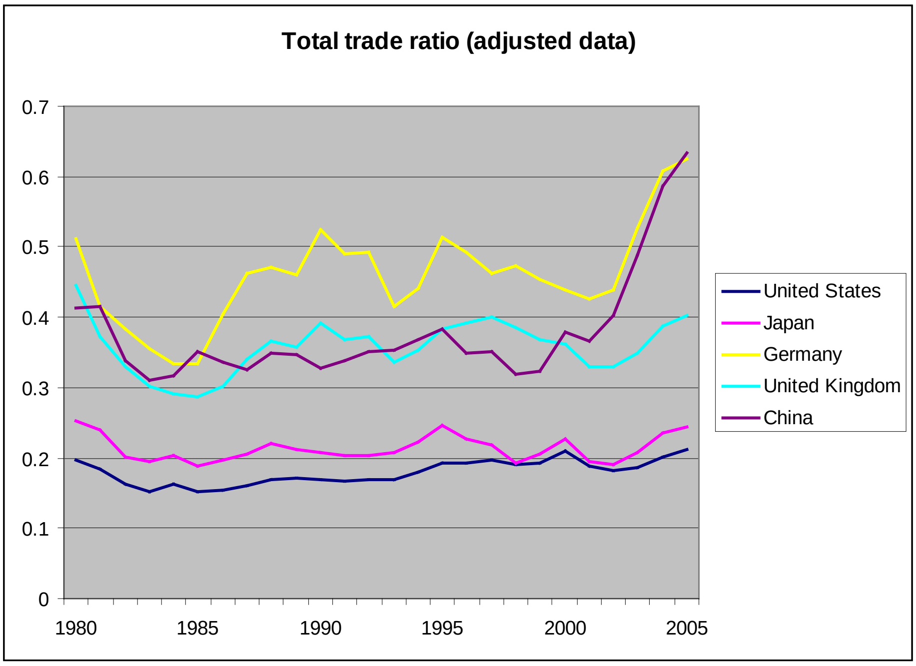


Figure 9: Total trade ratio to GDP of largest economies (adjusted value)



The primary reason against using the adjusted trade data is that it would become more likely for a trend to have a negative slope. In the long term, such a development would be very unrealistic, because trade itself approaches zero when the total trade ratio to GDP approaches zero.

Having decided to use the total trade ratio based on raw data (figure 8), either a linear trend or a logarithmic trend can be assumed. A potential problem here is that this might lead to very high total trade ratios when forecasting far into the future. It might seem odd for a country to have more imports and exports than GDP. However, there are already some countries, Singapore in particular, that have such a high total ratio. Aside from that, since trade is nominal and GDP is real, a future total trade ratio higher than 1 does not necessarily imply that the total import and export value has exceeded GDP.

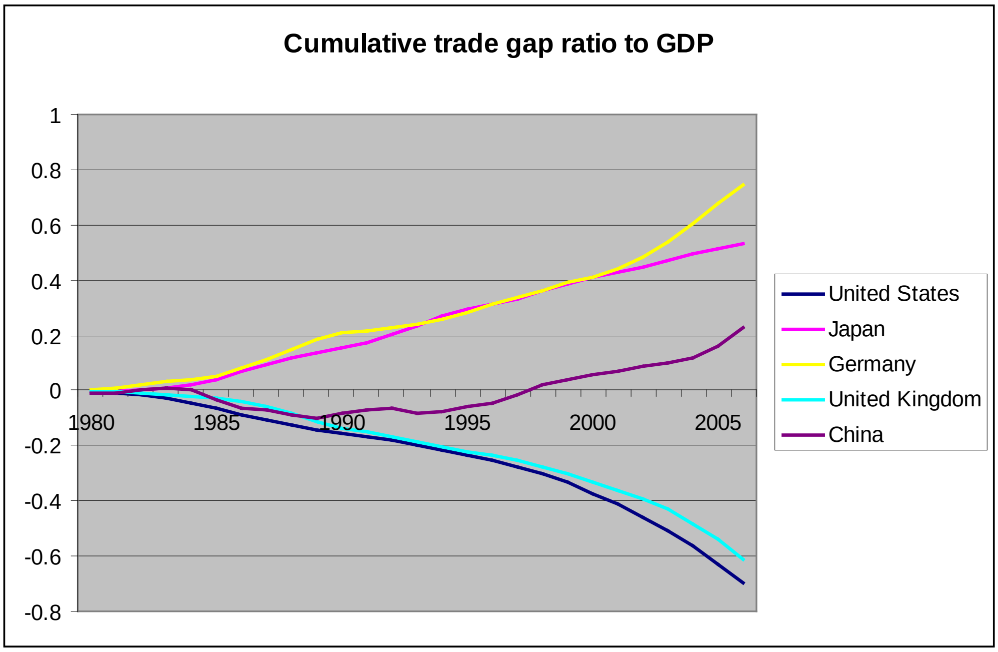
Keeping that in mind, assuming a linear trend seems feasible. A simple trend-based forecasting algorithm will be used to obtain a "target" trade ratio series (TTR_Y). Imports and exports are then adjusted up or down if the total trade ratio drifts too far from the target series.

The forecasting algorithm is based on first-order polynomial regressions. The forecast first emphasizes the short-term trend before converging to the long-term trend.

5.3.3 Effect of the trade gap

Modern economists have different views on the effects of running a trade deficit or a trade surplus. A relatively traditional view is that a persistent trade deficit (surplus) eventually causes the country's currency to depreciate (appreciate) which in turn causes imports to fall (grow) and exports to grow (fall). However, historical data does not always support this claim. Many countries have been running a trade surplus or deficit for years with no apparent effect on the real exchange rate, or trade itself.

Figure 10: Cumulative trade gap ratio to GDP of 5 biggest economies (WTO, 2006)



One of the most prominent examples of an ever increasing trade deficit is the United States. As can be seen in figure 10, both the US and the UK have sustained a worsening trade deficit since the 1980s. On the other hand, Germany and Japan have been able to maintain a surplus. China is the only one of the five largest economies that has switched from a deficit to a surplus (or the other way around) in the past 25 years.

There are also countries that do exhibit a trade gap that alternately rises and falls.

Figure 11: Cyclical cumulative trade gap ratio to GDP (WTO, 2006)

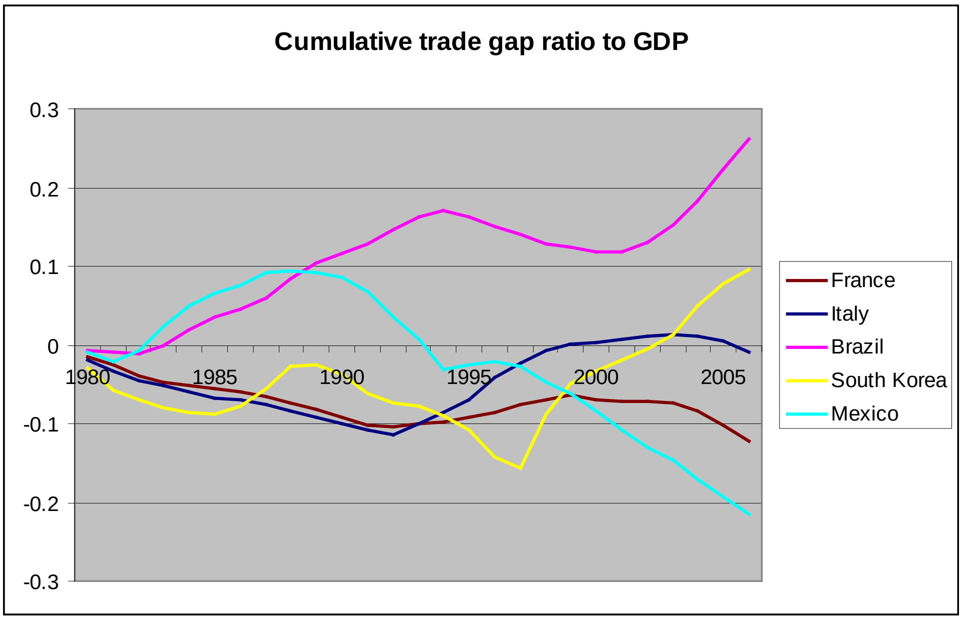
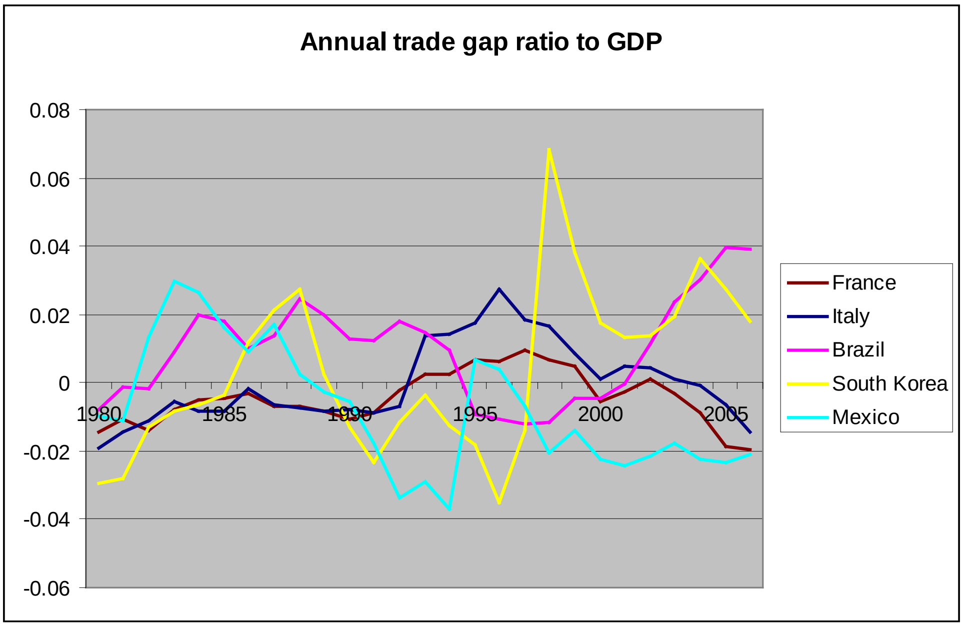


Figure 12: Cyclical annual trade gap ratio to GDP (WTO, 2006)



Figures 11 and 12 show the cumulative and annual trade gap ratio of some large economies that have had periods of surpluses and periods of deficits. This is the economic behaviour that is generally supported by macro-economic theory.

Table 10 shows the behaviour of the trade gap of the 100 largest economies.

Table 10: Trade gap behaviour of 100 largest economies (WTO, 2006)

Behaviour	# Countries	Largest countries
Consistent deficit	41	United States, United Kingdom, Spain, India, Australia
Mostly deficit	16	France, Mexico, Poland, Thailand, Czech Republic
Cyclical	14	Italy, Brazil, South Korea, Belgium, Switzerland
Mostly surplus	10	China, Denmark, Ireland, Finland, Iran
Consistent surplus	19	Japan, Germany, Canada, Netherlands, Sweden

The behaviour is based on data from the past 40 years (where available) and defined as follows:

- Consistent deficit (>90% of the available years show an annual trade deficit)
- Mostly deficit (60-90% of the available years show an annual trade deficit)
- Cyclical (No more than 60% of the available years show either a trade deficit or a trade surplus)
- Mostly surplus (60-90% of the available years show an annual trade surplus)
- Consistent surplus (>90% of the available years show an annual trade surplus)

The table shows that there is no clear relation between the location of a country and its economic policies. To understand a country's surplus or deficit it is almost always necessary to look at the countries individually. Factors that are of importance are the governments that it has had, the products it produces and consumes, the domestic economic activity, among others. Often, even when it is clear why a country has a surplus or deficit, it is difficult to predict what will happen to it in the future. Figure 12 also shows how erratic the annual trade gap ratio is.

This does not mean that the trade gap should simply be disregarded. A trade deficit implies a current account deficit and a capital account surplus. A capital account surplus means that foreign ownership of domestic assets increases. If that continues indefinitely, then eventually the entire country is in foreign hands. The model assumes that this will not happen in the real world. That is why the trade gap should eventually "corrects" itself, steering imports and exports in opposite directions when the annual trade gap or cumulative trade gap becomes too large. This can be done directly or indirectly by using another variable such as the real exchange rate.

The annual trade gap and the cumulative trade gap are of course highly correlated, so it would be ill-advised to have both predict next year's trade growth. If the annual trade gap is used as the constraining force, then the total deficit or surplus of a country is not constrained. With the cumulative trade gap as the constraining force, the total deficit or surplus is constrained. In this case, the ever-growing trade deficit of the United States (see figure 10) would quickly turn around; at least if the effect were strong enough.

Whether the annual or cumulative trade gap is used, neither, or both, is something that needs to be analyzed further when the model is fine-tuned. This issue is revisited in section 5.4.1.

5.3.4 Effect of the value of a currency

As was already discussed in the previous section, the effect of a trade deficit or trade surplus on the growth of imports and exports is in reality an indirect one. Economic theory states that a trade deficit increases demand for the foreign currency, which drives up its price in terms of the domestic currency. When the foreign currency becomes more expensive, foreign goods become less attractive, and so imports fall, and exports will most likely rise. This steers the trade deficit back to a balanced state.

The question is if this effect should be incorporated into the model as such. The first thing to note is that a large part of the global economy operates under fixed exchange rates. The euro is the most prominent example, as it is used by the majority of the EU, and there are several other European and African countries whose currencies have been pegged to the euro, meaning the exchange rate between them is fixed. Another example is the Chinese yuan, which was kept in a fixed exchange rate against the US dollar up to 2010. Only recently limited appreciation of the yuan has been allowed.

Other than that, the foreign exchange market as a whole is a very complicated market with many different players and many factors that affect the final exchange rate. It is also volatile, with exchange rates able to rise or fall a lot even *during* a specific year. The rates often react to current events like wars, natural disasters, or even newly released statistics about a country's economy. Politics also play a large part in the foreign exchange market. Countries can try to artificially lower the value of their currency to boost exports. Or they will take steps to maintain the value of a currency of which they have sizable reserves.

Still, it is worth exploring the idea that countries which share a currency, or at least the value of a certain currency, are jointly responsible for its value on the foreign exchange market. This is particularly interesting for the eurozone. An overall deficit within the whole of the eurozone may well affect the euro itself and all the individual countries that use it, even if their own current account is perfectly balanced (Berger, 2010).

The problem is how to single out this effect and how to measure it. The countries within the eurozone mostly trade with each other. An appreciation or depreciation of the euro only has an indirect effect on this trade. Theoretically, if the euro increases (decreases) in value, it would boost imports from (exports to) non-euro countries. If a trade surplus (deficit) of euro countries with non-euro countries were to have an effect on the value of the euro, then this would be another imbalance that in time should fix itself.

The effect of shared and pegged currencies on international trade is a study on its own and is not further pursued within this thesis. However, it can be incorporated in the model using parameters chosen by the user, as an optional effect that is turned off by default.

5.3.5 Model specification

Now that the factors that we assumed will influence the growth rates of the primary variables have been discussed, it is time to determine the form of the functions that are used to determine their year-to-year growth.

As was shown in section 5.3.1, population and GDP are calculated before running the model, leaving only the growth rates of total imports and total exports. The country's own variables and constants, as well as system-wide data, can be used to calculate them.

To summarise, these are the factors taken into account when determining growth in the current year:

- Growth in the previous year (ΔIM_{Y-1})
- The trade surplus or trade deficit in the previous year, expressed as a ratio to GDP (TGR_{Y-1})
- The cumulative trade surplus or trade deficit, expressed as a ratio to GDP ($CTGR_{Y-1}$)
- Difference between actual and target trade ratio ($TR_{Y-1} - TTR_{Y-1}$)

The growth in the previous year is taken as a starting point; if none of the other three factors influence growth in any way, then growth simply stays the same. This prevents the model from generating erratic growth rates.

A function was formed where the previous growth is manipulated in an additive way. For imports it looks as follows:

$$\Delta IM = \Delta IM_{Y-1} + f(TGR) + g(CTGR) + h(TR - TTR)$$

Here, the functions *f, g* and h take the explanatory variables and return values which in turn alter growth. Function *f* takes the following form:

$$f(x) = \begin{cases} \beta_2 \cdot \log(1 + |x - \beta_1|) & \text{if } x > \beta_1; \\ -\beta_2 \cdot \log(1 + |x - \beta_1|) & \text{if } x < -\beta_1; \\ 0 & \text{if } -\beta_1 \leq x \leq \beta_1. \end{cases}$$

The parameter β_1 acts as a threshold. Nothing happens to the growth rate if the explanatory variable falls within this threshold. Parameter β_2 indicates the direction and the strength of the effect. A logarithm is taken to lessen the impact of outliers.

Functions *g* and *h* are constructed in a similar manner, with parameters β_3/β_4 and β_5/β_6, respectively.

For exports the same functions and parameters are used, switching signs for (cumulative) trade gap as those effects should be reversed. Another option is to use different functions for exports and estimate the parameters for imports and exports separately. In the next section both methods are attempted, and a choice between the two is made.

5.4 Fine-tuning the model

The many parameters used in the model should be estimated. A dataset was constructed by taking the 100 largest economies and calculating the import and export growth rates along with relevant explanatory variables for the past few years. This resulted in 300 observations for imports and 300 observations for exports.

Before estimating the parameters, statistical tests should be performed on the dataset to check whether the specified functions are useful. This will show whether existing behaviour is replicated in the trade forecast or whether the expected behaviour is so far only theoretical.

5.4.1 Plotting the trade gap

First the effect of the trade gap is analysed. Both the annual trade gap ratio (the trade surplus or deficit in the previous year as a ratio to GDP) and the cumulative trade gap ratio (the total trade surplus or deficit, built up over the years, as a ratio to GDP) are taken as explanatory variables in the model. As was noted in section 5.3.3, the two are closely linked, and it therefore makes sense to use only one of them in the eventual model.

First both the annual and cumulative trade gap against the actual import and export growth rates are plotted. Note that the value of the trade gap is from the year prior to the observed import/export growth.

Figure 13: Import growth against the (cumulative) trade gap as ratio to GDP

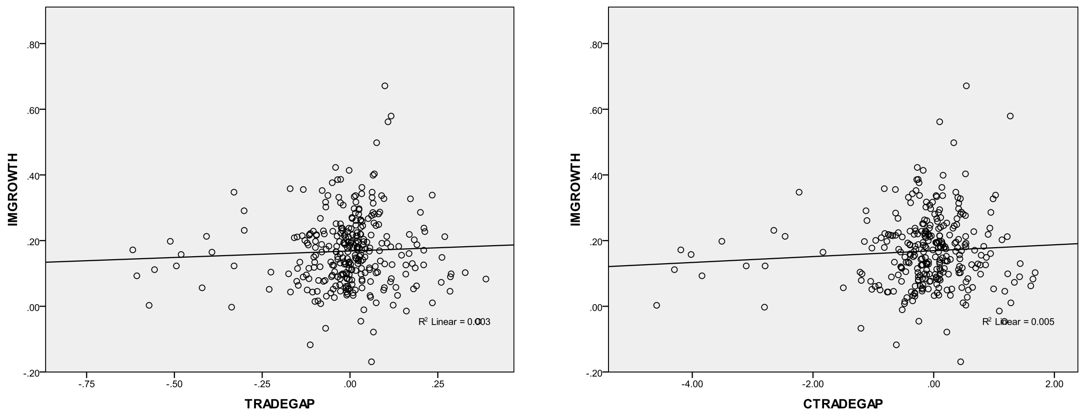
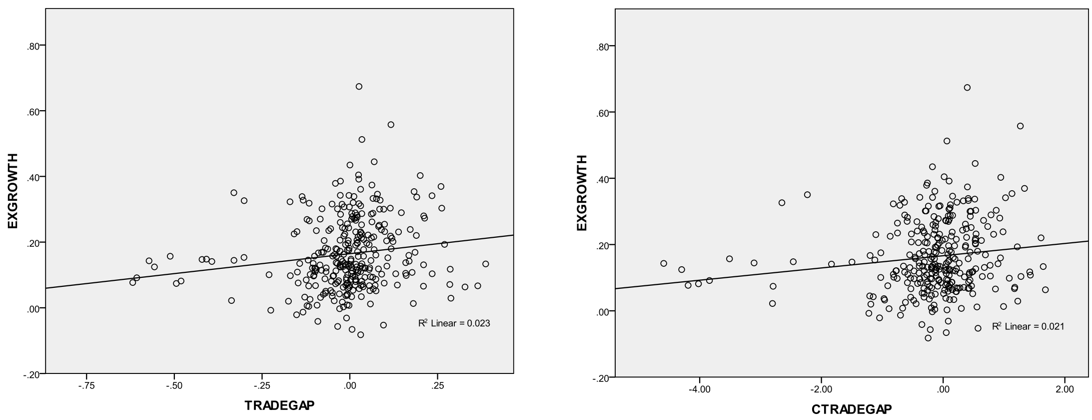


Figure 14: Export growth against the (cumulative) trade gap as ratio to GDP



Judging from figures 13 and 14 it is clear that there is little correlation between the variables. Both import and export growth are slightly lower for larger trade deficits. Countries that run large deficits (points at the left side of the figure) are expected to experience higher export growth to help close the gap, but these initial plots contradict that assumption. One of the reasons could be that a trade surplus indicates a healthy economy. That could lead to higher international trade growth in general.

Next the difference in import- and export growth (ΔIM_Y - ΔIM_{Y-1} and ΔEX_Y - ΔEX_{Y-1}) is plotted against the annual and cumulative trade gaps.

Figure 15: Import growth change against the trade gap as ratio to GDP

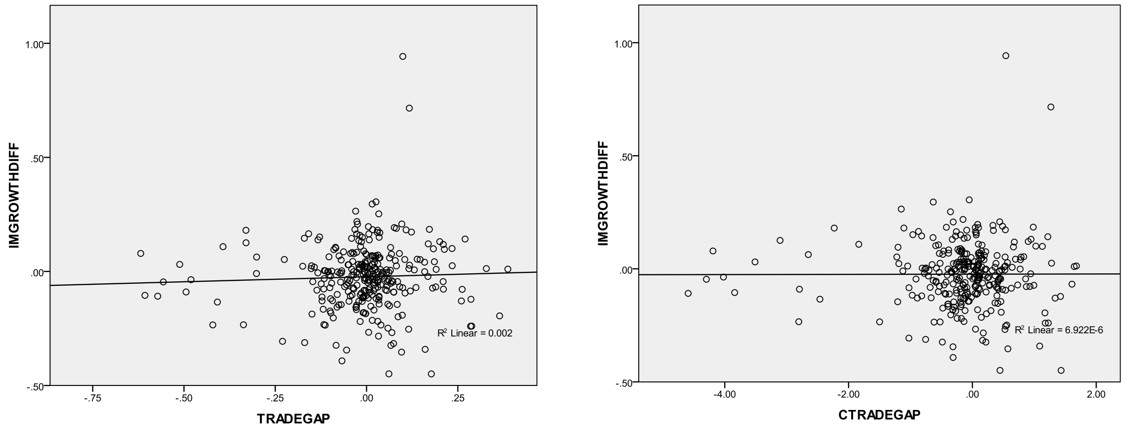
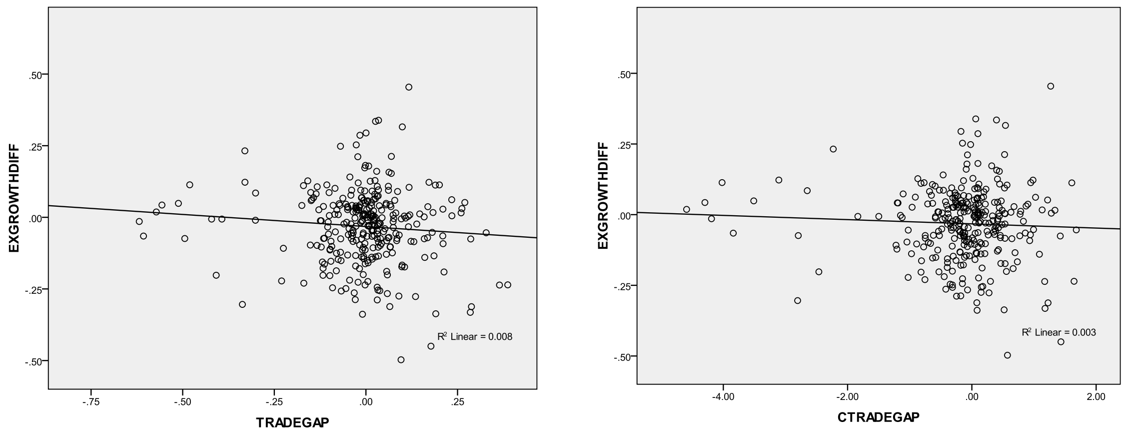


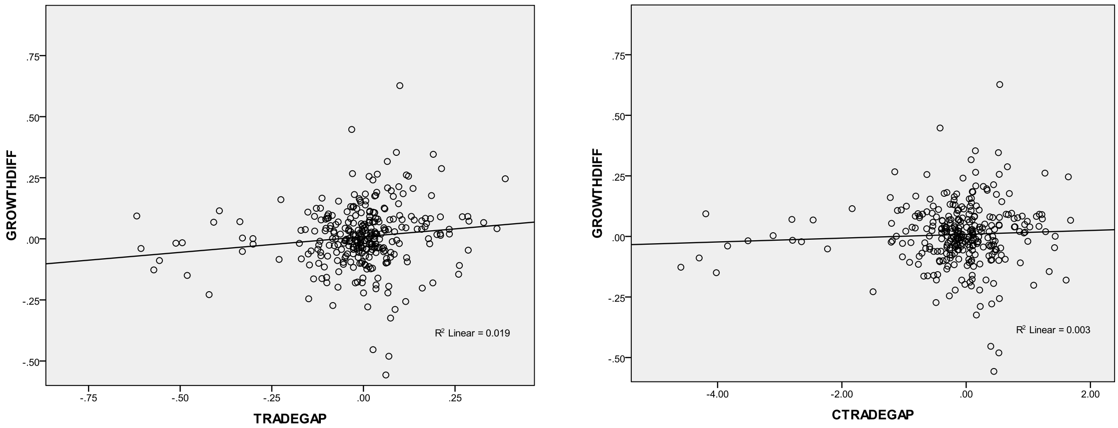
Figure 16: Export growth change against the trade gap as ratio to GDP



In this case a negative import or export growth difference means that growth has decreased from the previous year to the current one. Although the correlation is very weak, the scatter plots indicate that higher trade deficits lead to increasing export growth and decreasing import growth. This is in line with the assumption that a high trade deficit fixes itself by increasing exports and decreasing imports. The correlation is virtually non-existent in the case of the cumulative trade gap, while one would think that the pressure of historical deficits would be larger than that of only the current deficit.

Finally, the difference between the import growth difference and the export growth difference is tested as an explanatory variable $((\Delta IM_Y - \Delta IM_{Y-1}) - (\Delta EX_Y - \Delta EX_{Y-1}))$. This can be called the tendency of trade growth. If this variable is negative, then that corresponds with rising exports and falling imports. If it is positive, it's the other way around.

Figure 17: Tendency of trade growth against the trade gap as ratio to GDP



Again the plots in figure 17 indicate that higher trade deficits lead to higher export growth as opposed to import growth, although the correlation is very weak.

The consequences of a rising deficit or surplus do not yet seem to extend significantly to changes in the actual value of trade. One reason for this could be that the effect is too long-term and the workings of the global economy have not yet adapted to this relatively recent development. Countries also tend to intervene with other countries' economies, particularly the ones whose economic downfall would greatly affect their own economy. The major imbalances that are prevalent in the modern economy could be described as an assortment of bubbles supporting each other, in danger of bursting at any moment. But when they are going to burst and which ones will be first is impossible to foresee.

In the world trade model's case, the effect of the trade deficit will still be incorporated, even if the parameters themselves can't be estimated by real data. The main purpose of the model is to prevent deficits (or surpluses) from reaching unrealistic levels, and this is the best way to achieve that purpose. Each country will have its own parameters β_1 and β_2, which indicate the maximum allowable trade deficit (or surplus) and the strength of the correcting effect. This way it is up to the user to decide how large the trade gaps can become.

5.4.2 Behaviour of the total trade ratio to GDP

The upward trend visible in most countries' total trade ratio to GDP means that countries' trade growth is higher than their GDP growth. Essentially, it is an increase in globalization. The model assumes that the total trade ratio to GDP will not drift far from the "target" total trade ratio to GDP, a forecasted ratio that is initially based on the short-term trend and converges to the long-term trend (TTR_Y). So the main purpose of TTR_Y is to ensure that the forecasts follow the trend in globalization.

By allowing the actual trade ratio to drift from the target ratio and then at a certain point steering it back in the other direction, cyclical behaviour is simulated that corresponds with changes in the amount of foreign trade as a part of a country's total input and output. This cyclical behaviour could already be seen in figures 8 and 9, and in the model this is reflected by the values of the parameters β_5 and β_6.

For each individual country the following should be considered:

- Are they actual cycles or is it more like white noise?
- How long are the cycles?
- How strong are the cycles? (How far does the series drift from the trend?)
- How consistent are the cycles?
- Is it necessary to model the cycles at all?

Using a brute-force method, parameters for each individual country are estimated, so that the historical behaviour is also reflected in the forecast. The model will also include options to turn the behaviour off. In this case, the forecast would always agree exactly with the forecast of TTR_Y.

5.5 Model output

The model produces many different outputs, the most important of which are the total imports and exports per country. This section features a selection of example outputs.

The outputs are all in the form of time series. The model produces exact forecasts, there is no randomness. It is not a statistical model, so there are no confidence intervals.

The base year is 2010. The parameters chosen are the default ones, which means they are the same for each country, and the focus is on immediate trade gap reduction (both deficits and surpluses), and maintaining a low trade gap.

5.5.1 Imports and exports

Figure 18: Forecasted imports (world trade model vs. extrapolated trend)

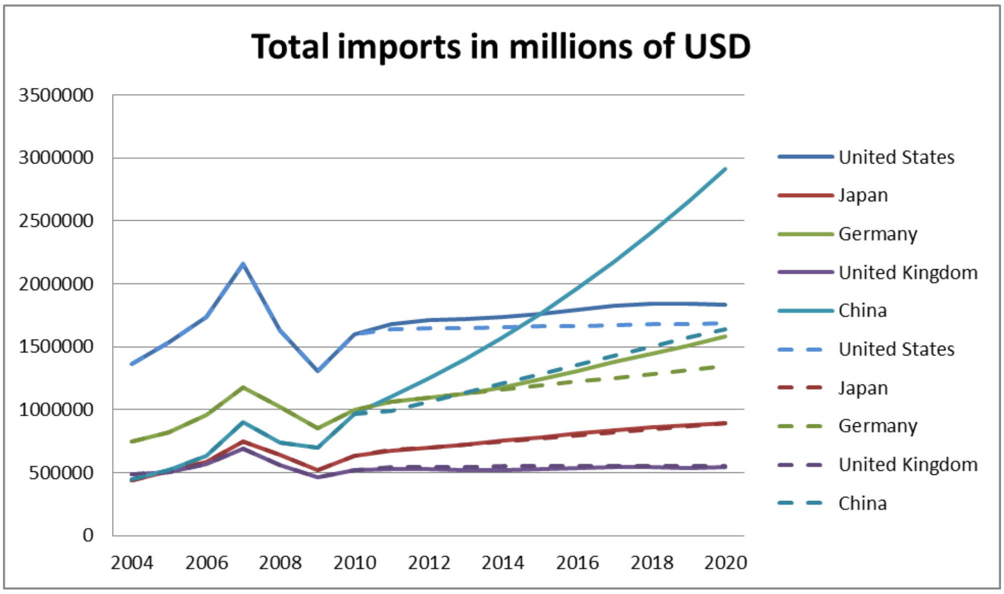
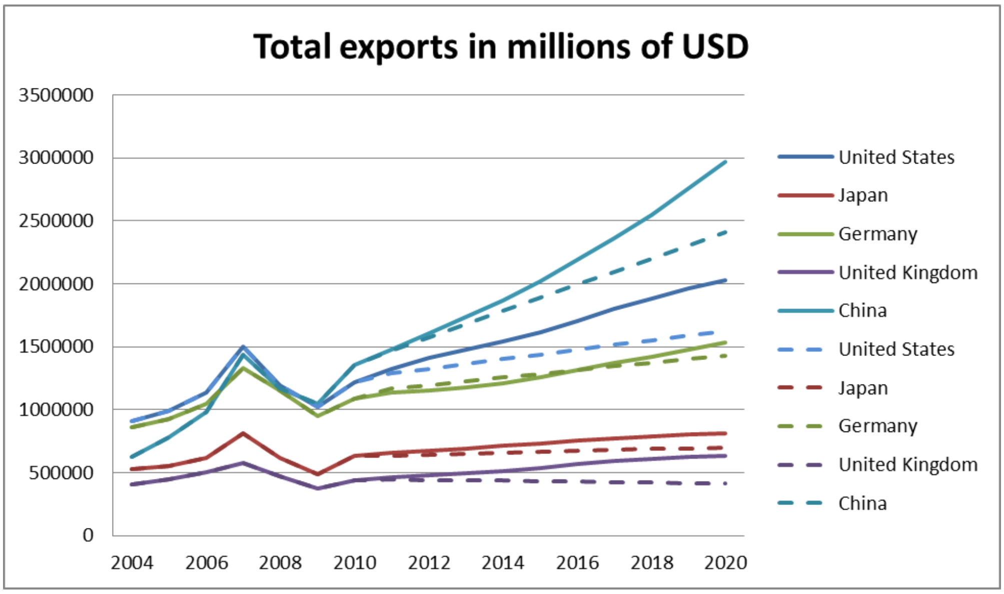


Figure 19: Forecasted exports (world trade model vs. extrapolated trend)



The long-term growth of imports and exports is mostly a result of GDP growth, so as expected China quickly moves ahead. The existing trade gap is the other significant factor that affects trade, but this effect is not that easy to see in these figures.

Compared to the extrapolated trend, the forecasts are quite a bit higher for both imports and exports. The economic downturn in the late 2000s does not affect the world trade model's output as much.

5.5.2 Trade gaps

Figure 20: Forecasted trade gaps (world trade model vs. extrapolated trend)

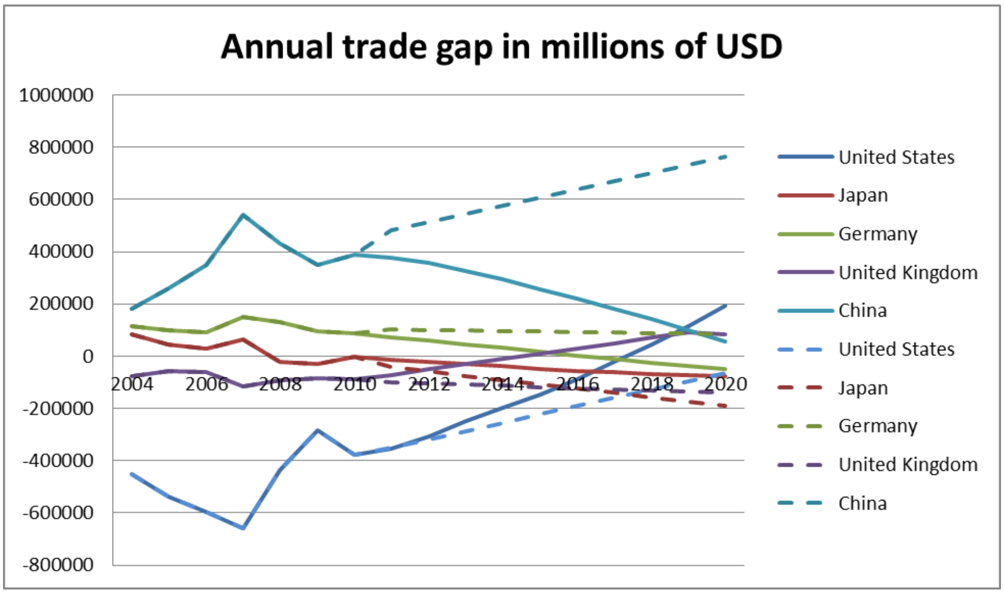
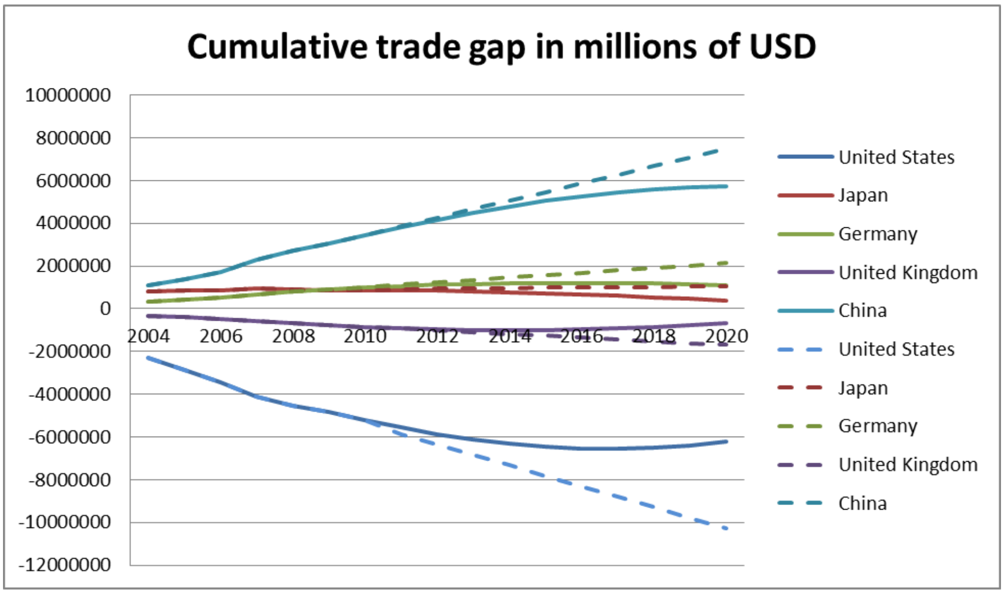


Figure 21: Forecasted cumulative trade gaps (world trade model vs. extrapolated trend)



Figures 20 and 21 show what happens to the trade gaps in the run with default settings. The model reacts quickly to the existing deficits. The United States manage an annual surplus in 2018 already. This is achieved mostly by keeping imports at a steady level (see figure 18) while exports continue to grow.

Countries that are running a trade surplus are expected to stray from the extrapolated trend towards a deficit. This is due to the assumption that gaps in both directions indirectly cause the opposite effect.

5.6 Implementation

The model is implemented entirely in Java. The advantage of this programming language is that it is object-oriented, and the model is as well. Java is also open-source, meaning it is free to use, and platform independent, so it can be installed on any machine.

However, there is no compelling reason to use Java. The model itself is relatively simple and any modern programming language could be used to implement it. It would even be possible to build it in a spreadsheet environment like Excel.

The program requires several input text files:

- a configuration file which contains the location of other input files, the target output directory, and model parameters such as the base year and the forecast year
- a file that lists all of the countries within the model along with their names, country codes, currencies and other basic info
- files with historical (and possibly future) GDP and population figures per country
- country-to-country merchandise trade per year (in US dollars) from Comext and Comtrade

Running the program takes about a minute, depending on the machine. It has about 5000 lines of code, although a large part of that is dedicated to producing attractive output for the user. There is no official documentation; this thesis is what comes closest to it. The current working version number of the program is 3.0, after 1.0 which severely lacked optimisation and 2.0 which had a less streamlined structure. Intermittent versions were mostly bug fixes.

To run the model one only needs to adjust the input files as needed, in particular the configuration file, and then run the main class. Output is written to both text files (for easy processing) and Excel files (for viewing and producing graphs and tables). There are output files per country and per variable.

6 Further analysis of existing trade deficits and surpluses

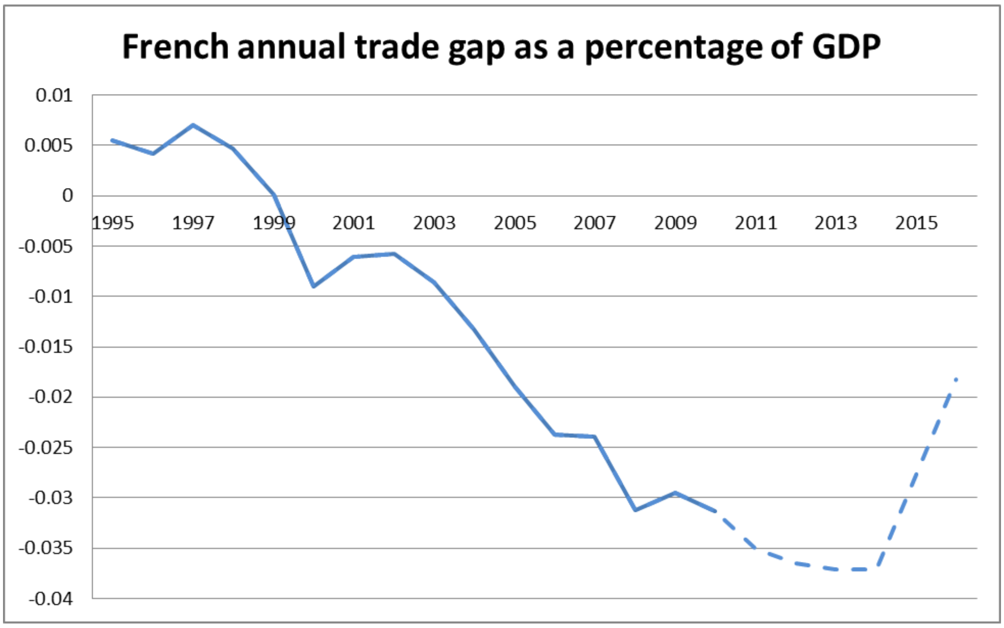
6.1 Introduction

Although the world trade model is a helpful tool to produce a large set of robust country-to-country trade forecasts, individual qualitative analysis will usually result in something more reliable. In this chapter a few countries' trade profiles will be analysed in depth: France, Portugal and Australia. France and Portugal are running a trade deficit, while Australia has recently recovered from one. It will be interesting to know if these countries' governments view a trade deficit as a problem and if they are doing anything to combat it.

The world trade model output (default scenario) will also be looked at it to see if the forecast it produces can be explained qualitatively.

6.2 France

Figure 22: French annual trade deficit as a percentage of GDP, including world trade model forecast



France's structural trade deficit is seen as a problem by the country's government, and many programs have been launched to stimulate exports, with little success. Ten percent of the value of French exports is related to the aerospace industry (such as Airbus airplanes), and a slowdown in that industry's performance has immediate, very negative effects.

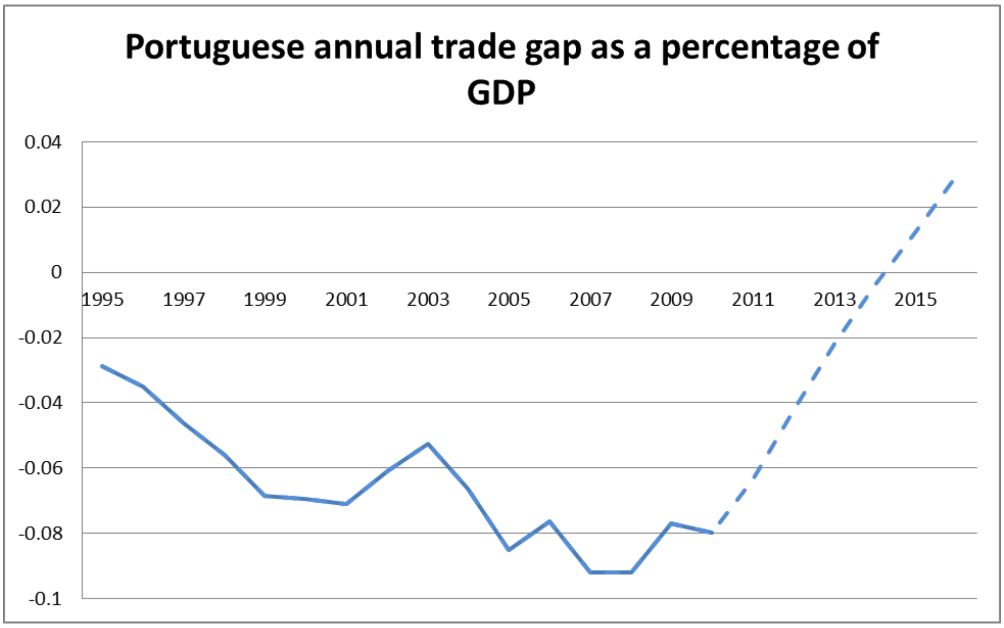
Due to its location and role within Europe, France's main competition is neighbouring Germany, and in recent years it has been falling behind. German medium-sized firms have been more successful in capturing valuable niche markets overseas, whereas French medium-sized firms produce mid-range goods that have less added value in the international marketplace.

As a member of the eurozone, the French trade deficit has little effect on the value of France's currency; devaluation is not an option. With the value of the currency remaining artificially high, France is stuck with its deficit. Imports will fall only due to the weakening economy, higher unemployment and reduced spending power of French consumers, and exports remain unaffected as the costs of French products and services remain the same to foreign buyers.

With no mechanism at their disposal to balance trade, the future of France's economy looks bleak. With that in mind, the assumption of the world trade model that trade will balance itself without any consequences to the GDP seems far-fetched. Figure 22 shows that the world trade model expects a sharp recovery in 2015.

6.3 Portugal

Figure 23: Portuguese annual trade deficit as a percentage of GDP, including world trade model forecast



The Portuguese chronic trade deficit is viewed as the cause of the current economic problems in Portugal. An annual deficit of 8% to 9% of GDP is very substantial, and quickly indebts the country to its trading partners.

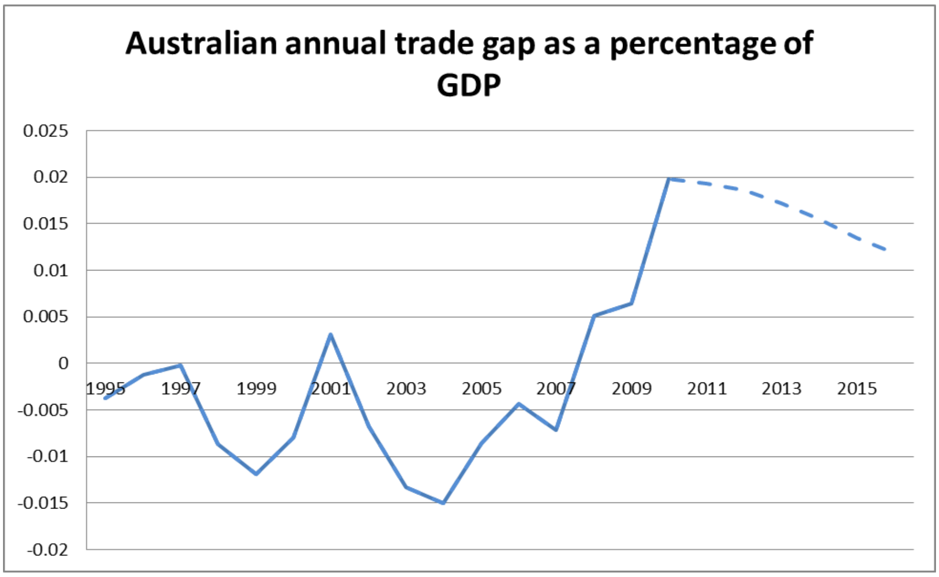
Portugal is in the same boat as France; both countries are stuck in the eurozone. But while the economic troubles in France are just starting, Portugal is already deep into crisis. That is why it is part of the so-called PIIGS countries (Portugal, Ireland, Italy, Greece, Spain), which run the largest budget deficits within the EU (and not coincidentally, the largest trade deficits).

If Portugal had never adopted the euro, then its former currency (the escudo) would have been devalued by now, which would boost exports and decrease imports, therefore reducing the trade deficit. But with that option off the table, the other EU countries have had to step in to save Portugal from disaster, with billions of euros in loans and aid. Meanwhile, Portugal has had to implement severe austerity measures, inducing a sort of “domestic devaluation”. By lowering the overall welfare standard, the people essentially become cheaper, and this makes Portuguese products cheaper and more competitive on the international market.

The austerity measures and the EU aid seem to be having an effect, as in 2011 the trade deficit is already rapidly decreasing. If Portugal can continue on this path and work towards a trade surplus, then its entire economy could eventually recover. This is something that the world trade model forecasts as well.

6.4 Australia

Figure 24: Australian annual trade deficit as a percentage of GDP, including world trade model forecast



Australia is very dependent on its mining industry, and so its trade balance is closely linked to it. Coal and iron ore together make up almost 50% of the value of Australian merchandise exports, with most of it going to its main Asian trading partners, China and Japan. A slowdown in these economies therefore also affects the Australian trade balance.

Since China is Australia’s main trading partner, the trade balance was not affected by the global recession in 2008 and on. In fact, it only improved. In the years that there was a trade deficit, the Australian government often pointed it out as a problem that needed to be fixed, even though it was a relatively small deficit as a ratio of GDP compared to many other countries. Australia’s main tool to boost exports is to directly support the exporting industries, which is what they have done in recent years.

7 Summary and conclusions

The global economy is a convoluted system of different agents with different agendas, and global trade plays a large part in it. It is subjected not only to the human state of mind and human choices, but also to other unpredictable events such as natural disasters, political changes and wars. This means that even with the data that we have available, it is impossible to make a well informed forecast for global trade.

However, many policy makers depend on such forecasts to make their decisions, and so it is necessary to create models that produce these forecasts. In this thesis, a new global trade model was developed that focuses on producing balanced, robust forecasts that can be used in combination with other models, and that takes into account all of the latest trade data. The model also has scenario capabilities.

The model works by dynamically forecasting successive years in the global economy, responding to historical trends and trade imbalances. The overall economic power of each country (expressed in GDP), can be either forecast within the model or given as an exogenous input. Other than trade imbalances, there are other optional drivers within the model that steer imports and exports in a certain direction, depending on parameters that control when the driver is activated and how strong the effect is.

The thesis aimed to estimate most of these parameters from real world data, but this proved to be a fruitless effort. While the assumptions about global trade imbalances are sound in theory, the real data usually does not (yet) reflect the assumptions. Some countries have a sustained trade deficit or trade surplus, and there is no evidence that this imbalance will ever show the assumed cyclical behaviour.

Despite the lack of empirical evidence to strengthen the model, it still accomplished what it set out to do. The forecasts are based on the latest available inputs, they respond well to different scenarios, and the very long-term forecasts don’t exhibit extreme trade imbalances. The forecasts have already been used many times in different projects related to freight trade and transport.

The fact that the model’s output reflects the chosen inputs in a transparent way actually helps its usability in practice, as it makes it easy to explain the outputs to third parties. In practice, users of the world trade model have found that it is just as valuable as models that are more empirically and economically sound.

8 Recommendations for further research

There are ways to further improve the world trade model.

Global trade imbalances are still a relatively new phenomenon. As the years pass, the effects of these imbalances will become clearer. While there is currently a lack of empirical evidence that supports the assumption that trade imbalances eventually correct themselves through various direct and indirect means, in the future such evidence could possibly be gathered from the data and used to strengthen this model.

Due to the way the model was constructed and programmed, it is also quite easy to implement additional modules so that there are more ways the outputs can be manipulated. These modules are beyond the scope of this thesis, as the aim was to keep the model relatively simple. Some ideas are:

- Make the GDP forecast more dynamic, so that GDP itself can respond negatively to grave imbalances.
- Add a political element, this way governments can directly exert influence over imports and exports within the model.
- Additional research into shared currencies and pegged currencies and what their effect is on trade imbalance.
- A feedback loop with the physical aspect of trade. Currently the model acts as the top financial layer that constrains the physical layer (trade in tonnes). This does not prevent physical impossibilities from happening within the model. It does not take scarcity of natural resources such as oil into account.

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ANNEX 1 – List of countries

1 United States
2 Japan
3 Germany
4 United Kingdom
5 China
6 France
7 Italy
8 Canada
9 Spain
10 Brazil
11 South Korea
12 India
13 Mexico
14 Russia
15 Australia
16 Netherlands
17 Turkey
18 Belgium
19 Switzerland
20 Sweden
21 Republic of China (Taiwan)
22 Saudi Arabia
23 Austria
24 Poland
25 Norway
26 Indonesia
27 Denmark
28 South Africa
29 Greece
30 Ireland
31 Finland
32 Iran
33 Portugal
34 Argentina
35 Hong Kong, PRC
36 Thailand
37 Venezuela
38 Malaysia
39 Israel
40 United Arab Emirates
41 Czech Republic
42 Colombia
43 Singapore
44 Chile
45 Pakistan
46 Hungary
47 New Zealand
48 Algeria
63 Croatia
64 Luxembourg
65 Cuba
66 Ecuador
67 Qatar
68 Slovenia
69 Angola
70 Oman
71 Belarus
72 Dominican Republic
73 Tunisia
74 Sudan
75 Guatemala
76 Syrian Arab Republic
77 Bulgaria
78 Lithuania
79 Serbia
80 Montenegro
81 Sri Lanka
82 North Korea
83 Lebanon
84 Costa Rica
85 Kenya
86 Turkmenistan
87 Cameroon
88 El Salvador
89 Uruguay
90 Cyprus
91 Côte d'Ivoire
92 Trinidad and Tobago
93 Latvia
94 Iceland
95 Panama
96 Yemen
97 Bahrain
98 Estonia
99 Jordan
100 Tanzania
101 Azerbaijan
102 Myanmar
103 Uzbekistan
104 Ethiopia
105 Ghana
106 Botswana
107 Jamaica
108 Brunei Darussalam
109 Bolivia
110 Bosnia and Herzegovina
125 Mauritius
126 Cambodia
127 Namibia
128 Republic of Congo
129 Chad
130 Bahamas, The
131 Republic of Macedonia
132 Burkina Faso
133 Malta
134 Mali
135 Madagascar
136 Nicaragua
137 Zimbabwe
138 Benin
139 Haiti
140 Papua New Guinea
141 Armenia
142 Niger
143 Guinea
144 Netherlands Antilles
145 Barbados
146 Moldova
147 Laos
148 Fiji
149 Swaziland
150 Somalia
151 Kyrgyz Republic
152 Tajikistan
153 Rwanda
154 Togo
155 Malawi
156 Mongolia
157 Mauritania
158 Lesotho
159 Central African Republic
160 Suriname
161 Sierra Leone
162 Belize
163 Cape Verde
164 Eritrea
165 Antigua and Barbuda
166 Bhutan
167 St. Lucia
168 Burundi
169 Maldives
170 Guyana
171 Djibouti
172 Seychelles

49 Nigeria	111 Uganda	173 Liberia
50 Romania	112 Gabon	174 Grenada
51 Philippines	113 Senegal	175 The Gambia
52 Egypt	114 Albania	176 St. Kitts and Nevis
53 Ukraine	115 Honduras	177 St. Vincent & Grenadines
54 Peru	116 Nepal	178 Comoros
55 Kuwait	117 Paraguay	179 Samoa
56 Bangladesh	118 Afghanistan	180 Vanuatu
57 Kazakhstan	119 Zambia	181 Timor-Leste
58 Morocco	120 Dem. Rep. of Congo	182 Guinea-Bissau
59 Vietnam	121 Equatorial Guinea	183 Solomon Islands
60 Slovakia	122 Macau	184 Dominica
61 Iraq	123 Mozambique	185 Tonga
62 Libya	124 Georgia	186 São Tomé and Príncipe

ANNEX 2 – Trade data smoothing algorithm

The pseudo code of this algorithm would be:

Input: all of the the time series from the Comtrade and Comext databases for a specific country-to-country flow

For each year, if there is more than one nonzero value available and the coefficient of variation of these nonzero values is smaller than *c*, mark that year as “accepted”

For each individual time series, fix the outliers unless they were already marked as “accepted”

Take the average of the individual time series

Output: the resulting time series

Put into words, the algorithm accepts the data in years where the available sources agree with each other (if there is more than one source). Then it checks each individual series for outliers, meaning values that lie more than *n* standard deviations from the mean, or values that exceed a certain growth limit *g* (both positive and negative growth: $[1/g]x_{T-1} < x_T < gx_{T-1}$). If found, it changes them to the closest acceptable value. Afterwards, it takes the average of the individual series to determine the final series.