DIPLOMARBEIT

Energy supply and demand in Europe

An agent based approach on competitiveness by modeling energy trade

Ausgeführt am Institut für

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unter der Leitung von

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durch

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Eidesstaatliche Erklärung

Hiermit versichere ich, die vorliegende Arbeit selbstständig und unter ausschließlicher Verwendung der angegebenen Literatur und Hilfsmittel erstellt zu haben.

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Abstract

Several political, economical and ecological factors have an impact on the attractiveness of business locations. Energy prices and security of supply are among the most important parameters and economies attempt to increase their competitiveness in particular through energy trade.

This work assesses energy trade between major global economies and investigates its impact on competitiveness from the perspective of the European Union. The first chapter presents the goals of European energy policy and the main drivers of energy prices with reference to literature from the European Comission and the OECD. In the second chapter a mathematical regression model is estimated from historical trade data. Finally the model is simulated for possible future scenarios.

Kurzfassung

Viele politische, ökonomische und ökologische Faktoren beeinflussen die Attraktivität von Wirtschaftsstandorten. Energiepreise und die Sicherheit der Versorgung gehören dabei zu den bedeutsamsten Kenngrößen. Insbesondere durch den Energiehandel versuchen Volkswirtschaften die Wettbewerbsfähigkeit ihrer Region zu erhöhen.

Diese Arbeit behandelt den Energiehandel zwischen globalen wirtschaftlichen Großmächten und untersucht die Auswirkungen auf die Wettbewerbsfähigkeit aus der Perspektive der Europäischen Union. Im ersten Kapitel werden die Ziele der europäischen Energiepolitik und die Einflussfaktoren auf Preise vorgestellt. Die Grundlage dafür bilden Studien der Europäischen Kommission und der OECD. Das zweite Kapitel präsentiert ein mathematisches Regressionsmodell des Energiehandels welches anhand historischer Daten ermittelt wurde. Abschließend wird dieses Modell für mögliche zukünftige Entwicklungen simuliert.

Danksagung

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Introduction

Energy is one of the main inputs in many industrial production processes. Consequently the availability and sustainability of domestic energy production and the resulting energy costs for household or manufacturing consumers play a major role in the international competitiveness of an economy. The necessity of energy imports required to cover total demand makes this topic a challenging one to assess. Europe in particular is a net importer of energy, a circumstance that increases its dependency from other countries and weakens its international position.

In addition, environmental issues arise that are a concern to policymakers and economists. To meet the goal of combining these needs with the business perspective, various ideas have to be included in the planning process. A deep and versatile understanding of interconnections of different factors and mutual influences is required to be able to make rational decisions.

The purpose of this work is to analyze historical trading behavior of Europe in energy matters and to investigate the main drivers of changes. This factors should be decomposed into monetary and real effects in order to distinguish between different causes. Finally a mathematical model should be derived that is able to explain past development but also offers possibilities to forecast different future scenarios.

This thesis pursues to answer the following questions:

- Which commonly available macroeconomic factors are necessary to describe bilateral trade flows between Europe and its main commerce partners?

- Whether and to which extent, this development is driven by real and nominal influences at national and international level?

- Which type of model could help to explain possible future evolution for various scenarios?

The goal is to find and present a well-specified model of energy trade. This task will be performed in two steps, namely a multivariate regression analysis on historical data and a simulation for assumed future values of exogenous variables. All econometric calculations will be performed with support from the econometric modeling software Eviews.

The envisaged results of this work are:

- A plausible explanation of trading behavior of Europe and the analysis of the variables that drive this development

- Comparison of different model possibilities and evaluation of their performances.

- A short term prediction (8 quarters) of possible future developments for different scenarios

Structure

This thesis is structured as follows:

The first chapter gives an overview over the situation in Europe by presenting the main goals of European energy policies, its impact on energy prices, development of renewable energy sources and the European trade balance.

The second chapter introduces the theoretical framework for developing a model of energy trade, describes the variables and the various approaches to link these into mathematical equations. This task is performed by multiple regression analysis over historical trade data and the appropriateness of these estimations is evaluated by back-testing. Subsequently four types of models with different levels of difficulty are presented.

These models are finally simulated into the future for three different scenarios in chapter three. The outlook of the different models is analyzed under varying assumptions of the exogenous variables. Possible developments and forecasts are presented.

Closing remarks and conclusions are summarized in the final chapter of this thesis.

Chapter 1

European Energy Situation

1.1 European Energy Policy

1.1.1 Goals

The global energy system is exposed to major challenges. The focus on long-term security and sustainability in particular should therefore be paramount for all economic decisions and measures undertaken by governments and political institutions. Energy consumption will increase over the next decades to satisfy the needs of growing populations and more production of the industry. Moreover energy-related CO_2 emissions will affect the balance of our ecosystem. Since many changes take not only a significant amount of time to implement, but also require longer transition periods to become effective, most of the discussions need to include a long-term orientation of the subject. Supply security impacts on energy prices and substantially the economical quality of an industrial site. With these concerns in mind, the world's leading economies do their best to develop and maintain a fruitful environment and supplement their international competitiveness.

The correct choice of the energy mix but also the energy trade balance are issues that warrant special consideration. A high import dependency has a negative impact on price stability and the global energy mix is dominated by fossil fuels. Therefore alternative energy sources must receive bigger attention in forthcoming years. Moreover these decisions must be amended by investments in domestic energy related infrastructure. Among those are suppliers, transporters, distributors and regulatory, financial and R&D institutions ([10]).

Consequently the OECD ([10]) follows the goals that can be summarized with the 3E's: energy security, economic development and environmental protection. For this purpose a greater diversity with respect to fuels, suppliers and sources is envisaged. The main focus is on coordinating relevant policy fields by realizing sustainable development strategies. The OECD suggests several good practices to address this issue, especially a common understanding of regulations and standards, governmental interventions with economic instruments, taxes and subsidies, the right investments in research and development and finally an adequate monitoring and evaluation of the practical implementation.

1.1.2 Impacts

The political decisions presented in the previous section obviously have an impact on energy prices. This section discusses how regulations and reforms may influence the competition on the global energy markets. A leeway for decision making purposes will be provided and policy determinants of energy prices will be identified. In the EU several strategical changes during the recent years have been made and implemented. The scope and effectiveness of this decisions will be investigated and confronted with empirical data.

These significant changes in policies in the EU were performed with the aim to maintain economic competitiveness, secure supply and prolong sustainability. The incentives undoubtedly reshaped energy markets and were primarily undertaken in these three areas: *market opening*, *renewables* *policy* and *climate change*.

Electricity and natural gas prices

An interesting observation that can be made is that retail prices in the electricity sector have risen much more than wholesale prices. This is alarming, because for the private or industrial consumer the price is the variable that matters most. A closer look on the average price changes among the EU Members shows clear evidence of this trend. Moreover, a decomposition into the tariff components demonstrates that this increase is justified with supernormal tax and levies rates. These rates increased by over 40 % for households and by over 65 % for industry between 2008 and 2011 ([6], [7]). This is a first indicator, that political interferences had been undertaken.

This figures must be interpreted with caution as they aggregate the development in the EU. A Separate evaluation, of all Member States reveals extremely heterogeneous performances during the observed period.

Moreover the tariff components shares in industry and household prices are not equally distributed: The household price consists mostly of taxes and levies whereas the industry price is mainly driven by energy and supply costs. Since national legislations are completely free in adopting such measures this varying development is explained by pursuing different objectives in industrial and social policy.

Similar to electricity prices the aggregated gas prices have been rising and the development is very heterogeneous among all Member States. The national governments were trying to satisfy different goals according to the national energy mix preferences.

Policy determinants of prices

Between 2004 and 2011 there have been two main changes in the European market philosophy. Firstly, the EU has started incentives to establish a market opening of electricity and gas markets. Secondly, reformation packages were drafted targeted to induce a shift to a low carbon economy.

In regard to the market opening, the biggest insufficiency is the varying degree of implementation of the envisaged changes. This lack of cooperation and egoistic behavior of some Member States is to some extend hindering to successfully realize a market-opening and to enhance a healthy competition. Without stricter sanctions, it may be difficult to ensure unhindered market functioning and minimize the costs of energy supply. The goal of the reforms is to make the price formation along the supply chain transparent and enable to lower wholesale prices from higher competition. The end-user price is formed by energy and supply costs, network costs and finally taxes and levies. As for now, the national governments are pursuing inconsistent intentions but more rigorous infringement procedures should help to ensure price equality over all Member States. When all reforms are fully adapted, only minimal cost differences should be reached which can be explained by varying transmission and distribution efforts. This development would also attract investors to fund projects in infrastructure where it is needed most with the result of lowering supply and network costs. As a consequence the consumer energy price would be affected in a positive manner.

The second type of political changes has a more ecological character. Here the aim is to induce a shift to a low carbon economy by the three 20%-goals. Firstly a 20% share of renewable energy sources in gross final production in 2020, secondly a 20% reduction in total EU greenhouse gas emissions from 1990 levels by 2020 and finally a 20% improvement in the EU's energy efficiency. Current estimations indicate that Europe is on track and will meet these goals by 2020 ([6]).

Price components

With this political background explained it is now possible to list the main components of retail electricity and natural gas prices ([6]):

- **Network costs**: the costs to transport electricity to the customers. They include the tariffs paid by suppliers to network operators for the use of their infrastructure
- **Energy costs**: the costs for purchasing and importation energy from external suppliers in the market. Also domestic generation and production is included here.
- **Taxes**: the costs set by legislations to pursue specific political goals
- **Retail costs and margin**: profits for entrepreneurs and industry

Carbon prices

The EU Members agreed to encourage a transition to a low carbon economy by 2020. In order to achieve that an market based instrument was used which should provide incentives to reduce emissions. This was supposed to lead to a carbon price that motivated investors to invest in clean technologies and minimize carbon emissions. In the following paragraphs the carbon price development, the carbon prize drivers and political framework is presented.

ETS - Emission Trading Scheme

The ETS is a market-based instrument that is supposed to regulate the carbon emissions because it internalizes CO_2 external costs. Through a cap and trade system the maximal level of emissions is set and then participants are allowed to buy and sell within these limits.

This procedure was executed in several phases. The first (2005-2007) was a learning process where Member States were encouraged to propose which quantities they would be intending to request. These numbers were brought into relation and first distributions were estimated. The second phase (2008-2012) was aimed to proof that the results of the first phase would meet the Kyoto commitments. Finally the third phase (2013-2020) is the current realization of the intended implementations that proved to function properly during the previous phases.

Drivers of prices

With the introduction of the ETS it was possible to investigate and define the main drivers of carbon prices. These prices depend mostly on economic and energy factors:

- **ETS cap**: this number fixes the supply of allowances
- **Economic growth**: a positive correlation between growth and carbon prices
- **Other Energy prices**: prices of oil, gas and coal also influence carbon prices as inputs may be substituted
- **Weather conditions**: Demand for heating and cooling
- **Institutional factors**: Political decisions influence expectations and behavior of market agents
- **Innovation**: Technological progress

The main conclusion is that the introduction of the ETS was the most cost-efficient way to reduce greenhouse gas emissions. The major weakness of this procedure of fixing and capping allowances made the carbon price more sensitive and responsive to demand factors.

1.2 Energy Costs and competitiveness

Energy costs

In order to compare energy costs, it is necessary to understand, that these costs are driven by two main factors. Firstly, the prices themselves may be subject to greater fluctuations but secondly the intensity of the usage of energy also may change over time. Therefore a combined consideration of both effects is needed.

Unit energy costs

The energy cost competitiveness is analyzed by introducing and discussing the concept of Unit Energy Costs (UEC). This indicator measures the energy cost per one unit of value added as it combines the key components: the value of energy inputs on the one hand and on the other hand the energy intensity.

Moreover it is required to distinguish between energy-related effects and nominal effects. As comparison takes place from a global perspective, one must not neglect the monetary fluctuations that may affect international competition and trade. In order to meet these demands, the UEC are decomposed into pure energy-related effects and macroeconomic developments as well. For this purpose two variables are defined: The Real Unit Energy Cost (RUEC) and the Nominal Unit Energy Cost (NUEC). These indicators are linked as follows:

$$NUEC = RUEC * \text{nominal effect} \tag{1.1}$$

The NUEC takes into account that prices are exposed to developments like exchange rate fluctuations and inflation differentials changes. Therefore it allows for a solid comparison among different isolated economies. On a global scale, as the NUEC is expressed in US dollars, in ensures a comprehensive understanding of the current market situation. Nevertheless, as many monetary forces may blur the specific developments in the energy sector, especially technological progress, it may be even more informative to analyze the RUEC indicator. This approach guarantees, that a qualitative discussion of the specific effects in the energy sector is possible. As mentioned above, the RUEC can be divided into two major parameters, which leads to the following equation:

$$NUEC = RUEC * \text{ nominal effect} = \tag{1.2}$$

$$= \text{real energy price } * \text{ energy intensity } * \text{ nominal effect} \tag{1.3}$$

The nominal effect is important from international competitiveness perspective, but to discuss energy-related effects it might be suitable to concentrate on the RUEC. In this way a detailed breakdown of energy inputs development and sensitivity to energy price shocks can be provided, as explicitly shown in Appendix A.

International comparison - aggregated perspective

The main actors of interest in all international comparisons are the following countries: USA, China, Russia and Japan. These global players will be put into relation to the aggregated EU member states. ([6], [16])

The first major conclusion is that the evolution and levels of energy costs are broadly similar across developed countries such as EU, US and Japan, but differ among developing countries such as Russia and China. A possible explanation for this fact is that in developed countries specialization towards high value added sectors explains similar prices. On the contrary, developing countries have more energy intensive production structures where energy inputs play a bigger role.

It also becomes evident, that not only the trend of the development differs, but also that the RUEC as a percentage of total value added as well as the gross output is nearly three times higher in Russia compared to the other countries. This is because energy intensive production structures are characterized by lower value added.

The second observation is the overall trend of RUEC increase in all compared economies. This might be an alarming sign of the rising importance of energy costs among the world industrial leaders. If no adaptations are made in the near future, this development may become an overwhelming problem for the manufacturing sector which is highly dependent on energy inputs.

International comparison - decomposition of RUEC

For a detailed analysis of RUEC the decomposition mentioned above into price and intensity levels can be performed. ([6], [7], [16], [15])

Starting with the price levels data shows that these are increasing among all economies. Moreover a rapid rise in prices in the US and Japan in 2008 can be noticed, what signals a higher sensitivity to oil prices of these two economies.

By observing the historical change of intensity levels it can be seen, that this indicator is decreasing for all considered countries. This signals a improvement in technology and production but also could be explained by a shift towards more energy efficient subsectors.

In addition comparing the annualized growth of EU and US reveals that both have been evolving almost similarly over the last few years.

International comparison - nominal effects

To take account for the monetary effects that may influence the relative prices, a confrontation of the NUEC and RUEC is beneficial. From the following table in figure 1.1 some interesting conclusions can be deducted.

	Real Energy Price	Energy Intensity	RUEC	Nominal effect	NUEC
EU27	6.12	-1.50	4.51	1.19	5.71
US	7.42	-2.51	4.72	0.01	4.73
JP	7.92	-1.07	6.76	-2.51	4.25
CN	8.24	-4.3	3.57	3.46	7.03

Figure 1.1: Decomposition of NUEC, average % annual change 1995 - 2009, Manufacturing [6]

Firstly, although the US was lagging behind Europe concerning the energy prices, it compensated this gap by a stronger performance in the intensity development. As a result the RUEC of EU and the US have been nearly identical over the considered period. Only the nominal effect has supplemented some additional pressure on the European countries which resulted in higher NUEC.

Secondly, Japan had to face the problem of high energy prices and a comparatively low improvement in intensity what led to a high RUEC. Nonetheless, due to the fact of internal deflation this trend was offset and consequently a respectable level of NUEC was reached.

Thirdly, China although not being blessed by low energy prices had the best performance in intensity betterments. With the lowest RUEC China might have benefited even more, if it was not for the sizable punishment by the nominal effect. For Chinas misfortune these macroeconomic dynamics have added significant pressure on the economy.

Shale gas and its impact on EU competitiveness

After the recent financial crisis the major world economies reacted differently to the arising challenges of increasing energy costs. The shale gas development in the US serves as a good example to show how miscellaneous policies can impact the global energy market and influence its participants. In the following paragraphs the resulting differences between EU and US in energy production, trade balance, import dependence, price gap and energy intensity are presented.

The effect of shale gas should not be overestimated, although as according to data ([6], [5]), the share of shale gas in the natural gas production has significantly risen. However it remains noteworthy that shale gas has revitalized the domestic natural gas sector which was struggling and had a historic low in 2005 and the exponential growth of production made the US the biggest gas producer in the world by 2011. Moreover the share of renewable energy sources as well as natural gas in the total energy mix of the US has increased.

Since both of these sources are produced mostly by domestic suppliers, this trend helped to reduce the energy dependence of the US. But it also becomes evident, that this decrease started in 2005 what cancels out the shale gas production as the major contributor to this effect. Europe on the contrary has become more and more dependent on energy imports during the last years. On the one hand this can be explained by a decline of domestic production with a simultaneous increase of consumption, but on the other hand the recoverable reserves of shale gas in the EU remained untouched. According to data ([6], [5]) Europe has 13,4 % of the estimated worldwide technically recoverable shale gas resources. Of this amount France (3,9 %) and Poland (4,2 %) account for the major part.

Comparison of gas and electricity prices in EU and US

Europe is therefore exhibited to the risk of high import dependency and is vulnerable to price changes. A closer look on the world gas market gains additional insight into this topic: In Europe the majority of natural gas is supplied through bilateral long-term contracts. To the disadvantage of Europe, the Asian markets offer higher returns and more robust demand what attracts the attention of the major suppliers and tempts them to penetrate these markets. Consequently, this drives European prices up.

US however can rely to a greater extent on domestic production and additionally the prices are protected by stricter export restrictions of energy. Since gas may be also used as a primary energy source for electricity generation, a similar, though not so manifest trend in the electricity prices can be observed ([6], [11]).

Comparison of electricity intensity in EU and US

As a consequence of the relatively higher energy prices in the EU, the European industry had an incentive to improve their productivity. In the US however, the high domestic supply with cheap energy did not initiate such a trend. As long as the high production of shale gas does provide industry with affordable energy, it is difficult to predict if improvement of technology and lowering of input costs will be attracted. Data ([6], [7]) shows, that not only the improvement of the energy intensity of industry has been bigger over 2001 - 2010 (EU: -19 %, US: -9 %), but also the total amount is about four times higher in the US than in the EU.

Comparison of trade in EU and US

Since the shale gas revolution the US managed to became self-sufficient in domestic gas consumption. Consequently the demand of oil and coal has sunk what affects the trade balance in a positive way. When compared as a fraction of the GDP Europe has a negative and decreasing trade balance of -3.5 % in 2012, whereas US is aiming upwards with almost -1.5 % in 2012.

The EU's trade deficit has increased, because Europe is more dependent on foreign suppliers. If no sufficient political measures are undertaken, Europe may drift into serious trouble and loose its competitiveness. A blind reliance on the energy intensity improvements that were responsible for evening out the disadvantages during recent years may turn out to be a hazardous venture.

One political factor that must be taken into consideration is that the US-EU price gap may be significantly reduced when shale gas manufacturers in the US would be forced to internalize all external costs on the environment and human health what currently is not the case. The controversial production of shale gas may then loose its attractiveness and profitability.

1.3 Renewables and competitiveness

Since 2007 Europe enhanced its efforts to accelerate the expansion of green technologies. This market gives a great opportunity for growth and jobs. It provides security of supply, lowers the dependence on foreign suppliers and increases diversification. Additionally greenhouse gas emissions are reduced. This chapter discusses how this development affected competitiveness especially with respect to European trade developments and the avoided fuel costs.

Evolution of renewables

Between 2000 and 2011 the share of renewable sources in gross electricity generation in the EU grew by 50% ([6], [7]). This trend is observable in all Member States, although it is characterized by different shares of energy sources. The growth varies for different energy types and for different countries. One explanation for this situation is, that smaller countries find it harder to develop a profitable production because of economics of scale associated with renewables.

Hence it is not surprising, that larger European countries have provided more incentives to shift domestic production to renewable sources. Germany, France and Italy are among the pioneers of this development. Various political arrangements were undertaken to invite investors to contribute to the constructions of the production facilities. The most common support schemes are: *feed-in tariffs*, *feed-in premiums* and *green certificates* ([6]).

These instruments help to compensate for the higher costs of renewable energy sources and firms are able to have similar rates of return as with conventional energy sources. The subsidies counter undesirable market failures as: positive externalities of renewables such as avoided green house gas emissions and pollution, huge fixed investment costs, contribution to technological progress and decreased long-term generation costs.

As a result, these economies who were willing to support domestic production of renewables have the highest combined share of wind and solar power in electricity generation. The subsidies are considered to be effective ([6], [7], [4]).

In a global comparison it becomes evident that there is a global expansion of renewable electricity. The global production nearly doubled between 2000 and 2010. China (+245%) is the major growth market, but the EU (+62%) comes in second place according to growth rates. As a consequence China has managed to establish its leading position as the worlds largest producer of green electricity.

This numbers are however very unequal with respect to the different energy sources. There seem to be favorite types of renewables for every region ([6], [5]).

Impact on competitiveness

Trade balances and innovation

An expansion of renewables impacts on the trade performance and competitiveness in two ways. On the one hand through the trade performance of renewables equipment and components, on the other hand via the role of innovation.

Increasing trade flows in components were observed during the last years. Especially noticeable is the fact that EU's trade flows were very unsymmetrical: For solar components the imports are predominantly from China whereas the exports are more diversified. Wind components however are mainly considered an export good and a trade surplus was generated ([6], [7]).

Secondly, with regard to the innovation it can be said, that the EU was a pioneer in most renewable industries. The number of patents measures the degree of innovation. The data shows clear evidence of the fact that EU is a precursor in green economy and Germany is the main contributor ([6], [11]).

Competitiveness indicators

International competitiveness is assessed using two indicators: **RCA** - revealed comparative advantage and **RTB** - relative trade balance. They are defined as follows ([6]):

The RCA index compares the share of the solar and wind sector exports in the EU's total goods exports with the share of the same sector's exports in the total world's exports. In formulaic terms this can be written as:

$$\mathrm{RCA}_i = \frac{\frac{x_{e,i}}{\sum_i x_{e,i}}}{\frac{x_{w,i}}{\sum_i x_{w,i}}} \tag{1.4}$$

where

$$\mathrm{RCA}_i \ldots \text{Revealed Comparative Advantage index of good i}$$
$$x_{e,i} \ldots \text{Value of EU's exports of good i}$$
$$\sum_i x_{e,i} \ldots \text{Value of EU's total exports}$$
$$x_{w,i} \ldots \text{Value of world's exports of good i}$$
$$\sum_i x_{w,i} \ldots \text{Value ofworld's total exports}$$

The final index is calculated by taking the average of the indizes from the last fives years. An RCA index higher than 1 suggests that there is a comparative advantage of the EU in comparison to the world economy.

The RTB index measures the trade balance relative to the total trade in the sector and is defined as:

$$\mathrm{RTB}_i = \frac{x_i - m_i}{x_i + m_i} \tag{1.5}$$

where

$$\mathrm{RTB}_i \ldots \text{Relative Trade Balance index of good i}$$
$$x_i \ldots \text{Value of exports of good i}$$
$$m_i \ldots \text{Value of imports of good i}$$

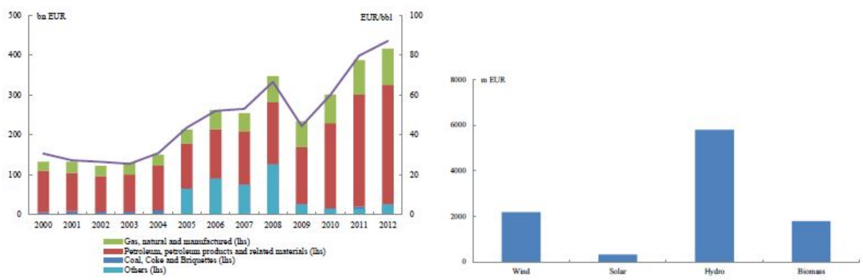
It ranges between -1 and 1 and is used for comparisons across countries and time.

By calculating these indizes for the main economies it is revealed that EU and US do not have comparative advantages in the solar industry. Chinas RTA however is over three times higher what signals activity and strength. In the wind industry the tables are turned and the EU performs best of all considered countries. Japan is strong in both industries ([6], [3]).

This situation is clearly visible when the trade balances of the solar and wind industry are taken into account. It is no surprise that the EU has performed worse in the solar and managed to improve in the wind industry. On most markets these two renewables sectors have benefited from recent support. Only the US has negative trade balances what again can be explained by the above average domestic shale gas production ([6], [3]).

Trade Balance and avoided fuel costs

One beneficial aspect of the intensified use of renewables was the positive impact on the EU trade balance. The EU is a net importer of energy and is traditionally struggling with its dependency from foreign suppliers. A goal must be to reduce the imports and thus the negative trade balance. Over the last years, the trade deficit was increasing. It is observable, that there seems to be a connection between the crude oil price which ban be explained by two arguments. Firstly oil has a high share in energy imports (63%) and secondly import prices of gas are often indexed to oil prices.



(a) EU Trade deficit in energy products and crude oil prices

(b) Avoided imported fuel costs

Figure 1.2: Trade deficit and avoided fuel costs [6]

This trade deficit increase was partially countered by the stronger use of green energy sources which are mainly produced within EU boarders. This effect can be seen by the calculation of avoided fuel costs. Because of renewable electricity Europe saved over 2000 mEur thanks to wind energy, over 6000 mEur thanks to hydro energy and over 2000 mEur thanks to biomass energy of imported fuel costs ([6], [7]).

This connetion between the trade deficit and the crude oil price serves as motivation for the choice of trade data presented in the model of the next chapter and listed in Appendix B.

Chapter 2

The Model

2.1 Framework

The science and art of building appropriate models for economic evaluations is covered by various scientists of different disciplines. Several approaches are suggested in order to create a satisfactory result. There is general consent in the literature that model building consists mostly of intuitive judgment and there are no clear rules for developing a model (Pindyck et al. [12]). Therefore only suggestions and recommendations can be made that result in widely divergent approaches taken by model engineers. However, a fact that is commonly accepted by scientists, is the usefulness of the combination of economic and statistical theory that merges in the econometric approach.

2.1.1 The econometric approach

According to Intriligator ([8]) econometrics is the field of science trying to explain economic relationships with empirical estimations. The main goal is to combine economic and statistical theory and evaluate relevant empirical data in an econometric model. As a result three different lessons can be drawn: structural analysis of the problem, forecasting of results, policy evaluation of interaction possibilities. Figure 2.1 summarizes the

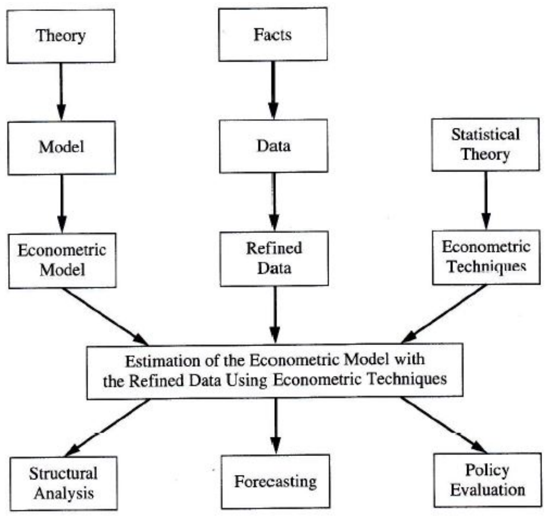


Figure 2.1: Econometric approach according to Intriligator [8]

econometric approach.

As can be seen in the graph the first ingredient is the theory of the problem and the most practical use is in form of a model. The goal here is to find a compromise between a realistic explanation of the problem and a simple enough and therefore handily practical solution. At first the model variables that explain the modeled phenomena need to be defined and next these variables must be put into relation in form of mathematical equations.

The next ingredient is a set of facts in form of empirical data. This data must be critically analyzed to filter out the relevant material that explains the underlying problem at best. Suitable data forms and sources need to be considered to make the outcome as realistic as possible.

The final component is the mathematical field of statistics with which help the first two ingredients can be combined and calculations can be made. Here statistical methods are taken into use with the goal to estimate the parameters of the modeled equations.

These three parts put together form the econometric model from which the following conclusions can be drawn.

Firstly, the structural analysis is used to analyze the economic relationships. With its help possible rival theories can be tested and evaluated. Being forced to formulate a concrete model of the problem helps to understand the reality and to question existing beliefs.

Secondly, forecasting is used to predict future values of variables and allows for foreseeing trends and risks of different scenarios.

Thirdly, policy evaluation helps to identify the best course of action and to select the most appropriate out of different policies. Whenever there are rivaling possibilities it is useful to estimate their outcomes. Hence many alternatives can be tested and the most suitable can finally be realized.

2.1.2 Draft of the model

The purpose of this work is to discuss the competitiveness of the European Energy Market by covering the trading behavior of Europe with its main trading partners. In order to achieve that goal, specific data is collected from different sources and afterwards econometric analyses on this data are performed to find significant relationships between different variables. From thereby derived interconnections some observations can be made and interpreted.

Since the agents of this model are different economies, some extent of heterogeneity must be taken into consideration. Although it is desirable to construct a model that is uniform for arbitrary trading partners this assumption may turn out to be too utopian and therefore inconsistent and unsupported by existing data. This situation is unproblematic, because according to Brillet different cases can be considered and differences in the specifications can be allowed [2]. The author suggests that the sub-models may be even completely different with the only restriction that they must be able to function together. If the intersections of the models work appropriately, no further limitations are necessary. However differences in a lesser extent are also acceptable. It is perfectly reasonable to use the same equations for sub-models that are only unequal in the coefficients. This case is especially applicable for this model, since trading behavior is most likely to be influenced by similar variables but with varying degree for different countries. Another consideration that must be taken into account is the influence of seasonality, therefore sub-models may differ with respect to this impact.

2.1.3 Agents and Model Structure

As this model is based on the report of the European Comission similar agents are taken into account as in this paper ([6]). Therefore interaction will take place between the EU, the US, the Russian Federation, Japan and China.

The goal is to explain trade between these countries, with specific focus on Europe and hence its competitiveness. Therefore the model can be roughly symbolized by the following figure 2.2 where the arrows represent trade flows.

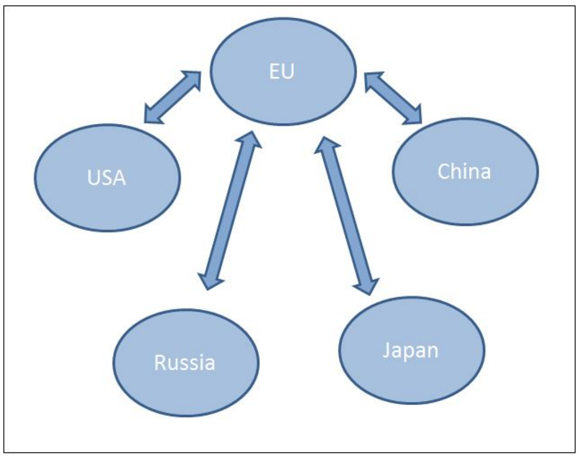


Figure 2.2: Model Structure

In order to explain these trade flows equations will be estimated to analyze by which factors recent and thus probably also future developments are influenced. To derive first insights and to get an intuition for the trends between concrete partners a data analysis is performed. All Variables are summarized and explained in Appendix C.

2.1.4 Data analysis

Since there is no existing unique prescription on how to connect the existing variables, most of the model equations are estimated from data analysis. Therefore in the next section all used variables and data sources are explained and also motifs for specific choices of equations are discussed.

The data is taken from common and freely accessible databases as the OECD (The Organisation for Economic Co-operation and Development) Database [11] and UN Comtrade Database (United Nations) [3].

The OECD Database was used to access the general macroeconomic data. From the National Accounts section GDP calculations by the expenditure approach were taken for all countries. The Financial Section provided the currency exchange rates and the Prices and Purchasing Power Parities Section provided the inflation rates.

The COMTRADE Database was used to access historical trading data between countries. This data is collected on the basis of reports of importing and exporting countries and is divided into many different categories according to specific categorizations. The Harmonized Commodity Description and Coding System (HS) is an internationally standardized system used to classify traded products. For the purpose of this analysis trade data from chapter 27 was used which summarizes all trades in the category "Mineral fuels, mineral oils and products of their distillation; bituminous substances; mineral waxes". Further details and a full list of this data is provided in Appendix B.

It is important to mention that the matching trades do not correspond for two reasons. Firstly, the database is based on explicit reports made by both countries therefore this numbers of imports in one category reported by one party need not necessarily coincide with the same exports mentioned by the other country. Secondly, what accounts for the majority of the difference is that both countries report on a different basis. Imports are reported on the basis of Cost, Insurance and Freight (CIF) while exports are reported on a Free on Board (FOB) basis, therefore imports values are usually higher and the difference might be regarded as trading and transportation costs. As a result these values differ depending on the perspective of the trader. To take this fact into consideration all data was regarded from the point of view of the EU and for the purpose of consistency in all cases the EU was taken as the reporting country.

GDP

To take the growth of the economies and the resulting rising energy needs into account data of the quarterly GDP of all countries was taken from the OECD Database [11]. Chinese data is not available on a quarterly basis and had to be estimated. All numbers are in millions of US Dollars.

Monetary effects

To consider monetary-driven influences data on the currency exchange rates and inflation rates of all economies was taken from the OECD Database [11]. The exchange rates are in quantity quotation of US Dollars which means the price of foreign currency equivalent to 1 USD.

The second monetary effect whose impact on trade behavior shall be estimated is inflation. For this purpose a dataset of consumer prices from the OECD database [11] is taken. Data is indexed to the year 2010 and includes the price change of all consumption items.

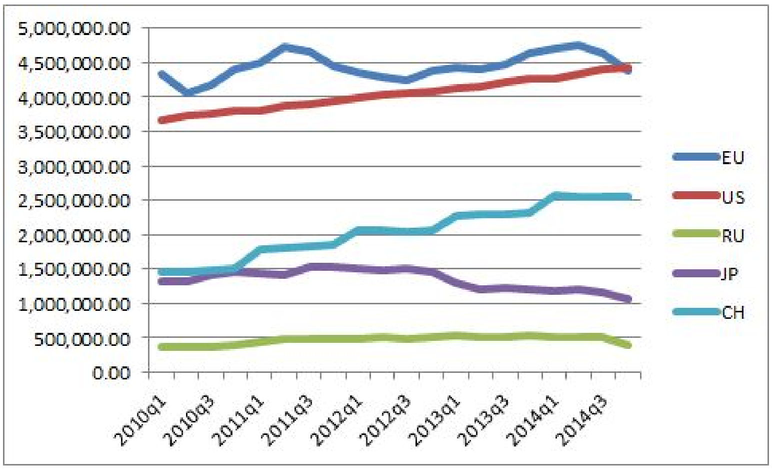


Figure 2.3: GDP in millions of US Dollars

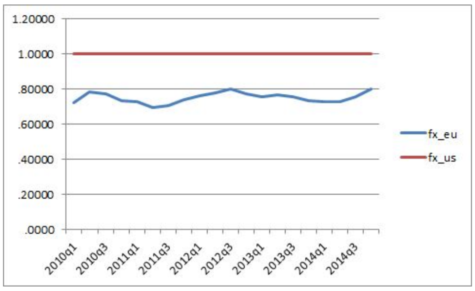
Trade Data

All trade data used in this analysis was retrieved from the COMTRADE Database [3] and is presented in US Dollars. Since the database provides the numbers either in annual or monthly periodicity, it was aggregated to a quarterly basis. Missing data points were estimated as averages of the previous years.

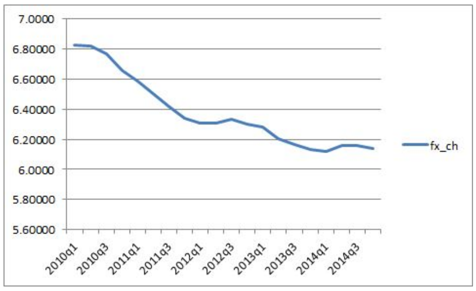
The most impressive comparison is the total European trade balance. Since total imports exceed total exports by far, Europe is a net importer and has a very high energy dependency. What is also very relevant in this context is the fact, that most of this imports can be attributed to Russia. The main exporting partner however is the US. Japan and China contribute comparatively negligible amounts both in imports and exports. However a high fluctuation is observable and can be linked to seasonal changes.

2.1.5 Mathematical methods

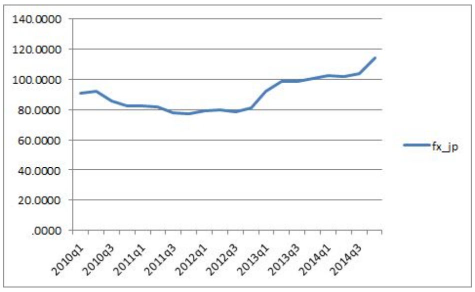
In order to build the model mathematical tools of regression analysis are used. Most of the following procedure is taken from Backhaus et al [1] and



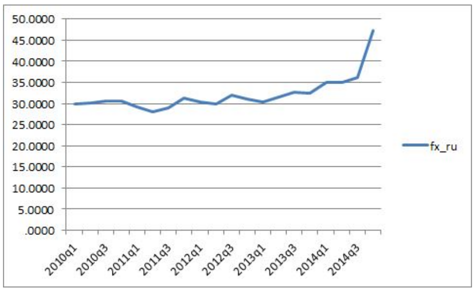
(a) Euro and Dollar



(b) Chinese Renminbi



(c) Japanese yen



(d) Russian ruble

Figure 2.4: Exchange rates

Pindyck et al [12].

Problem formulation

Regression analysis helps to determine connections and interactions of one dependent variable Y with one or more independent variables $X_1, \ldots, X_J$. Each of the variables may include up to K observations, thus for all i: $X_i = (x_1, \ldots, x_K)$. The goal is to to describe and explain dependencies and to estimate and predict values of Y.

A formal formulation of this problem can be represented by the following equation:

$$Y = f(X_1, X_2, \ldots, X_J) \tag{2.1}$$

which in the linear case might also be written as:

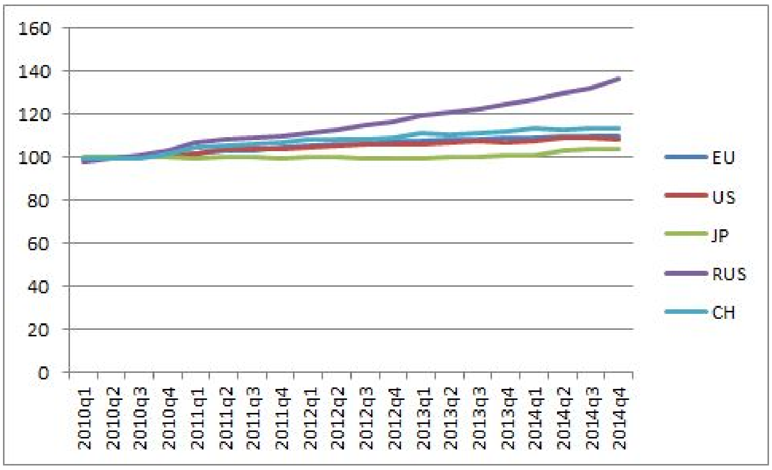


Figure 2.5: Consumer Prices - all items, Index = 2010

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_J X_J \tag{2.2}$$

where β_i is the i-th *coefficient* or *regression parameter* and especially β_0 is the *intercept* of the equation.

Solution

The aim of the regression is to find coefficients β such that the quadratic error term ϵ is minimized. This procedure is called Ordinary Least Squares (OLS) estimation and can be formalized by:

$$min_{\beta_i} \sum_{k=1}^{K} [y_k - (\beta_0 + \beta_1 x_{1k} + \beta_2 x_{2k} + \dots + \beta_J x_{Jk})]^2 \tag{2.3}$$

Model

Since in most practical cases the linear estimation will not perfectly describe all values of Y, finally a model can be formulated.

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_J X_J + \epsilon \tag{2.4}$$

Assumptions

In order to be allowed in the model the variables and error terms must fulfill several assumptions (Pindyck et al. [12]) :

i. The model specification is given by equation (2.4)

ii. The X's are nonstochastic

iii. $\epsilon \sim N(0, \sigma^2)$ and uncorrelated

2.2 Specific Case

2.2.1 Model idea

The main idea behind this model is to describe the historical trade flows by the corresponding development of the other variables. Since the observations in the first chapter suggest to decompose total effects into real and nominal factors, the goal in the following sections is to find such relationships and link them into equations. To test the reliability and credibility of these equations tools of regression analysis will be used to examine how they perform when confronted with historical data. When the results prove to be plausible, simulations and forecasts can be made to predict future developments.

2.2.2 Variables

This section is also summarized in Appendix C

Trade

Both imports and exports are examined, therefore for both flows variables are needed and will be specified by ${}_eIMP_i$ and ${}_eEXP_i$. Here e and i denote the exporting country and the importing country respectively, hence $e, i \in \{EU, US, RU, JP, CH\}$.

Total energy imports to the EU are denoted by $TIMP_{EU}$ and are the sum of all imports from other countries:

$$TIMP_{EU} = {}_{US}IMP_{EU} + {}_{RU}IMP_{EU} + {}_{JP}IMP_{EU} + {}_{CH}IMP_{EU} \tag{2.5}$$

Analogously total exports are denoted by ${}_{EU}TEXP$ and are calculated by summation of all exports.

$${}_{EU}TEXP = {}_{EU}EXP_{US} + {}_{EU}EXP_{RU} + {}_{EU}EXP_{JP} + {}_{EU}EXP_{CH} \tag{2.6}$$

Real Effects

The real effect will be covered by the evolution of the GDP in the trading economy. This variable will be denoted by GDP_c where c stands for the country and therefore $c \in \{EU, US, RU, JP, CH\}$

In a more sophisticated form of this model also the ratios of GDP to total trade will be introduced: $\frac{GDP}{{}_{EU}TEXP}$ and $\frac{GDP}{TIMP_{EU}}$.

Nominal Effects

The monetary influence will be examined by introducing variables such as Inflation INF_c and Foreign Exchange Rate FX_c where c stands for the country and therefore $c \in \{EU, US, RU, JP, CH\}$

2.2.3 Equations

Since the focus lies on finding relationships for European competitiveness represented by the trading behavior the main endogenous variables will be ${}_{e}IMP_{EU}$ and ${}_{EU}EXP_{i}$ for $e, i \in \{US, RU, JP, CH\}$.

The basic structure of the equations will take the form

$$\begin{aligned} {}_{e}IMP_{EU} = &\beta_0 + \beta_1 TIMP_{EU} + \beta_2 GDP_{EU} + \beta_3 GDP_e + \\ &\beta_4 FX_{EU} + \beta_5 FX_e + \beta_6 INF_{EU} + \beta_7 INF_e \end{aligned} \tag{2.7}$$

and

$$
\begin{aligned}
{}_{EU}EXP_i = &\beta_0 + \beta_{1EU}TEXP + \beta_2 GDP_{EU} + \beta_3 GDP_i + \\
&\beta_4 FX_{EU} + \beta_5 FX_i + \beta_6 INF_{EU} + \beta_7 INF_i
\end{aligned}
\tag{2.8}
$$

and will be adapted if comparisons of data and statistical tests suggest so.

2.2.4 Summary

To summarize, the goal is to find eight equations which describe the trade flows between Europe and its main trading partners.

The first tests will be performed on equations (2.7) and (2.8). If necessary, changes and adaptations will be made by adding or removing variables and by changing functional forms. It is desirable to characterize bilateral trade in the best way and afterwards to discuss how these patterns differ among various countries. Moreover influences of factors are to be found that may not seem obvious at first glance.

2.3 Model estimation

2.3.1 General procedure

All estimations and econometric analyses are performed with the help of the software Eviews. This software allows for direct calculations for comfortable use, but is also capable of more sophisticated procedures. In order to conduct all tests in a holistic approach an Eviews-program was written that supports automatic testing. This so called *Rolling Regression Analysis* provides for all contingencies as it permutes all possible combinations of explanatory variables to find the best regression of the endogenous variable.

The idea behind this program is as follows and can be explained by regarding equation (2.1). For one endogenous variable Y it is desired to select k exogenous variables $X_1, \ldots, X_k$ from all n considered variables as in chapter 2.2.2 such that these k variables describe the evolution of Y. These k regressors can be inserted in equations (2.7) and (2.8) that thenceforward serve as the model equations. In total $\binom{n}{k}$ regression outputs are to be calculated and compared.

The program performs all possible least square regressions on the given data and then provides the coefficients, corresponding t-statistics and the value of the coefficient of determination R^2 as an output. By further manual analyses on these results the best regressions with statistically significant coefficients can be found.

Moreover, to achieve superior results, this procedure can be repeated for different values of k. In this way more or less complicated models can be estimated and compared. Additional insights can be gained by exploring how much improvement in terms of R^2 an inclusion of more and different explanatory variables imply.

A full example of this program is provided in Appendix D.

2.3.2 Systematic approach

The estimation was performed with a varying degree of assumptions. As a consequence more or less complicated relationships between the variables could be calculated that resulted in more or less sophisticated models. In general, all tests can be summarized into 4 categories:

(i) **A1 Basic approach:** This fundamental approach considered only the GDPs, Foreign Exchange Rates and Inflation Rates of both trading countries. By adding a constant C, this results in 7 exogenous variables.

(ii) **A2 Basic approach with seasonal adjustments:** In addition to the variables of the basic approach, seasonal dummy variables were introduced to account for quarterly fluctuations.

(iii) **A3 Advanced approach:** This more sophisticated approach included the 7 variables of the basic approach, but also considered Total Exports, Total Imports and ratios of GDP to Total Trade. This definition should analyze the relationship between bilateral trade and total demand or total supply respectively. In total 12 variables were tested.

(iv) **A4 Advanced approach with seasonal adjustments:** The advanced approach was extended by adding seasonal dummy variables.

All equations have been estimated using the 16 observations from 2010Q1 to 2013Q4. Since data was available until 2014Q4 the remaining 4 datapoints were used for back-testing to measure the quality of the regressions. The results of these estimations are summarized in the following chapters.

2.3.3 Export

US

The goal was to find an equation for the exports from EU to the US denoted by ${}_{EU}EXP_{US}$ and represented by a modification of following formula:

$$\begin{aligned} {}_{EU}EXP_{US} =& \beta_0 + \beta_{1EU}TEXP + \beta_2 GDP_{EU} + \beta_3 GDP_{US} + \\ & \beta_4 FX_{EU} + \beta_5 FX_{US} + \beta_6 INF_{EU} + \beta_7 INF_{US} \end{aligned} \tag{2.9}$$

A regression analysis performed on this data for all types of models described in chapter 2.3.2 delivered estimations of the coefficients and measured the quality of the regression. Not surprisingly the coefficient of determination (R^2) is increasing when more sophisticated models are used. It is evident, that the basic model (A1) with $R^2 = 0.30$ only manages to follow the general trend of the time series and fails to represent the fluctuations. The more sophisticated models (A3 and A4) are more appropriate to replicate the actual trend, a fact that is characterized by high values of $R^2 = 0.83$ and $R^2 = 0.92$. No significant relationships could be found for tests with A2.

Figure 2.6 compares the actual trade flows to the estimations derived from the models. Although the models are differently suitable for describing past data (2010-2013), all delivered satisfactory results when confronted with data from 2014 that was excluded from the estimations. As a conclusion, all three equations could be used to predict future trends. See figure E.1 for more details on the regression.

A1:

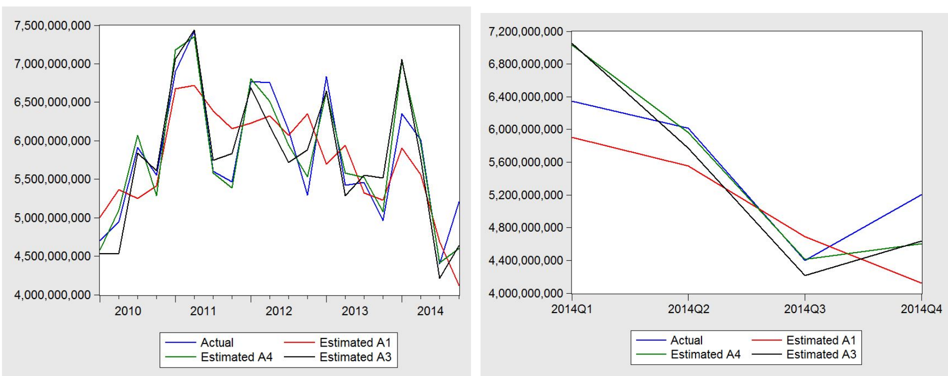
$$\begin{aligned} {}_{EU}EXP_{US} &= 9812.5\ GDP_{EU} - 15966.9\ GDP_{US} - \\ &2.9 * 10^{10}\ \frac{1}{FX_{EU}} + 6.2 * 10^{8}\ INF_{EU} \end{aligned} \tag{2.10}$$

A3:

$$ {}_{EU}EXP_{US} = -9.4 * 10^{12}\ \frac{GDP_{EU}}{{}_{EU}TEXP} + 9 * 10^{9}\ \frac{1}{FX_{EU}} \tag{2.11}$$

A4:

$$\begin{aligned} {}_{EU}EXP_{US} &= 1900.9\ GDP_{EU} - 8.63 * 10^{12}\ \frac{GDP_{EU}}{{}_{EU}TEXP} - \\ &- 8.6 * 10^{7}\ INF_{US} + 1.22 * 10^{10}\ q_1 + \\ &1.24 * 10^{10} q_2 + 1.21 * 10^{10} q_3 + 1.17 * 10^{10} q_4 \end{aligned} \tag{2.12}$$



(a) 2010 - 2014

(b) Detail on 2014

Figure 2.6: Estimation of exports from EU to US

Russia

Similarly an equation for the exports from EU to the Russian Federation denoted by ${}_{EU}EXP_{RU}$ was derived:

$$\begin{aligned} {}_{EU}EXP_{RU} = &\beta_0 + \beta_1 {}_{EU}TEXP + \beta_2 GDP_{EU} + \beta_3 GDP_{RU} + \\ &\beta_4 FX_{EU} + \beta_5 FX_{RU} + \beta_6 INF_{EU} + \beta_7 INF_{RU} \end{aligned} \tag{2.13}$$

Regression analysis shows that the basic model (A1) is capable to explain a general trend of the series with $R^2 = 0.40$. Inclusion of total trade variables and GDP to trade ratios in the A3 model helps only to improve the explanations to some extent and results in $R^2 = 0.45$. Only after addition of seasonal considerations a major betterment of the correlations is observable. See figure E.2 for more details on the regression.

A comparison of calculated and actual values for 2014 shows that all three models are suitable for explaining the future development. Although the differences are bigger than in the case of the United States and especially the most sophisticated model overestimates the fluctuations, a general convergence towards the last data point is visible. On the other hand the actual values of exports to Russia in 2014 changed radically in comparison to previous years what might explain the deviations in the models.

A1:

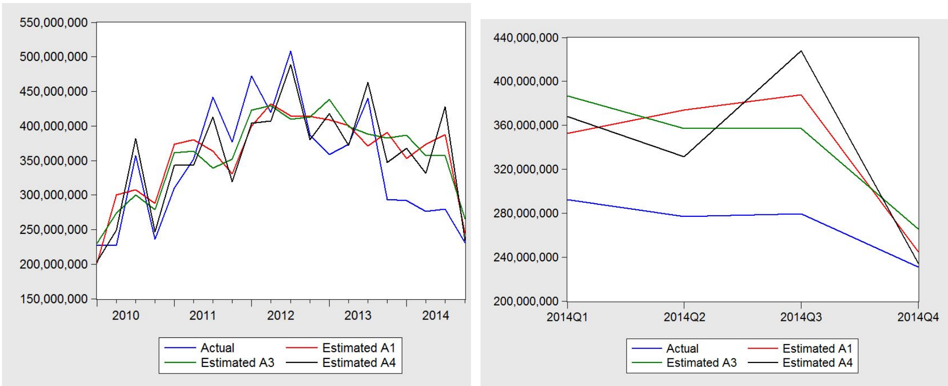
$$\begin{aligned} {}_{EU}EXP_{RU} = &\ 646.8\ GDP_{EU} - 2.55 * 10^9 \frac{1}{FX_{EU}} + \\ &+ 2.78 * 10^{10}\ \frac{1}{FX_{RU}} \end{aligned} \tag{2.14}$$

A3:

$$\begin{aligned} {}_{EU}EXP_{RU} = &\ 6.67 * 10^{12}\ \frac{GDP_{RU}}{{}_{EU}TEXP} + \\ &+ 391565.6\ \frac{{}_{EU}TEXP}{GDP_{EU}} - 7.1 * 10^8\ C \end{aligned} \tag{2.15}$$

A4:

$$
\begin{aligned}
{}_{EU}EXP_{RU} &= 6.43 * 10^{12} \frac{GDP_{RU}}{{}_{EU}TEXP} + 398724.9 \frac{{}_{EU}TEXP}{GDP_{EU}} \\
&- 7.28 * 10^{8}\ q_1 - 7.29 * 10^{8}\ q_2 \\
&- 6.27 * 10^{8}\ q_3 - 7.37 * 10^{8}\ q_4
\end{aligned} \tag{2.16}
$$



(a) 2010 - 2014 (b) Detail on 2014

Figure 2.7: Estimation of exports from EU to Russia

Japan

The exports from EU to Japan are represented by the following equation:

$$
\begin{aligned}
{}_{EU}EXP_{JP} =& \beta_0 + \beta_1 {}_{EU}TEXP + \beta_2 GDP_{EU} + \beta_3 GDP_{JP} + \\
& \beta_4 FX_{EU} + \beta_5 FX_{JP} + \beta_6 INF_{EU} + \beta_7 INF_{JP}
\end{aligned} \tag{2.17}
$$

In this case all different approaches (A1-A4) yielded in acceptable results. Since exports to Japan are characterized by strongly varying seasonal behavior the estimations in both models A1 and A3 were improved by the addition of dummy variables. The basic model describes the rough movement of the time series with a R^2 of 0.25 that can be increased up to 0.6 by inclusion of the seasonal fluctuations. Since the best outcome for A2 consisted of the same basic variables as A1, the comparatively low p-values of some coefficients can be neglected. This problem does not occur in the sophisticated model, since the consideration of the dummy variables achieved to rise the R^2 value from 0.44 to 0.58 without overwhelmingly decreasing the significance of the coefficients. See figure E.3 for more details on the regression.

A forecast based on a sample from 2010Q1 to 2013Q4 resulted in a similar outcome as in the Russian case. The values for the first quarters of 2014 are far apart, but towards the end the estimated series converges to the actual values. Thus, these models may prove to be suitable for general estimations.

A1:

$$ {}_{EU}EXP_{JP} = 390.29\ GDP_{EU} - 1.20 * 10^9 \frac{1}{FX_{EU}} \tag{2.18} $$

A2:

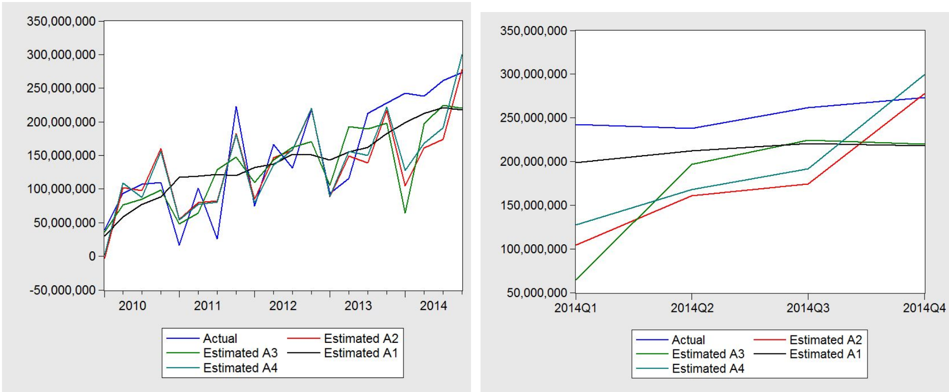
$$ \begin{aligned} {}_{EU}EXP_{JP} = &\ 239.62\ GDP_{EU} - 1.09 * 10^9 \frac{1}{FX_{EU}} \\ &+ 4.67 * 10^8\ q_1 - 5.16 * 10^8\ q_2 \\ &+ 5.08 * 10^8\ q_3 + 5.86 * 10^8\ q_4 \end{aligned} \tag{2.19} $$

A3:

$$ \begin{aligned} {}_{EU}EXP_{JP} = &-0.19\ {}_{EU}TEXP + 861.97\ GDP_{JP} \\ &- 5.49 * 10^{12} \frac{GDP_{JP}}{{}_{EU}TEXP} \\ &+ 13058471\ INF_{EU} \end{aligned} \tag{2.20} $$

A4:

$$ \begin{aligned} {}_{EU}EXP_{JP} = &\ 0.19\ {}_{EU}TEXP - 1.33 * 10^9 \frac{1}{FX_{EU}} \\ &- 912973\ \frac{{}_{EU}TEXP}{GDP_{EU}} \\ &+ 1.91 * 10^9\ q_1 + 1.95 * 10^9\ q_2 \\ &+ 1.95 * 10^9\ q_3 + 2.02 * 10^9\ q_4 \end{aligned} \tag{2.21} $$



(a) 2010 - 2014 (b) Detail on 2014

Figure 2.8: Estimation of exports from EU to Japan

China

Finally, the exports from EU to China represented following equation were estimated:

$$\begin{aligned} {}_{EU}EXP_{CH} =& \beta_0 + \beta_{1EU}TEXP + \beta_2 GDP_{EU} + \beta_3 GDP_{CH} + \\ & \beta_4 FX_{EU} + \beta_5 FX_{CH} + \beta_6 INF_{EU} + \beta_7 INF_{CH} \end{aligned} \tag{2.22}$$

An analysis of Chinese trade yields similar results to the other countries. It is possible to find an easy model that consists only of two exogenous variables, namely GDP and the development of the European Currency. By that, a simple trend of the exports can be described with a R^2 of 0.25. Once again, an equipment of this model with seasonal variables leads to no significant results. When all possible variables are involved in model A3, still the same equations as in A1 are calculated to match the data best which leads to the assumptions, that consideration of the total trade amounts does not play a major role in trade with China. It is more plausible to conclude, that this trade is sufficiently described by monetary factors only. Hence the figure E.4 that summarizes the results of the regression, presents also the second best solution. The most complicated model is characterized by a good fit with $R^2 = 0.70$ but also fails to predict the values of 2014 what is shown in figure 2.9. However the last datapoint of 2014 seems at odds with past years.

The seemingly most reliable forecasts are made by the basic models with no seasonal adjustments since they are more conservative and do not react so strongly to changes in values of the exogenous variables. Moreover, in some cases the best explanation is given only by inflation or the exchange rate. This behavior could indicate that trade with China is driven mainly by monetary factors and serves to supplement the supply when conditions are favorable.

A1/A3:

$$ {}_{EU}EXP_{CH} = 1666.618\ GDP_{EU} - 5.14 * 10^{9} \frac{1}{FX_{EU}} \tag{2.23} $$

A3 (second best):

$$ {}_{EU}EXP_{CH} = -1.11 * 10^{11} \frac{1}{FX_{CH}} + 1.67 * 10^{8}\ INF_{CH} \tag{2.24} $$

A4:

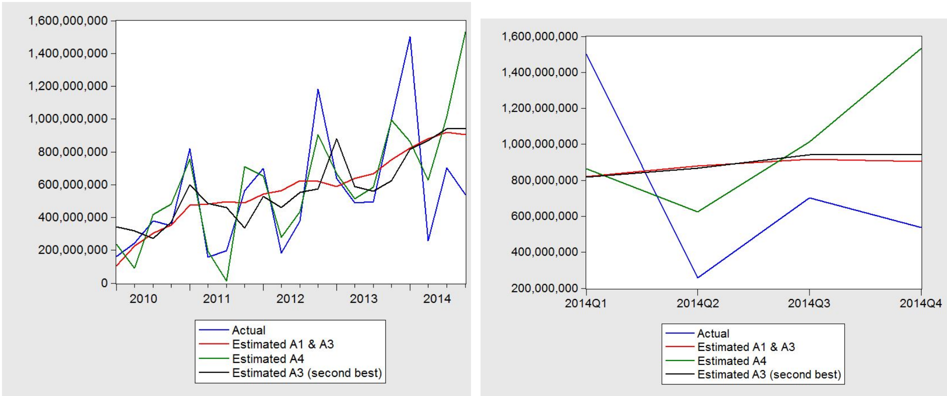
$$ \begin{aligned} {}_{EU}EXP_{CH} = {} & 1007.54\ GDP_{EU} - 9 * 10^{12}\ \frac{GDP_{EU}}{{}_{EU}TEXP} \\ & + 1.97 * 10^{13}\ \frac{GDP_{CH}}{{}_{EU}TEXP} - 1.9 * 10^{8} INF_{CH} \\ & + 1.67 * 10^{10}\ q_1 + 1.62 * 10^{10}\ q_2 \\ & + 1.64 * 10^{10}\ q_3 + 1.7 * 10^{10}\ q_4 \end{aligned} \tag{2.25} $$

2.3.4 Import

US

To model the imports from US to EU the following equation was estimated:

$$ \begin{aligned} {}_{US}IMP_{EU} = {} & \beta_0 + \beta_1 TIMP_{EU} + \beta_2 GDP_{EU} + \beta_3 GDP_{US} + \\ & \beta_4 FX_{EU} + \beta_5 FX_{US} + \beta_6 INF_{EU} + \beta_7 INF_{US} \end{aligned} \tag{2.26} $$



(a) 2010 - 2014 (b) Detail on 2014

Figure 2.9: Estimation of exports from EU to China

The results show, that in all statistically relevant models (A1, A3 and A4) the GDP and inflation rate in the United States contributed a major part in explaining the trade flows. A2 did not yield any significant results. The actual time series is captured by all models with increasing efficiency, a fact that is proven by $R^2 = 0.46$, $R^2 = 0.76$ and $R^2 = 0.77$ respectively. See figure E.5 for actual results.

All estimated equations tend to explain the trend for 2014 accurately, however remarkable deviations for the simplest model (A1) are not negligible. Figure 2.10 visualizes this fact. As these differences might be accounted to seasonal activities, it might be plausible to expect this model to perform better in the long run. For short-term forecasts the other two models (A3 and A4) are more suitable, since they respond significantly better to seasonal fluctuations.

A1:

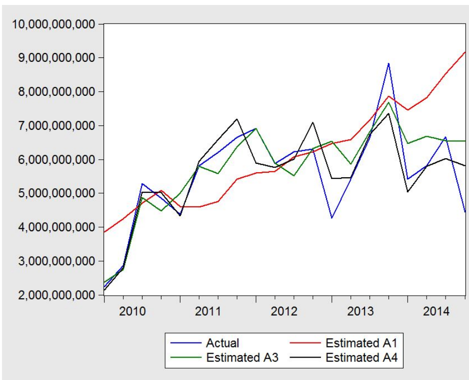
$$_{US}IMP_{EU} = 11568.48\ GDP_{US} - 3.9 * 10^8\ INF_{US} \tag{2.27}$$

A3:

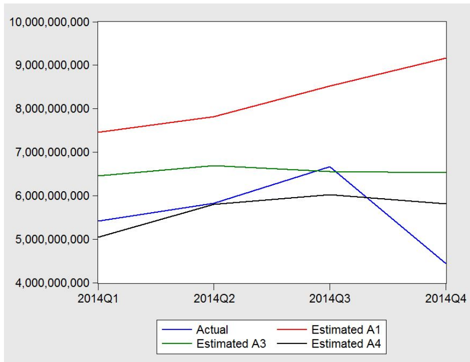
$$
\begin{aligned}
{}_{US}IMP_{EU} &= 10247.35\ GDP_{US} - 4.12 * 10^{8}\ INF_{US} \\
&+ 552499.3\ \frac{TIMP_{EU}}{GDP_{US}}
\end{aligned} \tag{2.28}
$$

A4:

$$
\begin{aligned}
{}_{US}IMP_{EU} &= 451980.5 \frac{TIMP_{EU}}{GDP_{US}} + 2.05 * 10^{8}\ INF_{US} \\
&- 2.3 * 10^{10}\ q_1 - 2.25 * 10^{10} q_2 \\
&- 2.17 * 10^{10} q_3 - 2.12 * 10^{10} q_4
\end{aligned} \tag{2.29}
$$



(a) 2010 - 2014



(b) Detail on 2014

Figure 2.10: Estimation of imports to EU from US

Russia

Russian imports are modeled by an alteration of the following equation:

$$
\begin{aligned}
{}_{RU}IMP_{EU} =& \beta_0 + \beta_1 TIMP_{EU} + \beta_2 GDP_{EU} + \beta_3 GDP_{RU} + \\
& \beta_4 FX_{EU} + \beta_5 FX_{RU} + \beta_6 INF_{EU} + \beta_7 INF_{RU}
\end{aligned} \tag{2.30}
$$

The tests performed by all four types of methods suggest a relationship between imports and the European GDP since this variable is significant for every variant of the model. The basic model performs satisfactorily and results in values of $R^2 = 0.73$ and $R^2 = 0.76$. In these both cases GDP, the exchange rate of the Euro and both inflation rates are used to explain the development. After inclusion of total trade variables, both sophisticated models deliver extraordinary values of R^2, namely 0.98 and 0.99. This outcome is justified by the relative contribution of Russian imports to total imports. Since Russia is the main supplier of Europe, such a strong correlation is not surprising. Nonetheless it is important to mention, that the basic models which do neglect this relationship also perform well. Results are displayed in figure E.6.

With respect to forecasting accuracy once again the distinction between the basic and advanced model has to be made. Here it is visible, that the predictions from A1 and A2 have greater difficulties to match the actual data and reproduce the actual decline that happened in 2014 more slowly. A3 and A4 on the other hand follow the trend accurately, as is shown in figure 2.11.

A1:

$$\begin{aligned} {}_{RU}IMP_{EU} &= 81134.15\ GDP_{EU} - 1.90 * 10^{11}\ \frac{1}{FX_{EU}} \\ &+ 4.7 * 10^{9}\ INF_{EU} - 2.19 * 10^{9}\ INF_{RU} \\ &- 3.03 * 10^{11} C \end{aligned} \tag{2.31}$$

A2:

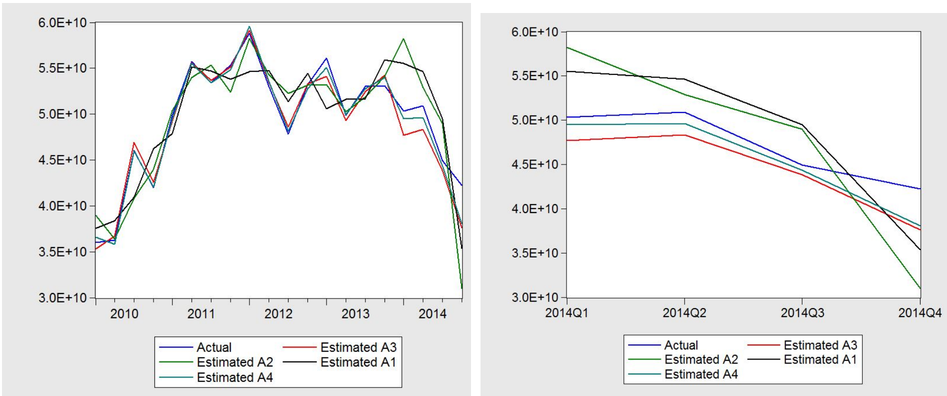
$$\begin{aligned} {}_{RU}IMP_{EU} &= 91949.56\ GDP_{EU} - 2.22 * 10^{11}\ \frac{1}{FX_{EU}} \\ &+ 5.40 * 10^{9}\ INF_{EU} - 2.52 * 10^{9}\ INF_{RU} \\ &- 3.40 * 10^{11}\ q_1 - 3.44 * 10^{11}\ q_2 \\ &- 3.43 * 10^{11}\ q_3 - 3.45 * 10^{11}\ q_4 \end{aligned} \tag{2.32}$$

A3:

$$\begin{aligned} {}_{RU}IMP_{EU} &= 0.87\ TIMP_{EU} - 2681.73\ GDP_{EU} \\ &+ 3.96 * 10^{11}\ \frac{1}{FX_{RU}} \end{aligned} \tag{2.33}$$

A4:

$$
\begin{aligned}
{}_{RU}IMP_{EU} &= 16128.32\ GDP_{RU} + 3.12 * 10^{10}\ \frac{1}{FX_{EU}} \\
&+ 3730227\ \frac{TIMP_{EU}}{GDP_{EU}} \\
&- 4.56 * 10^{10}\ q_1 - 4.61 * 10^{10}\ q_2 \\
&- 4.67 * 10^{10}\ q_3 - 4.7 * 10^{10}\ q_4
\end{aligned}
\tag{2.34}
$$



(a) 2010 - 2014 (b) Detail on 2014

Figure 2.11: Estimation of imports to EU from Russia

Japan

Japanese imports are modeled by an alteration of the following equation:

$$
\begin{aligned}
{}_{JP}IMP_{EU} =& \beta_0 + \beta_1 TIMP_{EU} + \beta_2 GDP_{EU} + \beta_3 GDP_{JP} + \\
& \beta_4 FX_{EU} + \beta_5 FX_{JP} + \beta_6 INF_{EU} + \beta_7 INF_{JP}
\end{aligned}
\tag{2.35}
$$

The imports from Japan have turned out to be very difficult to model. The basic approach (A1) resulted in a R^2 of only 0.22. This leads to the assumption, that imports from Japan depend on other factors as well that have not been considered in the model. Better results are achieved when total trade is take into account in the sophisticated models (A3 and A4). In these cases the coefficient of determination is 0.48 and 0.34 respectively and the main exogenous variables are GDP rates of both countries and the total import to Europe. Interestingly both models do not include monetary variables since they depend on real factors only. Moreover, the GDP rates seem to be very influential for trade with Japan since they are included in every model. See figure E.7 for details.

The analysis of the forecasts for 2014 shows that all models give a similar prediction and may prove to be suitable for future estimations. Compare figure 2.12

A1:

$$\begin{aligned} {}_{JP}IMP_{EU} &= 250.46\ GDP_{EU} + 2525.66\ GDP_{JP} \\ &- 2.99 * 10^{11} \frac{1}{FX_{JP}} - 9925822\ INF_{EU} \end{aligned} \tag{2.36}$$

A3:

$$\begin{aligned} {}_{JP}IMP_{EU} &= -997.61\ GDP_{EU} - 3553.50\ GDP_{JP} \\ &- 386544.8\ \frac{TIMP_{EU}}{GDP_{EU}} + 110072.6\ \frac{TIMP_{EU}}{GDP_{JP}} \end{aligned} \tag{2.37}$$

A4:

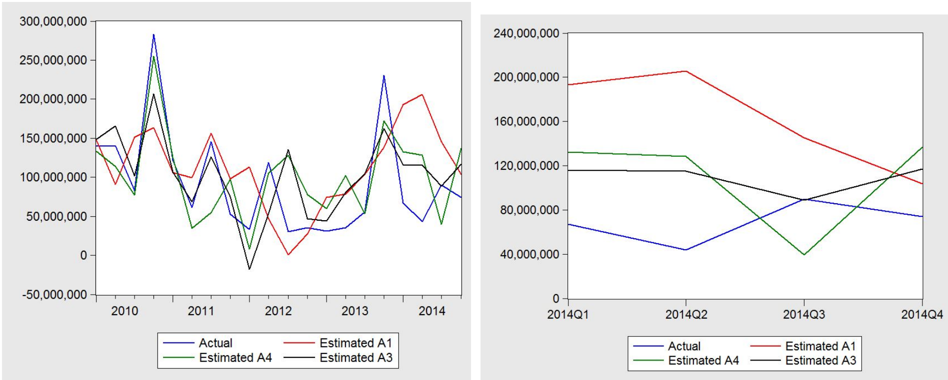
$$\begin{aligned} {}_{JP}IMP_{EU} &= -0.11\ TIMP_{EU} + 4721.02\ GDP_{JP} \\ &+ 146431.3\ \frac{TIMP_{EU}}{GDP_{JP}} \\ &- 5.96 * 10^9\ q_1 - 5.96 * 10^9\ q_2 \\ &- 6.03 * 10^9\ q_3 - 5.96 * 10^9\ q_4 \end{aligned} \tag{2.38}$$

China

Chinese imports are modeled by an alteration of the following equation:

$$\begin{aligned} {}_{CH}IMP_{EU} =& \beta_0 + \beta_1 TIMP_{EU} + \beta_2 GDP_{EU} + \beta_3 GDP_{CH} + \\ & \beta_4 FX_{EU} + \beta_5 FX_{CH} + \beta_6 INF_{EU} + \beta_7 INF_{CH} \end{aligned} \tag{2.39}$$

Imports from China present the following picture: The most significant models take solely monetary factors into account. Regardless if total trade



(a) 2010 - 2014

(b) Detail on 2014

Figure 2.12: Estimation of imports to EU from Japan

variables are involved or not, the best results are achieved by inflation in both countries and seasonal dummy variables. Thus A2 and A4 provide identical results with $R^2 = 0.52$. If seasonal adjustments are excluded, there are also acceptable models that base oneself on real and nominal relationships as well. A1 and A3 with $R^2 = 0.33$ and $R^2 = 0.48$ serve as plausible estimations of the general trend, but fail to replicate the amplitudes of the fluctuations. See figure E.8 for details.

A comparison of actual and estimated data for 2014 shows that all models converge to the actual data point towards the end of the forecasting period. In between the behavior is different and significant differences are visible. As can be seen in figure 2.13 the best fit is achieved by A3, a model that in general tends to follow the trend of the time series without excessive variance.

A1:

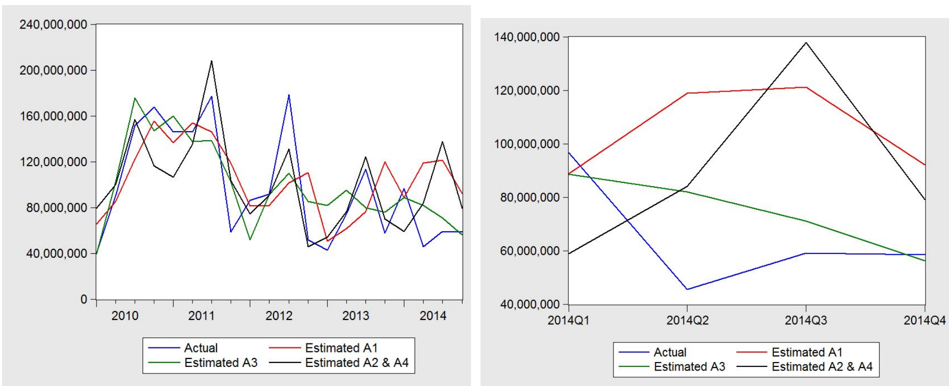
$$\begin{aligned} {}_{CH}IMP_{EU} &= 714.10\ GDP_{EU} - 256.28\ GDP_{CH} \\ &\quad - 1.91 * 10^9\ \frac{1}{FX_{EU}} \end{aligned} \tag{2.40}$$

A2 and A4:

$$
\begin{aligned}
{}_{CH}IMP_{EU} &= -44402303\ INF_{EU} - 29712211\ INF_{CH} \\
&\quad 1.53 * 10^9\ q_1 + 1.60 * 10^9\ q_2 \\
&\quad + 1.64 * 10^9\ q_3 + 1.57 * 10^9\ q_4
\end{aligned}
\tag{2.41}
$$

A3:

$$
\begin{aligned}
{}_{CH}IMP_{EU} &= -1.86 * 10^{13} \frac{GDP_{EU}}{TIMP_{EU}} - 126532.5\ \frac{TIMP_{EU}}{GDP_{EU}} \\
&\quad - 9911856\ INF_{EU} + 4.23 * 10^9\ C
\end{aligned}
\tag{2.42}
$$



(a) 2010 - 2014

(b) Detail on 2014

Figure 2.13: Estimation of imports to EU from China

2.4 Summary of the model

The estimations of the previous section showed several possibilities to link the equations into a model. Four types of models will be specified here and used for simulations in the following chapter. All of them have in common, that total trades are expressed by summation of bilateral trades:

$$TIMP_{EU} = {}_{US}IMP_{EU} + {}_{RU}IMP_{EU} + {}_{JP}IMP_{EU} + {}_{CH}IMP_{EU} \tag{2.43}$$

$${}_{EU}TEXP = {}_{EU}EXP_{US} + {}_{EU}EXP_{RU} + {}_{EU}EXP_{JP} + {}_{EU}EXP_{CH} \tag{2.44}$$

Basic Model - M1

This is the most intuitive version of the model and it reduces itself to the easiest equations. It only allows GDPs, inflation rates and currency exchange rates and merges the simplest connections for all bilateral flows. Therefore it is supposed to explain trade by growth of the economies and consequential growing or declining demand and supply. No focus is put on seasonal fluctuations, the goal is to give a rough estimate of the future long-term development.

Exports:

$$\begin{aligned} {}_{EU}EXP_{US} &= 9812.5\ GDP_{EU} - 15966.9\ GDP_{US} - \\ &2.9 * 10^{10}\ \frac{1}{FX_{EU}} + 6.2 * 10^{8}\ INF_{EU} \end{aligned} \tag{2.45}$$

$$\begin{aligned} {}_{EU}EXP_{RU} &= 646.8\ GDP_{EU} - 2.55 * 10^{9} \frac{1}{FX_{EU}} + \\ &+ 2.78 * 10^{10}\ \frac{1}{FX_{RU}} \end{aligned} \tag{2.46}$$

$${}_{EU}EXP_{JP} = 390.29\ GDP_{EU} - 1.20 * 10^{9} \frac{1}{FX_{EU}} \tag{2.47}$$

$${}_{EU}EXP_{CH} = 1666.618\ GDP_{EU} - 5.14 * 10^{9} \frac{1}{FX_{EU}} \tag{2.48}$$

Imports:

$$ {}_{US}IMP_{EU} = 11568.48\ GDP_{US} - 3.9 * 10^8\ INF_{US} \tag{2.49} $$

$$ \begin{aligned} {}_{RU}IMP_{EU} &= 81134.15\ GDP_{EU} - 1.90 * 10^{11}\ \frac{1}{FX_{EU}} \\ &+ 4.7 * 10^9\ INF_{EU} - 2.19 * 10^9\ INF_{RU} \\ &- 3.03 * 10^{11} C \end{aligned} \tag{2.50} $$

$$ \begin{aligned} {}_{JP}IMP_{EU} &= 250.46\ GDP_{EU} + 2525.66\ GDP_{JP} \\ &- 2.99 * 10^{11} \frac{1}{FX_{JP}} - 9925822\ INF_{EU} \end{aligned} \tag{2.51} $$

$$ \begin{aligned} {}_{CH}IMP_{EU} &= 714.10\ GDP_{EU} - 256.28\ GDP_{CH} \\ &- 1.91 * 10^9\ \frac{1}{FX_{EU}} \end{aligned} \tag{2.52} $$

Advanced Model - M2

This model relies on the same variables as the previous one, but wherever possible is fully supplemented by seasonal improvements. Although GDP remains the main driving force of demand and supply, more precise short-term predictions should be possible.

Exports:

$$ \begin{aligned} {}_{EU}EXP_{US} &= 9812.5\ GDP_{EU} - 15966.9\ GDP_{US} - \\ & 2.9 * 10^{10}\ \frac{1}{FX_{EU}} + 6.2 * 10^8\ INF_{EU} \end{aligned} \tag{2.53} $$

$$ \begin{aligned} {}_{EU}EXP_{RU} &= 646.8\ GDP_{EU} - 2.55 * 10^9 \frac{1}{FX_{EU}} + \\ &+ 2.78 * 10^{10}\ \frac{1}{FX_{RU}} \end{aligned} \tag{2.54} $$

$$
\begin{aligned}
{}_{EU}EXP_{JP} = \ & 239.62\ GDP_{EU} - 1.09 * 10^9 \frac{1}{FX_{EU}} \\
& + 4.67 * 10^8\ q_1 - 5.16 * 10^8\ q_2 \\
& + 5.08 * 10^8\ q_3 + 5.86 * 10^8\ q_4
\end{aligned} \tag{2.55}
$$

$$
{}_{EU}EXP_{CH} = 1666.618\ GDP_{EU} - 5.14 * 10^9 \frac{1}{FX_{EU}} \tag{2.56}
$$

Imports:

$$
{}_{US}IMP_{EU} = 11568.48\ GDP_{US} - 3.9 * 10^8\ INF_{US} \tag{2.57}
$$

$$
\begin{aligned}
{}_{RU}IMP_{EU} = \ & 91949.56\ GDP_{EU} - 2.22 * 10^{11}\ \frac{1}{FX_{EU}} \\
& + 5.40 * 10^9\ INF_{EU} - 2.52 * 10^9\ INF_{RU} \\
& - 3.40 * 10^{11}\ q_1 - 3.44 * 10^{11} q_2 + \\
& - 3.43 * 10^{11} q_3 - 3.45 * 10^{11} q_4
\end{aligned} \tag{2.58}
$$

$$
\begin{aligned}
{}_{JP}IMP_{EU} = \ & 250.46\ GDP_{EU} + 2525.66\ GDP_{JP} \\
& - 2.99 * 10^{11} \frac{1}{FX_{JP}} - 9925822\ INF_{EU}
\end{aligned} \tag{2.59}
$$

$$
\begin{aligned}
{}_{CH}IMP_{EU} = \ & -44402303\ INF_{EU} - 29712211\ INF_{CH} \\
& 1.53 * 10^9\ q_1 + 1.60 * 10^9\ q_2 + \\
& + 1.64 * 10^9\ q_3 - 1.57 * 10^9\ q_4
\end{aligned} \tag{2.60}
$$

Sophisticated Model - M3

This model is oriented on total trade. It does not longer rely on GDPs only, but rather bases its predictions on demand derived from total imports and exports. This model addresses the question how nominal changes will affect trading behavior, given that the amount of traded energy will most probably not be subject to remarkable changes. Its aim is to describe changes in bilateral trades compared to total supply and demand for all partners for which this relationship plays a major role. Consequently a characteristic property of this model is, that it reacts stronger to changes in input variables and therefore it may tend to propose solutions that diverge from the paths of the other models.

Exports:

$$ {}_{EU}EXP_{US} = -9.4 * 10^{12} \frac{GDP_{EU}}{{}_{EU}TEXP} + 9 * 10^{9} \frac{1}{FX_{EU}} \tag{2.61} $$

$$ \begin{aligned} {}_{EU}EXP_{RU} &= 6.67 * 10^{12} \frac{GDP_{RU}}{{}_{EU}TEXP} + \\ &+ 391565.6 \frac{{}_{EU}TEXP}{GDP_{EU}} - 7.1 * 10^{8}\ C \end{aligned} \tag{2.62} $$

$$ \begin{aligned} {}_{EU}EXP_{JP} &= -0.19\ {}_{EU}TEXP + 861.97\ GDP_{JP} \\ &- 5.49 * 10^{12} \frac{GDP_{JP}}{{}_{EU}TEXP} \\ &+ 13058471\ INF_{EU} \end{aligned} \tag{2.63} $$

$$ {}_{EU}EXP_{CH} = -1.11 * 10^{11} \frac{1}{FX_{CH}} + 1.67 * 10^{8}\ INF_{CH} \tag{2.64} $$

Imports:

$$ \begin{aligned} {}_{US}IMP_{EU} &= 10247.35\ GDP_{US} - 4.12 * 10^{8}\ INF_{US} \\ &+ 552499.3 \frac{TIMP_{EU}}{GDP_{US}} \end{aligned} \tag{2.65} $$

$$ \begin{aligned} {}_{RU}IMP_{EU} &= 0.87\ TIMP_{EU} - 2681.73\ GDP_{EU} \\ &+ 3.96 * 10^{11} \frac{1}{FX_{RU}} \end{aligned} \tag{2.66} $$

$$
\begin{aligned}
{}_{JP}IMP_{EU} &= -997.61\ GDP_{EU} - 3553.50\ GDP_{JP} \\
&\quad - 386544.8\ \frac{TIMP_{EU}}{GDP_{EU}} + 110072.6\ \frac{TIMP_{EU}}{GDP_{JP}}
\end{aligned} \tag{2.67}
$$

$$
\begin{aligned}
{}_{CH}IMP_{EU} &= -1.86 * 10^{13} \frac{GDP_{EU}}{TIMP_{EU}} - 126532.5\ \frac{TIMP_{EU}}{GDP_{EU}} \\
&\quad - 9911856\ INF_{EU} + 4.23 * 10^{9}\ C
\end{aligned} \tag{2.68}
$$

Advanced Sophisticated Model - M4

This model takes all variables into account and consists of the best fitting equations that were found in the analysis of the previous chapter.

Exports:

$$
\begin{aligned}
{}_{EU}EXP_{US} &= 1900.9\ GDP_{EU} - 8.63 * 10^{12}\ \frac{GDP_{EU}}{{}_{EU}TEXP} \\
&\quad - 8.6 * 10^{7}\ INF_{US} + 1.22 * 10^{10}\ q_1 + \\
&\quad 1.24 * 10^{10} q_2 + 1.21 * 10^{10} q_3 + 1.17 * 10^{10} q_4
\end{aligned} \tag{2.69}
$$

$$
\begin{aligned}
{}_{EU}EXP_{RU} &= 6.43 * 10^{12}\ \frac{GDP_{RU}}{{}_{EU}TEXP} + 398724.9\ \frac{{}_{EU}TEXP}{GDP_{EU}} \\
&\quad - 7.28 * 10^{8}\ q_1 - 7.29 * 10^{8}\ q_2 \\
&\quad - 6.27 * 10^{8}\ q_3 - 7.37 * 10^{8}\ q_4
\end{aligned} \tag{2.70}
$$

$$
\begin{aligned}
{}_{EU}EXP_{JP} &= 0.19\ {}_{EU}TEXP - 1.33 * 10^{9} \frac{1}{FX_{EU}} \\
&\quad - 912973\ \frac{{}_{EU}TEXP}{GDP_{EU}} \\
&\quad + 1.91 * 10^{9}\ q_1 + 1.95 * 10^{9}\ q_2 \\
&\quad + 1.95 * 10^{9}\ q_3 + 2.02 * 10^{9}\ q_4
\end{aligned} \tag{2.71}
$$

$$
\begin{aligned}
{}_{EU}EXP_{CH} = {} & 1007.54\ GDP_{EU} - 9 * 10^{12}\ \frac{GDP_{EU}}{{}_{EU}TEXP} \\
& + 1.97 * 10^{13}\ \frac{GDP_{CH}}{{}_{EU}TEXP} - 1.9 * 10^{8} INF_{CH} \\
& + 1.67 * 10^{10}\ q_1 + 1.62 * 10^{10}\ q_2 \\
& + 1.64 * 10^{10}\ q_3 + 1.7 * 10^{10}\ q_4
\end{aligned} \tag{2.72}
$$

Imports:

$$
\begin{aligned}
{}_{US}IMP_{EU} & = 451980.5 \frac{TIMP_{EU}}{GDP_{US}} + 2.05 * 10^{8}\ INF_{US} \\
& - 2.3 * 10^{10}\ q_1 - 2.25 * 10^{10} q_2 \\
& - 2.17 * 10^{10} q_3 - 2.12 * 10^{10} q_4
\end{aligned} \tag{2.73}
$$

$$
\begin{aligned}
{}_{RU}IMP_{EU} & = 16128.32\ GDP_{RU} + 3.12 * 10^{10}\ \frac{1}{FX_{EU}} \\
& + 3730227\ \frac{TIMP_{EU}}{GDP_{EU}} \\
& - 4.56 * 10^{10}\ q_1 - 4.61 * 10^{10}\ q_2 \\
& - 4.67 * 10^{10}\ q_3 - 4.7 * 10^{10}\ q_4
\end{aligned} \tag{2.74}
$$

$$
\begin{aligned}
{}_{JP}IMP_{EU} & = -0.11\ TIMP_{EU} + 4721.02\ GDP_{JP} \\
& + 146431.3\ \frac{TIMP_{EU}}{GDP_{JP}} \\
& - 5.96 * 10^{9}\ q_1 - 5.96 * 10^{9}\ q_2 \\
& - 6.03 * 10^{9}\ q_3 - 5.96 * 10^{9}\ q_4
\end{aligned} \tag{2.75}
$$

$$
\begin{aligned}
{}_{CH}IMP_{EU} & = -44402303\ INF_{EU} - 29712211\ INF_{CH} \\
& 1.53 * 10^{9}\ q_1 + 1.60 * 10^{9}\ q_2 \\
& + 1.64 * 10^{9}\ q_3 + 1.57 * 10^{9}\ q_4
\end{aligned} \tag{2.76}
$$

Chapter 3

Simulation

In this chapter the models derived from historical data and summarized in the previous chapter are simulated into the future. For this purpose different scenarios will be tested, since different developments are possible. The goal is to observe how and to which extent the different models will react to changes in the variables and which conclusions can be derived out of this. The time horizon for this simulations will be eight quarters into the future, therefore 2015Q1 to 2016Q4. In order to be able to execute these calculations, all future values of the endogenous variables had to be predicted which was done by exponential smoothing of the time series.

3.1 Scenarios

3.1.1 Scenario 1 - Continuation of global economic crisis

The first scenario imitates a prolongation of the current global economic crisis. The economies struggle to obtain price stability characterized by the aspired benchmark of 2% inflation and also generate only modest growth of GDPs. The currency exchange rates continue to follow the actual trend without great fluctuations. Figures 3.1 and 3.2 visualize these developments.

Under these circumstances the models predict slightly different out-

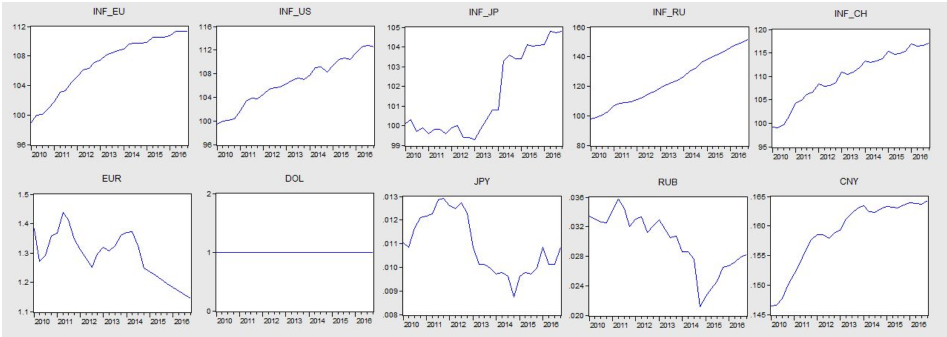


Figure 3.1: Scenario 1 Inflation and Foreign Exchange Rates

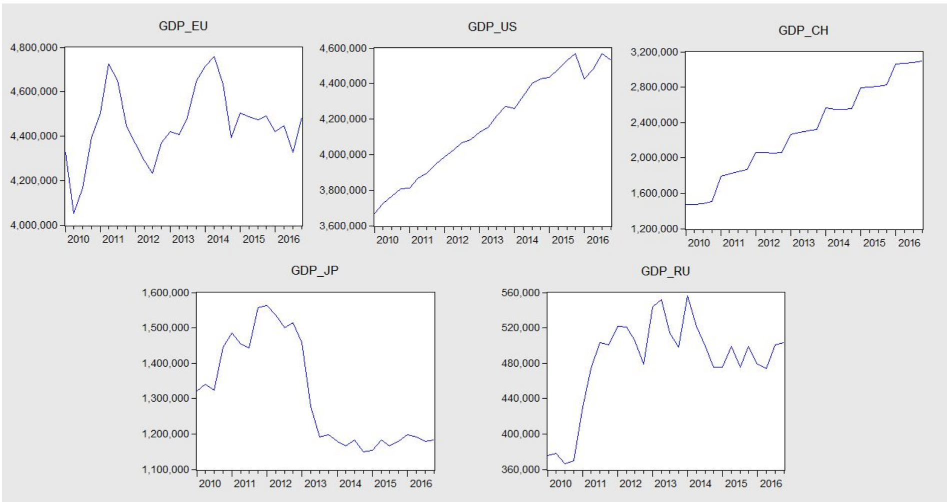
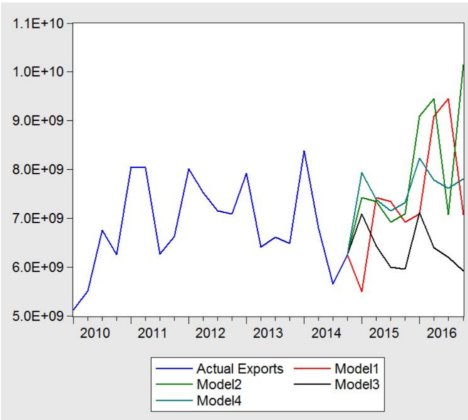
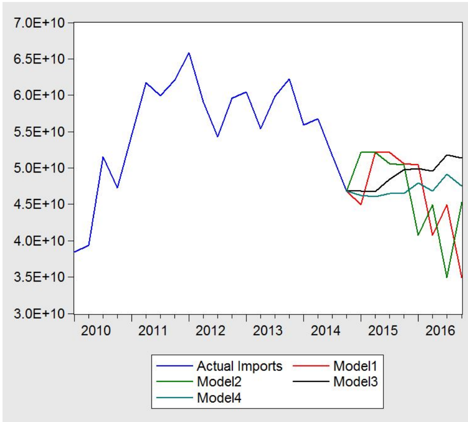


Figure 3.2: Scenario 1 GDP

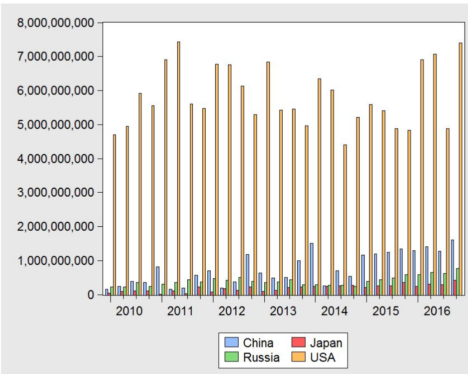
comes. The basic models (M1 and M2) foresee strong seasonal variations and a general tendency of rising exports. The imports on the contrary tend to decline but are also characterized by remarkable volatility. This type of models apparently suggest that Europe will become more competitive the longer the recession continues in that sense, that import dependency declines and more exports will become possible. An observation of the individual trade partners shows that this effect can be contributed to a rise of exports to the US that is projected to reach its peak values from 2011. In addition, Chinese exports are also forecast to maintain stable on a relatively high level and Japanese exports increase by 40 % over the period of 2015Q4 to 2016Q4. In both basic models the decline of total imports can be attributed to falling imports from Russia which are reduced by about 30 % in the given time frame.



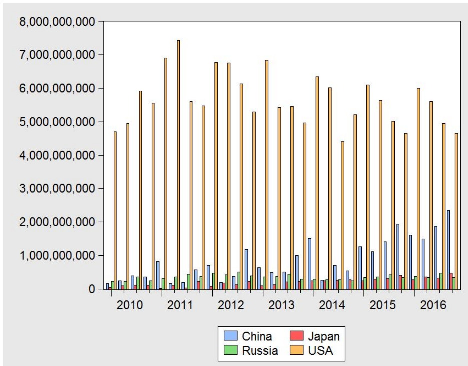
(a) Total Exports



(b) Total Imports



(c) M2 Exports by partner

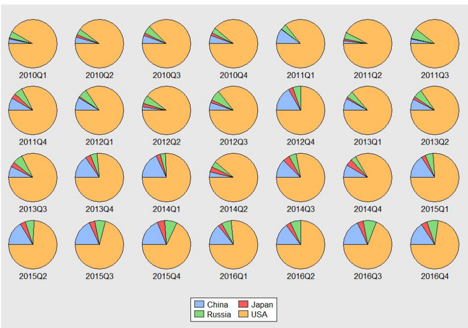


(d) M4 Exports by partner

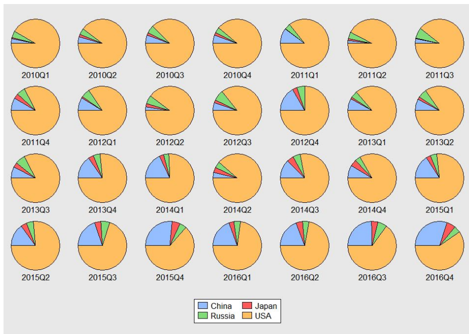
Figure 3.3: Scenario 1 Results

The sophisticated models (M3 and M4) submit another answer. With respect to the exports the picture is unclear and differs between the models depending if seasonal adjustments are included or not. Under no seasonal influences (M3) the development is predicted to continue on the same level within a constant bandwidth. A decomposition into bilateral trades exposes that these fluctuations can be fully attributed to commerce with the US, since all other developments are forecast to stay constant. When the model is equipped with seasonal variables (M4) Chinese exports no longer stay on the same level, but begin to rise with almost doubling within the projected period. Japanese exports follow this behavior although on a comparatively small stage. In total these two effects manage to cancel out the decline in US trade which results in a combined estimated increase in total values.

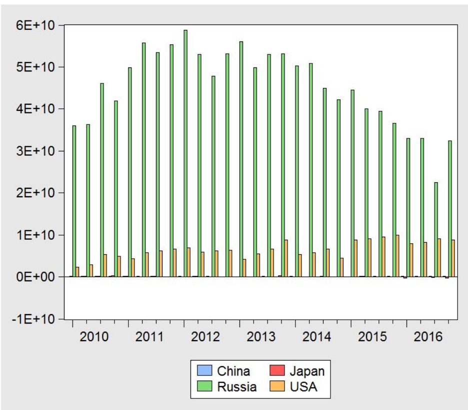
With respect to the imports the sophisticated models predict a slight increase in total business. In contrast to the basic case the imports from Russia stay roughly on the same level with a decent upward trend.



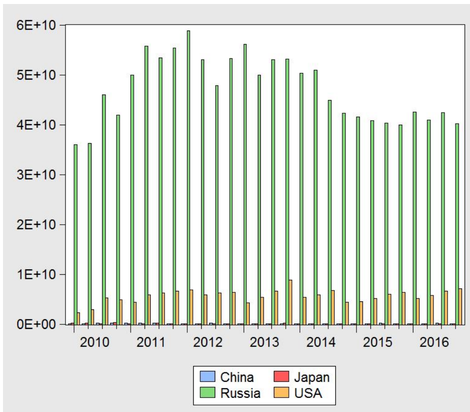
(a) M2 Export Shares



(b) M4 Export Shares



(c) M2 Imports by partner



(d) M4 Imports by partner

Figure 3.4: Scenario 1 Results (continued)

3.1.2 Scenario 2 - Resolution of economic crisis

The second scenario describes a state where all economies manage to overcome the current stagnation. It is characterized by a noticeable recovery of GDP growth and assumes a global inflation of 2 % throughout the next two years. Moreover, the American Dollar appreciates in value which results in falling exchange rates for the other monetary areas. Russian Ruble recovers, but not as significant as in the first scenario. These circumstances are summarized in Figures 3.5 and 3.6.

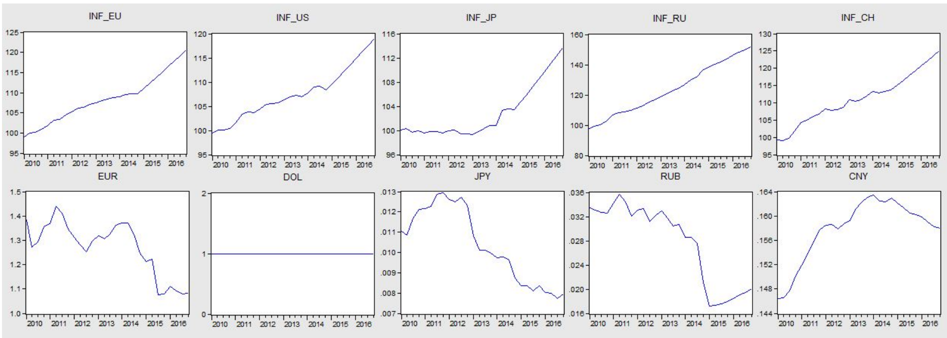


Figure 3.5: Scenario 2 Inflation and Foreign Exchange Rates

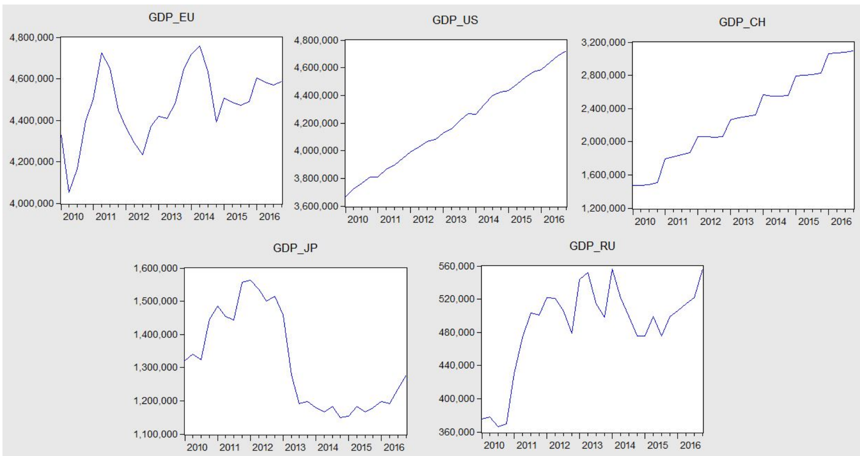
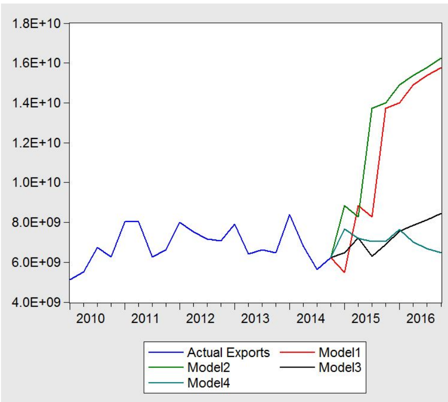
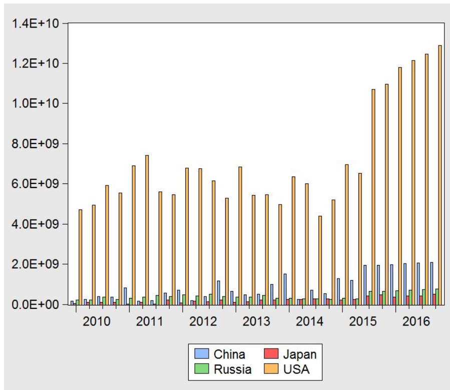


Figure 3.6: Scenario 2 GDP

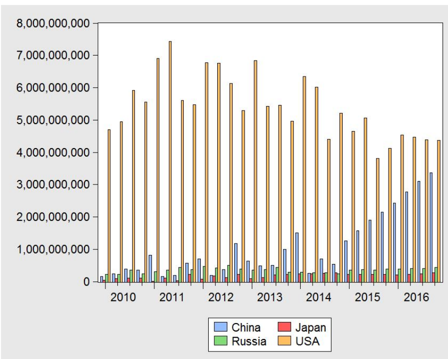
In this scenario the differences between the two types of models are rather extreme. The models that rely stronger on GDP evolution (M1 and M2) tend to overestimate the effects of the favoring conditions of the economies. Consequently they predict doubling of total exports and total imports, a result that is caused by increases of commerce with all trading partners. Although in reality and in absolute numbers this development seems questionable even if the circumstances indeed suggest greater possibilities for enhanced trade, an interpretation of this forecast might be as follows: Given the beneficial conditions Europe would strive to increase its trading activity because of comparative cost advantages. An outcome of this might be an induced shift to other suppliers or a change in the energy mix.



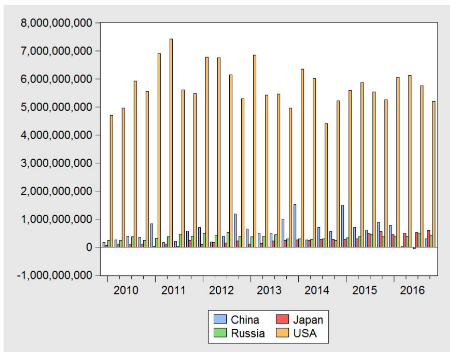
(a) Total Exports



(b) M2 Exports by partner



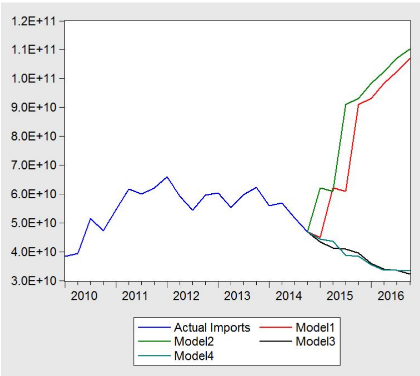
(c) M3 Exports by partner



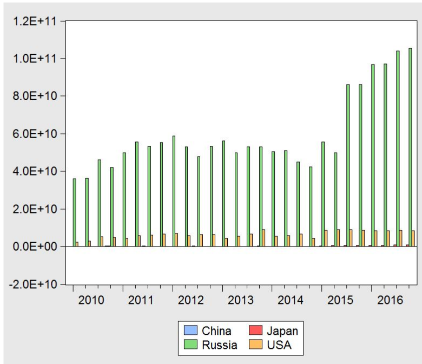
(d) M4 Exports by partner

Figure 3.7: Scenario 2 Results - Exports

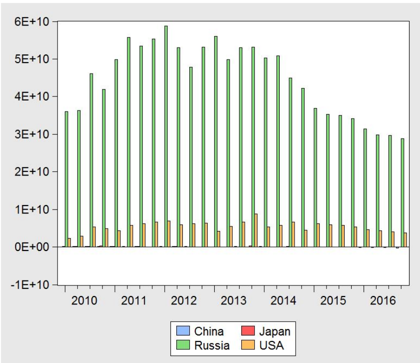
The models that are based on total trade ratios behave more conservative. They tend to follow the historical trend from the previous years and predict a stable development. The main observation that can be made here is that for the exports the major part of the difference between the models M3 and M4 is due to the varying evaluation of Chinese exports. Given that M3 explains this trend by monetary factors only, it comes as no surprise that in the favorable terms of scenario 2 these exports are predicted to increase substantially.



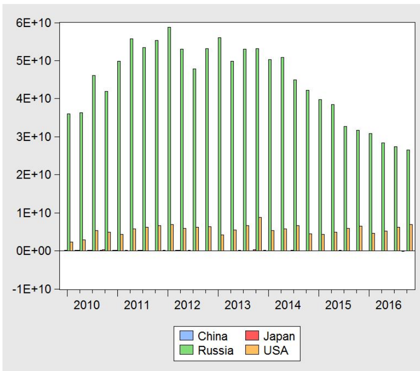
(a) Total Imports



(b) M2 Imports by partner



(c) M3 Imports by partner



(d) M4 Imports by partner

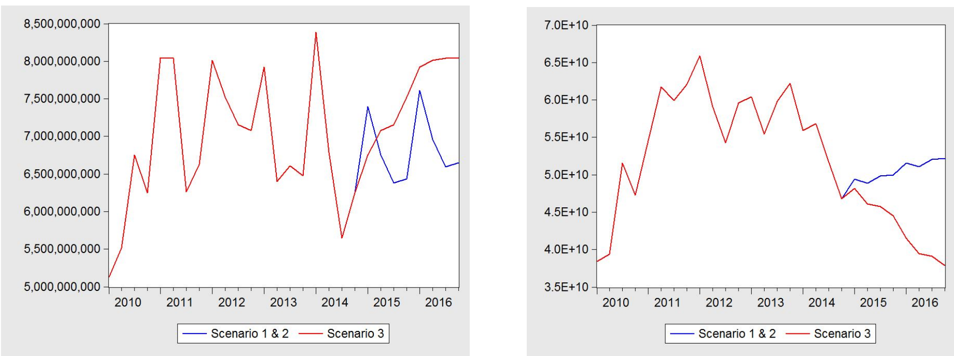
Figure 3.8: Scenario 2 Results - Imports

As the difference of the historical accuracy between these two models is remarkable (R^2 of 0.20 (M3) versus 0.72 (M4)) this outcome should be considered with some degree of caution. Altogether the analysis of this scenario shows, that the results predicted by M4 are not only the best with respect to statistical parameters but also suggest the most reasonable outcomes.

For the imports this picture shows no noteworthy differences between the models M3 and M4. This situation is underlined by the fact, that Russia as the major supplier is projected to behave similar in both models. Since the imports are steadily declining, this might signal a positive impact on competitiveness and a lesser energy dependency under such favorable conditions.

3.1.3 Scenario 3 - Europe's aspiration for self-sufficiency

The third scenario focuses on European efforts toward self-sufficiency. Under adequate policy measures the domestic production of renewables is intensified and will most probably cause the total energy imports to decline and might have a positive impact on total exports as well. Therefore this scenario will assume shrinking total imports and increasing total exports, in contrast to the previous both cases where total trade rates were assumed to be following an upward trend (Figure 3.9).



(a) Total Exports

(b) Total Imports

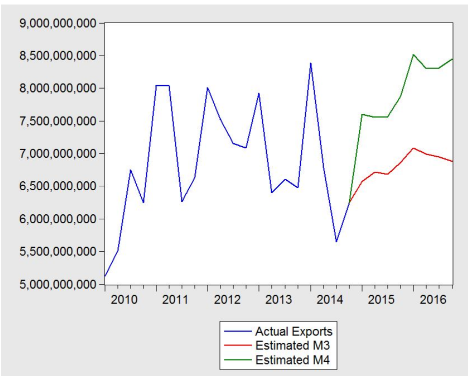
Figure 3.9: Total trade amounts

Moreover, this scenario is a mixture of the previous both and GDP growth follows the second example and is presented in figure 3.6 and inflation and currency exchange rates are similar to the first case, see figure 3.1. Since only the sophisticated models consider total trade amounts, only these two will be analyzed.

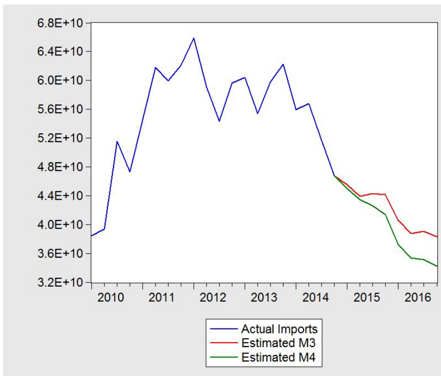
Both models show an increase in exports and an decline in imports but in the case of the model without seasonality this effect is much less pronounced. Figure 3.11 shows in detail, to which partner these changes can be attributed. The exports to China are predicted to be intensified in both models, but M4 also suggest more commerce activity with the US, Japan and Russia. In M3 this rise in numbers is also visible, although this impact is not so severe. Moreover, trade with the US is predicted to stay on a constant level.

Predictions imply the biggest victim of Europe's rising independence in energy matters to be its major supplier Russia, who will register declines in demand and thus shrinking business opportunities . The effect on other trading partners is negligible.

These results signal a clear positive outlook for Europe. It is in its own interest to strengthen its international position by bigger trust in domestic industry and greater reliableness of own energy production.

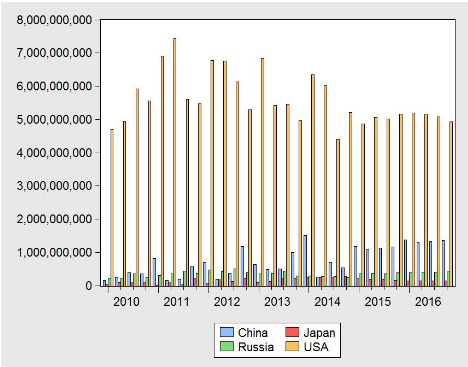


(a) Total Exports

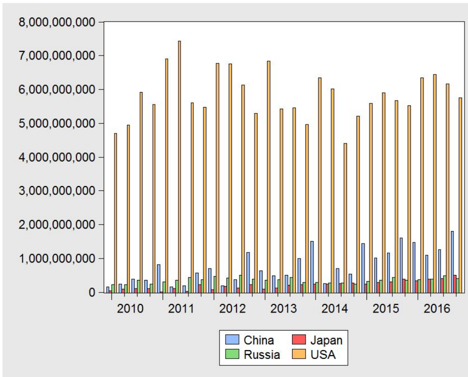


(b) Total Imports

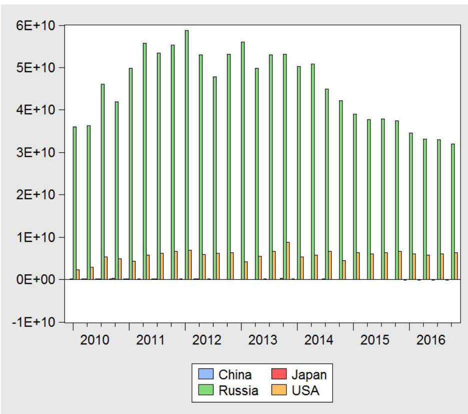
Figure 3.10: Total trade estimations



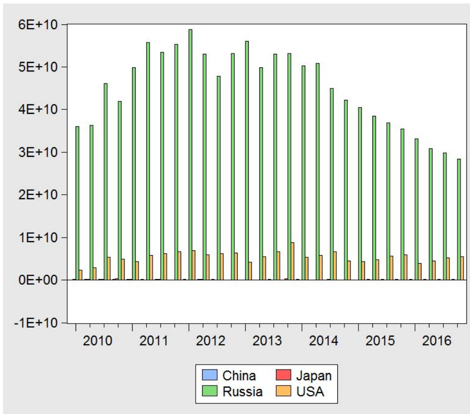
(a) M3 Exports



(b) M4 Exports



(c) M3 Imports



(d) M4 Imports

Figure 3.11: Scenario 3 Results - decomposed

Chapter 4

Conclusion

The aim of this work was to give an overview of European energy related trading behavior and its impact on international competitiveness. For this purpose a model was created that replicates bilateral trade flows between EU and its main trading partners US, Russia, Japan and China. This model merges two major effects that interact in the determination of imports and exports, namely real and nominal effects. Consequently, commerce development was described by GDP and total trade values on the one hand, but also by changes of the inflation rates and currency exchange rates.

To find the mathematical equations included in the model a multiple regression analysis was performed to examine the interconnections of the variables. To ensure a holistic approach, this task was performed with the help of a program that tested all possible combinations of the exogenous variables to find the best explanations of the endogenous variables.

Models in different degrees of sophistication were derived that were able to explain historical evolutions more or less accurately. A first finding during this process was, that trade flows are exposed to seasonal fluctuations and that an inclusion of seasonal variables in the model helps to increase the performance.

Moreover, although all possible combinations were tested the most significant results were achieved when European parameters were occurring in the equations. In total roughly 60% of the appearing variables can be assigned to this category and are either European GDP, Inflation in Europe or the foreign exchange rate of the Euro. Nonetheless, there was no clear evidence of the feasibility to formulate an uniform model for all trade flows. In some cases it was not even possible to include both nominal and real variables. One valid explanation for this phenomenon is the simple form of the model and the limitation with regard to the tested variables. Better outcomes would be achievable if other than linear forms of the equations and a greater diversity of exogenous variables would be considered. However, the results derived from this simple approach are more than satisfactory and allowed for implications and forecasts. In all cases the simulations deliver plausible results.

For the first example where a prolongation of the financial crisis is assumed, the prediction is that a longer duration of the stagnation could have an positive impact on the European economy. This is because favoring conditions enable the exports to increase and the imports to decline. This signals a lower trade dependency and therefore a higher competitiveness. Especially the energy imports from Russia are anticipated to decline, a circumstance that is accepted with pleasure in the context of the actual political disputes with the biggest supplier. These results signal a higher possibility for diplomatic measures and sanctions without exposing Europe to hazardous risks in supply security. A very positive effect that is also predicted in this scenario is the increase of export diversity. New markets are opening up and opportunities for versatile trade emerge. Europe does not longer have to rely on the USA as the major customer, but especially China and Russia show bigger interest in European energy products.

The second example imitates a situation where all economies grow and manage to maintain price stability, circumstances that are realistic should the economic crisis be resolved in the near future. In this case the predictions depend on the specifications of the model. According to the basic model that includes GDP values as the only real variable the imports and exports rise significantly under these conditions. This is because the effect of comparative cost advantages comes into play and results in a bigger specialization in most beneficial production sectors. Although the prediction of doubling both exports and imports due to this cause might not be realistic, the model foresees a higher willingness of increasing trade incentives. Especially the exports to the USA and China are intensified but also imports from Russia. The models where the development of the real effect is supplemented by total trade amounts behave more conservative. Nonetheless a clear picture is shown: The exports stay on the same level and the imports begin to decline. Here the outlook is not so radical, but also signals an increase in competitiveness. Again an increase in export diversity is predicted and a decline in import dependency from Russia.

The third example investigates how falling total demand would impact the trade behavior. This situation could be obtained by either intensifying domestic production of renewables or by exploiting shale gas resources that are available on European territory as suggested in the first chapter of this thesis. Not surprisingly under this scenario the competitiveness would benefit from an increase of avoided fuel costs. The exports are predicted to increase with a simultaneous decline in total imports. This development shows, that Europe can enhance its economical position by undertaking accurate policy measures. Nonetheless it is very important to remember that these positive effects are only possible when a common understanding of this issue from all Member States is ensured.

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Appendices

Appendix A

Energy Costs

There are different methods available to asses energy costs ([6]). The RUEC on the one hand only covers all energy related developments whereas the NUEC on the other hand takes also nominal effects into account.

with

$$
\begin{aligned}
\mathrm{EC} &\ldots \text{monetary value of energy costs in current prices} \\
\mathrm{Q}_E &\ldots \text{calorific value of energy inputs} \\
\mathrm{VA}_{curr} &\ldots \text{value added in current prices} \\
\mathrm{VA}_{const} &\ldots \text{value added in constant prices (2005)} \\
\mathrm{P}_{\mathrm{VA}} &\ldots \text{value added deflator}
\end{aligned}
$$

the RUEC can be written as:

$$
\begin{aligned}
\mathrm{RUEC} &= \frac{\mathrm{EC}}{\mathrm{VA}_{curr}} = \frac{\mathrm{EC}}{\mathrm{VA}_{const} * \ \mathrm{P}_{\mathrm{VA}}} && \text{(A.1)} \\
&= \underbrace{\frac{\mathrm{EC}}{\mathrm{Q}_E * \ \mathrm{P}_{\mathrm{VA}}}}_{\text{real energy price}} * \underbrace{\frac{\mathrm{Q}_E}{\mathrm{VA}_{const}}}_{\text{energy intensity}} && \text{(A.2)}
\end{aligned}
$$

Again the decomposition into the two main components of Real Unit Energy Costs becomes visible.

To consider monetary effects another variable is introduced:

$$\mathrm{s} \ldots \text{exchange rate}$$

and the NUEC can be written as:

$$\mathrm{NUEC} = \frac{\mathrm{EC}}{\mathrm{VA}_{const}} * \mathrm{s} = \frac{\mathrm{EC}}{\mathrm{VA}_{curr} * \frac{1}{\mathrm{P_{VA}}}} * \mathrm{s} \tag{A.3}$$

$$= \underbrace{\frac{\mathrm{EC}}{\mathrm{VA}_{curr}}}_{\text{RUEC}} * \underbrace{\mathrm{s} * \mathrm{P_{VA}}}_{\text{nominal effect}} \tag{A.4}$$

This model is useful to help to understand the difference between energy-related changes of prices and currency-related effects. It must be used with care as the nominal effect is expressed in sectoral purchase power parities (PPP). They are comparable among countries with similar per capita income levels, whereas have to be used with caution when countries with significantly different income levels come into consideration.

International comparison - shift share analysis

As the manufacturing industry is facing the price developments continuously, therefore it is able to react to changes dynamically. As a consequence of the rise of RUEC the industry might adapt and shift to different subsectors or even whole sectors of production. In order to take this restructuring into account a shift share analysis may be performed. By this approach a decline of the market share of energy intensive sectors becomes visible.

With

$$\{0, \mathrm{T}\} \ldots \text{periods of time}$$

$$\mathrm{i} \ldots \text{given subsector of total manufacturing}$$

$$\mathrm{m_{i,T}} \ldots \text{share of sector i in the value added of total manufacturing in period T}$$

$$\Delta\mathrm{RUEC}_T = \mathrm{RUEC}_T - \mathrm{RUEC}_0$$

$$\Delta\mathrm{m_{i,T}} = \mathrm{m_{i,T}} - \mathrm{m_{i,0}}$$

a decomposition into three effects is made:

$$\frac{\Delta \mathrm{RUEC}_T}{\mathrm{RUEC}_0} = \underbrace{\frac{\sum_i \Delta \mathrm{RUEC_{i,T}} * \mathrm{m_{i,0}}}{\mathrm{RUEC}_0}}_{\text{within subsector effect}} + \underbrace{\frac{\sum_i \Delta \mathrm{m_{i,T}} * \mathrm{RUEC_{i,0}}}{\mathrm{RUEC}_0}}_{\text{restructuring effect}} + \underbrace{\frac{\sum_i \Delta \mathrm{m_{i,T}} * \Delta \mathrm{RUEC_{i,T}}}{\mathrm{RUEC}_0}}_{\text{interaction effect}}$$

The effects are explained as follows [6]:

- **Within subsector effect**: shows the pure energy costs pressure without the effects of restructuring. Gives an answer to the question what would be the growth of the RUEC if the shares of the subsectors had remained the same.
- **Restructuring effect**: shows a static restructuring effect as it measures the contribution of changes in value added shares of subsectors to overall manufacturing RUEC growth.
- **Interaction effect**: shows a dynamic restructuring effect as it measures the comovement between RUECs and value added shares

With this methodology different impacts of these effects on the compared countries can be seen.

Appendix B

Trade data

All of the following items are summarized in Chapter 27 of the Harmonized Tariff Schedule of the United States: "Mineral fuels, mineral oils and products of their distillation; bituminous substances; mineral waxes".

This list has been retrieved from the Homepage of the United States International Trade Comission [14].

2701 Coal; briquettes, ovoids and similar solid fuels manufactured from coal

2702 Lignite, whether or not agglomerated, excluding jet

2703 Peat (including peat litter), whether or not agglomerate

2704 Coke and semicoke of coal, of lignite or of peat, whether or not agglomerated; retort carbon

2705 Coal gas, water gas, producer gas and similar gases, other than petroleum gases and other gaseous hydrocarbons

2706 Tar distilled from coal, from lignite or from peat, and other mineral tars, whether or not dehydrated or partially distilled, including reconstituted tars

2707 Oils and other products of the distillation of high temperature coal tar; similar products in which the weight of the aromatic constituents exceeds that of the nonaromatic constituents

2708 Pitch and pitch coke, obtained from coal tar or from other mineral tars

2709 Petroleum oils and oils obtained from bituminous minerals, crude

2710 Petroleum oils and oils obtained from bituminous minerals, other than crude; preparations not elsewhere specified or included, containing by weight 70 percent or more of petroleum oils or of oils obtained from bituminous minerals, these oils being the basic constituents of the preparations; waste oils

2711 Petroleum gases and other gaseous hydrocarbons

2712 Petroleum jelly; paraffin wax, microcrystalline petroleum wax, slack wax, ozokerite, lignite wax, peat wax, other mineral waxes and similar products obtained by synthesis or by other processes, whether or not colored:

2713 Petroleum coke, petroleum bitumen and other residues of petroleum oils or of oils obtained from bituminous minerals

2714 Bitumen and asphalt, natural; bituminous or oil shale and tar sands; asphaltites and asphaltic rocks

2715 Bituminous mixtures based on natural asphalt, on natural bitumen, on petroleum bitumen, on mineral tar or on mineral tar pitch

2716 Electrical energy

Appendix C

Variables

Variable	Acronym	Eviews	Source
Gross Domestic Product EU	GDP_{EU}	GDP_EU	OECD [11]
Gross Domestic Product US	GDP_{US}	GDP_US	OECD [11]
Gross Domestic Product Russia	GDP_{RU}	GDP_RU	OECD [11]
Gross Domestic Product Japan	GDP_{JP}	GDP_JP	OECD [11]
Gross Domestic Product China	GDP_{CH}	GDP_CH	OECD [11]
Inflation EU	INF_{EU}	INF_EU	OECD [11]
Inflation US	INF_{US}	INF_US	OECD [11]
Inflation Russia	INF_{RU}	INF_RU	OECD [11]
Inflation Japan	INF_{JP}	INF_JP	OECD [11]
Inflation China	INF_{CH}	INF_CH	OECD [11]
Currency exchange rate EU	$\frac{1}{FX_{EU}}$	EUR	OECD [11]
Currency exchange rate US	$\frac{1}{FX_{US}}$	DOL	OECD [11]
Currency exchange rate Russia	$\frac{1}{FX_{RU}}$	RUB	OECD [11]
Currency exchange rate Japan	$\frac{1}{FX_{JP}}$	JPY	OECD [11]
Currency exchange rate China	$\frac{1}{FX_{CH}}$	CNY	OECD [11]

Figure C.1: Variables

Variable	Acronym	Eviews	Source
Imports from US to EU	${}_{US}IMP_{EU}$	IMP_US_EU	COMTRADE [3]
Imports from Russia to EU	${}_{RU}IMP_{EU}$	IMP_RU_EU	COMTRADE [3]
Imports from Japan to EU	${}_{JP}IMP_{EU}$	IMP_JP_EU	COMTRADE [3]
Imports from China to EU	${}_{CH}IMP_{EU}$	IMP_CH_EU	COMTRADE [3]
Exports from EU to US	${}_{EU}EXP_{US}$	EXP_EU_US	COMTRADE [3]
Exports from EU to Russia	${}_{EU}EXP_{RU}$	EXP_EU_RU	COMTRADE [3]
Exports from EU to Japan	${}_{EU}EXP_{JP}$	EXP_EU_JP	COMTRADE [3]
Exports from EU to China	${}_{EU}EXP_{CH}$	EXP_EU_CH	COMTRADE [3]
Total Exports from EU	${}_{EU}TEXP$	TEXP_EU	calculated
Total Imports to EU	$TIMP_{EU}$	TIMP_EU	calculated
Ratio of EU's GDP to total trade, in case of imports $TIMP_{EU}$ in denominator	$\frac{GDP_{EU}}{{}_{EU}TEXP}$	RATIO1	calculated
Ratio of partner country's GDP to total trade, in case of imports $TIMP_{EU}$ in denominator	$\frac{GDP_c}{{}_{EU}TEXP}$	RATIO2	calculated
Ratio of total trade to EU's GDP, in case of imports $TIMP_{EU}$ in numerator	$\frac{{}_{EU}TEXP}{GDP_{EU}}$	RATIO3	calculated
Ratio of total trade to partner country's GDP, in case of imports $TIMP_{EU}$ in numerator	$\frac{{}_{EU}TEXP}{GDP_c}$	RATIO4	calculated
Constant	C	C	
Seasonal dummy, 1 for 1^{st} quarter, 0 else	q_1	Q1	
Seasonal dummy, 1 for 2^{nd} quarter, 0 else	q_2	Q2	
Seasonal dummy, 1 for 3^{rd} quarter, 0 else	q_3	Q3	
Seasonal dummy, 1 for 4^{th} quarter, 0 else	q_4	Q4	

Figure C.2: Variables (continued)

Appendix D

Eviews

```
'create group for exogenous variables'
group xs

'create vector to store r-squares'
vector(1000) r2s5
vector(1000) r2bar5
'create matrices to store coefficients and tvalues'
matrix(5,1000) coefs5
matrix(5,1000) tvalues5
'matrix for labels'
matrix(5,1000) variables5
vector(5) drinnen

'counter of equations'
!rowcounter=1

'assign x to group'
for %i texp_eu gdp_eu gdp_us ratio1 ratio2 ratio3 ratio4 eur dol
    inf_eu inf_us c
   xs.add {%i}
next
```

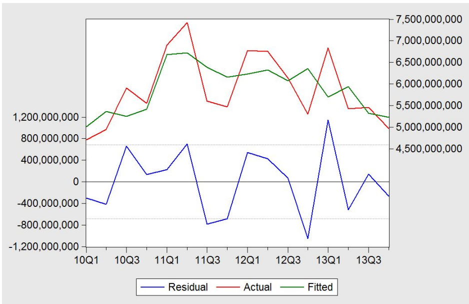
```
'run regressions between Y and five of the X'
for !i=1 to xs.@count-1
  %iname = xs.@seriesname(!i)
  for !j=!i+1 to xs.@count
    %jname = xs.@seriesname(!j)
      for !k=!j+1 to xs.@count
        %kname = xs.@seriesname(!k)
          for !m=!k+1 to xs.@count
            %mname = xs.@seriesname(!m)
              for !n=!m+1 to xs.@count
                %nname = xs.@seriesname(!n)
equation eq_{!i}{!j}{!k}{!m}{!n}.ls exp_eu_us {%iname} {%jname}
   {%kname} {%mname} {%nname}

r2s5(!rowcounter) = eq_{!i}{!j}{!k}{!m}{!n}.@r2
r2bar5(!rowcounter) = eq_{!i}{!j}{!k}{!m}{!n}.@rbar2
colplace(coefs5,eq_{!i}{!j}{!k}{!m}{!n}.@coefs, !rowcounter)
colplace(tvalues5,eq_{!i}{!j}{!k}{!m}{!n}.@tstats, !rowcounter)
drinnen(1) = !i
drinnen(2) = !j
drinnen(3) = !k
drinnen(4) = !m
drinnen(5) = !n
colplace(variables5,drinnen, !rowcounter)
!rowcounter = !rowcounter+1
              next
          next
      next
  next
next
```

Appendix E

Results

On the following pages all estimation results from chapter 2.3 are presented.

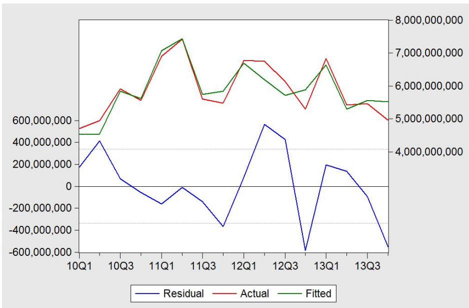


(a) A1 Regression

	Coefficient	Std. Error	t-Statistic	Prob.
GDP_EU	9812.563	3576.000	2.744005	0.0178
GDP_US	-15966.97	5554.868	-2.874411	0.0140
EUR	-2.90E+10	1.09E+10	-2.661445	0.0207
INF_EU	6.19E+08	2.19E+08	2.824234	0.0153

R-squared	0.447068	Mean dependent var	5.88E+09
Adjusted R-squared	0.308835	S.D. dependent var	8.23E+08
S.E. of regression	6.84E+08	Akaike info criterion	43.73702
Sum squared resid	5.61E+18	Schwarz criterion	43.93016
Log likelihood	-345.8961	Hannan-Quinn criter.	43.74691
Durbin-Watson stat	2.672123		

(b) A1 Parameters

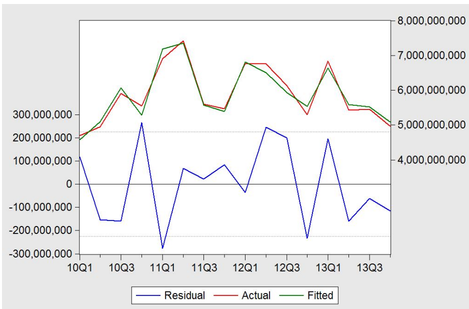


(c) A3 Regression

	Coefficient	Std. Error	t-Statistic	Prob.
RATIO1	-9.41E+12	1.08E+12	-8.687979	0.0000
EUR	9.01E+09	5.34E+08	16.89590	0.0000

R-squared	0.841507	Mean dependent var	5.88E+09
Adjusted R-squared	0.830186	S.D. dependent var	8.23E+08
S.E. of regression	3.39E+08	Akaike info criterion	42.23749
Sum squared resid	1.61E+18	Schwarz criterion	42.33406
Log likelihood	-335.8999	Hannan-Quinn criter.	42.24244
Durbin-Watson stat	1.642024		

(d) A3 Parameters



(e) A4 Regression

	Coefficient	Std. Error	t-Statistic	Prob.
GDP_EU	1900.897	369.1907	5.148821	0.0006
RATIO1	-8.63E+12	7.77E+11	-11.11072	0.0000
INF_US	-86217781	26016524	-3.313962	0.0090
Q1	1.22E+10	2.70E+09	4.516497	0.0015
Q2	1.24E+10	2.73E+09	4.528173	0.0014
Q3	1.21E+10	2.74E+09	4.413701	0.0017
Q4	1.17E+10	2.75E+09	4.233304	0.0022

R-squared	0.954900	Mean dependent var	5.88E+09
Adjusted R-squared	0.924833	S.D. dependent var	8.23E+08
S.E. of regression	2.26E+08	Akaike info criterion	41.60566
Sum squared resid	4.58E+17	Schwarz criterion	41.94367
Log likelihood	-325.8453	Hannan-Quinn criter.	41.62297
Durbin-Watson stat	2.787218		

(f) A4 Parameters

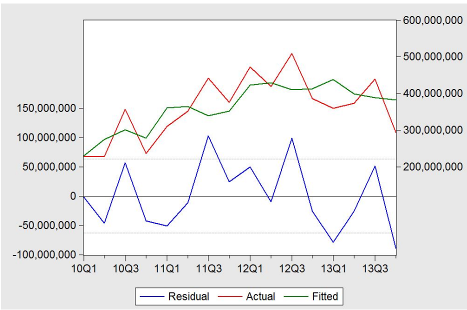
Figure E.1: Regression results for exports from EU to US

(a) A1 Regression

	Coefficient	Std. Error	t-Statistic	Prob.
GDP_EU	646.8222	169.4803	3.816504	0.0021
EUR	-2.55E+09	7.51E+08	-3.396580	0.0048
RUB	2.78E+10	1.44E+10	1.923543	0.0766

R-squared	0.483876	Mean dependent var	3.61E+08
Adjusted R-squared	0.404472	S.D. dependent var	85506926
S.E. of regression	65986098	Akaike info criterion	39.01515
Sum squared resid	5.66E+16	Schwarz criterion	39.16001
Log likelihood	-309.1212	Hannan-Quinn criter.	39.02257
Durbin-Watson stat	2.138446		

(b) A1 Parameters

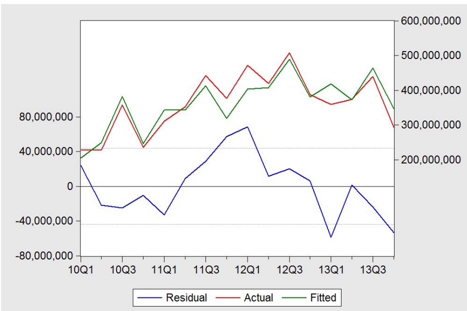


(c) A3 Regression

	Coefficient	Std. Error	t-Statistic	Prob.
RATIO2	6.67E+12	2.48E+12	2.692141	0.0185
RATIO3	391565.6	103895.6	3.768838	0.0023
C	-7.10E+08	2.97E+08	-2.390145	0.0327

R-squared	0.528419	Mean dependent var	3.61E+08
Adjusted R-squared	0.455868	S.D. dependent var	85506926
S.E. of regression	63074438	Akaike info criterion	38.92489
Sum squared resid	5.17E+16	Schwarz criterion	39.06975
Log likelihood	-308.3991	Hannan-Quinn criter.	38.93231
F-statistic	7.283423	Durbin-Watson stat	2.061799
Prob(F-statistic)	0.007553		

(d) A3 Parameters



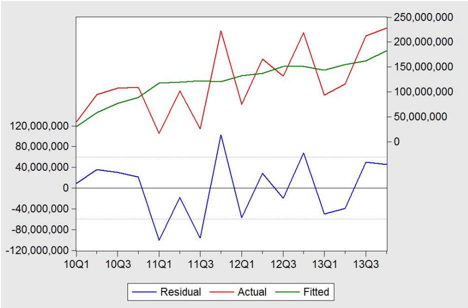
(e) A4 Regression

	Coefficient	Std. Error	t-Statistic	Prob.
RATIO2	6.43E+12	1.80E+12	3.574819	0.0051
RATIO3	398724.9	72725.70	5.482586	0.0003
Q1	-7.28E+08	2.06E+08	-3.524112	0.0055
Q2	-7.29E+08	2.10E+08	-3.473594	0.0060
Q3	-6.27E+08	2.09E+08	-2.998934	0.0134
Q4	-7.37E+08	2.10E+08	-3.507955	0.0057

R-squared	0.824951	Mean dependent var	3.61E+08
Adjusted R-squared	0.737427	S.D. dependent var	85506926
S.E. of regression	43815336	Akaike info criterion	38.30886
Sum squared resid	1.92E+16	Schwarz criterion	38.59858
Log likelihood	-300.4709	Hannan-Quinn criter.	38.32370
Durbin-Watson stat	0.980019		

(f) A4 Parameters

Figure E.2: Regression results for exports from EU to Russia

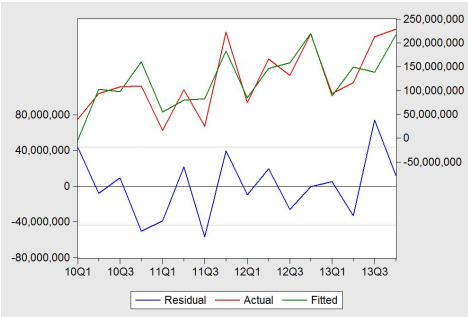


(a) A1 Regression

	Coefficient	Std. Error	t-Statistic	Prob.
GDP_EU	390.2862	146.9237	2.656387	0.0188
EUR	-1.20E+09	4.86E+08	-2.468136	0.0271

R-squared	0.303969	Mean dependent var	1.22E+08
Adjusted R-squared	0.254253	S.D. dependent var	69717232
S.E. of regression	60205477	Akaike info criterion	38.78089
Sum squared resid	5.07E+16	Schwarz criterion	38.87747
Log likelihood	-308.2471	Hannan-Quinn criter.	38.78584
Durbin-Watson stat	2.628640		

(b) A1 Parameters

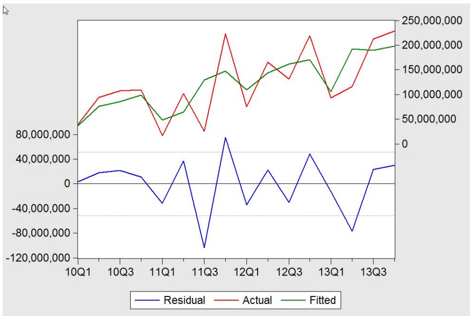


(c) A2 Regression

	Coefficient	Std. Error	t-Statistic	Prob.
GDP_EU	239.6185	115.5408	2.073886	0.0649
EUR	-1.09E+09	3.95E+08	-2.760781	0.0201
Q1	4.67E+08	3.10E+08	1.507984	0.1625
Q2	5.16E+08	3.06E+08	1.686294	0.1226
Q3	5.08E+08	3.06E+08	1.659949	0.1279
Q4	5.86E+08	3.11E+08	1.884675	0.0888

R-squared	0.734997	Mean dependent var	1.22E+08
Adjusted R-squared	0.602496	S.D. dependent var	69717232
S.E. of regression	43955257	Akaike info criterion	38.31524
Sum squared resid	1.93E+16	Schwarz criterion	38.60496
Log likelihood	-300.5219	Hannan-Quinn criter.	38.33008
Durbin-Watson stat	2.527990		

(d) A2 Parameters

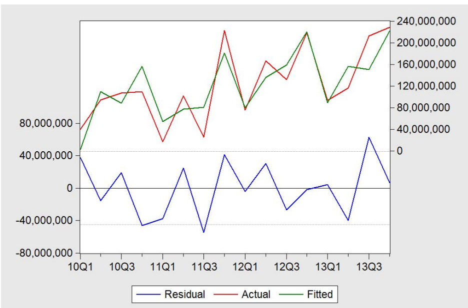


(e) A3 Regression

	Coefficient	Std. Error	t-Statistic	Prob.
TEXP_EU	-0.191243	0.059747	-3.200895	0.0076
GDP_JP	861.9729	333.0826	2.587865	0.0238
RATIO2	-5.49E+12	1.71E+12	-3.206727	0.0075
INF_EU	13058471	3258339.	4.007708	0.0017

R-squared	0.559743	Mean dependent var	1.22E+08
Adjusted R-squared	0.449679	S.D. dependent var	69717232
S.E. of regression	51718769	Akaike info criterion	38.57286
Sum squared resid	3.21E+16	Schwarz criterion	38.76600
Log likelihood	-304.5829	Hannan-Quinn criter.	38.58275
Durbin-Watson stat	3.136022		

(f) A3 Parameters



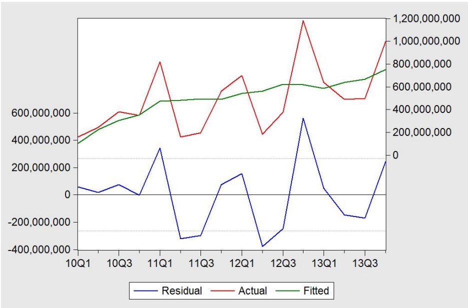
(g) A4 Regression

	Coefficient	Std. Error	t-Statistic	Prob.
TEXP_EU	0.199275	0.098272	2.027788	0.0732
RATIO3	-912973.1	480616.2	-1.899589	0.0899
EUR	-1.33E+09	5.38E+08	-2.477060	0.0352
Q1	1.91E+09	8.10E+08	2.354844	0.0430
Q2	1.95E+09	7.97E+08	2.441833	0.0373
Q3	1.95E+09	7.95E+08	2.445215	0.0370
Q4	2.02E+09	7.91E+08	2.550468	0.0312

R-squared	0.751422	Mean dependent var	1.22E+08
Adjusted R-squared	0.585703	S.D. dependent var	69717232
S.E. of regression	44874121	Akaike info criterion	38.37626
Sum squared resid	1.81E+16	Schwarz criterion	38.71426
Log likelihood	-300.0101	Hannan-Quinn criter.	38.39357
Durbin-Watson stat	2.791227		

(h) A4 Parameters

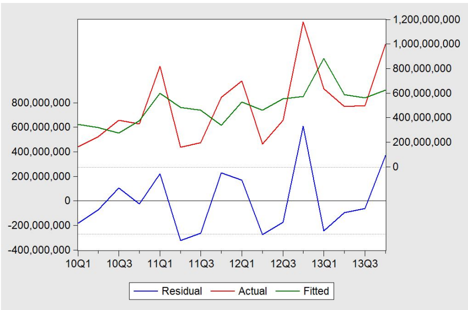
Figure E.3: Regression results for exports from EU to Japan



(a) A1 Regression

	Coefficient	Std. Error	t-Statistic	Prob.
GDP_EU	1666.616	645.8982	2.580308	0.0218
EUR	-5.14E+09	2.14E+09	-2.406296	0.0305
R-squared	0.305920	Mean dependent var	4.96E+08	
Adjusted R-squared	0.256343	S.D. dependent var	3.07E+08	
S.E. of regression	2.65E+08	Akaike info criterion	41.74235	
Sum squared resid	9.81E+17	Schwarz criterion	41.83892	
Log likelihood	-331.9388	Hannan-Quinn criter.	41.74730	
Durbin-Watson stat	2.189722			

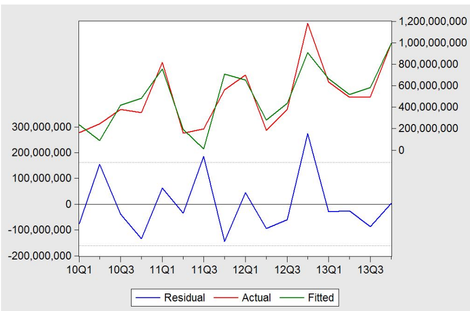
(b) A1 Parameters



(c) A3 Regression

	Coefficient	Std. Error	t-Statistic	Prob.
CNY	-1.11E+11	5.70E+10	-1.941330	0.0726
INF_CH	1.67E+08	83495731	1.997784	0.0656
R-squared	0.262639	Mean dependent var	4.96E+08	
Adjusted R-squared	0.209971	S.D. dependent var	3.07E+08	
S.E. of regression	2.73E+08	Akaike info criterion	41.80284	
Sum squared resid	1.04E+18	Schwarz criterion	41.89941	
Log likelihood	-332.4227	Hannan-Quinn criter.	41.80779	
Durbin-Watson stat	2.328356			

(d) A3 Parameters

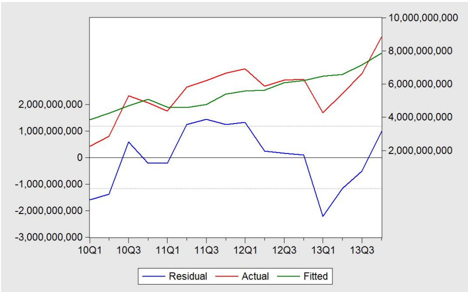


(e) A4 Regression

	Coefficient	Std. Error	t-Statistic	Prob.
GDP_EU	1007.538	506.0592	1.990949	0.0817
RATIO1	-9.00E+12	2.82E+12	-3.188869	0.0128
RATIO2	1.97E+13	6.56E+12	2.997831	0.0171
INF_CH	-1.90E+08	74731329	-2.539905	0.0347
Q1	1.67E+10	6.09E+09	2.737107	0.0256
Q2	1.62E+10	6.03E+09	2.683641	0.0278
Q3	1.64E+10	6.06E+09	2.699078	0.0271
Q4	1.70E+10	6.13E+09	2.767827	0.0244
R-squared	0.852691	Mean dependent var	4.96E+08	
Adjusted R-squared	0.723795	S.D. dependent var	3.07E+08	
S.E. of regression	1.61E+08	Akaike info criterion	40.94230	
Sum squared resid	2.08E+17	Schwarz criterion	41.32859	
Log likelihood	-319.5384	Hannan-Quinn criter.	40.96208	
Durbin-Watson stat	2.769874			

(f) A4 Parameters

Figure E.4: Regression results for exports from EU to China

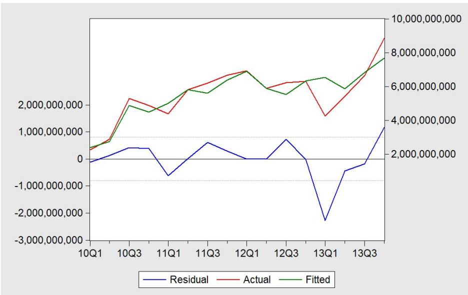


(a) A1 Regression

	Coefficient	Std. Error	t-Statistic	Prob.
GDP_US	11568.48	3560.722	3.248914	0.0058
INF_US	-3.88E+08	1.36E+08	-2.853657	0.0128

R-squared	0.496386	Mean dependent var	5.55E+09
Adjusted R-squared	0.460414	S.D. dependent var	1.60E+09
S.E. of regression	1.18E+09	Akaike info criterion	44.72490
Sum squared resid	1.94E+19	Schwarz criterion	44.82147
Log likelihood	-355.7992	Hannan-Quinn criter.	44.72984
Durbin-Watson stat	0.876501		

(b) A1 Parameters

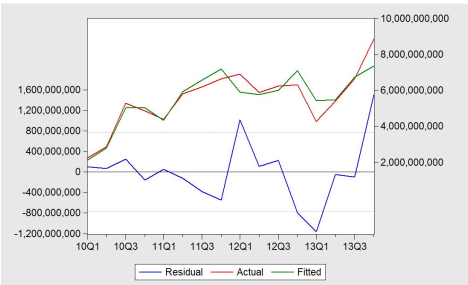


(c) A3 Regression

	Coefficient	Std. Error	t-Statistic	Prob.
GDP_US	10247.35	2467.258	4.153336	0.0011
RATIO4	552499.3	135322.7	4.082829	0.0013
INF_US	-4.12E+08	93609896	-4.405176	0.0007

R-squared	0.779336	Mean dependent var	5.55E+09
Adjusted R-squared	0.745388	S.D. dependent var	1.60E+09
S.E. of regression	8.08E+08	Akaike info criterion	44.02473
Sum squared resid	8.48E+18	Schwarz criterion	44.16959
Log likelihood	-349.1978	Hannan-Quinn criter.	44.03214
Durbin-Watson stat	1.590746		

(d) A3 Parameters



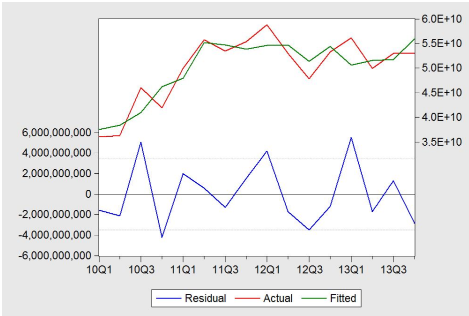
(e) A4 Regression

	Coefficient	Std. Error	t-Statistic	Prob.
RATIO4	451980.5	139013.6	3.251340	0.0087
INF_US	2.05E+08	88616754	2.318672	0.0429
Q1	-2.30E+10	8.23E+09	-2.798378	0.0188
Q2	-2.25E+10	8.33E+09	-2.704427	0.0221
Q3	-2.17E+10	8.33E+09	-2.608086	0.0261
Q4	-2.12E+10	8.32E+09	-2.551430	0.0288

R-squared	0.847125	Mean dependent var	5.55E+09
Adjusted R-squared	0.770688	S.D. dependent var	1.60E+09
S.E. of regression	7.67E+08	Akaike info criterion	44.03270
Sum squared resid	5.88E+18	Schwarz criterion	44.32243
Log likelihood	-346.2616	Hannan-Quinn criter.	44.04754
Durbin-Watson stat	1.455205		

(f) A4 Parameters

Figure E.5: Regression results for imports to EU from US

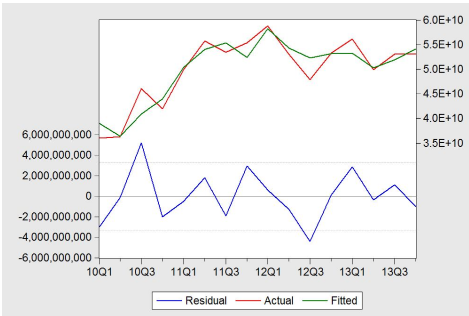


(a) A1 Regression

	Coefficient	Std. Error	t-Statistic	Prob.
GDP_EU	81134.15	29576.07	2.743237	0.0191
EUR	-1.90E+11	9.65E+10	-1.969271	0.0746
INF_EU	4.76E+09	1.99E+09	2.391492	0.0358
INF_RU	-2.19E+09	7.71E+08	-2.842189	0.0160
C	-3.08E+11	1.52E+11	-2.033407	0.0669

R-squared	0.804253	Mean dependent var	5.00E+10
Adjusted R-squared	0.733072	S.D. dependent var	6.81E+09
S.E. of regression	3.52E+09	Akaike info criterion	47.05134
Sum squared resid	1.36E+20	Schwarz criterion	47.29278
Log likelihood	-371.4107	Hannan-Quinn criter.	47.06371
F-statistic	11.29875	Durbin-Watson stat	2.678447
Prob(F-statistic)	0.000690		

(b) A1 Parameters

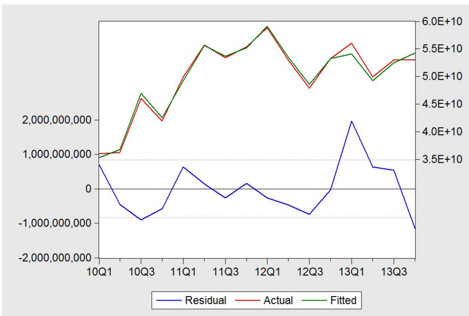


(c) A2 Regression

	Coefficient	Std. Error	t-Statistic	Prob.
GDP_EU	91948.56	29386.75	3.128913	0.0140
EUR	-2.22E+11	9.66E+10	-2.293168	0.0510
INF_EU	5.40E+09	1.99E+09	2.709983	0.0267
INF_RU	-2.52E+09	7.57E+08	-3.337022	0.0103
Q1	-3.40E+11	1.53E+11	-2.229949	0.0563
Q2	-3.44E+11	1.53E+11	-2.253045	0.0543
Q3	-3.43E+11	1.52E+11	-2.254654	0.0542
Q4	-3.45E+11	1.53E+11	-2.260442	0.0537

R-squared	0.874150	Mean dependent var	5.00E+10
Adjusted R-squared	0.764032	S.D. dependent var	6.81E+09
S.E. of regression	3.31E+09	Akaike info criterion	46.98461
Sum squared resid	8.76E+19	Schwarz criterion	47.37090
Log likelihood	-367.8769	Hannan-Quinn criter.	47.00439
Durbin-Watson stat	2.250168		

(d) A2 Parameters

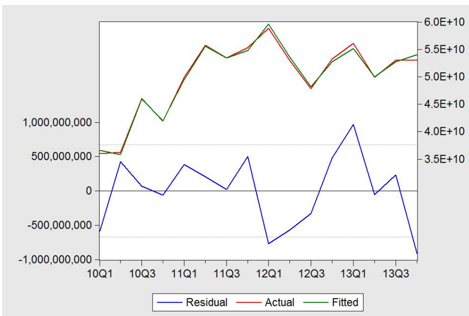


(e) A3 Regression

	Coefficient	Std. Error	t-Statistic	Prob.
TIMP_EU	0.876336	0.034324	25.53148	0.0000
GDP_EU	-2681.731	1307.506	-2.051028	0.0610
RUB	3.96E+11	1.43E+11	2.767298	0.0160

R-squared	0.986973	Mean dependent var	5.00E+10
Adjusted R-squared	0.984969	S.D. dependent var	6.81E+09
S.E. of regression	8.35E+08	Akaike info criterion	44.09155
Sum squared resid	9.07E+18	Schwarz criterion	44.23641
Log likelihood	-349.7324	Hannan-Quinn criter.	44.09897
Durbin-Watson stat	1.450135		

(f) A3 Parameters



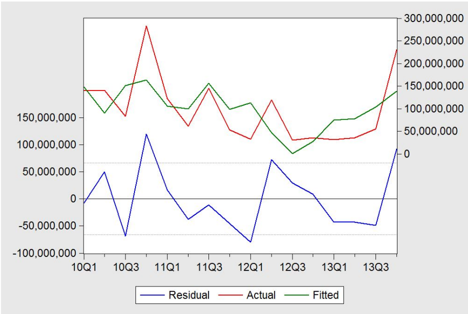
(g) A4 Regression

	Coefficient	Std. Error	t-Statistic	Prob.
GDP_RU	16128.32	5446.924	2.960996	0.0159
RATIO3	3730227.	199170.1	18.72885	0.0000
EUR	3.12E+10	3.48E+09	8.975298	0.0000
Q1	-4.56E+10	4.99E+09	-9.137711	0.0000
Q2	-4.61E+10	4.91E+09	-9.377719	0.0000
Q3	-4.67E+10	4.93E+09	-9.471126	0.0000
Q4	-4.70E+10	5.00E+09	-9.405256	0.0000

R-squared	0.994152	Mean dependent var	5.00E+10
Adjusted R-squared	0.990253	S.D. dependent var	6.81E+09
S.E. of regression	6.73E+08	Akaike info criterion	43.79069
Sum squared resid	4.07E+18	Schwarz criterion	44.12870
Log likelihood	-343.3256	Hannan-Quinn criter.	43.80800
Durbin-Watson stat	1.657428		

(h) A4 Parameters

Figure E.6: Regression results for imports to EU from Russia

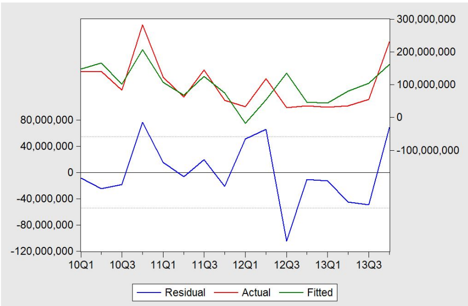


(a) A1 Regression

	Coefficient	Std. Error	t-Statistic	Prob.
GDP_EU	250.4552	101.7460	2.461572	0.0300
GDP_JP	2525.657	1207.636	2.091405	0.0584
JPY	-2.99E+11	1.40E+11	-2.132900	0.0543
INF_EU	-9925822.	4317226.	-2.299120	0.0403

R-squared	0.382569	Mean dependent var	99850224
Adjusted R-squared	0.228211	S.D. dependent var	75362853
S.E. of regression	66207396	Akaike info criterion	39.06680
Sum squared resid	5.26E+16	Schwarz criterion	39.25995
Log likelihood	-308.5344	Hannan-Quinn criter.	39.07669
Durbin-Watson stat	2.232336		

(b) A1 Parameters

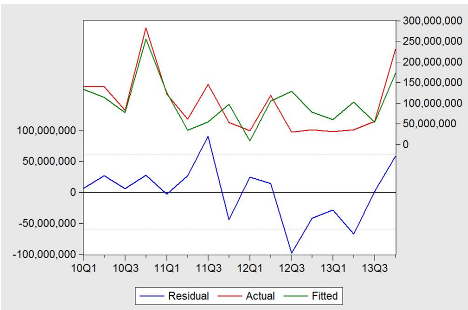


(c) A3 Regression

	Coefficient	Std. Error	t-Statistic	Prob.
GDP_EU	-997.6134	422.3526	-2.362039	0.0359
GDP_JP	3553.501	1357.622	2.617446	0.0225
RATIO3	-386544.8	136862.0	-2.824339	0.0153
RATIO4	110072.6	42067.97	2.616542	0.0225

R-squared	0.584427	Mean dependent var	99850224
Adjusted R-squared	0.480534	S.D. dependent var	75362853
S.E. of regression	54317003	Akaike info criterion	38.67089
Sum squared resid	3.54E+16	Schwarz criterion	38.86404
Log likelihood	-305.3671	Hannan-Quinn criter.	38.68078
Durbin-Watson stat	2.101729		

(d) A3 Parameters



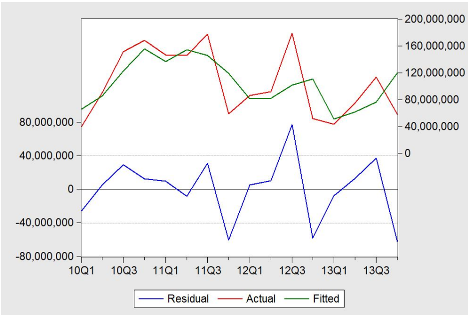
(e) A4 Regression

	Coefficient	Std. Error	t-Statistic	Prob.
TIMP_EU	-0.114648	0.048392	-2.369158	0.0420
GDP_JP	4721.018	2087.725	2.261322	0.0501
RATIO4	146431.3	64183.26	2.281456	0.0484
Q1	-5.96E+09	2.78E+09	-2.144347	0.0606
Q2	-5.96E+09	2.78E+09	-2.143704	0.0607
Q3	-6.03E+09	2.81E+09	-2.144182	0.0606
Q4	-5.96E+09	2.81E+09	-2.116421	0.0634

R-squared	0.606839	Mean dependent var	99850224
Adjusted R-squared	0.344732	S.D. dependent var	75362853
S.E. of regression	61005187	Akaike info criterion	38.99045
Sum squared resid	3.35E+16	Schwarz criterion	39.32846
Log likelihood	-304.9236	Hannan-Quinn criter.	39.00776
Durbin-Watson stat	1.669687		

(f) A4 Parameters

Figure E.7: Regression results for imports to EU from Japan

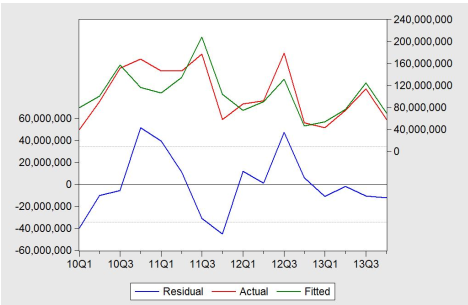


(a) A1 Regression

	Coefficient	Std. Error	t-Statistic	Prob.
GDP_EU	714.1035	265.9486	2.685118	0.0187
GDP_CH	-256.2879	85.00291	-3.015048	0.0099
EUR	-1.91E+09	7.67E+08	-2.494666	0.0269

R-squared	0.423244	Mean dependent var	1.05E+08
Adjusted R-squared	0.334513	S.D. dependent var	49808224
S.E. of regression	40632260	Akaike info criterion	38.04538
Sum squared resid	2.15E+16	Schwarz criterion	38.19024
Log likelihood	-301.3631	Hannan-Quinn criter.	38.05280
Durbin-Watson stat	2.457907		

(b) A1 Parameters

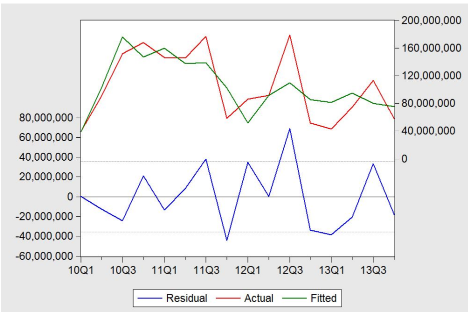


(c) A2 and A4 Regression

	Coefficient	Std. Error	t-Statistic	Prob.
INF_EU	-44402303	17162505	-2.587169	0.0271
INF_CH	29712211	12875101	2.307726	0.0437
Q1	1.53E+09	4.85E+08	3.151435	0.0103
Q2	1.60E+09	5.01E+08	3.186828	0.0097
Q3	1.64E+09	4.98E+08	3.298817	0.0080
Q4	1.57E+09	4.98E+08	3.156671	0.0102

R-squared	0.680912	Mean dependent var	1.05E+08
Adjusted R-squared	0.521368	S.D. dependent var	49808224
S.E. of regression	34458955	Akaike info criterion	37.82843
Sum squared resid	1.19E+16	Schwarz criterion	38.11815
Log likelihood	-296.6275	Hannan-Quinn criter.	37.84327
Durbin-Watson stat	1.243541		

(d) A2 and A4 Parameters



(e) A3 Regression

	Coefficient	Std. Error	t-Statistic	Prob.
RATIO1	-1.86E+13	5.15E+12	-3.603057	0.0036
RATIO3	-126532.5	38794.63	-3.261598	0.0068
INF_EU	-9911856.	4107268.	-2.413248	0.0327
C	4.23E+09	1.01E+09	4.201727	0.0012

R-squared	0.589178	Mean dependent var	1.05E+08
Adjusted R-squared	0.486473	S.D. dependent var	49808224
S.E. of regression	35692972	Akaike info criterion	37.83112
Sum squared resid	1.53E+16	Schwarz criterion	38.02427
Log likelihood	-298.6490	Hannan-Quinn criter.	37.84101
F-statistic	5.736586	Durbin-Watson stat	2.631934
Prob(F-statistic)	0.011340		

(f) A3 Parameters

Figure E.8: Regression results for imports to EU from China