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Abstract

This paper examines the development of carbon dioxide emissions in Sweden, especially with a focus on the absolute reductions during the post-war period, during the 1970s and 1980s. The paper shows that the largest reductions were achieved before the introduction of an active climate policy in 1991. This was in turn the result of significant improvements in energy efficiency and energy conversion, while structural changes were considerably less important. One reason behind this decoupling process may be that the active energy policy put pressure on households and industries to conserve energy and to substitute from oil to electricity and biofuels. The process was substantially reinforced by the development of world oil prices in combination with the development of domestic electricity prices, where nuclear power seems to have played an important role.

Keywords: Sweden, climate policy, economic growth, carbon dioxide reduction, carbon tax

1 Introduction

The Swedish climate policy was introduced in the early 1990s as a measure to stabilize and reduce emissions of greenhouse gases. In line with national objectives, and in addition to national policy measures, Sweden ratified the Kyoto protocol in 2002 and became part of the EU-ETS in 2005. Sweden is today recognized as a country with high ambitions in the climate policy arena.

Since the implementation of the climate policy, the Swedish carbon dioxide emissions have been slightly reduced. The active climate policy, especially the carbon dioxide tax, has been advocated as the main explanation for achieving a decoupling between emissions and GDP. Even though this may be correct, it cannot explain the CO2 reductions in Sweden prior to the 1990s. In comparison, carbon dioxide emissions were reduced by approximately 40 percent between the early 1970s and the late 1980s, while the reduction between 1990 and 2005 was less than 5 percent. Interestingly enough, the largest reduction of carbon dioxide emissions were achieved before the era of active climate policy. Puzzled by the fact that the largest reduction in Sweden took place during a policy regime focused, we will focus, through analysis of the period, why increasing emissions during the 1950s and 1960s and the subsequent reduction during the following two decades occurred. The objective is to account for the proximate factors in position to explain this; these factors being structural change, energy efficiency and energy substitution on the aggregated carbon dioxide emissions. In the next step we analyze the ultimate factors that are in position to explain the incentives to reduce oil consumption and thereby carbon emissions.

This paper contributes to the literature by examining the long-term factors fostering one of the largest reductions of CO2 emissions reported from a single country. By uncovering the impact of structural change, energy efficiency and energy substitution, this paper accounts for the proximate causes of carbon dioxide reduction at a more detailed level and as an exention of Kander and Lindmark (2004). From a policy perspective, this paper contributes a historical context for analyzing and interpreting central mechanisms which may govern reductions of carbon emissions. This paper contributes important insights for industrial regulators, legislators and others with a business and policy interest regarding one of the largest reductions of carbon dioxides emissions.

The study has the following structure. Section 1 provides an outline of the long-term development of carbon dioxide emissions. Section 2 outlines the methodology employed to decompose for structural and technical change. Section 3 shows the decomposition results during the period 1950-1990, while section 3 provides an overview of policy tools at work during this period and an analysis of how energy taxation affected relative prices. Section 4 concludes.

2 The long-term development of carbon dioxide

As shown in figure 1, the direct emissions from domestic economic activities peaked in 1970. The emissions decreased by approximately 10 percent in the 1970s and 40 percent in the 1980s. After 1990, the emissions have been slightly reduced.

The carbon dioxide intensity increased throughout the 1950s and 1960s, while the intensity has generally been reduced thereafter. The first half of the 1990s reveals that the intensity was roughly constant, while further decreases are noticed from the mid 1990s. In general terms, it may be noticed that the intensity has closely followed the development of carbon dioxide emissions. The decoupling was, however, stronger than the reduction of emissions both during the period 1970 to 1990 and from the period after 1995.

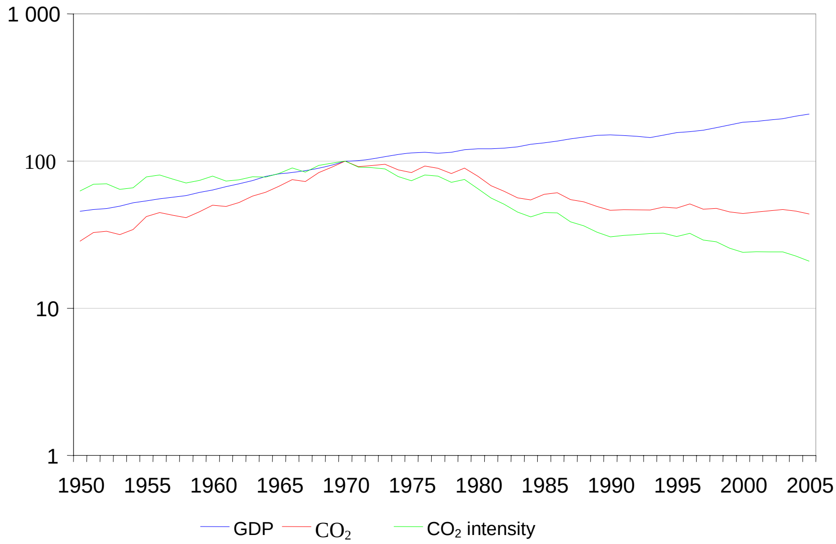

Figure 1: National carbon dioxide emissions, GDP and carbon dioxide intensity (index 1970=100).

The trajectory of Swedish carbon dioxide emissions since the 1950's may be divided on three sub-periods: (i) 1950-70, (ii) 1970-90), (iii) 1990-2005. The first sub-period is characterized by increasing emissions and an energy policy with few environmental concerns. The energy policy was focused on securing supply of cheap energy to the expanding manufacturing. The second sub-period is characterized by decreasing emissions and an energy policy which aimed at reducing the dependency on oil. One major part was the expansion of nuclear power from 1973 and onwards. The third period is characterized by slowly decreasing emissions and growing climate policy concerns. Although a climate concerns grew in the early 1990s, we cannot find a rapid reduction in the carbon dioxide emissions. To account for the shift in the decoupling process we need to go back to the period before the 1990s where we will account for how different factors contributed to the developments of GDP and carbon dioxide intensity during the first and second periods.

3 Method

The general approach taken is to account for the decoupling between carbon dioxide emissions and economic growth by decomposing changes with respect to their proximate causes. Multiplying by GDP growth rates provides a transformation to absolute emissions changes. For decomposing intensity changes, we use a shift-share decomposition method, which allows us to account for effects due to improvements within sectors and effects of structural change. The CO2 intensity, denoted COI, is defined as industry CO2 emissions/industry value added. Following the methodology suggested by Fagerberg (2000) and Pender (2003), equation (1) shows how we decompose the aggregate COI into three separate effects:

$$\Delta COI_T = \frac{\overbrace{\sum_{i=1}^{n} \Delta COI_i \cdot VAS_{i,b}}^{(1)\ WE} + \overbrace{\sum_{i=1}^{n} COI_{i,b} \cdot \Delta VAS}^{(2)\ SE} \overbrace{\sum_{i=1}^{n} \Delta COI_i \cdot \Delta VAS_i}^{(3)\ DE}}{COI_{T,b}} \qquad 1.$$

where *COI* is CO_2 intensity, *b* is the base year, Δ denotes the change between the base year and comparison year and VAS_i is the share in industry i of total value added (GDP). T denotes ∑ over industries *i*;

The within effect (WE) measures the improvements that have taken place within an industry under the counterfactual constraint that no structural shifts have taken place. In other words, each industry has maintained its value added share as in the base year. The within effect may be caused by improved energy savings or substitution from high CO2 intensive energy to low CO2 intensive energy, but may also arise from such effects as improved output quality. The within effect is decomposed on energy intensity and energy carbon intensity according to equation 2.

The static shift effect (SE) is the sum of relative changes of value added across industries between the base year and the comparison year, where value added is weighted with the COI in the base year. The static effect is accordingly resulted from changes in the production structure. The static effect may contribute to an improved aggregated COI if low COI industries expand and high COI industries contract (see equation 3) The Dynamic shift effect (DE), is calculated as the sum of changes in VAS and COI. The dynamic effect will have an impact on the aggregated COI if expanding VAS levels also improve COI levels.

In equation 2, the within effect is decomposed into two separate effects:

$$\Delta IE_T = \sum_{i=1}^{n} (\Delta EI_i + \Delta ECI_i) \cdot VAS_{ib} \qquad 2.$$

where *IE* is the within effect, *b* is the base year, Δ is the change between the base and final year, T denotes ∑ over industries *I* and VAS_i is the share of total value added for industry i. EI is energy intensity and ECI is the CO2 per unit of energy.
EI is calculated as follows from equation 3:

$$\Delta EI_i = \frac{\Delta E_i}{\Delta VA_i} \qquad 3.$$

where E is energy levels and VA is value added. A reduction in energy intensity arises as a result of an improved relation between industry output and energy use. This proc 4. denoted as energy saving, while the opposite (declining EI) is denoted as energy squandering. ECI is calculated according to equation 4:

$$\Delta ECI_i = \frac{\Delta CO2_i}{\Delta E_i}$$

where CO_2 is carbon dioxide levels and E is energy levels. A reduction in the COI of energy may occur due to a shift between energy carriers with different carbon intensities, such as a shift from oil to electricity. The latter process is denoted energy conversion

The decomposition allows us to single out the importance of structural change, energy efficiency and energy conversion whilst ensuring a measurement of the contribution of proximate factors to the aggregated decoupling process. In the next section the results are presented.

The data employed in this study emanates from new sectoral estimates of historical carbon dioxide emissions in Sweden. The point of departure for the reconstructions is the aggregated data on fuel and electricity consumption, based on the official statistics and with additional information from the Swedish Petroleum Institute.[1] In the next step, the fuels were distributed on the economic sectors. Energy consumption divided on carriers in the manufacturing and energy sectors are directly obtained from the official statistics.[2] Special attention is given to assure that we are not double counting fuels that are used for further conversions to other energy carriers, foremost coal for coke manufacturing and for gas production. We also pay attention to the fact that the contemporary statistics treats coke in steel plants as an intermediate good rather than an energy carrier. There are also statistics on fuel consumption in agriculture[3]. For the first few years we use the number of tractors in agriculture as an indicator of fuel consumption in agriculture. Also railroads are covered in the official statistics. Distribution of fuels for the transport industry depart from

[1] http://www.spi.se/eng/statistics.asp?stat=64
[2] SOS *Industrin*
[3] SOS Jordbruket

the wholesales of petrol and diesel, where we use kilometers traveled per person in private cars and tons transported by trucks in kilometers as indicators for the distribution between households and commercial transports.[4] Further adjustments for trucks during the 1950s and 1960s are based on work by Krantz (1986). Furthermore, kerosene is distributed on commercial airlines, in the transport sector, and military aviation in the service sector. Available official statistics are also used for bunker fuels in maritime use and for fuels in the building and construction sector. For the residential sector, we have used a combination of residual heating oil, after other uses have been deducted for, and other various historical bench marks.[5] The residual heating oil, after accounting for households, is distributed within the service sector.

Concerning the sectoral division, we use one combined sector for manufacturing and agriculture. This is purely motivated by practical reasons since the latter sector is very small with respect to both VA and emissions. The service sector combines public and private services, due to the difficulties in separating fuel consumption between the two. The service sector also includes building and construction, which is purely motivated by simplification of showing results. We are also using a sector for private cars, where according to the national accounting system; this should be included as an emission occurring due to final consumption. Since we do not have a fully reliable input-output framework for the whole period, we decided to treat private cars as a service produced by households for own consumption. The value added in this sector is based on an estimate of the service flow from the stock of private cars, based on a PIM calculation on investments in private cars.[6] All value added data is in fixed prices in order to avoid biased shift effects as pointed out by Kander (2005).

4 The impact of structural change, energy efficiency and energy conversion on the decoupling process in Sweden 1950-1990

Figure 2 shows that within effects increased the GDP carbon dioxide intensity by approximately 1.5 percent annually between 1950 and 1970. Also the shift effects tended to increase the intensity during the first period and contributed to the reduction by roughly 5 percent annually. However, these shift effects were close to zero. During the period 1970 to 1990, figure 2 shows that within effects contributed to a decreased intensity by 1.5 percent

[4] SIKA http://www.sika-institute.se/Templates/Page____1331.aspx
[5] SOU 1951:32 and SOU 1957: as well as modern bench-marks
[6] National Accounts, consumption, COICOP 07

annually. We also know that the shift effects contributed, to some extent, for a lower intensity during this period. The small contribution of shift effects motivates why they are ignored in the following:

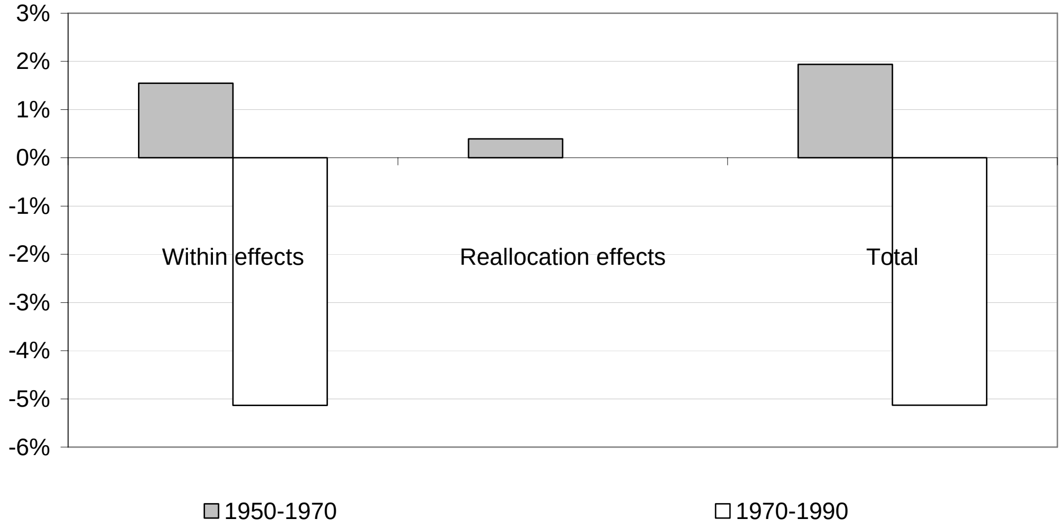

Figure 2: Contribution to changes in carbon dioxide intensity by component and sub-period

The decomposition of within effects on energy efficiency, effects from a changing energy carrier mix[7], and the carbon dioxide intensity of energy, is shown in figure 3. The first period is characterized by a slight improvement of the energy efficiency which is coupled with a significant increase of the carbon dioxide intensity of energy. Carbon intensive energy carriers became increasingly more important during the period. Improved energy efficiency was also stronger during the period 1970 to 1990, while the carbon dioxide intensity of energy decreased almost three times more in comparison. The reduction of carbon emissions during the 1970s and 1980s was accordingly the result of a changing energy mix, and to some extent improved energy efficiency.

[7] For the sectoral division see appendix

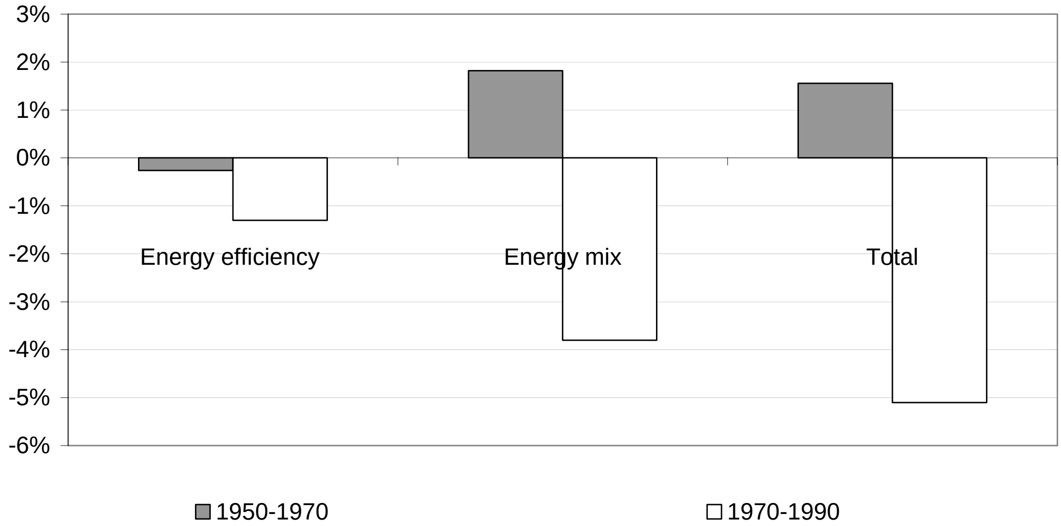

Figure 3: Average annual contribution to the within effect by component and sub-period

We can see that the contribution to the carbon intensity is varied between sectors. As shown in figure 4, manufacturing (shown together with agriculture), did not contribute to the increasing carbon dioxide intensity during the first period. This is an effect of carbon emissions growing at almost the same rate as manufacturing value added, which in turn increased at the same rate as GDP. The increase was instead allocated to all other sectors, dominated by the energy sector.

On the contrary, during the period 1970 to 1990, it was the manufacturing industry that accounted for the largest contribution to the decreased intensity. Also the energy sector, closely followed by the residential sector, was important for decreased intensity levels while services, which in the investigation comprises of private and public services as well as building and construction, had a contribution half that size. Even the commercial transport sector contributed to some extent to the decoupling. The contribution from household transports, which in the analysis is treated as a service produced by households for own consumption, is very small.[8]

[8] The method facilitates the estimation of shift effects. One consequence is that GDP is slightly adjusted upwards.

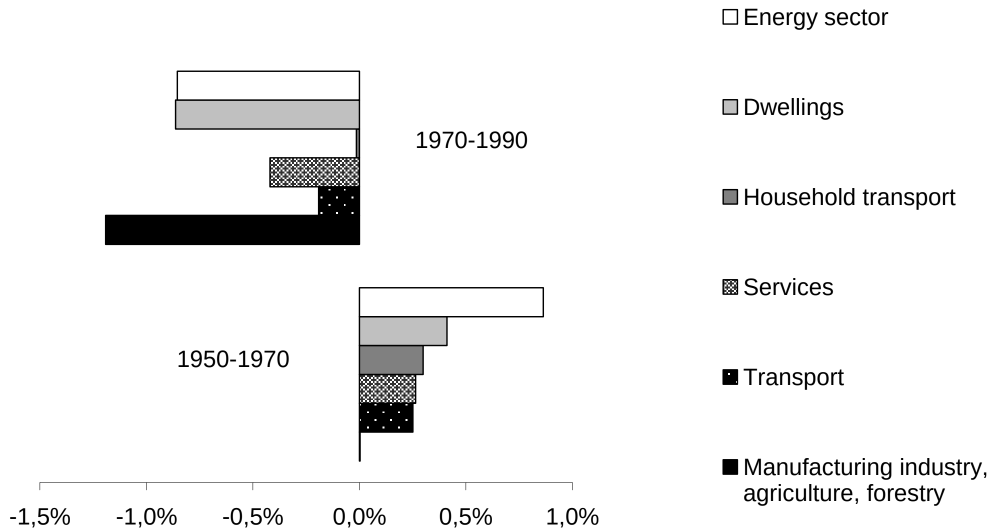

Figure 4: Average annual contribution to the carbon dioxide intensity by sector and sub-period

In conclusion, it is therefore evident that the proximate factors explaining the development of the carbon dioxide emissions were almost entirely depending on technical change, of which 2/3 were due to changes in the energy mix and 1/3 was due to changes in energy efficiency. To see how the effects are related to policy regimes, the next section outlines the characteristics of the energy policy over each designated period.

5 Energy and climate policy

Outlines of the developments during the 1970s and 1980s are possible to trace already in Swedish post-war planning. Major concerns related to energy supply during the mid 1950s were not only related to energy production as such, but also macroeconomic policy concerns, such as the balance of trade and energy security in the case of military conflicts. Here, the experiences of the Second World War dominated thinking and priorities. This resulted in the promotion of an energy system not relying on imports of either technology or energy carriers. In 1956, an official investigation concluded that nuclear power based on domestic uranium deposits would be the best option to achieve this goal.[9] Nuclear power, however, necessitated electrification of areas of use that previously had been covered by imported fuels. This especially involved heating of dwellings outside densely populated areas, but also stricter building codes for enhanced energy efficiency and development of certain electricity-based manufacturing processes, such as electro-steel. It was further concluded that steam generated electricity would first need to expand before nuclear power would be an option.

[9] SOU 1956:46 *Bränsleförsörjningen i atomåldern*, Stockholm 1956

The energy policy of the 1950s and 1960s were focused on investment in energy producing capacity, foremost hydroelectricity but also large central heating and, to some extent, district heating based on oil combusting thermal plants, sometimes with auxiliary electricity producing capacity. The introduction of nuclear power in 1973, which happened to coincide with the OPEC I crisis and a few years later with 1970's economic crisis, saw the emergence of various policy measures intended to reduce dependence on imported oil. Even though nuclear power was a new cornerstone in the energy system, policy tools were seen as essential to ensure that actors actually left the oil. One unintended effect of this policy was certainly a reduction of CO_2 emissions due the shift in energy mix and the growing energy efficiency previously shown. In table 1 an overview of the measures is outlined:

	Policy measures potentially reducing CO2 emissions	Energy expansion 1950-1970	Energy saving 1970-1990	Climate policy 1991-
1.	Supply of CO2 neutral sources	Partly	Fully	Fully
1.1	Nuclear power*	No	Yes	Yes
1.2	Hydroelectric power*'	Yes	Yes	Yes
1.3	Biofuel***	No	Yes	Yes
2.	Taxes	Partly	Yes	Fully
2.1	Energy taxes	Some	Yes	Yes
2.2	Carbon dioxide tax	No	No	Yes
2.3	Specific fuel tax	No	No	Yes
2.4	EU ETS	No	No	Yes
3.	Subsidies	None	Partly	Partly
3.1	Local climate programmes	No	No	Yes
3.2	Energy saving in dwellings	No	Yes	Yes
3.3	Energy saving in industry	No	Yes	Yes
3.4	Oil substitution fund	No	Yes	No
3.5	District heating	No	Yes	Yes
3.6	Household subsidies and loans	No	Yes	Partly
4	Legislation, information	None	Partly	Fully
4.1	Building codes	Partly	Yes	Yes
4.2	Energy certificate	No	No	Yes
4.3	Information and education	No	Yes	Yes

Note: *Investments in nuclear plants was exclusively public financed. **Investments in hydroelectric power plants was due to a high extent to public finances *** Investments in biofuel was partly public financed
Source: Vedung (1982), Ds 2005:55.

Table 1: Climate and energy policy measures in Sweden, 1950-2005

Energy taxes had first been implemented for fiscal reasons in the 1950s (an electricity tax in 1951 and a general energy tax in 1957). During the 1970s and 1980s, these taxes were raised with the main objective to reduce oil consumption in the manufacturing industry and in the household sectors. To stimulate the reduction of oil further, advantageous loans and subsides to households and industries were offered along with information campaigns and stricter building codes with respect to energy conservation.

As part of the oil substitution agenda, the government also ensured that the manufacturing industry was offered cheap electricity. Due to the increased tax pressure on oil, the substitution for oil was reinforced in the 1980s. Although the oil consumption was reduced, we also notice that fiscal reasons may have been a motive. During the 1980s, the total income/revenue from energy taxation as share of GDP increased from 2.5 to 3.7 percent. In addition to the oil substitution objective, this energy policy also aimed at reducing total energy consumption. During the 1980s, the general tax on energy was raised as a measure to improve energy efficiency. In total, the unintended climate policy affected the decoupling process by promoting substitution from oil to CO_2 neutral energy sources and by reinforcing the growing energy efficiency. The impact of this policy became strong due to the fact that oil was priced internationally and electricity nationally. By keeping national electricity prices fairly low during the OPEC crisis the substitution from oil was perhaps more associated by increasing oil prices than increasing oil taxes.

6 Conclusions

This paper shows that the largest carbon dioxide reduction took place before the implementation of climate policy of the 1990s in Sweden. The estimated reduction of approximately 40 percent was attributed to foremost improvement in energy efficiency and energy conversion. Changes in the production structure, i.e. structural change due to the decline of manufacturing production and expansion of service production, falls short in explaining the decoupling between growth and emissions. The Swedish energy policy put hard pressure on the household and the industry to save on energy and to substitute from oil to electricity. The impact of the national energy policy was also reinforced by the development of world oil prices.

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Appendix

	Sector	Industry	Institutional sector
1	Manufacturing and primary industries	Agriculture, hunting, forestry and fishing (SIC A,B); Mining and quarrying (SIC C); Manufacturing (SIC D)	Corporate
2	Transport	Transport and storage and communication (SIC I)	Corporate
3	Services and construction	Construction, wholesale and retail trade, Financial intermediation, real estate, renting and business activities, community social and personal services (SIC F, G, H, J, K, L, M, N, O)	Corporate and government
4	Household transport	The household production of transport services for own consumption	Household
5	Dwellings	The household consumption of own real estate services	Household
6	Energy	Electricity, gas and water supply (SIC E)	Corporate

Table 2: Classification of sectors

Variable	**Time period**	**Source**
GDP	2005-1950	SCB, Nationalräkenskaper [National accounts] 1993-2005, NR 10 SM 0701
Value added	2005-1950	SCB, Nationalräkenskaper [National accounts] 1993-2005, NR 10 SM 0701 SCB, Nationalräkenskaper [National accounts] 1980-1995, N 10 SM 9601 SCB, Nationalräkenskaper [National accounts] 1980-1970, N 1981:2.5 SCB, Nationalräkenskaper [National accounts] 1950-1971, N 1972:9
Carbon dioxide (CO2)	1950-1990	SCB, Industri [manufacturing industry] 1950-1990. SCB, Energistatistik [energy statistics] 1950- SOU 1951:32
	1993-2004	SCB, MiR 1993-2007.

Table 3: Sources for the time series of GDP, VA, and CO2.