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Crises and their impact on the energy system: Sweden 1900-2013

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Abstract: Throughout history, changes have occurred in the energy system, where social and economic factors have been identified as drivers for these changes. The purpose of this study is to investigate whether crises, financial crises and energy supply crises, have been drivers for changes in the energy system in Sweden for the period 1900-2013. To investigate these changes, energy prices is measured as the mechanism of changes in the energy system by using relative prices. The data for energy consumption, energy intensity and CO_2 emissions are based on the manufacturing industry and are investigated as the impact of changes that occur in the energy system. The results for this study show that crises have had an impact on the energy system. Furthermore, the study also indicates that there is a difference between energy supply crises and financial crises and their respective impact on the energy system. Energy supply crises appears to create long-term changes in the energy system, due to shortages in the energy supply, which have increased energy prices as well as the demand for substituted energy carriers. Financial crises appear to only have had short-term impacts on the Swedish energy system.

Keywords: Crises; Sweden; Energy System; Energy Transition

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1. Introduction

Recently, in order to get a broader understanding of changes in the energy system, there has been a considerable body of research on the historical changes in the economy, society, technology and in the environment (O'Connor & Cleveland 2014; Grubler 2012). Thanks to this body of research, patterns of energy transitions and drivers of changes in the energy system have become clearer (Grubler 2012). The historical pattern of energy transition generally includes the shift from traditional energy carriers (e.g. wood, peat) to fossil energy carriers (e.g. oil, gas) and the latest modern energy transition (e.g. renewables) (Kander et al 2013). Several researchers, with diverse areas of expertise, have examined the different drivers for changes to occur in the energy system. The drivers for changes in the energy system have in literature been mentioned as historical developing events, such as urbanization, technological innovations, technological knowledge, and the energy services (Kander et al 2013; O'Connor 2010). O'Connor (2010) identifies the technological innovations as the major driver for changes in the energy system. In addition, Kander et al (2013) highlights the changes in energy systems as the resultant from technological knowledge and connected innovations. Except for the technological innovations, Fouquet & Pearson (2012), O'Connor & Cleveland (2014) illustrate the opportunities to produce cheaper and better energy services to the consumer as one of the most important drivers for energy transitions. Furthermore, through this opportunity it would be possible to avoid that new quality energy or energy technology will have a higher price than what the already incumbent one has. By successfully finding this opportunity, which will happen sooner or later, the transition process will speed up and most likely occur. Economic growth, more particularly structural and technical change, is another factor that have been identified by Kander (2000) as one of the drivers of changes in the energy system. These changes were identified as changes in the energy consumption, energy intensity and in the amount of CO_2 emissions. As seen, considerable research has been done on the impact of different types of drivers on change in the energy system.

This chapter partly draws on my paper Research Design – Crises impact on changes in the energy system in Sweden, 1900-2014 (2016).

Table 1.1: Identified Drivers for Changes in the Energy system

Author	Identified Driver
Kander (2000)	Economic Growth, i.e. structural & technical change.
O'Connor (2010)	Technological innovations.
Fouquet & Pearson (2012)	Cheaper & better energy services.
Kander et al. (2013)	Technological knowledge & connected innovations.
O'Connor & Cleveland (2014)	Cheaper & better energy services.

With the discovery that economic and social factors function as drivers for changes in the energy system, it is relevant to extend this field to identify further drivers. A small research niche, which identifies historical crises as one of the drivers for changes in the energy system, exists on the field (Peters et al. 2011; Kaijser & Kander 2012; Swilling 2013). However, research on crises impact on changes in energy system has mostly concerned the global energy supply crises that occurred in the twentieth century. Kaijser & Kander (2012) investigate global energy supply crises in a context of development blocks and industrial revolution and how it globally, as well as domestically (Sweden) have had an impact on changes in the energy system. However, research on historical financial crises' impacts on the energy system has not been studied to the same extent as energy supply crises. However, the body of research that exists on the financial crises as a driver of changes in the energy system are much more limited. Existent research concerns especially the Global Financial Crisis in 2008 and how it has been interpreted as the start of a change towards a sustainable energy system (Swilling 2013). Financial crises have not received attention from a historical perspective on this field, nor its impact on the changes that occurred in relation to the crises occurrence. Although a few attempts have been made on the field but the topic still remains neglected.

To add breadth to the literature, this study will investigate and compare historical crises, in particular financial- and energy supply crises, global crises as well as domestic crises, with the purpose to examine to what extent these crises have been a driver of changes in the energy system. It will in particular add breadth to the literature by studying crises impact on changes on the Swedish energy system between 1900-2013. Although Sweden has managed relatively well throughout the global crises, such as the World Wars and various financial crises, it has its own unique development and history regarding crises and the energy system. Furthermore, given the fact that Sweden can provide access to long time series makes it possible to conduct this type of study.

Research on the case of Sweden and the country's historical crises as the driver of changes in the energy system does exist but the angles are diverse. Bergquist & Söderholm (2015) investigated the energy transition in the Swedish pulp and paper industry between 1973-1990. A major finding in this study was a steady decrease in CO_2 emissions in the pulp and paper industry because of the transition from oil to biofuels in the pulp manufacturing process. Moreover, increased oil prices during the oil crisis in 1973 were identified as an important driver to reduce the oil dependency in the Swedish industry. In addition, Jewert (2008) has also identified the OPEC[2] crises' impact on the energy prices. She did also identify the transition from oil to nuclear and waterpower, as well as an increase in the consumption of biofuels in the manufacturing industry. The increased consumption of biofuels has led to a decrease in consumption of oil from 48 per cent to 10 per cent in the manufacturing industry's total energy use. The oil crisis has also been identified as a driver for the decrease in CO_2 emissions between the time period 1970-1990, as it was a reason for the shift from oil (Jewert 2008). Furthermore, Schön (1992) finds an increase in the use of wood fuel after the energy crises in Sweden in the 1970's. However, Schön's (1992) research differ in some manner, as he also found that the consumption of wood fuels increased temporarily in Sweden during World War I, as well as during World War II. This was notable, and partly path breaking, as this was the first time since the 1880's that an increase in the consumption of wood fuels had been observed. However, the studies that have been done on the case of Sweden have focused on the industrial sector and in particular the energy supply crises as the driver of changes in the energy system.

The principal aim of this study is to investigate the role of crises as a driver of changes in the energy system in Sweden during the period 1900-2013. To do this we make the following research questions. (1) To which extent have crises had an impact on changes in the energy system? (2) How do the impacts of an energy supply crisis differ compared to the impacts of a financial crisis?

OPEC: Organization of the Petroleum Exporting Countries. Iran, Iraq, Kuwait, Saudi Arabia and Venezuela were the countries, which founded the organization. The organization's aims are to co-ordinate and unify policies among the member countries with the purpose to for instance control the prices for producers. (OECD 2016)

The upcoming Section 2 defines different types of crises and practical terms. Section 3 reviews the previous research and the theoretical background on crises impact on the energy system. Section 4 provides country background and overview of the Swedish energy system as well as the economy within a historical context. Section 5 describes in detail the method and the data used in this study. Section 6 presents the results and analyses. Section 7 concludes the papers findings.

2. Definitions

2.1 Definitions of different forms of crises

An outbreak of a crisis involves a sequence of events. The change of these events is the common denominator, and it could lead to a better or a worse outcome of the former situation. Crises can be expressed in different sizes and shapes depending on the type and on what arena it happens to occur in.

2.1.1 Financial Crisis

Financial crises can be explained by the economic cycle and a disturbance in the financial market capability to meet the liquidity need and redistribute the risks in the economy (Claessens & Kose 2013). To determine what causes financial crises or explain financial crises with one indicator would be difficult. However, financial crises are in general related to asset and credit booms. These booms have a turning point where they turn into a bust. However, there is not only one shape of crisis that can be classified as a financial crisis.

Currency crises nature has changed over time, however, currency crises are related to a speculative attack on a country's currency (Claessens & Kose 2013). The speculative attack means that investors have forecasted that the governments have too big deficit. By using this information the investors' holds the currency (fixed or pegged) until the forecast says that the exchange rate will drop. The major risk is that the country's currency might collapse because the quantity of money in relation to the central banks reserves increases as an outcome of financial deficit. Moreover, a notable sign of a currency crisis is that the country's current account depreciates; boom-bust cycle on the stock market and the real exchange rate is higher than the average level.

Banking crises is a shape of a financial crisis where disturbance can occur when a country or the credit institutions are exposed to risk, which can lead to liquidity problems for the financial sector. Banks are especially fragile and exposed to a risk when their loans and securities lose their value. Historically there has been a significant relationship between banking crises and the movement in prices of real estates (Reinhart & Rogoff 2009). This was together with the mortgage loans the underlying reason for the burst of the Global Financial

Crisis in 2008. The financial crisis had its breakthrough because of a burst in the housing mortgage market in the United States in 2008. However, there are mixed opinions regarding the impacts the Global Financial Crisis actually created.

2.1.2 Energy Supply Crisis

The general definition of an energy supply crisis is a shortage in supply of an energy carrier, compared to what is demanded (Chapman et al. 2009). A diminished availability in the energy supply leads to increased energy prices for the society (Kepplinger & Roth 1979). The decade between 1970 and 1980 was a period where the world was globally affected by energy supply crises (Kepplinger & Roth 1979). This was an outcome of decisions made by the major oil exporting countries, such as Saudi Arabia, Iraq and Qatar. These decisions concerned increasing prices, declines on delivery and restrictions on output. The burst of the energy supply crises was noted as one of the factors that slowed down the economic growth in many countries during this decade (Tverberg 2012). Moreover, when wars burst out between countries it can encumber the supply of energy, especially if it happens between countries that possessed large stocks of energy.

2.2 Definitions of Practical Terms

2.2.1 The Energy System

A change that occurs in the energy system can also be referred to as an energy transition. Energy transitions incorporate changes in the sources of energy used, the level of energy consumption or the relation between energy and the economy, among others. Energy transitions differ depending on what factors that have led to the change, for instance factors as different drivers; challenges and opportunities.

2.2.2 Energy Price

The energy price is highly dependent on the balance in the supply and demand of an energy carrier (Eurostat 2015). It is also dependent on factors such as the geographical situation, trade balance, taxation, environmental protection costs and network costs.

2.2.3 Energy Consumption

The energy consumption refers to the amount of energy (measured in calorific units) consumed by a certain system, sector or society. When talking about primary energy consumption it refers to the consumption of primary energy sources, as they are found in nature. Moreover, final energy consumption reflects to the amounts of energy, which are delivered to the final consumers (agriculture, industry, services and transportation) after the transformation losses of converting primary energy source into deliver forms i.e. converting coal to electricity. (Henriques, 2011)

2.2.4 Energy Intensity

The Energy intensity is a measure expressed as a ratio between total energy consumption (primary or final) per unit of total output, i.e. gross domestic product (GDP). The energy intensity is useful when one want to know the energy productivity in a country or sector and if its energy resources are used effectively. An economy that is energy intense needs more energy to produce one unit of output, it has in that sense low energy productivity (Kander et al. 2013).

2.2.5 CO_2 emissions

CO_2 stands for carbon dioxide and is one of the most common greenhouse gas emitted into the atmosphere (OECD 2005). The level of carbon dioxide emissions released depends on what type of energy carrier that is consumed (Table C.1).

3. Previous Research & Theoretical Background

This section will give the underlying background to narrate how and why different crises have changed the energy system throughout history. It will moreover narrate how crises occur and possible explanatory theories behind the aftermath of a crisis.

3.1 Development Cycles & New Paradigm

Crises are not easy to handle or to understand and can disrupt future directions as well as open up for opportunities, which deviates from its former trajectories (Geels 2013). These opportunities depend on how the crises' causes and solutions are interpreted. Crises can create new paths, such as technological development as well as new paths in people's behavior (Schön 2011). The occurrence of crises might be dependent on a specific development, but how an economy react in response to the occurrence of a crisis, could be interpreted as path breaking rather than path dependent (Magnusson & Ottosson 2009). This interpretation where done on the basis on how developments are pushed into new directions rather than on confirming old ones. Schön (2011) argues that new paths have been developed out of crises. This argument is in line with Swilling (2013) who argues that crises have divided history into different development cycles. However, Geels & Schot (2007) argues that successful socio-economic changes do not happen automatically. The transitions are complex processes that are a mixture of crises; old and new ideas; innovative approaches and behaviors.

The expansion of the global energy system has throughout history been disrupted by fluctuations in the economy (Podobnik 2006). These disruptions have been expressed in different types of crises, which have had an impact on the energy system. One field of research argues that these crises are dependent on innovations and new technologies. Perez (2013) argues that a crisis is an event, which have happened in between five successful technological revolutions i.e. techno-economic paradigm shifts. When a paradigm is going through a change it means a radical transformation and the intention is to improve for instance a product, process, or a technology. This improvement has the purpose to reach better productivity and profit opportunities. Moreover, the occurrence of new paradigms, i.e. new innovations and technologies, and its "installation period" have led to major bubbles in the economy and resulted into crises. The reason for the occurrence of the crises is a miss-match in the widening and the diffusion of the implementation for the new paradigm. After the crises, adjustments such as policy changes have been done to be able to implement the new innovation fully within a wider range of the economy. The technological revolution with its investments in cars, electricity in the 1920's was classified as this paradigms' installation period, which was followed by the Great Depressions burst in 1929, i.e. the turning point. This crisis was followed by its "deployment period", which more specifically was the start of the golden age and the post-war period. However, there are some key factors that need to be fulfilled to successfully make the transition from a former paradigm to a new paradigm. These factors involve for instance a rapidly falling relative cost and unlimited availability in supply over long periods. This means on the other hand that the transition from one paradigm will not be possible until the former paradigm have increasing relative costs and declining availability in supply.

3.2 Energy supply crises effect on the energy system

When the energy supplies have been cut from countries, and the energy demand of the particular energy carrier has become larger than the energy supply, a shortage in the energy supply has arisen (Tverberg 2012). As energy supply crises, in general leads to shortages, it has in that sense led to a sharp rise in the price of that particular energy carrier. The combination of an increased energy price on an energy carrier with a shortage in this energy carrier will increase relative prices to other energy carriers (Assarsson 2004; Chapman et al 2009). When the relative prices have increased, the substitution for a relatively cheaper alternative increases. Because of the increased demand for a substitute, energy supply crises have trough history, encouraged the finding of new energy carriers and new ways how to conserve it (Energy Future 2015).

In a global perspective, the changes in trajectories, for instance in energy prices, have been clearest during the energy supply crises in forms of World War I, World War II and the period of the oil crises in the 1970s (Peters et al. 2011). The trajectories of energy consumption, energy intensity and CO_2 emissions have also changed when an energy supply crisis has occurred. This has been register both on a global level, as well as on national levels.

Trajectories of energy consumption have changed because higher prices decrease the demand among consumers. In line with the energy consumption the CO_2 emissions have decreased. The CO_2 emissions do not have to follow the same line as the energy consumption. This is because the amount of CO_2 emissions depends on what type of energy carriers the energy consumption concerns. Different types of energy carriers produce different amounts of CO_2 emissions. An identified decline in energy intensity in conjunction with an energy supply crisis has been explained by the substitution of a different energy carrier (Ekins et al. 2015). New substituted energy carriers have been shown to have higher quality, which in that sense has created the declining ratio for the energy intensity. Furthermore, these declining ratios for energy intensity have been clearest in the shift from wood to coal, coal to oil/natural gas, and the shift from oil/natural gas to primary electricity.

During World War I, in 1917 a blockade occurred and sharply reduced the trade of coal between countries, which led to a need to regulate supply (Schön 2012). This shortage in coal, have also been argued as one of the reasons for the beginning of the global shift from coal to liquid fuels. Moreover, World War II had a similar sequence of events. Theory stated that World War II created new development blocks, which aroused around a widening of electrification and automobile vehicles (Schön 2001), and in that sense increased the demand for liquid fuels (Podobnik 1999). With this new development blocks, a new behavior in humans' life styles were notable (Schön 2012).

The energy supply crises occurrences in 1973 and 1979, created serious shortages in oil all over the world (Solomon & Krishna 2011). This shortage resulted into a price shock, which generated major problem for energy consumers and a change in the patterns of energy consumption followed. This was a decrease in the reliance of oil. This decrease in consumed amount of oil also decreased the CO_2 emissions during the periods of energy supply crises in the 1970's. This decade has been interpreted as the turnover from oil as the main energy carrier to natural gas and renewable energy carriers.

3.3 Financial Crises Effect on the Energy System

Changes that the financial crises have caused in energy system during the twentieth- and twenty-first century mainly concerned the price on energy, in particular the price on oil. As the price on energy increased, this also affected the energy consumption with a decreasing reaction (International Energy Agency 2009). Lower energy consumption has also depended on lower economic activity because of a crisis (Force 2005; World Economic Forum 2012).

The changes in energy prices, have been clearest during the financial crises in form of the Great Depression in the 1930's and Global Financial Crisis in 2008 (Peters et al. 2011). The energy consumption, energy intensity and CO_2 emissions have also changed its trajectory. The price on oil increased sharply when the Global Financial Crisis busted in 2008. The oil prices both dropped and peaked in 2008 because of the recession. This was more specifically noticed as a change of the trajectory of global fossil fuel and industrial CO_2 emissions. In addition to the decreasing consumption of energy, the International Energy Agency (2009) identified a decrease in the global energy consumption of electricity after the financial crisis in 2008. This decrease was registered as a drop in 2009, one year after the financial crisis starting point. Moreover, despite the slow economic recovery in developed countries, World Economic Forum (2012) explains the quick global recovery from drop in energy prices in 2008 with the growth in developing countries. Especially China and oil rich countries in the Middle East covered for the consumption that was missed from developed countries for this period, which helped the oil price to recover again.

Peter et al (2011) have also highlighted the impacts on the energy systems associated with energy crises. The largest difference they have discovered between the impacts caused by these types of crises is the time period that the change has lasted. The changes in energy prices that arose in connection with a financial crisis have been more of short-term changes. However, the changes in prices that were identified in connection with an energy supply crisis were more persistent changes. Furthermore, the International Energy Agency (2009) acclaimed a decline in the energy investment, which was due to a decline in final energy demand as an outcome of the crisis. Geels (2013) also identified that investment in renewable energy increased when the crisis busted in 2008. These investments concerned various categories such as stimulus packages. However, there were some indicators in 2012 that various investments in renewable energy had started to decline (Geels 2013). The crisis has also been classified as an opportunity for an energy transition towards more sustainable energy forms (Antal & Van Den Bergh 2013). Moreover, the Global Financial Crisis has been discussed by Geels (2013) as the move from the installation period of the ICT revolution towards the deployment of ICT in the society. However, the opportunity to move towards a sustainability transition, created by the crisis, need to be taken by intuitions and politicians to make it real (Gore 2010).

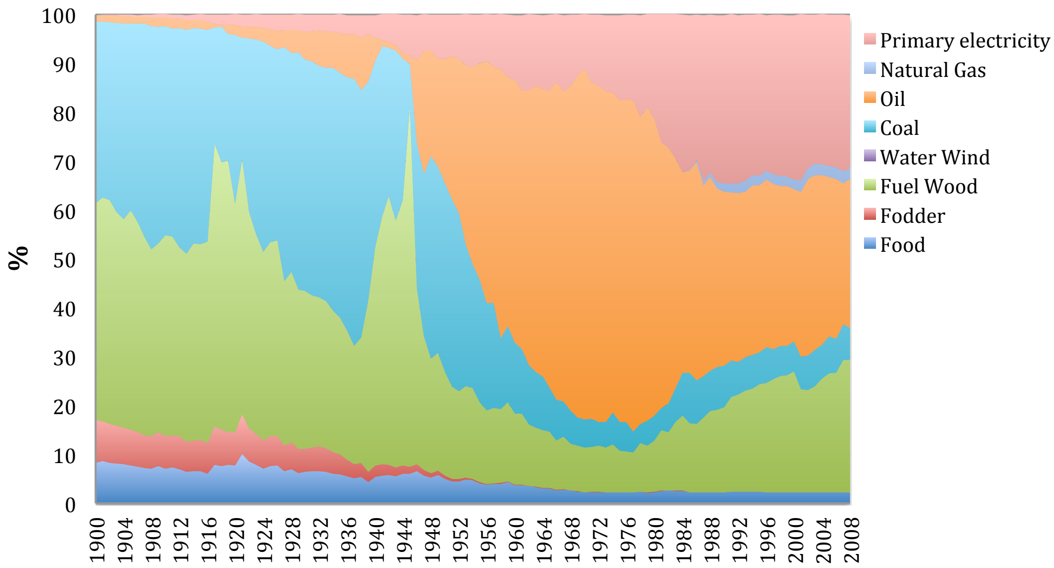
4. The Swedish Background

4.1 The Swedish Energy System

As can be seen in Figure 4.1, oil and electricity started to increase their share on the market in the beginning of 1900. However, the major consumed fuels in 1900 were represented by 44 % of coal and 37 % of firewood (Kander et al 2013). During the period of World War I (1914-1918), Sweden's import of energy declined during the war period because of various blockades (Schön 2012). This created a shortage and increased price on imported energy carriers, in particular on coal, and Sweden had to find alternative energy carriers to end the dependency on other countries. This was the period when electricity became more economically reliable for the Swedish society. The increased use of electricity is thus explained by the combination of electric power and the Swedish natural resources (water, wood). In figure 4.1 it is shown how the consumption of coal declined after World War I. Consumption of wood increased during the war as a substitute for coal to produce electricity, which also increased the share of electricity.

In Figure 4.1, the transition from wood, and in particular from coal to oil, after World War II is significant. Sweden had after the shift from coal to oil a large consumption of oil for several decades. However, the Oil Crises in the 1970's led to an increase in price, as well as a sharp decline in their oil supply (Kander et al, 2013). The declining availability of oil led to increased investment in the production of nuclear power and hydropower. Other energy carriers such as coal, peat and biofuels replaced heating oil. After the oil crises, the modern energy system started its development in the 1980's with a diversified approach. Electricity could be produced by any primary energy sources; nuclear power expanded and became as big as the use of waterpower; biofuels increased and could replace oil in some uses; import of natural gas from Denmark increased (Kaijser & Kander 2012). Today, Sweden uses renewable energy to a larger extent, such as wind power and solar power. This is partly explained as an outcome of an increased attention to climate change since the 1980 (Kaijser & Kander 2012).

Figure 4.1: Sweden Primary Energy Consumption by Fuels, 1900-2008



Source: Own Construction from Kander et al (2013)

4.2 The development of the Swedish Economy

It was during 1850-1890 that the modern growth had its breakthrough in Sweden. GDP per capita rose from 0.5% to 1-1.5% per year, and around 1890, Sweden took the lead in the growth league for developed countries, which they kept for almost 60 years. Industry and infrastructure were the driving forces for this growth. This was also the first step from a dominating agriculture sector. Moreover, the conditions required for the industrialization to happen were the development of electrical technology, natural resources, industrial structure, traditions and institutions, which laid the foundation for cooperation between companies, banks and government. In addition, a growing proportion of the population went to the industry and the industrial output grew. The marginal rate of return in agriculture fell to a lower level than in the industry. The main reason for the industry sectors growth was new manufacturing industries; especially in pulp and paper; and in consumer goods. Despite the industrialization, agriculture was still the dominant sector in the beginning of the twentieth century. (Schön 2012)

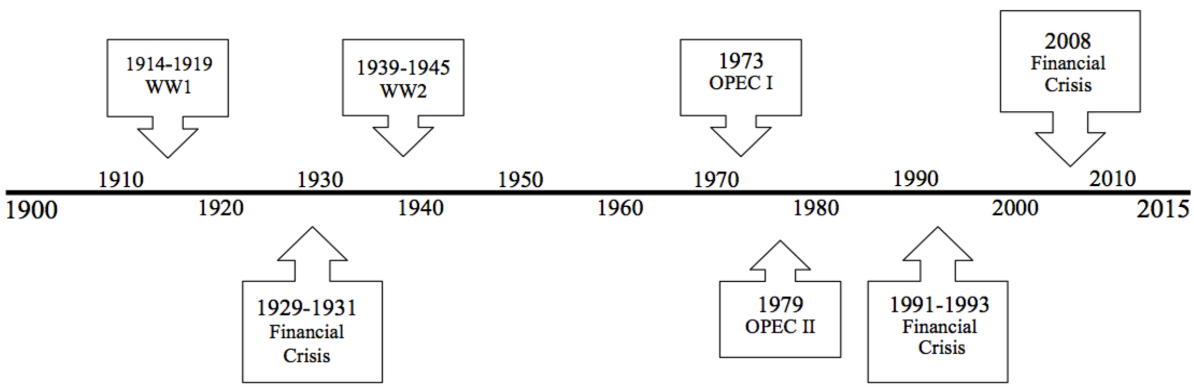
In addition to a growing manufacturing industry, the service sector started to grow between 1922-1930. The growth rate decreased significantly 1910-1930 because of crises that affected the sectors stability, and production, with the exception of the services sector (Hagberg &

Jonung 2005; Schön 2012). In 1930s, after several crises in the economy, the Swedish economy started to stabilize itself again. By 1960 the economy in Sweden were strong and this time period is known as "the golden age" with a high economic activity and a constant increase in the economic growth (Schön 2012). The background to this growth was especially three main sectors that formed the basis for Swedish growth during the 1930s and 40s. These sectors were the transport sector (spread of cars, railway transport, post and telecommunications); the manufacturing industry; the public sector. The period 1950-1975 is characterized by a huge growth and improvement in the living standard. Within industrialism the growth and financial stability is unusually high for this period. Competition intensified on a global market and a new consumer habit occurred. The period did also bring development blocks in many areas and dissemination of innovations (Schön 2012). Upswings in the economy in the beginning of the 1970's caused waves of optimism in the country.

4.3 Chosen Crises in the Swedish Economy

However, the Swedish economy has been affected by several ups and downs during the twentieth century. Only a few of these downs have been chosen for this study and will be further explained in the subsections below.

Figure 4.2: Chosen Crises in the Swedish Economy, 1900-2013



Source: Own Construction

4.3.1 World War I

World War I started in July 1914, and was classified as a global war but it was mainly centered in Europe (Hadenius 1987). Sweden was one of the countries in Europe, which stayed neutral through the whole war. This meant, more specifically, that all the politic parties in Sweden made a contract to keep a neutral position in the international politics and in that manner they kept a passive role during the war. Although the World War are not usually classified as economic crisis, World War I affected the pace for a continuing growth and GDP fell rapidly (Hagberg & Jonung 2005). However, the war contributed to high demand for exported goods, such as iron ore, meat, paper and industrial products, and Sweden continued their trade with both the Allies and the Entente. This also created surpluses in the current account. In one perspective Sweden benefited in World War I because of the high amount of exported goods, which created high revenues for Sweden (Schön 2012).

4.3.2 Great Depression & the Kreuger Crash

The decades between the World Wars included alternating cycles. One of these cycles was associated with the global Great Depression in the 1930s in Sweden this crisis have also come to be associated with the name Ivar Kreuger (Hadenius 1987). Kreuger had a business idea to have a monopoly on matchstick manufacturing in the world, and in 1928 he had managed half of his goals. Meanwhile, Wall Street was hit by a crash in 1929, a crisis that hit the global economy. At first it seemed, as Kreuger would be unmoved by the unstable financial market, but in 1931, the rates of Kreuger's shares fell. The unstable economy became a fact, and for the Swedish economy the Kreuger crash meant that many Swedes lost their fortunes and their savings decay- Furthermore, companies that had links with Kreuger also suffered and bankruptcies drag across the country. When the Great Depression reached Sweden in 1931 it led to a decline in export, employment and in the industrial production (Hagberg & Jonung 2005). Despite this, Sweden recovered fairly quickly from 1930’s crisis compared to many other countries around the world (Schön 2012).

4.3.3 World War II

When World War II started in 1939, Sweden had a stable market for the economy, politics and employment. However, World War II did not have a big financial impact on Sweden, mainly because the economic policy was tighter than during World War I (Hagberg & Jonung 2005). Despite this, GDP fell rapidly the fist year of the War. During World War I the export increased, but during World War II the export declined, which resulted in larger losses in the industrial production. Sweden remained neutral even during World War II. Because of inflation in the aftermath of the war, including a monetary value deterioration that came with the war, this affected households with small savings and pensioners. In 1947 the government imposed restrictions on imports of automobiles and rationing of gasoline in order to achieve balance in foreign trade (Hadenius 1987).

4.3.4 OPEC I & II in the 70s

Oil accounted for 70 per cent of the Swedish energy supply during the 70s. Most of the Swedish oil imports came from the OPEC countries, the crisis that occurred through October War in the Middle East 1973 was hard on Sweden. The October War meant that the price of oil increased by four times in only three months. Moreover, in 1979 a revolution broke out in Iran. This led to further increases that doubled the already high price of oil in Sweden. The overall result for these two crises that rigidly affected Sweden was restrictions and regulations with the purpose to governing the use of oil. (Jewert 2008)

4.3.5 Banking - and Currency Crisis, 1991-93

The end of the 80s generated a speculative bubble with rising rates of nearly 125 per cent of the aggregating assets, which in turn led to a high inflation and large amount of debts in the private sector (Force 2009). Because of the high inflation, the currency was overvalued, the export decreased related to the import and the decision to have a fixed exchange rate was questioned (Force 2009; Hagberg & Jonung 2005). Moreover, the combination of fixed exchange rate and an overvalued currency lead to high nominal interest rates, which resulted in decreasing asset prices and a decreasing economic activity. The crisis had its breakthrough during the summer of 1991 until the summer in 1993 with its deepest point during the fall in 1992 (Force 2009). During these three years, GDP decreased with 6 per cent, and the unemployment increased, which worsened the situation for the public sector. Households and companies got bankrupted which lead to big credit losses for the Swedish banking sector, and these credit losses was nearly the end for many of the Swedish banks (Lönnborg et al. 2011; Force 2009).

4.3.6 Global Financial Crisis, 2008

Although Sweden is a small country, their finances have developed to be well intertwined with the outside world due to their trade and financial markets. This meant that the Global Financial Crisis in 2008 had an impact on the Swedish economy and market. How that expresses itself was most apparent in exports and imports, more specifically the current account. Moreover, Sweden could register an increase in exports in 2007. This increase in exports changed when the financial crisis busted, beating hard against the Swedish production and employment as foreign demand for Swedish goods declined. The Swedish financial sector was also strongly affected by the crisis. This was due to increased integration with foreign financial markets, where 60 per cent of the Swedish banks' funding was from international markets. (Öberg 2009)

5. Data & Methodology

5.1 Data

The data for this study consist of annual data on energy prices, final energy consumption and GDP for the manufacturing industry. The data have been derived from the databases of Gentvilaite et al. (2015); Kander et al. (2013); Kommerskollegium (1918); Krantz & Schön (2007); Official Statistics of Sweden (2012); Schön & Krantz (2012); Schön & Krantz (2015); Swedish Energy Agency (2015). As the long-run series have been constructed from more than one database, the additional data was adjusted to include same consistency of data as the former dataset. The constructed datasets are based on data for the manufacturing industry, except for the data in energy prices. As the data on energy are compiled in the manufacturing industry have mostly concerned data on the final energy.

5.1.1 Data on Energy Prices

The dataset on energy prices have been constructed from the database from Gentvilaite et al. (2015). The data on energy prices were given in annual prices on the different energy carriers of coal, oil, wood fuels and electricity. The energy prices were given in Swedish crowns per one unit petajoule (SEK/PJ).

5.1.2 Data on Energy Consumption

The dataset for energy consumption between have been self-constructed. The dataset has been based on figures for the manufacturing industry from Official Statistics of Sweden's for the period 1921-1995; Kommerskollegium (1918) for the period 1913-1917; Swedish Energy Agency for the Global Financial Crisis, 2006-2013. The industrial sector includes the following branches: Ore mining and metal industry; soil and rock industry; wood industry; paper and printing industry; the food industry; textiles and clothing industry: leather, wool and rubber goods industry; chemical-technical industry. Data for energy consumption have been collected for the time period when crises have been identified in Sweden, with two years extended before and after the crises had started and ended. The energy consumption data for World War II, 1937-1947; Great Depression/Kreuger Crash, 1927-1933; 1970's OPEC Crises, 1971-1981; Banking & Currency Crisis in 1990's, 1989-1995 and the Global Financial

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This chapter partly draws on my paper Research Design – Crises impact on changes in the energy system in Sweden, 1900-2014 (2016).

Crisis, 2006-2013 However, the data for World War I, should have been collected for the years 1912-1921. Because of absent data for the intact period the data were collected for the years 1913-1916 and 1921. The datasets specify the total energy consumption in the manufacturing industry by type of energy carrier for each year. The energy carrier that were included in the dataset for energy consumption was coal and coke; peat; liquid fuels; charcoal, gas; wood fuels and electricity. Data on consumption of electricity between 1900-1987 was supplemented to the dataset from Schön (1990) and the electricity data for the time period 1988-2013 was supplemented from the Swedish Energy Agency (2015)

Adjustments were needed on all the data for energy consumption. First, the data for energy consumption before 1970 included the electricity industry in the manufacturing industry. To get the data before 1970 consistent with the data after 1970 it was adjusted by separating the energy consumption, consumed by electricity industry, from the energy consumption, consumed by the manufacturing industry. Second, as the different energy carriers were given in different units, data has been converted into the same unit by using conversion factors adapted to each respectively energy sources. The constructed dataset and conversion factors are shown in Appendix D, Table D.1.

5.1.3 Data on CO_2 emissions

To obtain the data for the annual amount in tons of CO_2 emissions the data on energy consumption of coal, peat, liquid fuels and gas were used. Calculations were created by conversion factors tailored to what each type of energy carrier releases per one unit of gigajoule (Table C.1). As the data consist of the energy consumption in the manufacturing industry, it has the same timing and availability of data during the concurrency of the different crises.

5.1.4 Data on Energy Intensity

Energy intensity (i) was obtained from the ratio between total energy input i.e. total energy consumption (E_i) and GDP for the manufacturing industry (Y) (See the equation below). The GDP were given in Million SEK; constant prices with 1910/12 price level. The data on GDP for manufacturing industry were collected from Krantz & Schön (2007); Schön & Krantz (2012); Schön & Krantz (2015) and covers the time period between 1900-2010. The calculation gave the data for the amount of energy, given in petajoules, needed to produce one unit of output in the manufacturing industry.

$$i = Ei/Y$$

5.2 Method

The constructed datasets identify possible changes in the energy system in the context of a crisis occurrence. The included datasets on the mechanism of energy prices are representative for all sectors. However, the datasets for the impacts, energy consumption; energy intensity; CO_2 emissions, are more specifically for the manufacturing industries, with the purpose to limit the study. By compiling the data using figures; tables and indexes, it is possible to determine if there has been a change in the mechanism (energy prices) and how this is expressed as an impact on the energy consumption, energy intensity and CO_2 emissions.

5.2.1 Relative Prices

The mechanism within the energy system that is investigated in-depth is the energy prices. Changes in energy prices will be analyzed in relative prices. Relative prices are expressed as the relation for prices on one particular good relative to another good. In this study, the different energy carriers (e.g. oil, gas, coal, wood fuels, electricity) will be the goods on the market. This method will make it possible to analyze whether a decrease in energy carrier x could be explained by a surplus in energy carrier y, or the other way around. Moreover, an increase in energy carrier x could be explained by a shortage in energy carrier y. By using relative prices, different energy carriers can be compared at the same moment of time as well as a comparison between different time periods.

The formula for relative prices is here expressed as a ratio between the prices of two different goods.

$$\mathbf{P^R = (P_x/P_y)}$$

Where P^R is the relative price between two goods. The P_x represent the price on good x, which is set in relation to P_y, the price on good y.

Example with the two goods oil and gas:

$$(\mathbf{P_{oil}}/\mathbf{P_{gas}} \downarrow) = \mathbf{P^R} \uparrow$$

$$(\mathbf{P_{oil}} \uparrow /\mathbf{P_{gas}}) = \mathbf{P^R} \uparrow$$

If the price on oil increases in relation to the price on gas, the relative price between these two goods will increase and vice versa.

The ratios for relative prices is converted into index with the purpose to see how the prices fluctuates from two years before the crisis burst until two years after the crises has ended. For instance World War II lasted between 1939-1945, but the time period between 1937-1947 is the one to study. The base year for the index is for World War II set as 1937. The relative price for each year until 1947 is then divided by the relative price for 1937 to get the changes into index values. Moreover, to be able to analyze whether the possible changes in the energy system were changes that sustained, or changes that was temporarily occurring, the short-term index for relative prices is set in relation to the relative prices with a long-term index for the possible changes. The long-term index has its base year in 1900. Moreover, when the crises and potential changes of the mechanism and the impact of this changes have been identified and determined, the final step of the method will be a comparison between crises. The purpose of this comparison is to find possible differences to what extent, for instance, an energy supply crisis have been a driver to changes in the Swedish energy system compared to a financial crises.

The major limitation of this method is the possible ambiguity of the causality. The causality is ambiguous because there is no indicator in the collected data that for certain can determine that crises are the only driver for changes to occur in the energy system. There is in that sense a risk that possible changes in the energy system can depend on other factors than the occurrences of crises. Possible biases for the data in this study could be the risk to exclude mechanisms, which could be used as an indicator for changes in the energy system, by only using energy prices, energy consumption, energy intensity and CO_2 emissions. There might be other mechanism that can work as an indicator for this type of study, which is a bias that will be taken into account when interpreting the results. However, despite this method's weaknesses, it does also have its benefits. Except for the description above in this section, relative price of good can tell us how much one good is worth in terms of another good. Relative price have been used as a tool in several studies with a similar purpose as this one has. For instance, Henriques (2011) applies relative price in her study with the purpose to analyze changes of the energy system in Portugal. Also Kander (2002) uses relative measures and motivates it with the benefits of being able to do comparisons between for instance different time periods as well as contribute with information to absolute measures.

6. Results & Analysis

This section presents the results obtained by applying the previous presented method and datasets. The observed results are analyzed and interpreted continuously using previously presented theory. The result section ends with a comparison of the impacts of the financial crises compared to the energy supply crises, as well as a discussion concerning the long-term trends and changes.

6.1 Energy Supply Crises

6.1.1 World War I

As can be seen in Table 6.1 the most visible changes for World War I were the declining ratios on the electricity price relative to the price on coal; oil; wood. The decade before World War I distinguished itself as a period where electricity took shape in the society (Kaijser & Kander 2013). As an outcome of World War I, electricity became more economic viable partly explained because of sharp increases in the prices of imported fuels (Schön 2012). Especially the ratio between electricity and coal stands out with a decline between 1912-1920, where the ratio nearly fell 100% to a new lower level in 1918. This declining ratio reflects a lower price on the petajoule (PJ) of electricity, as well as a higher price for the PJ of coal. Lower relative price on electricity-coal were notable in several countries including Sweden that had poor coal endowments (Betrán 2005). During World War I, there was a shortage in particular in the supply of coal because of a blockade in 1917, which halved the imports of coal. As a result, the Swedish government had to adjust the supply of wood fuels (Kaijser & Kander 2013). Moreover, the shortage in the coal supply made the PJ of coal more expensive relative to other energy carriers and an increased demand for substituted energy sources followed. Especially wood fuels were high in demand and became the most common substituted energy carrier for coal, which also can explain the declining ratio for wood relative to coal during the war period, especially from 1917 when the blockade happened (Table 6.1). The relative prices of electricity and oil; wood showed a similar but minor decline. The development of hydropower and the extension of the distribution network, which was in favor for the production of electricity, could further explain the lower price on PJ of electricity relative to PJ of oil; coal and wood fuels (Betrán 2005; Schön 2012). Moreover, this result matches the characteristic behavior of an energy supply crisis, with shortage in supply and increasing prices.

In 1921, three years after World War I had ended, the ratio of relative prices between electricity and coal were nearly 7 times larger compared to the ratio in 1918. This increase was also notable in the ratio between electricity and oil as well as in the ratio between electricity and wood. This could further be explained by a short but deep recession in the beginning of the 1920's (Schön 2012). But despite the recession the industries grew rapidly with increased production and productivity.

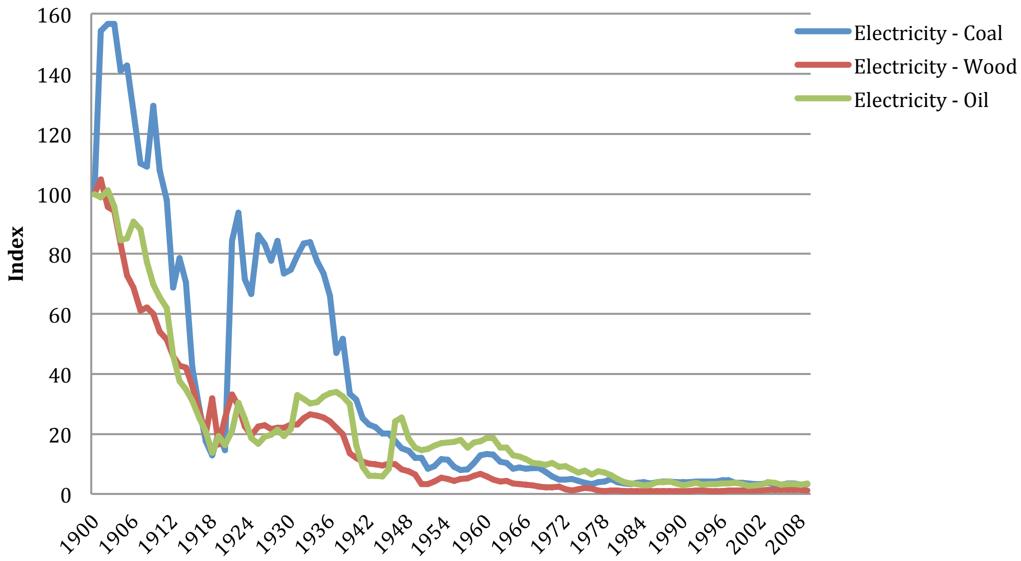
Table 6.1: Relative Prices SEK/PJ, 1912-1921

Relative Prices	**1912**	**1913**	**1914**	**1915**	**1916**	**1917**	**1918**	**1919**	**1920**	**1921**
Electricity										
Electricity – Coal	**66,02**	**75,64**	**67,58**	**40,73**	**27,41**	**17,02**	**12,47**	**19,62**	**14,10**	**81,35**
Index 1912=100	*100*	*115*	*102*	*62*	*42*	*26*	*19*	*30*	*21*	*123*
Electricity – Oil	**13,96**	**11,41**	**10,55**	**9,36**	**7,63**	**6,32**	**4,14**	**5,82**	**4,95**	**6,35**
Index 1912=100	*100*	*83*	*76*	*67*	*55*	*45*	*30*	*42*	*35*	*45*
Electricity – Wood	**67,51**	**62,90**	**61,73**	**52,72**	**40,16**	**29,34**	**46,74**	**24,36**	**37,14**	**48,69**
Index 1912=100	*100*	*93*	*91*	*78*	*59*	*43*	*69*	*36*	*55*	*72*
Oil										
Oil – Coal	**4,75**	**6,62**	**6,44**	**4,33**	**3,60**	**2,69**	**3,01**	**3,37**	**2,85**	**12,78**
Index 1912=100	*100*	*139*	*136*	*91*	*76*	*57*	*63*	*71*	*60*	*269*
Wood										
Wood – Coal	**0,98**	**1,20**	**1,10**	**0,77**	**0,68**	**0,58**	**0,27**	**0,81**	**0,38**	**1,67**
Index 1912=100	*100*	*122*	*112*	*78*	*70*	*59*	*27*	*82*	*39*	*170*

Source: Own Construction from Gentvilaite et al. (2015).

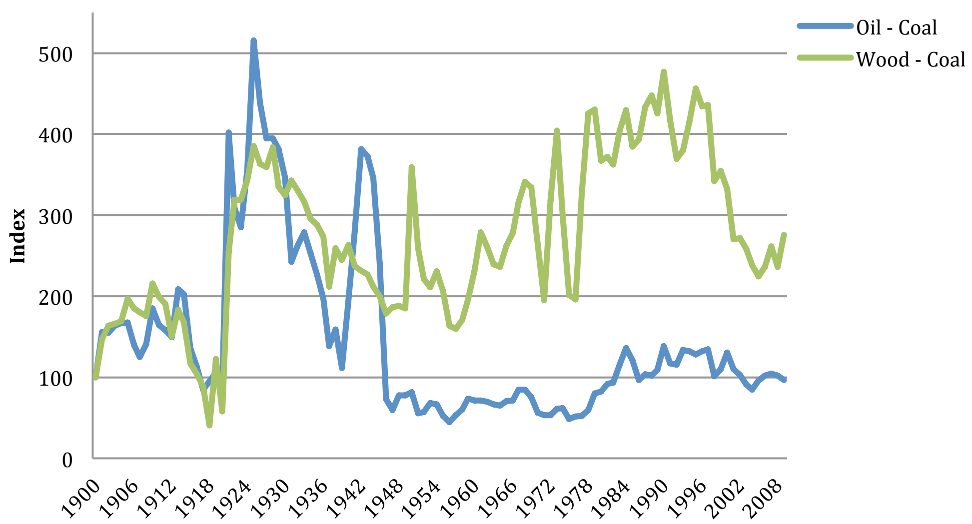
The long-term trend in relative prices for electricity and oil; coal; wood is shown in Figure 6.1. The long-term index shows a downward sloping trend for the ratios since the beginning of 1900, which could imply that World War I was not the driver for the declining change even if it strengthened it. However, the declining trend regarding the ratio of electricity and coal stopped after World War I had ended in 1918. As the decline ended in 1918, it was followed by a remarkable increase between electricity and coal. This change showed an increase of more than 100 % between 1918-1921.

Figure 6.1: Long Term Changes in Relative Prices (Electricity - Coal; Oil)



Source: Own Construction from Gentvilaite et al. (2015).

Figure 6.2: Long Term Changes in Relative Prices (Oil - Coal; Wood - Coal)



Source: Own Construction from Gentvilaite et al. (2015).

There was no remarkable change in the total energy consumption for the manufacturing industry during the year 1913-1916. Unfortunately, data on the energy consumption for the years between 1917-1920 are missing but in 1921 there is a noteworthy decline in the total energy consumption (Table 6.2). The decline in energy consumption could be due to lower production as an outcome of decreased private consumption (Kaijser & Kander 2013), and the recession in the beginning of the 1920’s (Schön 2012).

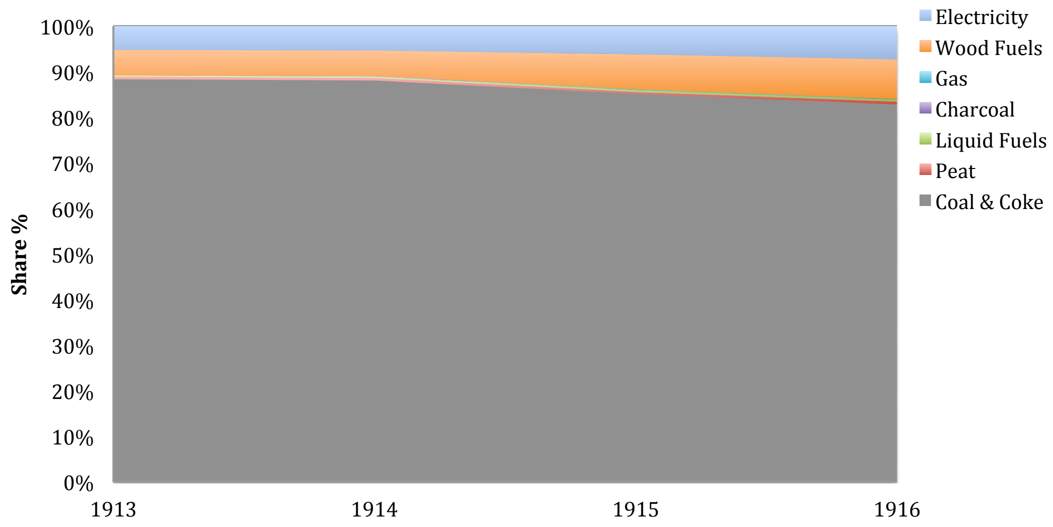
Table 6.2: Manufacturing Industries Total Energy Consumption, 1913-1916; 1921

	Year									
	1912	**1913**	**1914**	**1915**	**1916**	**1917**	**1918**	**1919**	**1920**	**1921**
Energy Consumption PJ	**-**	**87**	**85**	**91**	**93**	**-**	**-**	**-**	**-**	**77**
Index 1912=100	*-*	*100*	*98*	*104*	*107*	*-*	*-*	*-*	*-*	*89*

Source: Own Construction from Kommerskollegium (1918); Schön (1990)

The main forms of energy consumed during the war period were coal; wood fuels and electricity, where coal represents more than 80 % of the energy consumption (Figure 6.3). Coal was still the energy source that dominated the energy consumption in the manufacturing industry in 1921 (Table D.1). However, the amount of wood fuels consumed almost doubled between 1916-1921. The increased amount of wood fuels for this period matches the shortage and increased prices of coal, which made the government adjust the wood supply. Replacing coal with wood did not cause any major complications, probably because they had the same function and that they were both solid fuels (Kaijser & Kander 2013).

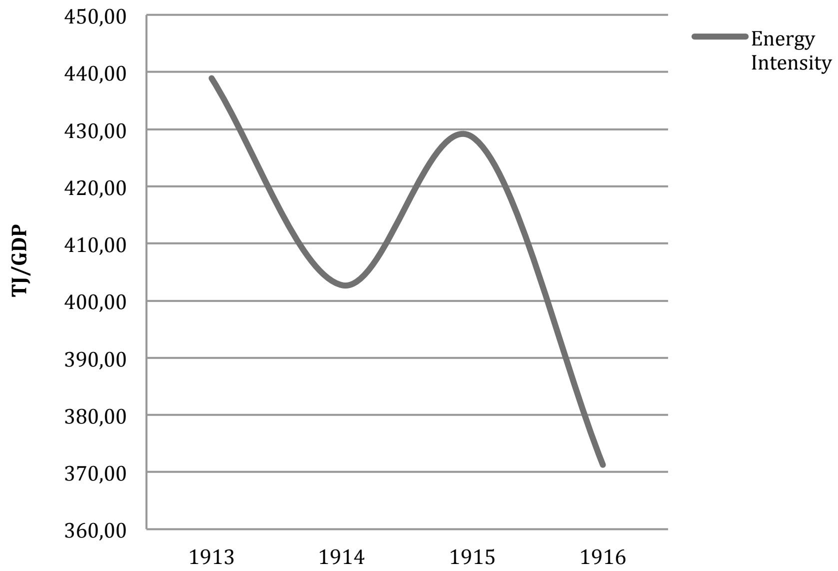
Figure 6.3: Manufacturing Industries Energy Consumption by Energy Carrier, 1913-1916



Source: Own Construction from Kommerskollegium (1918); Schön (1990)

The amount of tons in CO_2 emissions had a downward slope in 1914, but increased shortly afterwards and got back to the levels it had before the war, which meant that the CO_2 emissions followed the same pattern as the energy consumption (Figure C.1). The impact on the energy intensity was similar with a downward slope in 1914, which was followed by an increase the year after (Figure 6.4). However, the energy intensity differs from the other investigated impacts (energy consumption and CO_2 emissions) because it also had a downward slope in the intensity from 1915. A downward slope in the energy intensity could be due to a decline in the production because of a slowdown in the private consumption during the war period (Schön 2012). An identified decline in energy intensity in conjunction with an energy supply crisis has been explained by the substitution of a different energy carrier, these declining ratios for energy intensity have been clearest in the shift from wood to coal (Ekins et al. 2015; Kaijser & Kander 2013).

Figure 6.4: Energy Intensity in the Manufacturing Industry, 1913-1916



Source: Own Construction from Krantz & Schön (2007); Schön & Krantz (2012); Schön & Krantz (2015); Official Statistics of Sweden; Schön (1990)

6.1.2 World War II

The ratio between electricity and coal; oil; wood fuels declined during World War II (Table 6.3). The import of oil and coal became a major problem for Sweden during World War II when the Germans occupied Denmark and Norway. As the major import of coal and oil came from Allied countries, such as the UK, a shortage of fuels arose in Sweden (Kaijser & Kander 2013). The major change was noticed in the relative prices between electricity and oil, where the PJ of electricity was almost 10 times more expensive before World War II broke out in 1937. During the war the PJ of electricity declined and was nearly 2 times more expensive than the PJ of oil. Lower price on electricity was explained by its availability, as electricity could be created by any primary energy source, water or coal (Betrán 2005), and became in that sense a substitute to increasing price on oil. The price on oil increased because of the shortage in supply, which further can explain the increasing ratio between oil and wood; coal. In particularly the PJ of oil were 4 times more expensive than the PJ of coal in 1937, which increased and were 12 times more expensive in 1942 (Table 6.3). Increased oil prices in relation to coal prices could imply that the oil shortage was persistent during the war period. The shortage in coal was adjusted when Sweden turned to Germany with the request to increase their coal import. As a result, Sweden became the second largest importer of German coal during World War II (Kaijser & Kander 2013).

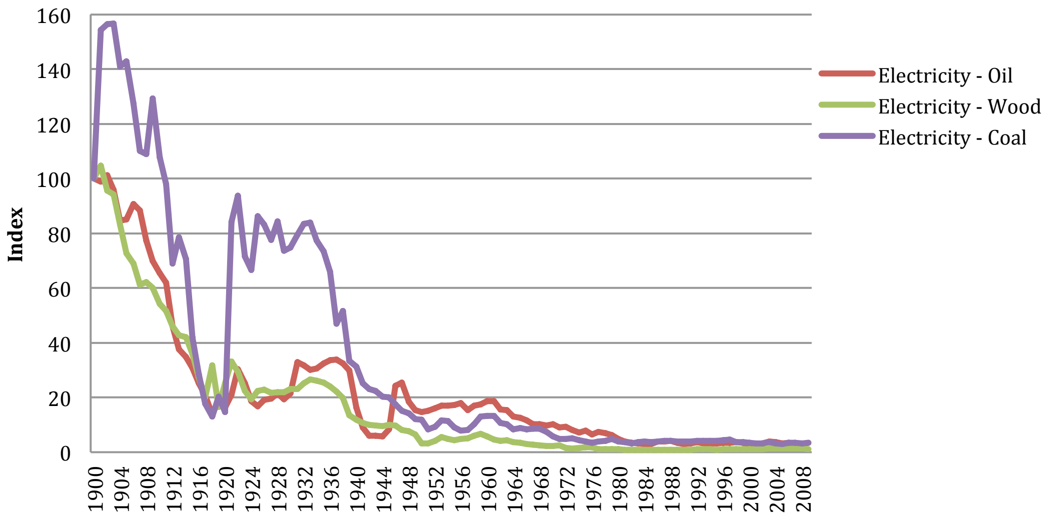
Table 6.3: Relative Prices SEK/PJ, 1937-1947

					Year						
Relative Prices	**1937**	**1938**	**1939**	**1940**	**1941**	**1942**	**1943**	**1944**	**1945**	**1946**	**1947**
Electricity											
Electricity – Coal	**45,05**	**49,59**	**32,04**	**30,22**	**24,30**	**22,27**	**21,55**	**19,49**	**19,39**	**16,92**	**14,58**
Index 1937=100	*100*	*110*	*71*	*67*	*54*	*49*	*48*	*43*	*43*	*38*	*32*
Electricity – Oil	**10,28**	**9,84**	**9,08**	**4,91**	**2,73**	**1,84**	**1,82**	**1,77**	**2,53**	**7,33**	**7,71**
Index 1937=100	*100*	*96*	*88*	*48*	*27*	*18*	*18*	*17*	*25*	*71*	*75*
Electricity – Wood	**32,54**	**29,23**	**19,96**	**17,53**	**15,66**	**14,70**	**14,50**	**14,00**	**14,77**	**14,48**	**11,92**
Index 1937=100	*100*	*90*	*61*	*54*	*48*	*45*	*45*	*43*	*45*	*45*	*37*
Oil											
Oil – Coal	**4,39**	**5,05**	**3,54**	**6,15**	**8,92**	**12,11**	**11,83**	**11,00**	**7,65**	**2,31**	**1,89**
Index 1937=100	*100*	*115*	*80*	*140*	*203*	*276*	*269*	*250*	*174*	*53*	*43*
Oil – Wood	**3,16**	**2,97**	**2,20**	**3,57**	**5,74**	**7,98**	**7,97**	**7,91**	**5,84**	**1,98**	**1,55**
Index 1937=100	*100*	*94*	*70*	*113*	*181*	*252*	*252*	*250*	*185*	*62*	*49*

Source: Own Construction from Gentvilaite et al. (2015).

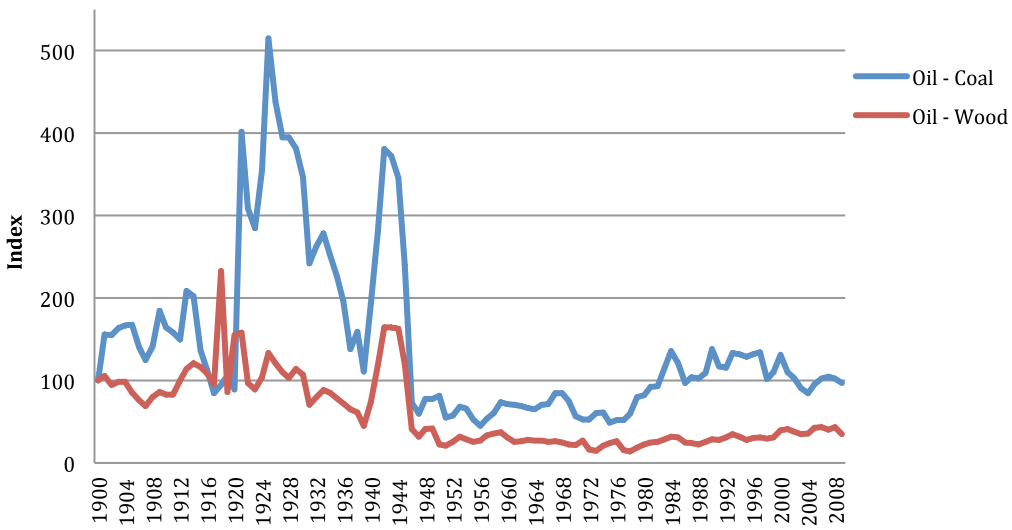
As shown below in Figure 6.5, the long-term impact that is important to highlight is the ratio between electricity and coal. There was a similar decline during both World War I and World War II. However, the declines differ since the decline after World War II seemed to have been a consistent change. It was in particular after World War II that electrification rooted its important position in the energy system and were an outcome shortage in fuels and the natural resource in form of hydropower (Schön 2012). As can be seen in Figure 6.6, the price on the PJ of oil relative to the price on the PJ of coal and wood declined to lower price levels after World War II. This in combination with the strong development of the combustion engine; the diffusion of automobiles and the oil's penetration on the market, could imply that World War II was the driver for this long-term change.

Figure 6.5: Long Term Changes in Relative Prices (Electricity - Coal; Oil; Wood)



Source: Own Construction from Gentvilaite et al. (2015).

Figure 6.6: Long Term Changes in Relative Prices (Oil - Coal; Wood)



Source: Own Construction from Gentvilaite et al. (2015).

The total energy consumption varied, with the lowest decrease by 25 % in 1941, (Table 6.4). However, World War II's impact on changes in the energy system is easier to identify by studying the total energy consumption divided by carrier.

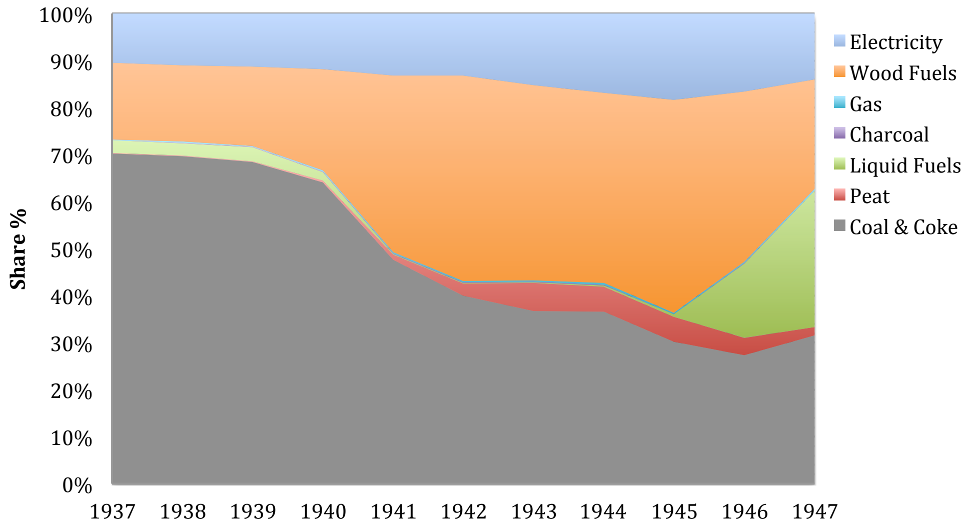
Table 6.4: Manufacturing Industries Total Energy Consumption, 1937-1947

	Year										
	1937	**1938**	**1939**	**1940**	**1941**	**1942**	**1943**	**1944**	**1945**	**1946**	**1947**
Energy Consumption PJ	**190**	**181**	**193**	**163**	**142**	**154**	**150**	**152**	**153**	**173**	**192**
Index 1937=100	*100*	*95*	*101*	*86*	*75*	*81*	*79*	*80*	*81*	*91*	*101*

Source: Own Construction from Official Statistics of Sweden; Schön (1990)

The fluctuations in relative prices during World War II were additionally mirrored in the manufacturing industries' energy consumption. Figure 6.7 shows the energy consumption divided into shares of fuels, where coal, wood, peat, liquid fuels and electricity dominated in the manufacturing industry. One of the most interesting results to highlight is the shift to a lower level of coal consumed, due to the shortage of coal during the war period. Coal was substituted with especially wood fuels, which is notable as an increase in the consumption of wood together with the declining consumption of coal. However, the most interesting finding during the war period was the increased consumption of liquid fuels in the end of the war, which increased even more after the war ended in 1945. As shown in Figure 6.7, the changes in the energy system were significant after World War II ended in 1945. The major change shown is a decrease in both wood fuels and coal after 1945, and a beginning of an increase in the consumption of electricity and liquid fuels. In addition, as the oil prices started to fell in the post war period, oil started to increase its shares related to especially coal as well as wood fuels (Kaijser & Kander 2012). This transition from coal to oil is also classified as the most rapid breakthrough in the history of shifts that have occurred in the energy system (Kander 2002).

Figure 6.7: Manufacturing Industries Energy Consumption by Energy Carrier, 1937-1947



Source: Own Construction from Official Statistics of Sweden; Schön (1990)

The changes in the amount of CO_2 emissions, produced by coal, liquid fuels, and peat from this time period followed the changes in the energy consumption in respective fuels (Figure C.3). As the consumption of coal slowed down, the pattern of CO_2 emissions from coal followed the same pattern. The CO_2 emissions from liquid fuels started to increase in line with an increasing consumption of liquid fuels. The energy intensity temporarily decreased during the war period. The impact on energy consumption, CO2 emissions and energy intensity matches the results in previous research. The decrease in energy intensity can further be explained by the substitution of other energy carriers, which could have had higher quality than the former energy carrier and in that sense decreased the intensity. (Figure B.3).

6.1.3 Oil Crises in the 1970's

The energy supply crises that occurred during the 1970's were mainly associated with oil. The October War in the Middle East in 1973 (OPEC I) and the revolution in Iran in 1979 (OPEC II) became notable in the relative prices due to the increasing oil price. It was in particular the energy supply crisis in 1979 that had the most significant impact on the relative prices in general (Table 6.5). The ratio between oil and coal; electricity had an increasing change after OPEC II in the end of the 1970's. However, the relative prices between oil and wood showed a declining trend, which differed from the other results. Moreover, the price on wood fuels increased relative to coal and electricity. This could imply that wood fuels were more expensive than oil, coal and electricity during this decade. High prices on wood fuels can further be explained by the fact that wood fuels was only used locally in the 70's and 80s, where access was good and the prices thus low (Schön 1992).

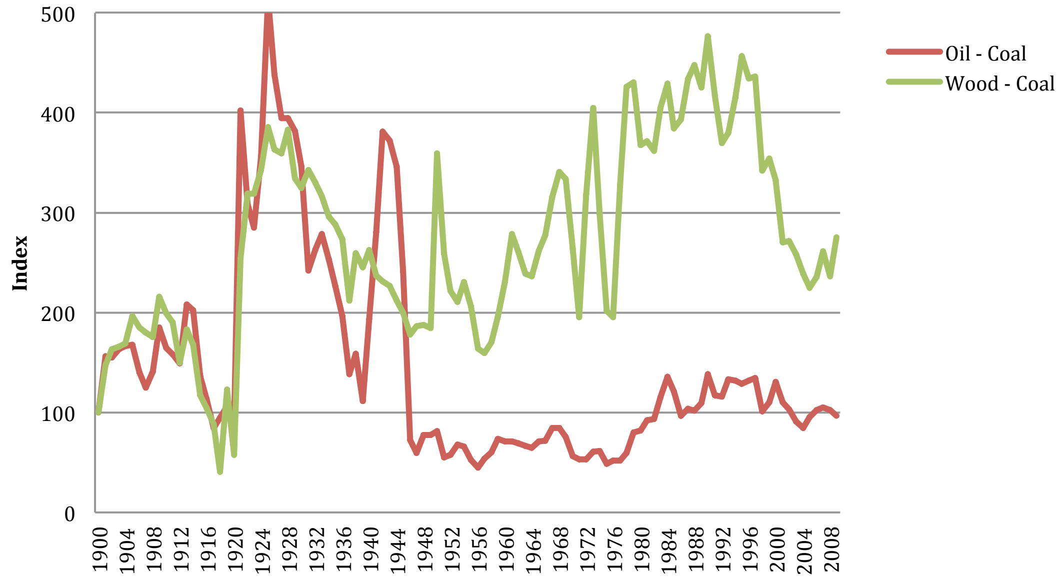
Table 6.5: Relative Prices SEK/PJ, 1971-1981

	Year										
Relative Prices	**1971**	**1972**	**1973**	**1974**	**1975**	**1976**	**1977**	**1978**	**1979**	**1980**	**1981**
Oil											
Oil – Coal	**1,68**	**1,68**	**1,93**	**1,96**	**1,55**	**1,65**	**1,66**	**1,90**	**2,53**	**2,61**	**1,89**
Index 1971=100	*100*	*100*	*115*	*116*	*92*	*98*	*98*	*113*	*150*	*155*	*174*
Oil – Wood	**1,32**	**0,80**	**0,73**	**1,00**	**1,17**	**1,28**	**0,77**	**0,68**	**0,90**	**1,08**	**1,20**
Index 1971=100	*100*	*61*	*55*	*76*	*89*	*98*	*58*	*52*	*68*	*82*	*91*
Oil – Electricity	**0,37**	**0,36**	**0,40**	**0,46**	**0,42**	**0,51**	**0,44**	**0,47**	**0,53**	**0,68**	**0,84**
Index 1971=100	*100*	*98*	*110*	*126*	*116*	*140*	*121*	*128*	*146*	*185*	*231*
Wood											
Wood – Coal	**1,28**	**2,09**	**2,65**	**1,96**	**1,32**	**1,28**	**2,15**	**2,79**	**2,82**	**2,41**	**2,44**
Index 1971=100	*100*	*163*	*207*	*153*	*103*	*100*	*168*	*218*	*221*	*188*	*190*
Wood – Electricity	**0,28**	**0,45**	**0,55**	**0,46**	**0,36**	**0,40**	**0,58**	**0,69**	**0,59**	**0,62**	**0,70**
Index 1971=100	*100*	*161*	*199*	*166*	*130*	*143*	*207*	*248*	*214*	*225*	*254*

Source: Own Construction from Gentvilaite et al. (2015).

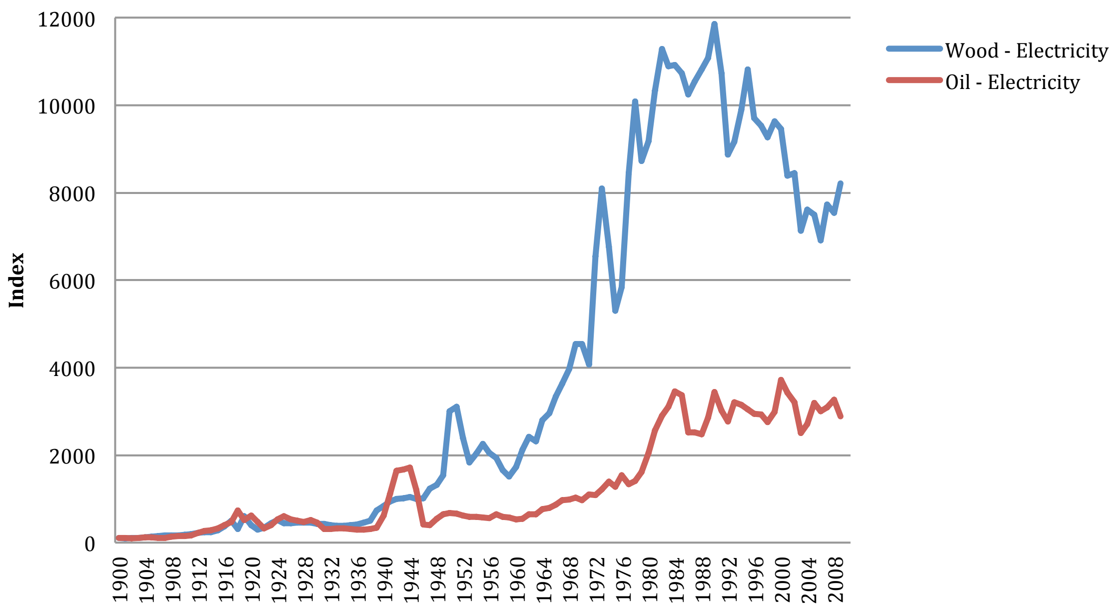
The first and second graph below shows the long-term changes in the relative prices and as can be seen, the most significant changes occurred in the ratio of oil price relative to coal and electricity price (Figure 6.8; Figure 6.9). These changes imply that the energy supply crises in the 1970's were a driver for the changes that occurred in the price of oil and wood relative to other energy carriers. Given the fact that energy supply crises in general lead to sharp rises in the price of energy, these results give a strong indication that the crises were a driver for this change.

Figure 6.8: Long Term Changes in Relative Prices (Oil - Coal; Wood - Coal)



Source: Own Construction from Gentvilaite et al. (2015).

Figure 6.9: Long Term Changes in Relative Prices (Wood - Electricity; Oil – Electricity)



Source: Own Construction from Gentvilaite et al. (2015).

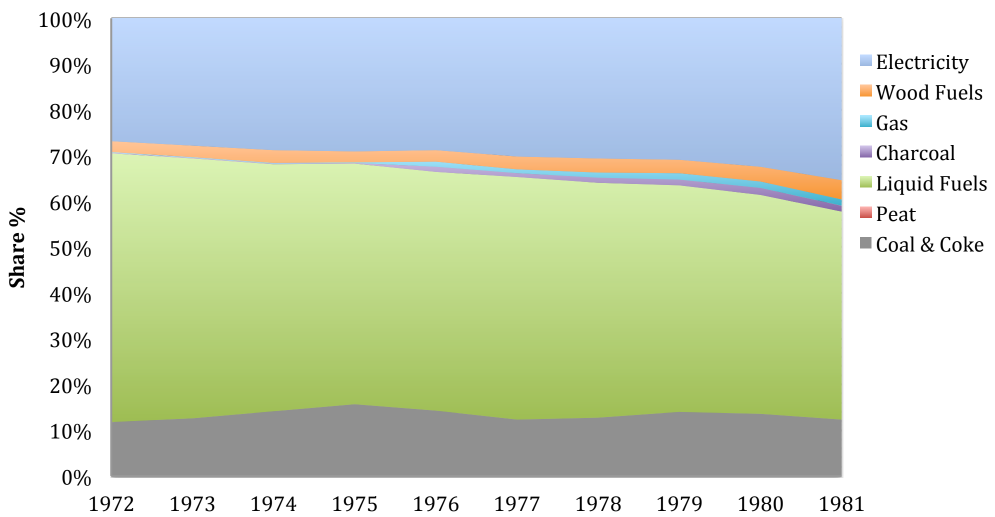
Table 6.6: Manufacturing Industries Total Energy Consumption, 1971-1981

	Year										
	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Energy Consumption PJ	-	200	220	229	229	235	215	221	236	228	219
Index 1972=100	-	*100*	*110*	*114*	*114*	*117*	*107*	*110*	*118*	*114*	*109*

Source: Own Construction from Official Statistics of Sweden; Schön (1990)

Similar to World War II, the total energy consumption for the manufacturing industry was effected by the crisis. A noteworthy change of 18 % increase was identified in 1979 (Table 6.6). However, the change differs for this period as the change for World War II was identified as a decrease in the consumption. As the oil prices increased in the 1970's, a decrease in the consumption of liquid fuels was to be expected, which Figure 6.10 shows from 1975. It was also notable that the consumption of charcoal, electricity and gas increased. Especially the increased consumption of gas and charcoal could be further explained by a more diversified energy consumption from the mid 1970's because of the crisis (Kaijser & Kander 2013). This was an outcome of the constant development of electricity during the whole twentieth century and that diverse forms of energy could produce electricity as well as investments in new energy carriers such as natural gas (Betrán 2005).

Figure 6.10: Manufacturing Industries Energy Consumption by Energy Carrier, 1972-1981



Source: Own Construction from Official Statistics of Sweden; Schön (1990)

The tons of CO_2 emissions from liquid fuels, coal and gas followed the same fluctuating pattern as the total energy consumption (Figure A.4; Figure C.4). The energy intensity started to decrease between 1973-1975, followed by a recovery, which lasted until 1979, when the energy intensity started to decrease again (Figure B.4). The background to the fluctuations in energy intensity could be the diversified consumption of different energy carriers that occurred in the 1970's (Kaijser & Kander 2012). As different energy carriers can affect the intensity because of their different qualities.

6.2 Financial Crises

6.2.1 The Great Depression & the Kreuger Crash

As it can be seen from Table 6.7, the PJ of oil was 12 times more expensive than coal in 1927. During the crisis the PJ of oil declined and became only 7 times more expensive than coal. As shown in the index, the price on wood fuels increased by more than 50 % relative to the price on oil in 1931.

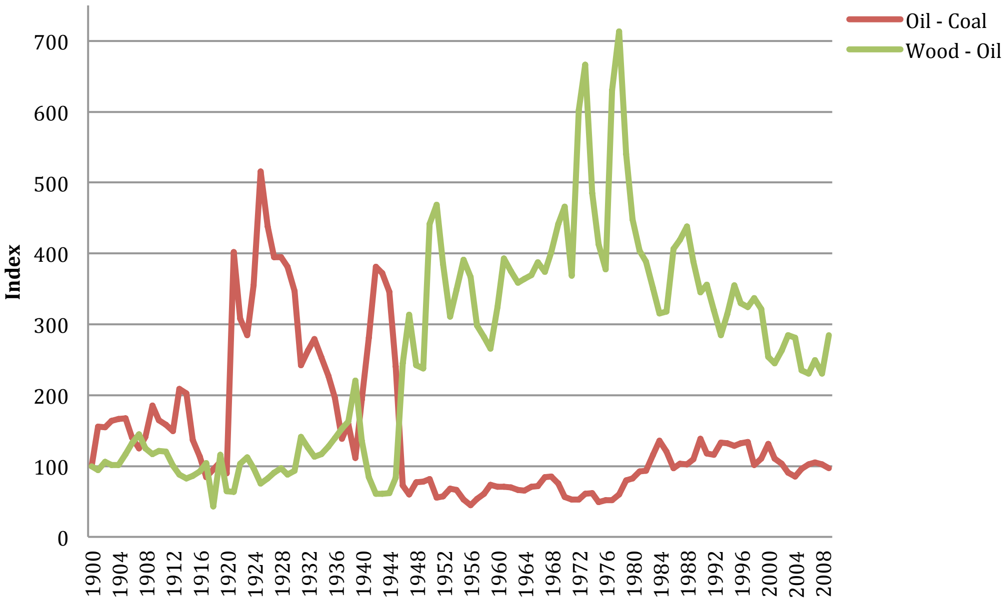
Table 6.7: Relative Prices SEK/PJ, 1927 – 1933

	Year						
Relative Prices	**1927**	**1928**	**1929**	**1930**	**1931**	**1932**	**1933**
Oil							
Oil – Coal	**12,54**	**12,54**	**12,12**	**11,01**	**7,70**	**8,37**	**8,36**
Index 1927=100	*100*	*100*	*97*	*88*	*61*	*67*	*71*
Wood							
Wood - Oil	**0,19**	**0,20**	**0,18**	**0,19**	**0,29**	**0,26**	**0,23**
Index 1927=100	*100*	*107*	*96*	*103*	*155*	*138*	*125*

Source: Own Construction from Gentvilaite et al. (2015).

As can be seen in Figure 6.11, the declining trend in the relative prices of oil and coal lasted until 1941, which could imply that the financial crisis in the 1930's had no effect on the long-term changes in the energy system. This matches previous research, which has noticed that financial crisis in general only had a short-term impact on the energy system (Peters et al 2011). However, the occurrence of World War I & II and the Great Depression happened close in time. With this in mind, it is important to note that there could be some difficulties to determine whether the changes in relative prices happened because of an aftermath of World War I or because of the financial disturbance from the 1930's crisis.

Figure 6.11: Long Term Changes in Relative Prices (Oil - Coal; Wood - Oil)



Source: Own Construction from Gentvilaite et al. (2015).

Table 6.8 below presents the total energy consumption for the manufacturing industry. In 1930 the consumption increased with 13 % compared to the consumption in 1927.

Table 6.8: Manufacturing Industries Total Energy Consumption, 1927 - 1933

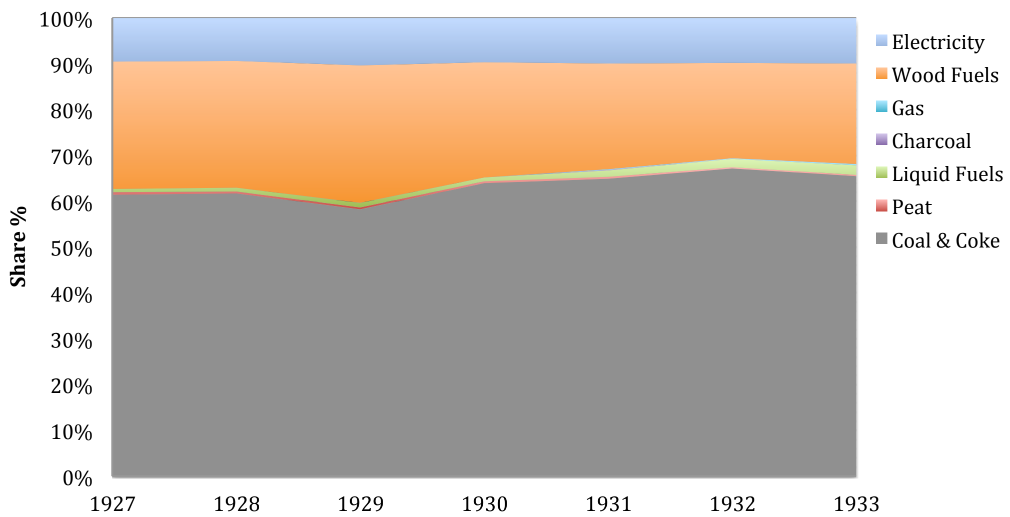
	Year						
	1927	1928	1929	1930	1931	1932	1933
Energy Consumption PJ	**119**	**120**	**125**	**134**	**127**	**122**	**134**
Index 1927=100	*100*	*101*	*105*	*113*	*107*	*103*	*113*

Source: Own Construction from Official Statistics of Sweden; Schön (1990)

Figure 6.12 presents the manufacturing industry's total energy consumption divided into shares by energy carrier. It is clear that there was no major change in the shares by energy carriers. When the financial crisis broke out in 1929, the share of consumed coal and liquid fuels increased slightly and reached a higher level of consumed quantity. As seen from Table 6:8, there was a decline in oil price relative to the price on coal. The interpretation of this result could be that oil became cheaper relative to coal, which should have increased the consumption of oil, which is noticed in Figure 6.12. However one could also have expected a decrease in the consumption of coal. If oil became cheaper it could also depend on increasing prices of coal. Moreover, as the consumption of coal and oil increased, tons of CO_2

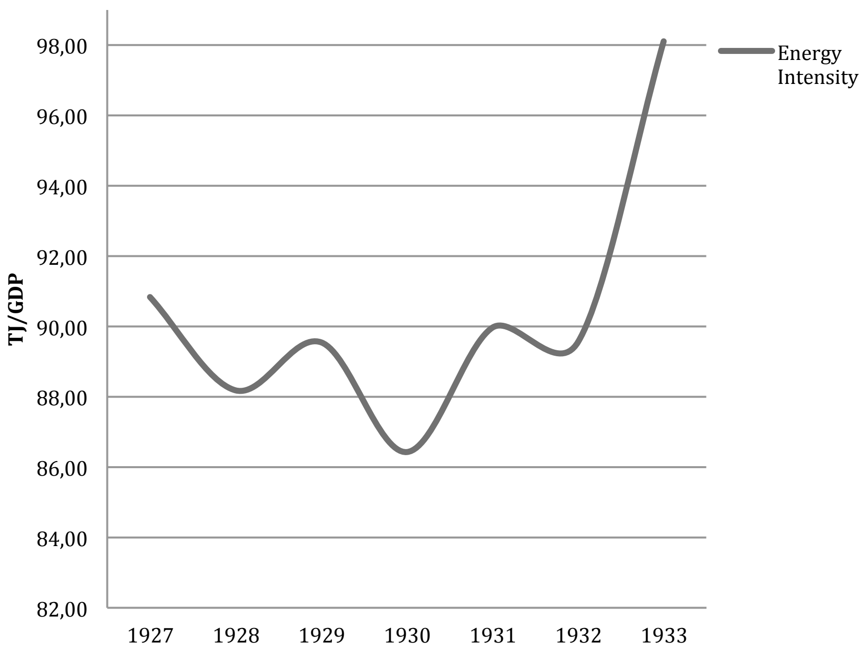
emissions from coal and liquid fuels followed the same path (Figure C.3). The energy intensity fluctuated during the crisis and increased after the end of the crisis (Figure 6.13). As the consumption of coal slightly increased in relation to wood fuels, it could imply that that there were two fuels with different energy quality, which could have affected the intensity.

Figure 6.12: Manufacturing Industries Energy Consumption by Energy Carrier, 1927-1933



Source: Own Construction from Official Statistics of Sweden; Schön (1990)

Figure 6.13: Energy Intensity in the Manufacturing Industry, 1927-1933



Source: Own Construction from Krantz & Schön (2007); Schön & Krantz (2012); Schön & Krantz (2015); Official Statistics of Sweden; Schön (1990)

6.2.2 The Banking & Currency Crisis in the 1990's

There was no remarkable change in the relative prices during the financial crisis in the 1990's in Sweden. However, the changes that were notable in relative prices concerned the oil price in relation to the price on wood fuels as well as the electricity relative to wood fuels and oil. As shown in Table 6.9, both oil and electricity had an increasing trend set relative to wood. The ratio between oil and wood could imply that oil prices increased relative to wood. The increasing oil prices would in that sense match Peters et al. (2011) founding that crises through history have had an effect by increasing energy prices. This founding could also be the background to the decreasing electricity prices relative to the oil prices.

Table 6.9: Relative Prices SEK/PJ, 1989-1995

	Year						
Relative Prices	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**
Oil							
Oil – Wood	**21,25**	**1,41**	**1,36**	**1,52**	**1,70**	**1,54**	**1,36**
Index 1927=100	*100*	*113*	*109*	*122*	*136*	*124*	*109*
Electricity							
Electricity – Wood	**1,33**	**1,24**	**1,37**	**1,66**	**1,60**	**1,49**	**1,36**
Index 1927=100	*100*	*93*	*103*	*125*	*121*	*112*	*102*
Electricity - Oil	**1,06**	**0,88**	**1,00**	**1,09**	**0,94**	**0,96**	**1,00**
Index 1927=100	*100*	*83*	*95*	*103*	*89*	*91*	*94*

Source: Own Construction from Gentvilaite et al. (2015).

Table 6.10 below presents the index of the total energy consumed in the manufacturing industry between 1989-1995, which decreased with 20 % until 1994. Lower energy consumption could imply a dependency on the lower economic activity, which came with the crisis (Force 2005; World Economic Forum 2012).

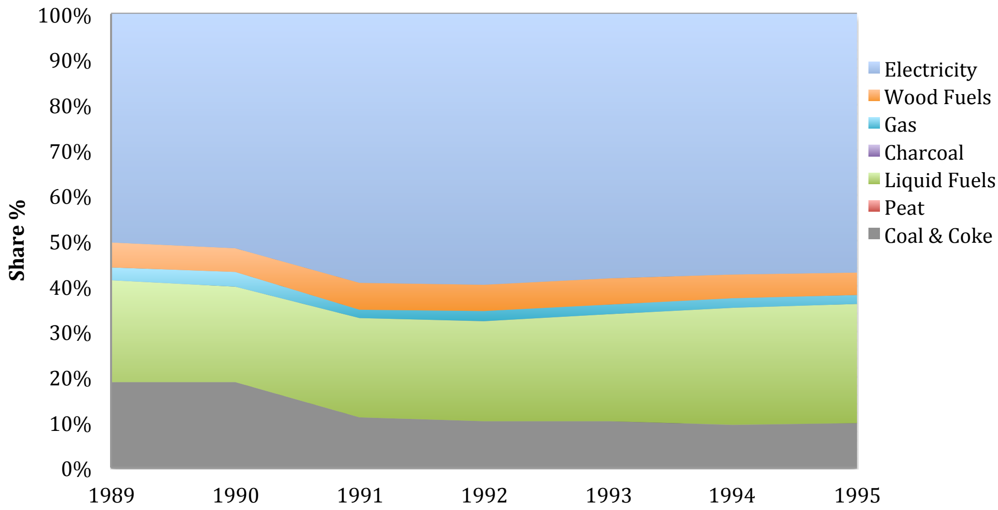
Table 6.10: Manufacturing Industries Total Energy Consumption, 1989 - 1995

	Year						
	1989	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**
Total Energy Consumption PJ	**290**	**295**	**247**	**235**	**232**	**237**	**246**
Index 1989=100	*100*	*102*	*85*	*81*	*80*	*82*	*85*

Source: Own Construction from Official Statistics of Sweden; Schön (1990)

As can be seen from Figure 6.14 electricity was the major consumed energy carrier by the manufacturing industry during the financial crisis in the 1990's. Moreover, coal, liquid fuels and wood fuels were also dominating the energy consumption. The financial crisis had a decreasing impact on the total energy consumption, and by breaking down the total energy consumption by fuels it is clear that the decrease in consumption were equal among all energy carriers during this crisis (Figure 6.14). This could imply that the smaller decline in the total energy consumption for the manufacturing industry, but no rearrangement in the consumption by energy carrier, was due to a lower private consumption, which also decreased the production (Force 2005). Tons of CO2 emissions decreased in line with the decreasing energy consumption of coal and liquid fuels (Figure C.5). The energy intensity decreased frequently during these years, a smaller decrease but still notable (Figure B.5).

Figure 6.14: Manufacturing Industries Energy Consumption by Energy Carrier, 1989-1995



Source: Own Construction from Official Statistics of Sweden; Schön (1990)

6.2.3 The Global Financial Crisis in 2008

An interesting finding related to the Global Financial Crisis in 2008 was that the major changes in relative prices only occurred in 2009 (Table 6.11). However, the most significant change could be identified when oil; coal; electricity were set relative to wood. This is interpreted as the price of all three energy carriers decreased in relation to the price on wood fuels. The decrease in energy prices, in particular on oil, do not match Peters et al. (2011) research on financial crises global impacts on increased energy prices.

Table 6.11: Relative Prices SEK/PJ, 2006-2009

	Year							
Relative Prices	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Oil								
Oil – Wood	**2,11**	**1,94**	**2,10**	**1,70**	-	-	-	-
Index 2006=100	*100*	*92*	*100*	*80*	-	-	-	-
Electricity								
Electricity – Wood	**2,12**	**1,90**	**1,95**	**1,79**	-	-	-	
Index 2006=100	*100*	*90*	*92*	*84*	-	-	-	-
Coal								
Coal – Wood	**0,65**	**0,58**	**0,65**	**0,55**	-	-	-	-
Index 2006=100	*100*	*90*	*100*	*85*	-	-	-	-

Source: Own Construction from Gentvilaite et al. (2015).

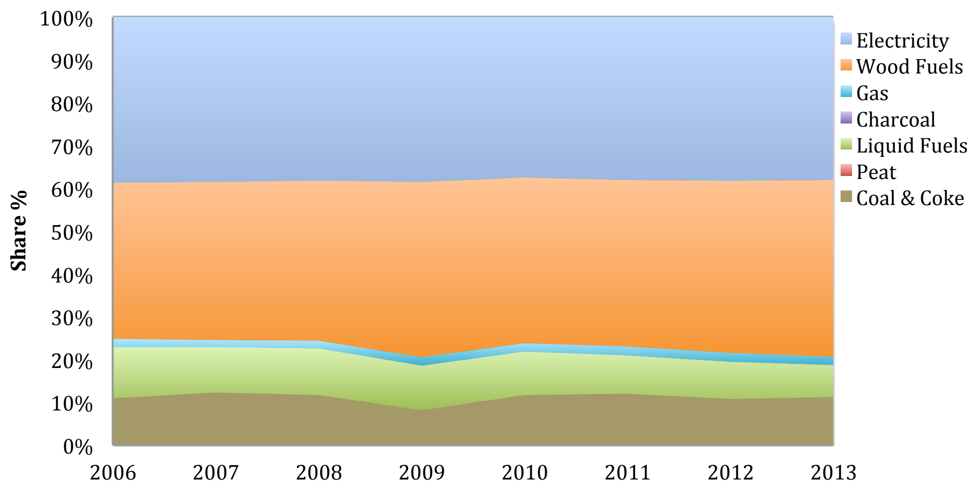
The total energy consumption was almost unchanged in the manufacturing industry between 2006-2013, except for a relatively big decrease by 10 % in 2009 (Table 6.12). However, the decrease in the energy consumption in 2009 are in line with the global effect that have been identified by International Energy Agency (2009); Peter et al. (2011) research on how the crisis affected the energy consumption.

Table 6.12: Manufacturing Industries Total Energy Consumption, 2006 - 2013

	Year							
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Energy Consumption PJ	**466**	**484**	**470**	**418**	**458**	**459**	**455**	**448**
Index 2006=100	*100*	*104*	*101*	*90*	*98*	*98*	*98*	*96*

Source: Own Construction from Swedish Energy Agency (2015)

Figure 6.15: Manufacturing Industries Energy Consumption by Energy Carrier, 2006-2013



Source: Own Construction from Swedish Energy Agency (2015)

As can be seen in Figure 6.15 the energy carriers that were dominated in the manufacturing industry was in particular wood fuels and electricity, as well as coal, electricity, liquid fuels and gas. The pattern for energy consumption by fuels did not change during the Global Financial Crisis in 2008. However, there was an indication of a decrease in coal, liquid fuels and gas between 2008-2009. The International Energy Agency (2009) found a global decrease in the consumption of electricity during the crisis. This was nothing that was identified in the manufacturing industry of Sweden for this period. The CO_2 emissions had a remarkable decrease between 2006-2008, and when the bubble busted in 2008, the CO_2 emissions decreased even more (Figure C.6). The decreasing trend between 2006-2008 recovered in 2009 but the amount of CO_2 emissions became lower after the crisis, compared to the years before. The decrease in CO_2 emissions matches Peter et al (2011) results as well as for the energy intensity. The intensity decreased two years before the bubble busted in 2008, and reached a new lower level compared to before the crisis (Figure B.6).

Table 6.15: Summarize of the Changes in the Energy System for Each Crisis

	Energy Prices	**Energy Consumption**	**Energy Intensity**	**CO_2 Emissions**
World War I	Increasing trend in the energy price on coal because of shortage. Low relative price on electricity set to other energy carriers, especially to coal.	Decrease in the total energy consumption. Consumption of wood fuels doubled between 1916-1921.	Decreasing pattern in the energy intensity. This could imply that the substituted energy carrier had different quality.	CO_2 followed the changes in the energy consumption
Great Depression 1930s	Declining trend for oil relative to other energy carriers.	The total consumption increased. Consumption of coal and liquid fuels increased	Energy intensity fluctuated, which could imply that it followed the different energy quality on different energy carriers that were consumed.	CO_2 emissions from coal and liquid fuels increased
World War II	Increasing trend in energy price on coal and oil because of shortages. Low relative price on electricity to other energy carriers.	Decrease in total energy consumption. Increased consumption of liquid fuels	Decreased temporary during the war period.	CO_2 emissions followed the changes in the energy consumption by each type of energy carrier.
Oil Crises in the 1970s	Increasing energy price on oil because decisions made by OPEC countries regarding limited oil supplies and higher prices.	Increase in the total energy consumption. As well as increased diversity among consumed energy carriers after the two crises.	Decreasing trend between 1973-75 and after 1979, i.e. when the oil crises occurred.	CO_2 emissions from liquid fuels, coal and gas followed the pattern in the energy consumption.
Financial Crisis in the 1990s	Increased relative price between oil-wood as well as between electricity-wood. Lower relative prices for electricity- oil.	The total energy consumption decreased with 20% until 1993. The decrease was notable for all energy carriers, except for electricity.	A smaller constant decrease during the crisis.	CO_2 emissions decreased in line with decreasing consumption of coal and liquid fuels.
Global Financial Crisis 2008	Decreasing prices on oil; coal and electricity relative to oil.	A short-term decrease in the energy consumption with 10% between 2008-2009.	Decrease in the energy intensity and reached a lower level compared to the level before the crisis.	Decrease in CO_2 emissions, which reached a new lower level after the crisis.

6.3 Financial & Energy Supply Crises as a Paradigm Shift

This part will briefly present the general trend for energy supply crises and financial crises that have occurred in Sweden since 1900. Moreover, the identified trends will be related to Perez's (2013) theory regarding the techno-economic paradigm and its key factors. These key factors function as indicators with the purpose to determine whether a change between an old and a new paradigm has occurred.

6.3.1 Energy Supply Crises & Paradigm Shift

Some of the changes that have been noticed in the occurrence of an energy supply crisis between 1900-2013 could be interpreted as long-term changes in the energy system. The overall changes in the energy system during the energy supply crises are shortages in energy supply, which have increased energy prices. This has created a chain effect, where higher prices have affected the energy consumption, CO_2 emissions and the energy intensity. The energy consumption has mostly been affected by a rearrangement in the consumption of energy carriers because of the increased demand for substituted energy carriers. The crisis that gives the most significant result of being a driver for changes in the Swedish energy system is World War II and to some extent OPEC I & II. The results could imply that World War II was a driver in the shift from coal to especially liquid fuels. The changes depended on shortages and higher prices, which were notable as long-term changes in the decreasing ratio between oil prices relative to coal prices. It could also be interpreted as increasing prices on coal relative to oil. The shortage of coal and increasing relative prices matches Perez's (2013) theory of the key factors that need to be fulfilled for a transition of an old paradigm to a new paradigm. This could imply that World War II was the driver for the change in energy system with the transition from coal to oil.

Moreover, the short-term impacts on energy prices that are associated with World War I do not fulfill the key factors for a transition to be possible. The results could be interpreted as a miss-match with Perez (2013) theory regarding how transition towards a new paradigm need to fulfill its key factors over a long-term period. The oil crises have showed some signs of long-term changes in the energy system. This has been clear in the increasing energy prices and shortage of the oil supply. This occurred for almost a whole decade, which could imply that the oil crises shifted the Swedish energy system into a new paradigm. This is supported by Perez's (2913) theory of which factors that needs to be fulfilled to go through a transition.

6.3.2 Financial Crises & Paradigm Shift

The changes that have been identified in the energy system and are associated with financial crises have affected the energy prices. The background to increasing energy prices differs comparing to energy supply crises. Moreover, the changes that have occurred have only had a short-term impact on the energy system. The increasing energy prices have not happened because of shortages in the country's energy supply. As the financial crises only had short-term impacts on the energy prices it implies that they do not matches Perez's (2013) theory of a transition to a new paradigm. However, according to previous research, the Global Financial Crisis in 2008 has been classified as the start towards the renewable transition. This could imply that the Global Financial Crisis was the bubble that followed the "installation period" of a new paradigm shift, which now has entered its "deployment period". Financial crises are in that sense more a part of the process to a new paradigm, since they do not fulfill the key factors for the actual transition towards the new paradigm to be completed.

7. Conclusions

7.1 Conclusions

The paper has examined the role of crises as a driver of changes in the energy system during the period 1900-2013. In particular, the paper has examined to which extent crises have had an impact on changes in the energy system. It has also examined how the impacts have differed between energy supply crises and financial crises. The paper finds that crises in general have had an impact on the changes in the Swedish energy system. However, the type of crises does appear to matter, as different types of crises have had various impacts. Thus, the paper finds that there are differences between energy supply crises' and financial crises' respective impact on changes in the energy system.

The main conclusion regarding energy supply crises' impact on changes in the energy system concerns in particular the shortage in energy supply. This shortage created increased prices on energy, which became notable as changes in relative prices and a demand as well as a need for substituted energy carriers. World War I, World War II and the Oil Crises in the 1970's could all be interpreted as drivers for the change towards new energy carriers. The manufacturing industry doubled their consumption of wood fuels between 1916-1921, which was an outcome of the shortage of coal caused by the war. After World War II there was a significant increase in the consumption of liquid fuels and a decrease in the coal consumption, which could imply a shift from coal to oil. This was in line with previous research as well as the key factors needed in order to accomplish a shift from an old paradigm to a new paradigm. After the Oil Crises in the 1970's the pattern of more diversified energy consumption was identified. It further meant a decline in the consumption of liquid fuels and increased consumption of electricity, wood, charcoal and gas. The general pattern for all three crises concerning CO_2 emissions were that it followed the changes that occurred in the consumption for each energy carrier, rather than the total energy consumption. The energy intensity fluctuated but the overall trend was notable as a decline in the intensity. This could imply that the consumption of substituted energy carriers were of higher quality, which could have affected the energy intensity.

The general trends for the financial crisis in the 1990's and in 2008 and their impact on changes in the energy system where in particular notable as short-term changes in the relative prices. However, the change in relative prices during the financial crises could not be explained by a shortage in the energy supply to the same extent as the energy supply crises could. Moreover, changes that were notable in the energy consumption, CO_2 emissions and energy intensity followed the same decreasing short-term effect. Furthermore, there were no results that could give the indication that the changes in the energy system during the financial crises were any long-term changes. In addition, there was no rearrangement in the consumption per energy carrier. Moreover, the financial crisis in the 1930's differed compared to the later financial crises because the changes in the energy system lasted longer than 1-2 years. However, there were no long-term changes in relative prices and the total energy consumption fluctuated but kept an increasing trend through the crisis. Furthermore, it is hard to determine weather the changes were an aftermath from the war or an impact from the actual crisis. But as well as for the other two financial crises the changes could not imply that a shift in the energy system had occurred. Conclusively, the pattern of changes related to a financial crisis do not match Perez's (2013) theory regarding the long-term key factors that need to be fulfilled in order to accomplish the transition from an old paradigm to a new paradigm.

7.2 Limitation of the Study and Future Research

Although the results give the indication of crises being a driver for changes in the energy system, there are several other factors that are interrelated for these changes to occur that might have been excluded from this research.

Changes in the energy system could depend on regulation and restriction by a governmental decisions and policy changes. For the sustainability transition to be fulfilled, Gore (2010) argues that governments and institutions have the responsibility to take this opportunity and to make it happen. Therefore, it would be interesting to further investigate how institutions and governments can accomplish such changes. It is possible that the governmental influence has had an impact on the historical changes in the energy system. Furthermore, excluding governmental and institutional policy changes and decisions regarding new opportunities, the amount of investments, such as stimulus packages in new energy, could have an impact on the occurrence of changes in the energy system. This would also be interesting to investigate further with a historical perspective.

This study does also only consider the impacts in the energy consumption, energy intensity, and CO_2 emissions in the manufacturing industry. However, it would have been interesting to investigate how the crises impacted the energy system by using data of private households. In addition to this approach, it would be possible to make comparisons between changes in the manufacturing industry with changes in the private household sector.

Furthermore, the study only considers the crises' impact of changes that have occurred in the Swedish energy system. Given the fact that Sweden has been depending on other countries and their supply of energy, it would be interesting to examine a country with its own energy supply.

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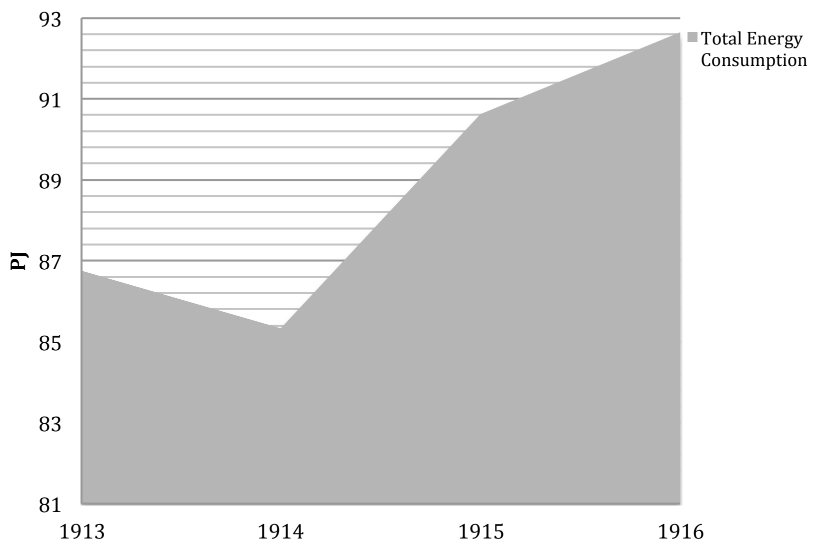
Appendix

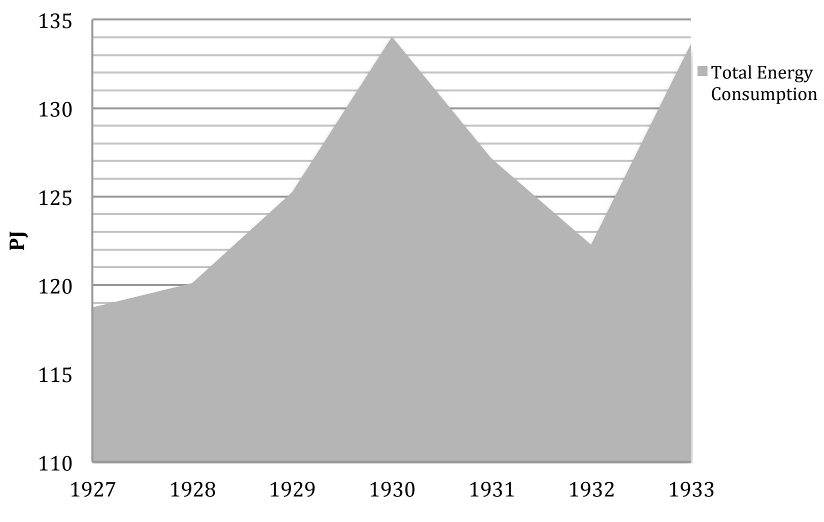
Appendix A

Figure A.1: Total Energy Consumption in Manufacturing Industry, 1913-1916



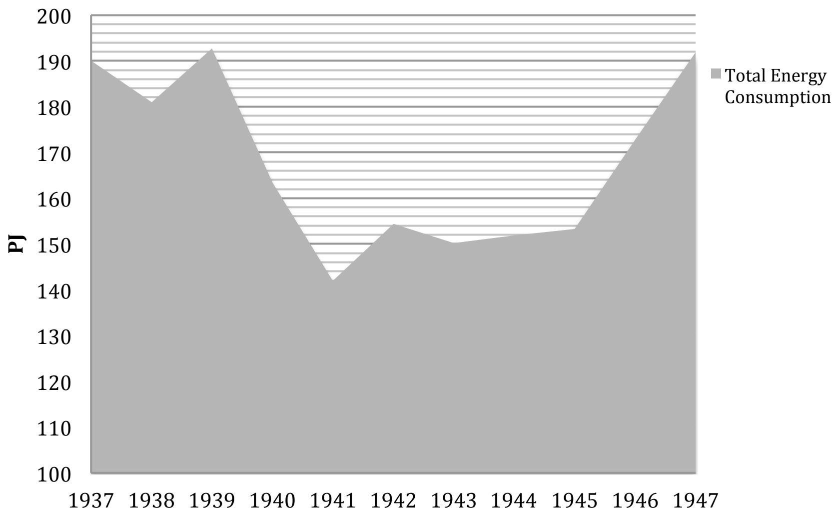
Source: Own Construction from Kommerskollegium (1918); Schön (1990)

Figure A.2: Total Energy Consumption in Manufacturing Industry, 1927-1933



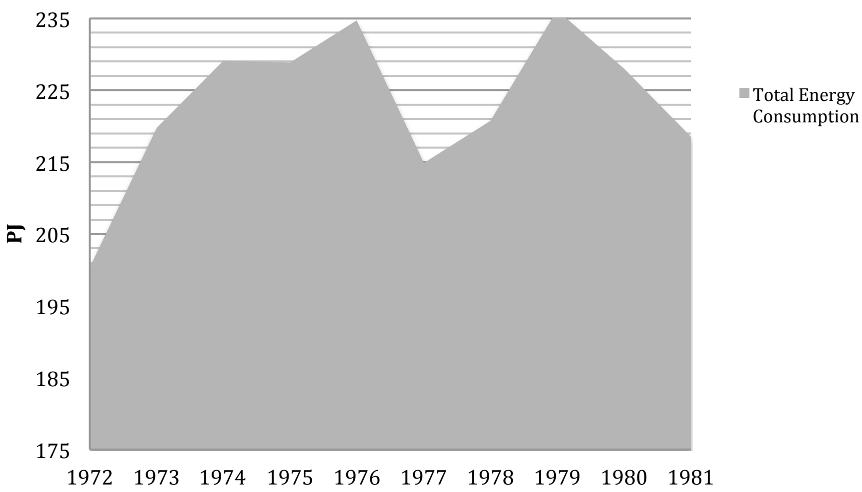
Source: Own Construction from Official Statistics of Sweden; Schön (1990)

Figure A.3: Total Energy Consumption in Manufacturing Industry, 1937-1947



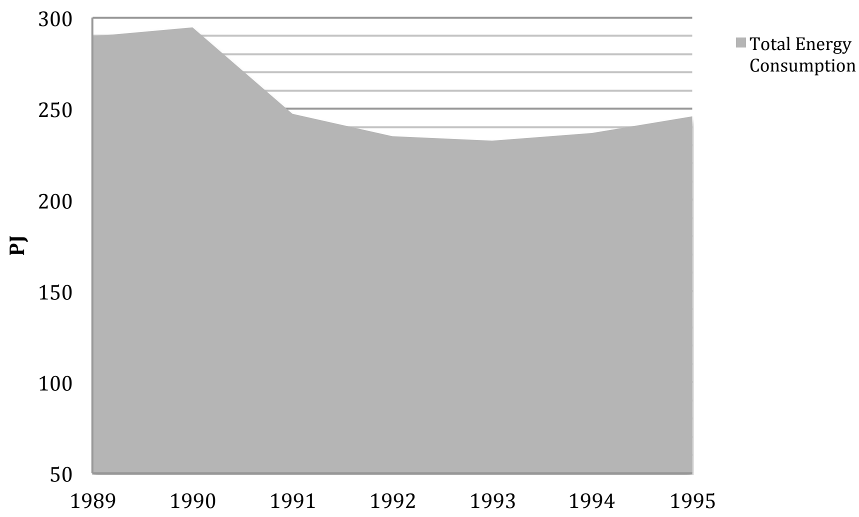
Source: Own Construction from Official Statistics of Sweden; Schön (1990)

Figure A.4: Total Energy Consumption in Manufacturing Industry, 1972-1981



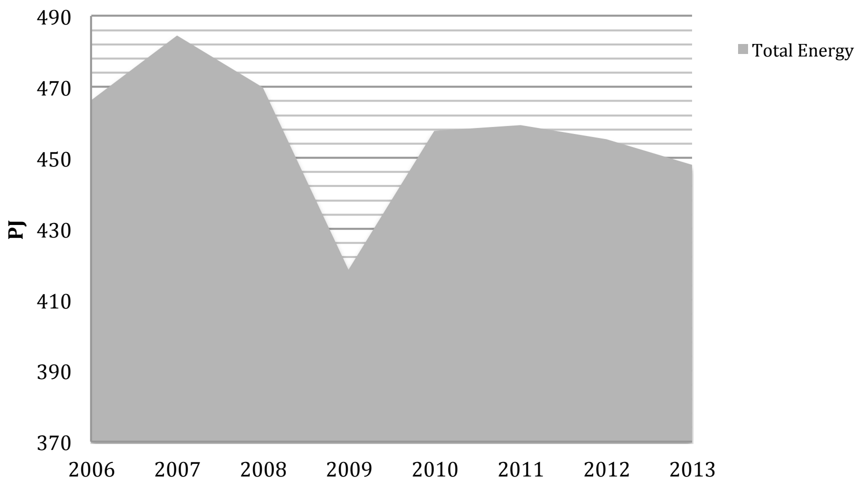
Source: Own Construction from Official Statistics of Sweden; Schön (1990)

Figure A.5: Total Energy Consumption in Manufacturing Industry, 1989-1995



Source: Own Construction from Official Statistics of Sweden; Schön (1990)

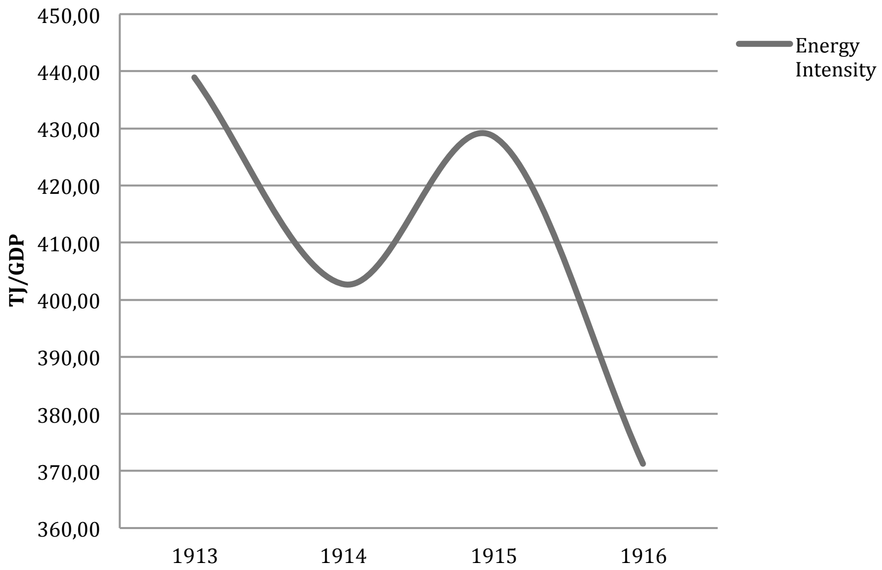
Figure A.6: Total Energy Consumption in Manufacturing Industry, 2006-2013



Source: Own Construction from Swedish Energy Agency (2015)

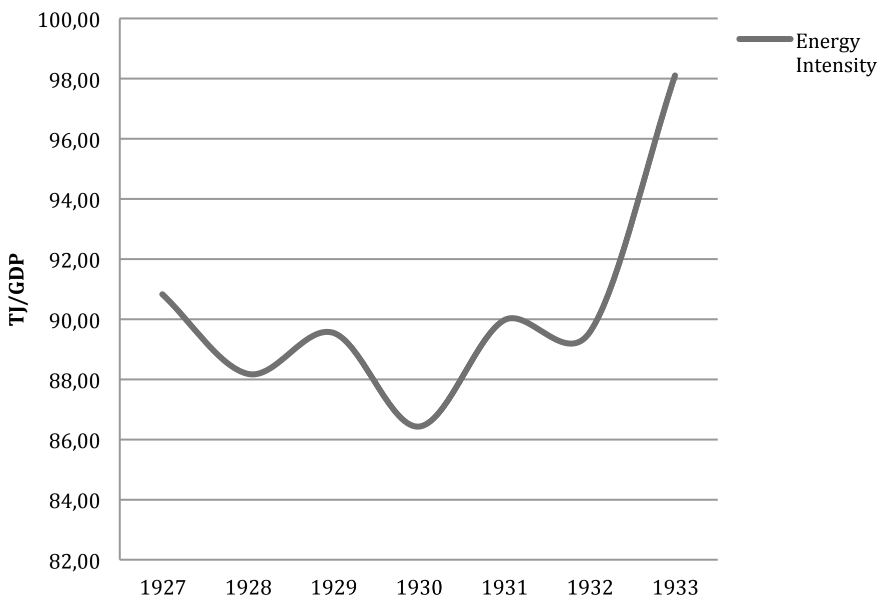
Appendix B

Figure B.1: Energy Intensity in the Manufacturing Industry, 1913-1916



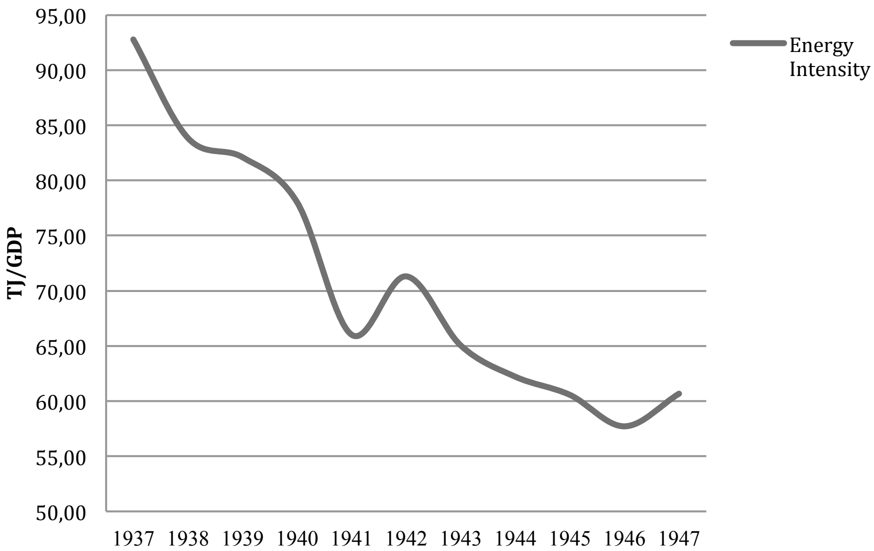
Source: Own Construction from Krantz & Schön (2007); Schön & Krantz (2012); Schön & Krantz (2015); Official Statistics of Sweden; Schön (1990)

Figure B.2: Energy Intensity in the Manufacturing Industry, 1927-1933



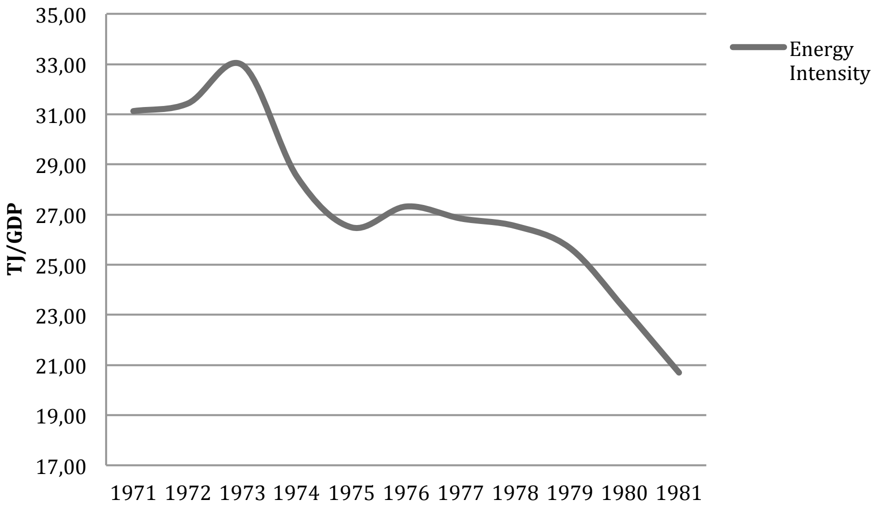
Source: Own Construction from Krantz & Schön (2007); Schön & Krantz (2012); Schön & Krantz (2015); Official Statistics of Sweden; Schön (1990)

Figure B.3: Energy Intensity in the Manufacturing Industry, 1937-1947



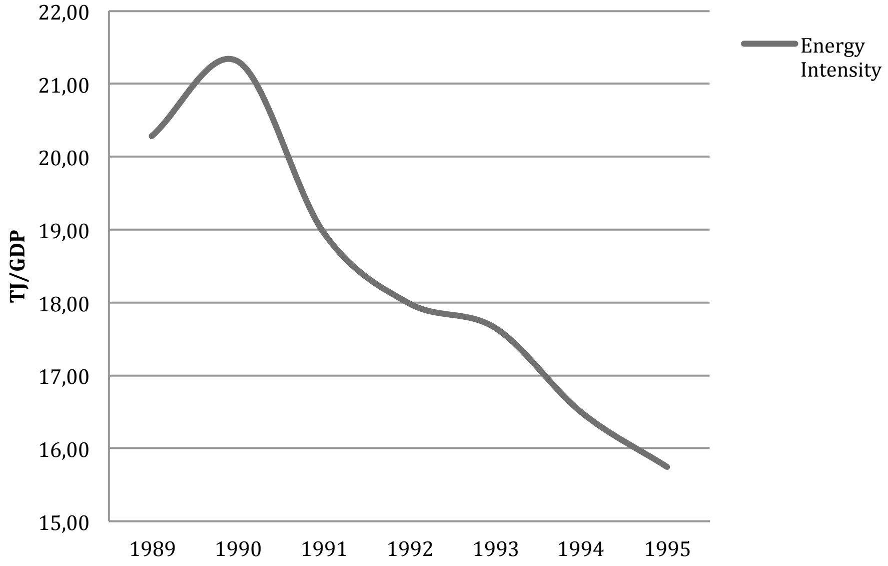
Source: Own Construction from Krantz & Schön (2007); Schön & Krantz (2012); Schön & Krantz (2015); Official Statistics of Sweden; Schön (1990)

Figure B.4: Energy Intensity in the Manufacturing Industry, 1971-1981



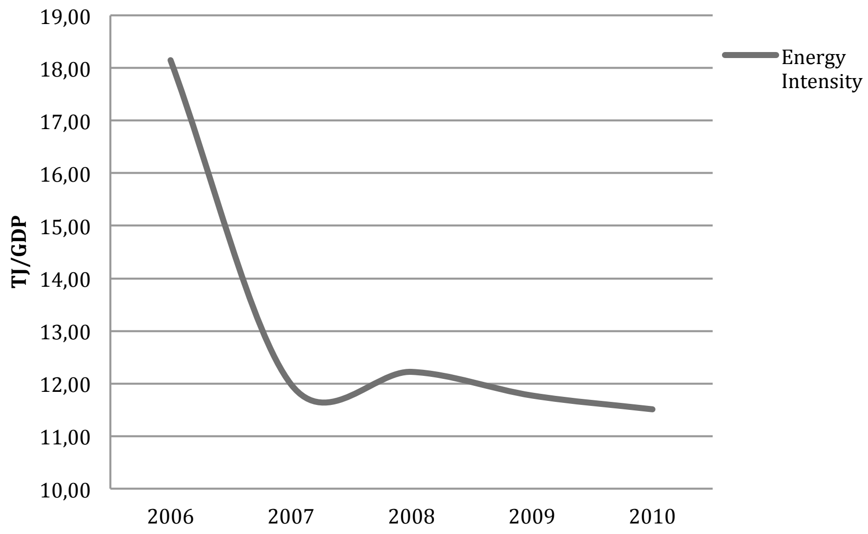
Source: Own Construction from Krantz & Schön (2007); Schön & Krantz (2012); Schön & Krantz (2015); Official Statistics of Sweden; Schön (1990)

Figure B.5: Energy Intensity in the Manufacturing Industry, 1989-1995



Source: Own Construction from Krantz & Schön (2007); Schön & Krantz (2012); Schön & Krantz (2015); Official Statistics of Sweden; Schön (1990)

Figure B.6: Energy Intensity in the Manufacturing Industry, 2006-2010



Source: Own Construction from Krantz & Schön (2007); Schön & Krantz (2012); Schön & Krantz (2015); Official Statistics of Sweden; Schön (1990)

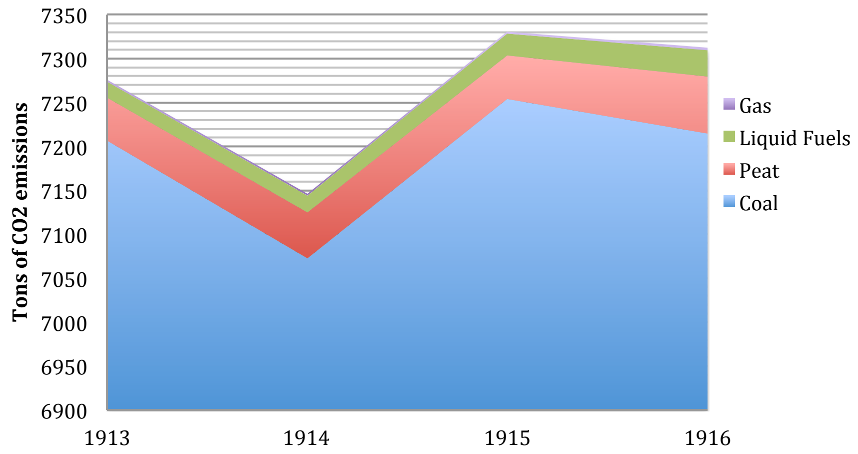
Appendix C

Table C.1: Conversion Factors – Tons of CO_2 Emissions

Energy Carrier	Coal 1 Gigajoule =	Peat 1 Gigajoule) =	Liquid Fuels 1 Gigajoule =	Gas 1 Gigajoule =
Tons of CO_2 Emissions	94,1	106	73,3	56,2

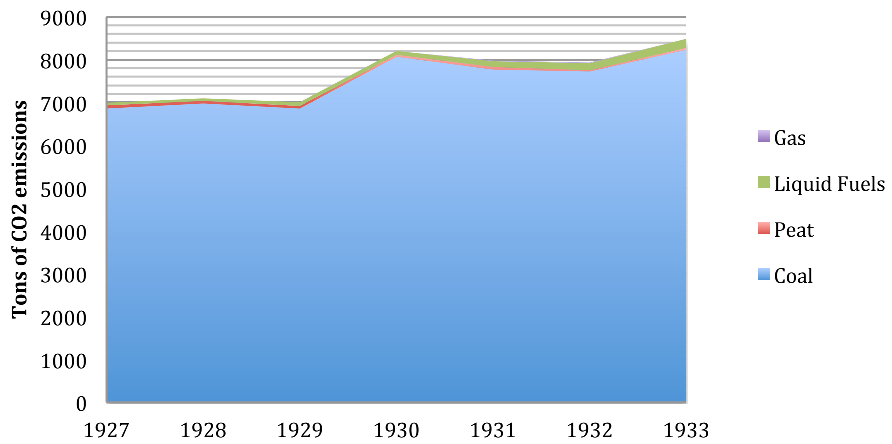
Source: IPCC 2006

Figure C.1: Tons of CO_2 Emissions Produced by the Manufacturing Industry, 1913-1916



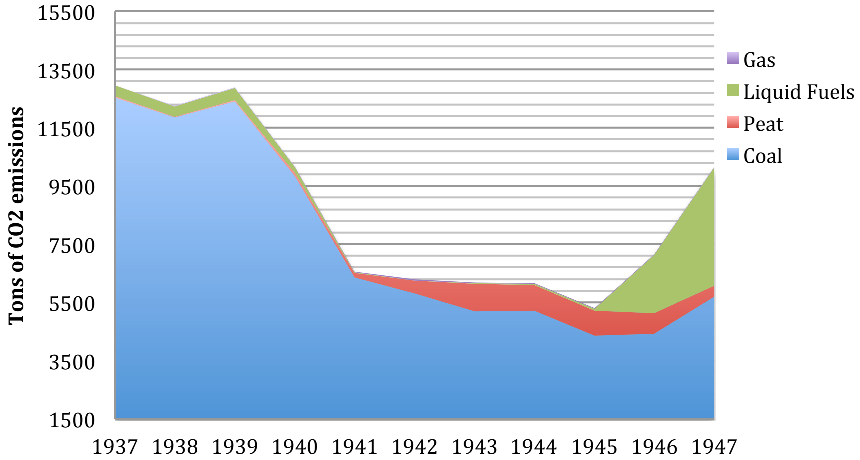
Source: Own Construction from Kommerskollegium (1918)

Figure C.2: Tons of CO2 Emissions Produced by the Manufacturing Industry, 1927-1933



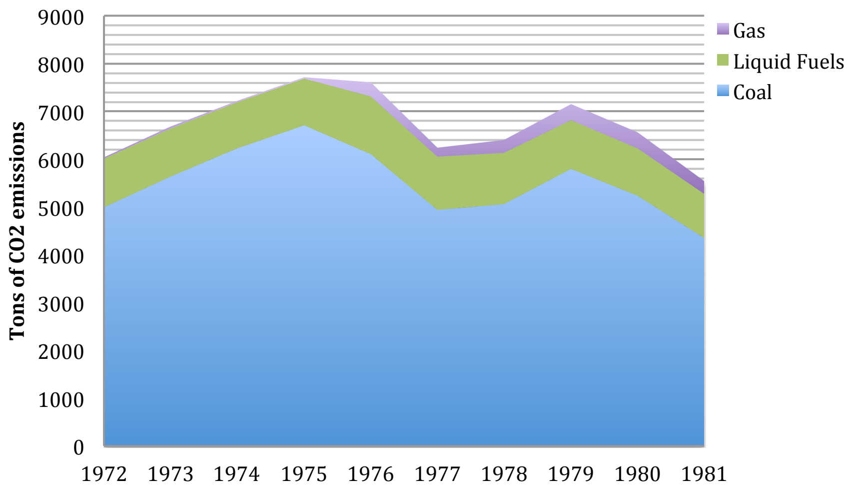
Source: Own Construction from Official Statistics of Sweden

Figure C.3: Tons of CO_2 Emissions Produced by the Manufacturing Industry, 1937-1947



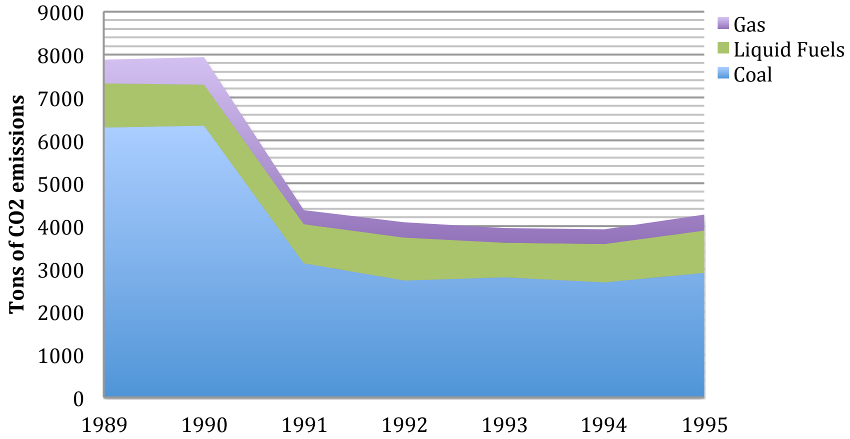
Source: Own Construction from Official Statistics of Sweden

Figure C.4: Tons of CO_2 Emissions Produced by the Manufacturing Industry, 1972-1981



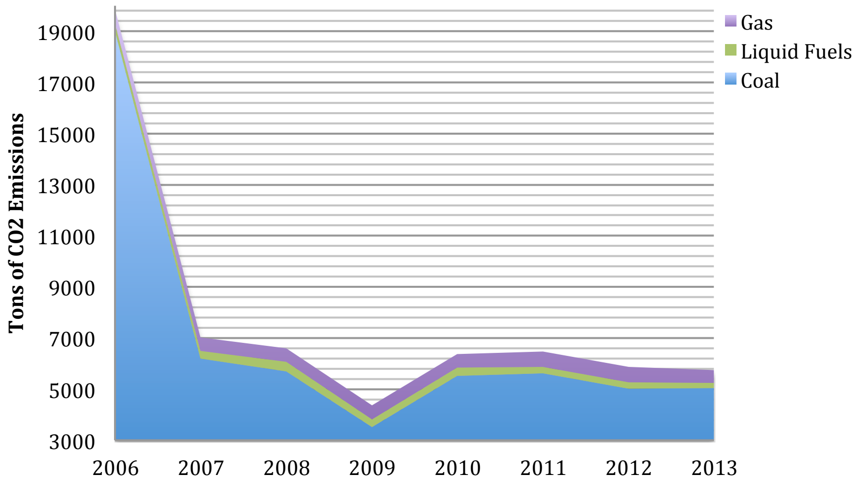
Source: Own Construction from Official Statistics of Sweden

Figure C.5: Tons of CO_2 Emissions Produced by the Manufacturing Industry, 1989-1995



Source: Own Construction from Official Statistics of Sweden

Figure C.6: Tons of CO_2 Emissions Produced by the Manufacturing Industry, 2006-2013



Source: Own Construction from Swedish Energy Agency (2015)

Appendix D

Table D.1: Total Energy Consumption in the Manufacturing Industry, by Energy Carrier

Pegajoule

Year	Coal & Coke	Peat	Liquid Fuels	Charcoal	Gas	Wood Fuels	Electricity	Total
1913	76,58	0,47	0,24	0,02	0,04	4,81	4,60	**86,75**
1914	75,16	0,49	0,27	0,02	0,04	4,75	4,64	**85,34**
1915	77,09	0,47	0,34	0,02	0,04	7,00	5,69	**90,62**
1916	76,67	0,61	0,41	0,02	0,05	8,11	6,79	**92,64**
1921	41,08	2,59	0,55	0,08	0,00	27,26	5,42	**76,90**
1927	72,90	0,63	0,90	0,09	0,00	32,89	11,34	**118,75**
1928	74,08	0,56	0,98	0,09	0,00	33,13	11,29	**120,12**
1929	72,95	0,51	1,15	0,10	0,00	37,55	12,95	**125,23**
1930	85,71	0,51	1,11	0,09	0,00	33,60	13,00	**134,04**
1931	82,60	0,47	1,86	0,07	0,29	29,27	12,61	**127,16**
1932	82,04	0,37	2,24	0,05	0,24	25,37	11,98	**122,28**
1933	87,56	0,34	2,78	0,05	0,25	29,36	13,28	**133,62**
1937	133,36	0,34	5,10	0,09	0,15	31,07	19,90	**190,01**
1938	125,97	0,24	4,88	0,11	0,44	29,51	19,85	**181,00**
1939	131,95	0,24	5,80	0,10	0,45	32,45	21,69	**192,68**
1940	104,61	0,84	2,87	0,12	0,47	35,19	19,27	**163,37**
1941	67,59	1,45	0,25	0,12	0,52	53,31	18,65	**141,89**
1942	61,75	4,02	0,21	0,12	0,50	67,50	20,31	**154,41**
1943	55,20	8,89	0,23	0,13	0,53	62,30	22,86	**150,15**
1944	55,50	8,18	0,44	0,13	0,57	61,45	25,62	**151,90**
1945	46,23	8,09	0,82	0,12	0,49	69,40	28,16	**153,32**
1946	47,10	6,54	27,29	0,10	0,56	62,49	28,71	**172,78**
1947	60,63	3,38	55,58	0,07	0,54	44,79	26,87	**191,88**
1972	53,12	0,00	13,78	0,00	0,56	10,86	121,92	**200,25**
1973	59,91	0,00	13,80	0,00	0,58	12,13	133,32	**219,73**
1974	66,18	0,00	13,17	0,00	0,56	12,99	136,22	**229,11**
1975	71,35	0,00	13,24	0,00	0,58	10,86	132,80	**228,83**
1976	64,95	0,00	16,33	0,00	5,25	11,01	137,19	**234,73**
1977	52,57	0,00	15,04	0,00	3,45	12,14	131,72	**214,91**
1978	53,81	0,00	14,66	0,00	4,71	13,00	134,59	**220,76**
1979	61,65	0,00	13,87	0,00	5,97	13,10	141,54	**236,14**
1980	55,60	0,00	13,66	0,00	5,88	13,53	139,26	**227,93**
1981	46,29	0,00	12,51	0,00	4,96	16,11	138,70	**218,57**
1989	66,95	0,00	13,92	0,00	9,99	19,44	179,27	**289,56**

1990	67,35	0,00	13,08	0,00	11,33	19,00	183,92	**294,68**
1991	33,28	0,00	12,42	0,00	5,73	17,77	177,91	**247,10**
1992	28,91	0,00	13,71	0,00	6,30	16,39	169,44	**234,75**
1993	29,74	0,00	11,05	0,00	6,06	16,75	168,82	**232,42**
1994	28,54	0,00	12,11	0,00	6,30	16,01	173,66	**236,62**
1995	30,82	0,00	13,48	0,00	6,62	15,26	179,45	**245,63**
2006	57,24	0,00	4,35	0,00	9,57	191,88	203,28	**466,32**
2007	65,73	0,00	4,14	0,00	9,33	198,36	206,88	**484,44**
2008	60,44	0,00	5,06	0,00	9,53	195,12	199,68	**469,84**
2009	37,40	0,00	4,06	0,00	9,58	189,36	178,09	**418,50**
2010	58,55	0,00	4,44	0,00	9,58	195,84	189,25	**457,66**
2011	59,69	0,00	3,35	0,00	10,70	194,40	191,05	**459,18**
2012	53,27	0,00	3,64	0,00	10,70	198,72	188,89	**455,21**
2013	53,64	0,00	2,51	0,00	9,33	199,08	183,49	**448,05**

Source: Own Construction from Official Statistics of Sweden; Kommerskollegium (1918); Swedish Energy Agency (2015); Schön (1990)

Table D.2: Conversion Factors to Tons of Coal Equivalent (TCE)

Energy Carrier	**Coal & Coke** Ton	**Peat** Ton	**Liquid Fuels** Kg	**Charcoal** m^3	**Gas** m^3	**Wood Fuels** m^3	**Electricity** Mwh
Conversion Factor TCE	1,05	0,5	1,55	0,17	0,72	0,12	8,14

Source: Own Construction from Official Statistics of Sweden

Table D.3: Conversion Factors to Units of Energy

UNIT	**1 TCE** Ton of Coal Equivalent	**1 TJ** Terajoule	**1 PJ** Petajoule
GJ Gigajoule	29,307	1 000	1 000 000

Source: Own Construction from Henriques (2011)