Economic drivers of greenhouse gas-emissions in small open economies: A hierarchical structural decomposition analysis

Croner, Daniel and Koller, Wolfgang and Mahlberg, Bernhard

Institute for Industrial Research, Vienna University of Technology, Vienna University of Economics and Business

15 February 2018

Economic drivers of greenhouse gas-emissions in small open economies: A hierarchical structural decomposition analysis[1]

Daniel Croner[a,b], Wolfgang Koller[a] and Bernhard Mahlberg[a,c,#]

[a] *Institute for Industrial Research (IWI), Mittersteig 10, 1050 Vienna, Austria*

[b] *Vienna University of Technology (TU Wien), Wiedner Hauptstraße 8, 1040 Vienna, Austria*

[c] *Vienna University of Economics and Business (WU Wien), Welthandelsplatz 1, 1020 Vienna, Austria*

Abstract

The Paris agreement has prescribed strict Greenhouse Gas (GHG) reduction targets for participating countries. Implementation of climate protection policies is challenging, especially if the economy is export driven. We introduce a hierarchical structural decomposition model in order to investigate the effects of exports, imports, economic structure, consumption patterns, consumption level, outsourcing and insourcing on national GHG emissions. This model is applied to the data of national environmental accounts and to a harmonized and price-deflated series of national input-output tables of Austria for the years 1995, 2000, 2005 and 2010. Over the whole time period, the results indicate that the final demand effect was the main driver of GHG emissions, with exports as most important factor. Surprisingly, emission intensity contributed to an increase of GHG emissions during the period 2000-2005 as well, mostly due to increasing emission intensity in the transport sector.

Keywords: Leontief Model, Emissions Embodied in Exports, Trade Integration, Economic Structure, CO_2-Intensity, Competitiveness

JEL Classification: Q53, Q56, C67, L16

[1] The authors gratefully acknowledge the valuable comments received on earlier versions of this paper from Martin Bruckner, Stefan Giljum, and Hanspeter Wieland. The authors also would like to thank the Anniversary Fund of the Oesterreichische Nationalbank for supporting the project under project number 17040. The usual disclaimer applies.

[#] Corresponding author: Bernhard.Mahlberg@wu.ac.at and Mahlberg@iwi.ac.at

1 Introduction

The relevance of climate policy has changed the view on a country's economic performance. While classical measures for economic well-being, like gross domestic product (GDP), total factor productivity (TFP) or unemployment, are still very important indicators, the evaluation of the economic performance of a country would not be complete without looking at sustainable indicators like inequality, health, safety or, with respect to climate change, carbon dioxide (CO2) emissions. The Paris Agreement has prescribed specific targets for participating countries and decision entities like the European Union. For instance, in the year 2030, there should be a cut of greenhouse gas emissions (GHG) of at least 40% of the 1990 level. The share of renewable energy should be 27% and the energy efficiency also should improve by at least 27%.[2] The economic challenges arising from these requirements are fairly different between countries. The EU members have different structures of the economy, some relying more on heavy manufacturing some more on the service sector. The energy efficiency also varies strongly, often depending on the stage of development of a country.[3] Export intensive economies might face additional challenges by producing carbon intensive products for consumption elsewhere. Furthermore, small economies within the EU are highly dependent on economic conditions in other EU countries.

We analyze the competitiveness of Austria as an example of a small open economy with respect to GHG emissions. A small open economy participates in international trade, but is small enough compared to its trading partners so that its policies do not alter world prices, exchange rates, interest rates, or incomes. Such an economy is characterized by particularly pronounced trade integration and outsourcing. For such countries competitiveness is of special importance. This is also the case in terms of environmental measures: For an economy which is highly exposed to international competition, environmental policy might be especially expensive due to the threat of loss in competitiveness. However, there are two more points of views on this issue. The link between competitiveness and environmental regulation is often discussed in the context of the Porter Hypothesis (Porter and van der Linde, 1995) which states that impeding environmental damage does not have to be a contradiction to economic competitiveness. As Pasurka (2008) highlights, pollution abatement lowers productivity due to higher costs but might increase productivity due to higher efficiency and research and development efforts. Those studies still take long term economic output as reference point for competitiveness. The third perspective was developed by Aiginger and Vogel (2015) who introduce a new notion of competitiveness by including social and environmental pillars which extend the traditional notion of competitiveness with indicators like resource productivity, CO_2 emissions and renewable energy share. However, this might be conflicting with the classical factors of competitiveness as stronger pollution abatement gives incentives to outsource pollution intensive industries which might be competitive in a purely economic sense.

Due to the considerations above we treat environmental sustainability itself as a measure for competitiveness and therefore analyze the development of GHG emissions and its determinants on a detailed level for a small economy with high trade integration. The main question addressed in this paper is which determinant factors were crucial for the emission development and to what extent? More exactly, we introduce a hierarchical structural decomposition model (HSDA) in order to exam-

[2] http://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/2030-energy-strategy (accessed on December 15th, 2017)

[3] See Croner and Frankovic (2018) and Voigt et al. (2014) for trends of energy intensity in 40 major economies

ine the contribution of emission intensity, structural change, consumption level, consumption patterns, outsourcing, insourcing and the exports of final goods on domestic GHG emissions of a small economy. We also conduct this analysis on the commodity level in order to get detailed insights on the most polluting commodities and its development over time. In a case study, we apply this model to Austria for the years 1995 to 2010, using data of national environmental accounts and a harmonized and price-deflated time series of national input-output tables. We divide the sample period in the three subperiods 1995 to 2000, 2000 to 2005, and 2005 to 2010.

This paper is mainly based on the growing literature of structural decomposition analysis and CO_2 emissions. The methodological prerequisites are developed in Koller and Stehrer (2010). They introduce the HSDA and apply it to examine the influence of trade integration and outsourcing on the Austrian labour market. The effect of increasing international trade linkage on CO_2 emissions has been studied by various research works, like e.g. Wiedmann et al. (2007), Xu and Dietzenbacher (2014), Hoekstra et al. (2016), Malik and Lan (2016), and Kaltenegger et al. (2018).[4] Most of these studies use a Multi Region Input-Output Model to obtain an overview of global CO_2 trends. Another strand of the literature analyzes only country specific CO_2 emissions, like e.g. Chang and Lahr (2016) or Guevara and Rodrigues (2016). The reason for this is often a more detailed disaggregation of the sectors or commodities of an economy which allows for more detailed examinations of the origin of emission. Also notably, we apply a production-based approach to the Austrian economy (as opposed to a consumption-based approach). There are several advantages and disadvantages of production-based accounting (Peters, 2008). As emission data are collected directly at the place of production, this approach requires considerably less assumptions and uncertainty. More important, the production-based approach is the preferred method when the focus is on indicating possible areas of mitigation efforts and national policy action rather than the allocation of responsibility towards consuming countries.

Our contribution to the literature is threefold: First, the HSDA model provides a fairly detailed view on a country's GHG emission. We are able to decompose the changes in emissions over time into the typical factors of emission intensity, technology and final demand on the first level of the model hierarchy. On the second level we further decompose these factors into domestic and export factors while on the third level we account for outsourcing, insourcing, export- and domestic demand structure and level. Second, the analysis of the Austrian economy offers a detailed view on the performance of a small open economy with respect to GHG emissions. Third, the analysis is based on a commodity-by-commodity input-output table, not, like many other studies, on an industry-by-industry table. This gives a more accurate view on where emissions really come from as sectors often produce various, and sometimes very different, goods.

Our results for Austria indicate that the highest increase in GHG emissions occurred in the subperiod 2000 to 2005. The main driver in all periods is the final demand level where especially the increase of GHG emissions in exports contributed strongly. Surprisingly, the intensity effect contributed to an increase of GHG emissions between 2000 and 2005. The commodity level analysis reveals that this is mainly due to transport services.

---

[4] See Lenzen (2016) for a more complete overview of the recent literature on this issue.

The structure of the paper is as follows: In section 2 we introduce the hierarchical structural decomposition model applied on GHG emissions. In section 3 we explain the data preparation steps for the case of Austria. In section 4 we present the results of the analysis. Section 5 concludes.

2 Method

The methodological approach of this paper relies mainly on a hierarchical decomposition (HDSA) model introduced by Koller and Stehrer (2010). We adapt this model to analyze the development of GHG emissions, whereby we leave the basic hierarchical structure of the model unchanged. The HSDA builds on the classical Leontief input-output model which is our starting point:

$$q = A_d q + f_d = L_d f_d \tag{1}$$

where q is the vector of gross outputs of the goods produced in the economy, A_d the matrix of domestic input coefficients (i.e., including imports), and f_d the final demand for domestic products. The domestic Leontief inverse is defined as:

$$L_d = \left(I - D_A \otimes A\right)^{-1} \tag{2}$$

where A is the technical coefficient matrix and $D_A = A_d \varnothing A$ the matrix of domestic shares. Hereby, $\varnothing$ and $\otimes$ denote element wise division and multiplication. Equation (1) gives the required gross output of all goods for a given final demand for goods produced in the domestic economy. By adding the emission coefficient c we obtain the GHG emissions E which are associated with final demand:

$$E = c^T L_d f_d \tag{3}$$

The emission coefficient c is defined as $c = m \varnothing q$ where m is the emission vector which indicates the direct emissions occurring in production of a certain good and q the gross output of this good. The superscript T is used for transposing the vector. While E is a scalar which gives the overall emissions associated with domestic production the formula

$$e = \hat{c} L_d f_d \tag{4}$$

gives the vector of emissions associated with production of each specific good. $\hat{c}$ is the matrix resulting from the diagonalization of vector c.[5]

In our analysis we are interested in the details of the structure of intermediate production and final demand which determines the development of E and e. Therefore we analyze L_d and f_d in more detail.

Throughout the paper we denote the change in a variable between two time periods with $\Delta x = x_1 - x_0$. On the first level of the hierarchy we decompose Δe (or ΔE respectively) in the factors in (4):

[5] Note that this approach is production-based and not consumption-based as would be achieved with a diagonalization of f_d.

$$\Delta e = e(\Delta \hat{C}) + e(\Delta L_d) + e(\Delta f_d) \tag{5}$$

where $e(\Delta x)$ denotes the change of e due to the variation of x when all other factors of e remains unchanged. Those decomposition factors are again decomposed in its elements further down the hierarchy.

Figure 1: Hierarchical Decomposition

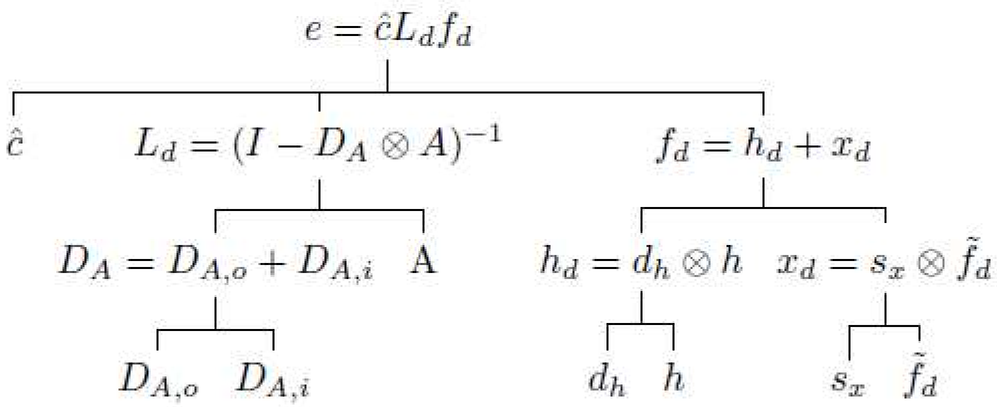


Figure 1 gives an overview of the complete model. The share of domestic input coefficients D_A is decomposed into outsourcing $D_{A,o}$ and insourcing $D_{A,i}$. More exactly, if the domestic share of an intermediate input increases (decreases), we observe insourcing (outsourcing). Formally we write,

$$D_{A,o} = \begin{cases} D_{A;m,n}, & if\ \Delta D_{A;m,n} < 0 \\ 0, & otherwise \end{cases} \tag{6}$$

$$D_{A,i} = \begin{cases} D_{A;m,n}, & if\ \Delta D_{A;m,n} \geq 0 \\ 0, & otherwise \end{cases} \tag{7}$$

Final demand for goods of domestic origin f_d can be decomposed into final demand (excluding exports) of domestically produced goods h_d and exports x_d. In the last step, we distinguish between final demand excluding exports h and the share of domestic demand d_h. We use the relationship $x_d = s_x \otimes \tilde{f}_d$ to further decompose (changes in) x_d in (changes in) the shares of export in final demand and (changes in) the level of final demand (f_d and $\tilde{f}_d$ denote the same variable; we use the˜ sign to denote that in the decomposition model their time stamp is varied independently of each other).

This decomposition analysis gives a clear picture of the effects of trade integration on the domestic production-based emissions. For example, those domestic emissions depend on whether the supply chain of domestic production is also domestic or production relies more on foreign intermediates. Under strict environmental policies in the European Union, countries might have an incentive to outsource emission intensive production in order to improve its balance. This can be backtraced with the variable $D_{A,o}$ in our model.

Another aspect of trade in our model is the export of goods. The export share effect s_x, $\Delta E(s_x)$, shows the change in GHG emissions that are due to a change in the shares of export demand in overall final demand for domestic goods. If this effect rises, an economy is confronted with a higher challenge in achieving its environmental goals. Especially economies which are specialized on carbon intensive sectors should carefully monitor the development of this effect.

3 Data

For our analysis we obtain the GHG data for Austria from the air emission accounts of Statistics Austria. We calculate CO_2 equivalents for a global warming potential (GWP) of a 100 year time horizon. GWP factors are taken from the UNFCCC (2012). Beside CO_2, we use methane (CH_4) with a GWP factor of 25 and Nitrogen oxide (NO_x) with GWP 298. We focus on GHG emissions in the production process, and hence we do not account for the emissions which occur by private persons, e.g. use of private cars. The data are available for 55 different sectors, according to the ÖNACE[6] segmentation.

We use input-output tables from Statistics Austria for the years 1995, 2000, 2005 and 2010 and choose a product-by-product rather than an industry-by-industry approach, because goods produced in an industry might be very heterogeneous with respect to GHG emissions and therefore the industry-by-industry results could be distorted. However, CO_2 emission data and equivalents are only available in the dimension of industries (ÖNACE). In order to be able to use them in the framework of an input-output model that is formulated in the product-by-product dimension, the emission data also have to be transformed into the product dimension. Usually, for that purpose two different basic approaches are available, the commodity technology assumption and the industry technology assumption (ITA). Which one is to be preferred is, ultimately, an empirical question. For most types of variables, as also for energy inputs and GHG emissions, the commodity technology assumption (CTA) is considered as more realistic. While GHG emissions by unit of production are expected to vary over different industries that produce the same commodity, they will not vary as much as over different commodities, even when produced by the same industry. In the present application a further advantage of the CTA is its logical consistency with an input-output model specified in the product-by-product dimension. However, due to the well known problem of negatives in the CTA, various approaches have been devised to allow for (small) deviations from the CTA, one of them being the algorithm by Almon (2000). Elements of the transformed data vectors and matrices that are negative with plain CTA come out as zero when the algorithm by Almon is used. Since this (zero emissions of GHG) is still not considered as plausible in many applications such as the present one, some approaches combine the CTA and the ITA in a heuristic way or define lower bounds for those elements. In this paper we apply a hybrid approach where we use the well established commodity technology assumption to 75% and the industry technology assumption to 25%.

Additionally, in order to obtain consistent input-output tables we reclassify the table of 2010 from ÖCPA 2008 to ÖCPA 2002.[7] All tables are deflated and expressed in constant prices of 1995 using price information from Austrian national accounts (Statistics Austria). We aggregate all tables to 50 commodity groups in order to reach consistency over the whole time period. For our analysis, data

[6] ÖNACE is the Austrian version of NACE Rev. 2, the classification of economic activities. For details see http://statistik.at/web_en/classifications/implementation_of_the_onace2008/ development _of_the_onace2008/index.html

[7] ÖCPA is the Austrian version of CPA, the classification of products by activity.

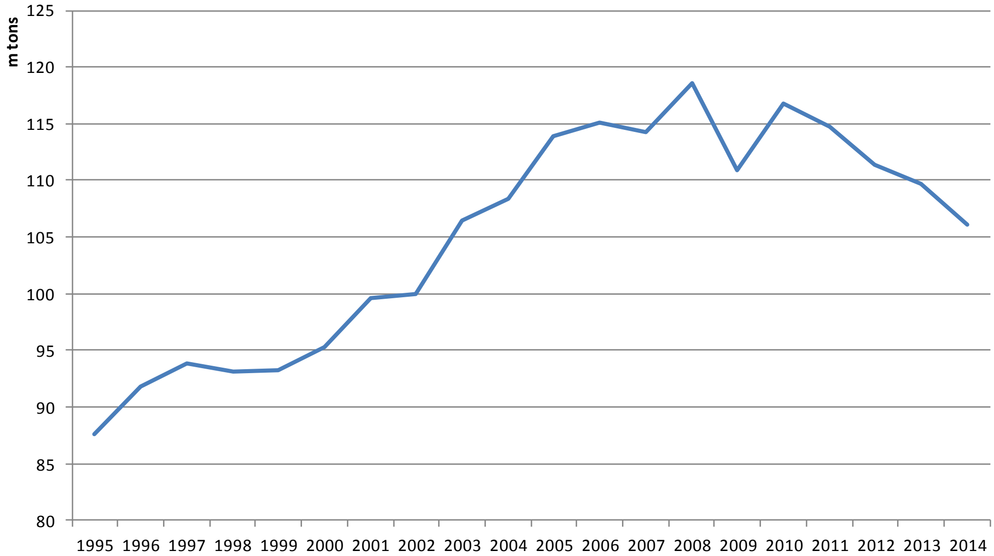
from Statistics Austria provides more detailed and reliable information for the Austrian economy and therefore we prefer this data source to other commonly used international input-output tables such as World Input Output Database (WIOD) or EORA MRIO database. Data include intermediate deliveries of each domestic sector, imports, exports and final demand. After deflating the Input-Output tables we correct the horizontal accounting equation in order to ensure the sum of intermediate deliveries and final demand to be equal to overall output of a commodity.[8] In the Appendix the interested reader can find more details on the rationale and procedures applied in the preparation of the deflated input-output tables.

4 Results

4.1 Results for the whole economy

Greenhouse gas emissions in Austria exhibited a sharp increase from about 87 million tons in 1995 to 118 million tons in 2008 (Figure 2). After the global financial crisis emissions decreased probably due to reduced economic activity. During the time of economic recovery, the drop was partly offset in 2010 but the development shows a persistent negative trend afterwards.

Figure 2: GHG Emissions in Austria from 1995 to 2014 excluding household emissions



We are interested in the reasons of the increase of GHG emissions in the period between 1995 and 2010.[9] Emissions increased by 29.2 million tons in this time period which makes an increase of 33.4% compared to the 1995 level.

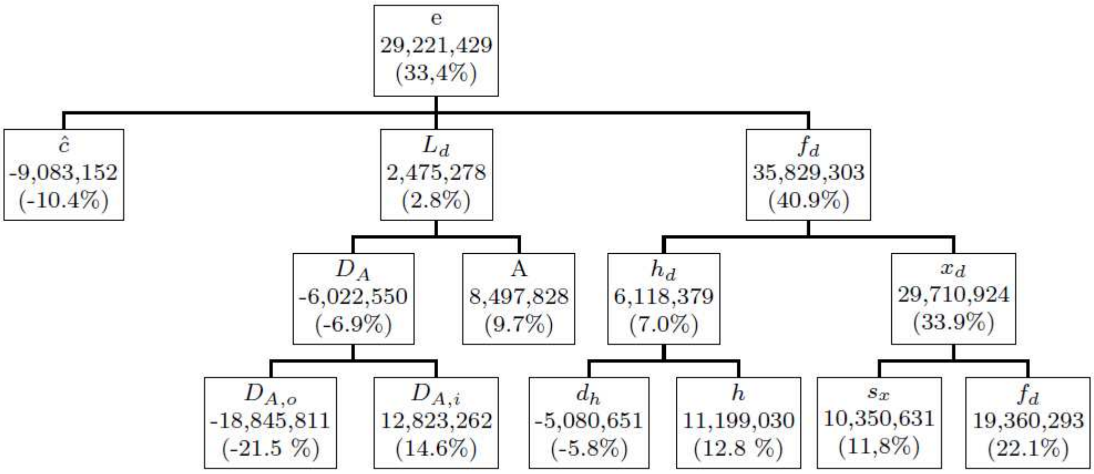
Figure 3 provides an overview of the results for every decomposition variable from 1995 to 2010. The number in brackets gives the percentage of factor contribution relative to the overall emissions in 1995. Main reason of the increase was the final demand (f_d) which contributed 35.8 million tons to the rise of emissions. Interestingly, most of this effect was due to GHG embodied in exports (x_d)

[8] The data for 1995 are converted from Austrian Schilling, which was the national currency of that time, to EURO.

[9] The choice of this period is motivated by the availability to data. It depicts the period of increasing emissions in Austria. More recent trends will be analysed in future.

with 29.7 million tons. The emission weighted increase of domestic demand (h_d) on the other hand was quite moderate with only 6.1 million tons. On the third level, we can reveal the effects of change in trade integration of Austria on emissions. The increasing share of exports (s_x) in final demand led to an 11.8% increase in domestic emissions. The reversed pattern can be observed for the share of domestic demand for goods of domestic origin (d_h) which contributed to a 5.8% decline of emissions during that period. More important was the overall demand level effect which amounted to 19.4 million tons for exports ($\tilde{f}_d$) and 11.2 million tons for domestic demand (h).

Figure 3: Overall Results for the period from 1995 to 2010



Opposed to this, the intensity effect ($\hat{c}$) decreases overall emissions. Technology and efficiency improvements led to a decline of 10.4% relative to the 1995 level. Changes in the domestic Leontief inverse did not alter the emissions much at the first view. The overall increase due to a changing input structure of the economy (L_d) was 2.5 million tons which accounted for only 2.8% percent. However, by looking deeper into the reasons for that, we can observe strong heterogeneity. First, there was an opposite effect between the domestic share matrix (D_A) and the matrix of technical input coefficients (A). While there was a decline of emissions embodied in domestic inputs, which led to a 6.9% drop of emissions, the overall structure of technology inputs (A) did not change in favor of the environment and increased by 9.7%. The decline in the emissions due to domestic emissions was caused by a relatively strong trend of outsourcing. In fact, leaving everything else in the economy fixed, outsourcing ($D_{A,o}$) would have decreased domestic emissions at 21.5%. Thus, Austria tends to outsource carbon intensive industries. The reversed factor, insourcing ($D_{A,i}$), augmented emissions at 14.6%. The strong peculiarity of both trends is an indicator of increasing trade integration.

Table 1 shows all these trends divided in the three subperiods. Remarkably, the intensity effect shows a fairly different pattern across the subperiods. While in the first subperiod, intensity declined strongly (8.9% relative to 1995 level), it even increased in the second subperiod with 2.5% relative to the 2000 level and finally slightly decreased by 3.3% compared to 2005. We will go more into detail in the analysis of individual activities in the next section.

Leontief Inverse and final demand showed both a continuous trend. While the changes in the input structure led to a decrease in emissions in the first subperiod, this changed for the last two subperiods. In the last subperiod it even was the strongest factor towards a more polluting economy. The effect of final demand declined over time, although it was always positive. The drop in the final demand effect was most importantly due to the declining emissions embodied in exports of final goods, which dropped from an 18.5% increase in the first interval to 2.2% in the last. The domestic demand effect was declining as well, even resulting in a lowering of GHG emissions in the last subperiod. This was due to an overall declining domestic demand and also because the share of imported final demand goods increased (indicated by the declining share of domestic demand). Trade integration of intermediate goods tends to reverse its tendency during the time under consideration. In the first subperiod, the carbon content of outsourcing was dominating that of insourcing resulting in a 5% drop of CO_2 equivalents due to the domestic share matrix. However, the results show that this trend weakened in the next subperiod and even reversed in the last subperiod.

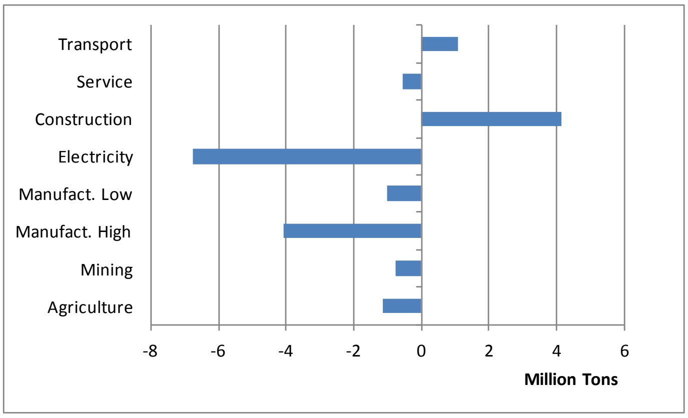
Tab. 1: Overall Results for 1995-2000, 2000-2005, and 2005-2010

Effect	Variable	1995-2000	Percentage	2000-2005	Percentage	2005-2010	Percentage
Intensity	c	-7,800,849	-8.9	2,387,221	2.5	-3,669,525	-3.2
Leontief Inv.	L_d	-5,637,231	-6.4	2,142,065	2.2	5,970,444	5.2
.Domestic Share	D_A	-4,403,078	-5.0	-2,823,641	-3.0	1,204,169	1.1
..Outsourcing	D_{Ao}	-6,499,840	-7.4	-6,443,632	-6.8	-5,902,339	-5.2
..Insourcing	D_{Ai}	2,096,762	2.4	3,619,991	3.8	7,106,508	6.2
.Structure	A	-1,234,153	-1.4	4,965,706	5.2	4,766,275	4.2
Final Demand	f_d	21,140,700	24.1	14,071,910	14.8	616,693	0.5
.Domestic Demand	h_d	4,932,719	5.6	3,038,461	3.2	-1,852,801	-1.6
..Share of dom. Demand	d_h	-790,025	-0.9	-920,528	-1.0	-3,370,098	-3.0
..Domestic Demand	h	5,722,744	6.5	3,958,989	4.2	1,517,297	1.3
.Export of final goods	x_d	16,207,980	18.5	11,033,449	11.6	2,469,494	2.2
..Share of Exports	s_x	3,675,394	4.2	4,896,806	5.1	1,778,432	1.6
..Final Demand Export	f_{dx}	12,532,586	14.3	6,136,643	6.4	691,063	0.6

4.1.1 Results on commodity level

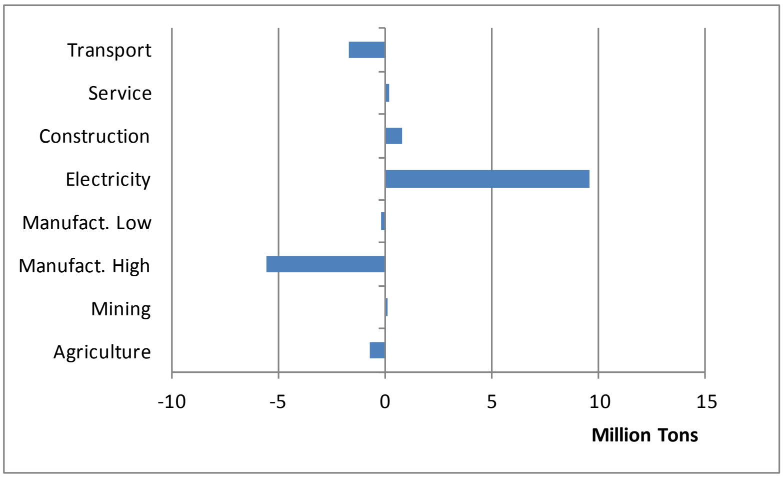
First, we present results on an aggregated activity level for the whole sample period 1995 to 2010. We distinguish between transport, service, construction, electricity, manufacturing with low and high carbon intensity, mining and agriculture. As Figure 4 shows, the intensity effect in the production of the most commodities contributed to a decline of GHG emissions during that period.

Figure 4: Intensity Effect 1995-2010



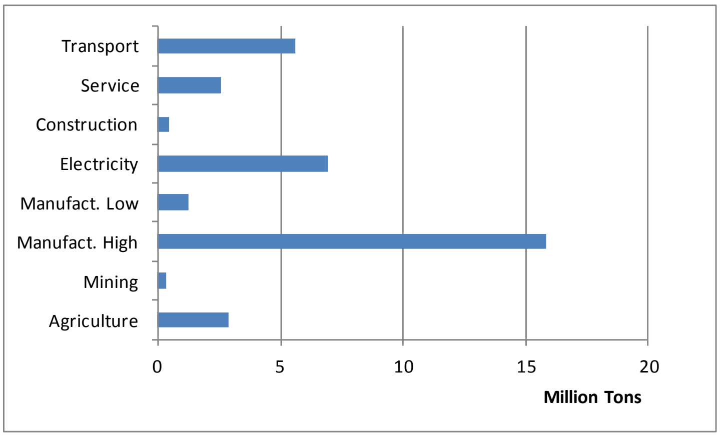
Exceptions are transport and construction. Especially the latter one had a remarkable bad performance, a pattern which is persistent across all subperiods. Most improvements were done in the electricity sector where the change of intensity in production almost saved 7 million tons of GHG emissions. This effect was more than offset by the change in the input structure which indicates changes in the intermediate input structure (Figure 5).

Figure 5: Effects of the Input Structure 1995-2010



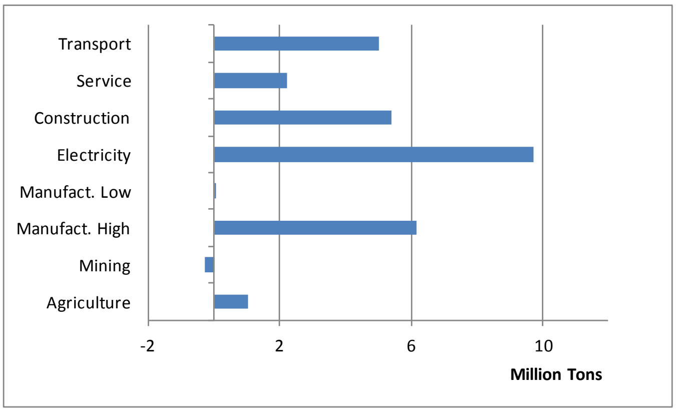
As a more detailed analysis reveals (see supplementary material for the tables with all results on a commodity level), this was due to the matrix of technological input coefficients, and, more in detail, it was due to the higher requirements of electricity in the production of electricity itself. This effect might be parallel to improving intensity due to accounting specifics.

Figure 6: Final Demand Effect 1995-2010



For services, construction and mining, the input structure was also positive. The other activities improved their emission balance due to the intermediate input structure. Final demand, the main driver of increasing GHG emissions, was positive for all activities, whereby highly GHG intensive manufacturing contributed most (Figure 6). Everything else fixed, the growing demand of such goods would have caused an increase of more than 15 million tons of GHG emissions. Electricity and Transport, the second and third most demand driven areas, raised emissions by 6.9 and 5.6 million tons, respectively.

Figure 7: Total Effect 1995-2010



All effects together, electricity was the main driver of the rise of CO_2 equivalents between 1995 and 2010. Carbon intensive manufacturing, transport and construction were also strongly responsible for increasing emissions. Production of low carbon intensive manufacturing goods and mining were the only activity which did not increase its emissions but exhibited a rise in final demand. Therefore, in those fields, the technological improvements were sufficient to offset raise of demand.

The trends show some heterogeneity across the three subperiods. As shown in the detailed breakdown across the three subperiods in the supplementary material, especially the second subperiod exhibits a decline of emissions efficiency in many sectors. This is particularly striking for transport activities, where emissions increased more than 2 million tons due to poorer emission intensity. This pattern reversed in the last subperiod where transport activity showed considerably improved emission intensity.

Table 2 shows a more detailed pattern of emissions on activity level. It depicts the five worst performing and the five best performing commodities according to the intensity and the total effect in each subperiod. As already seen in the aggregated view, construction and transport contributed strongly toward increasing emissions in the first two subperiods. Especially land transport raised carbon intensity until 2005, where it was the best performing sector between 2005 and 2010 and totally offsets the intensity effect of the former subperiods. Land transport contributes most to the overall raise of emissions in Austria in the first two subperiods. Between 2000 and 2010, the production of electricity contributed most to the increase in emissions. Besides the afore-mentioned commodities, air transport, basic metals and the production of wood and wooden products strongly contributed to emission increase. In the last subperiod, agriculture exhibited a strong increase of CO_2 equivalent emissions as well, mainly due to poorer emission intensity. The importance of the electricity sector for overall emissions motivates a closer look. Figure 7 shows the detailed decomposition result for the electricity production for the whole time period 1995 to 2010. Overall, in supply of electricity there was an increase of 9.3 million tons of CO_2 equivalents. This was a 71.6% growth compared to the 1995 level and makes 31.9% of the total emission increase of the economy. The growth of emissions in the electricity sector was considerably faster than the average growth of emissions.

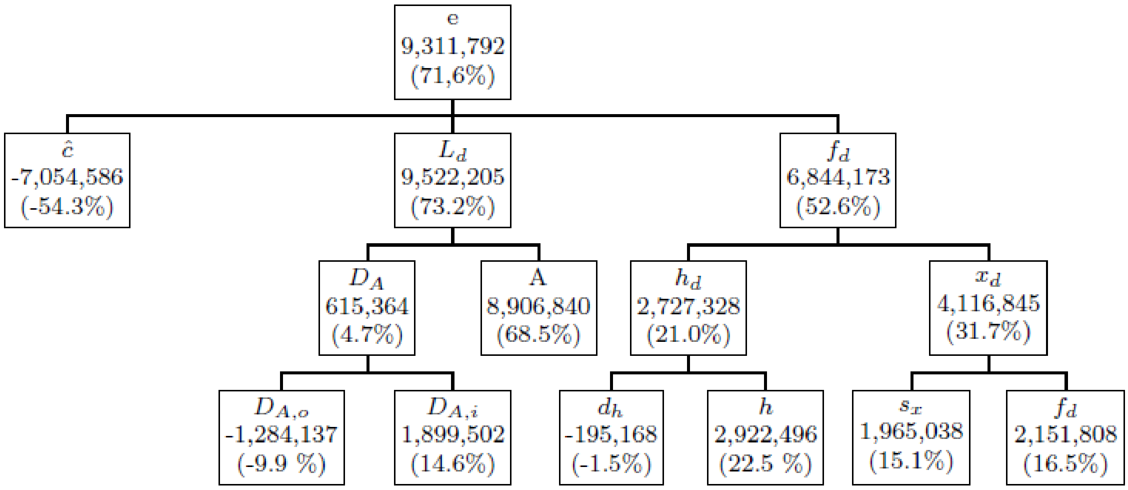
Tab. 2: Intensity effect and total effect on the five worst and the five best performing sectors

1995-2000	Intensity	2000 - 2005	Intensity	2005-2010	Intensity
Construction	1,377,408	Land Transport	2,347,372	Construction	1,831,168
Land Transport	1,260,626	Other non-metallic mineral	1,217,943	Wood	1,797,706
Air Transport	666,138	Pulp, paper and paper	984,013	Other non-metallic minerals	1,191,275
Food+ beverages + tobacco	372,972	Construction	938,288	Agriculture	1,018,045
Wood	178,870	Coke, refined petroleum	912,908	Supporting Transp. Activity	276,474
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
Recovery of Secondary …	-1,033,717	Chemicals	-223,022	Coal and lignite etc.	-398,452
Electricity, Water …	-1,242,907	Food+ beverages + tobacco	-267,399	Recovery of sec. raw material	-747,871
Agriculture	-1,499,579	Recovery of Secondary …	-387,936	Coke, refined petroleum	-1,197,625
Pulp, paper and paper	-1,670,710	Agriculture	-658,924	Electricity	-2,392,096
Basic metals	-2,249,058	Electricity, Water …	-3,419,583	Transport	-3,659,667

1995-2000	Total	2000 - 2005	Total	2005-2010	Total
Land Transport	2,936,479	Electricity, Water …	5,915,148	Electricity	3,151,804
Air transport	2,918,295	Land Transport	3,152,912	Construction	2,655,576
Construction	1,644,503	Basic metals	2,488,594	Wood	1,654,834
Chemicals	993,466	Other non-metallic mineral	1,193,098	Agriculture	1,474,970
Basic metals	771,684	Construction	1,079,630	Chemicals	395,189
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
Agriculture	-409,861	Membership organisation n.e.c.	-17,998	Education	-233,275
Coal and lignite etc.	-413,535	Renting services of machinery …	-26,062	Recovery of sec. raw mat.	-377,481
Pulp, paper and paper	-415,094	Agriculture	-48,579	Coal and lignite etc.	-383,841
Recovery of Secondary …	-685,716	Recovery of Secondary …	-109,969	Coke, refined petroleum	-724,186
Coke, refined petroleum	-711,072	Chemicals	-156,382	Land Transport	-5,004,275

The second layer of Figure 8 reveals the reasons for that pattern in more detail. While there was a strong improvement in emission intensity, the intermediate input structure and final demand led to more pollution. By analyzing the Leontief inverse it becomes clear that the major increase stemed from the matrix of technical input coefficients. However, as mentioned before, change in the intensity and in the matrix of technical input coefficients might be complementary as we observe the major change in A due to changes in the self demand of electricity. Therefore, accounting issues could lead to this strong manifestation of intensity and input structure. Final demand of electricity led to an increase of 52.6%, where the main part was due to exports (31.7%). Finally, we can investigate the role of trade integration of the Austrian economy for the GHG emissions of the electricity sector. Austrian firms which rely more on domestic intermediate inputs caused higher production in the domestic electricity sector and therefore increase its emissions. Due to insourcing, emissions in the production of electricity increased with 1.9 million tons. Outsourcing works in the opposite direction and caused a decline of 1.3 million tons. On the final demand side, the level of domestic demand was the most important driver, causing an increase in electricity related emissions of 22.5%. However, the share of domestic demand for goods with domestic origin did not alter the emission balance much. The opposite was the case for the share of exports in final demand. The share of electricity produced for foreign demand increased and due to those changes, emissions associated with the production of electricity increased with 15.1% while it rose with 16.5% due to the overall demand level.

Figure 8: Decomposition Results for Electricity between 1995 and 2010



5 Conclusion

We analyse the development of greenhouse gas (GHG) emissions and its drivers by applying a hierarchical structural decomposition (HDSA) analysis. Our model is particularly suitable for investigating small open economies which are characterized inter alia by pronounced trade integration and outsourcing. The approach is applied to analyse the development for the Austrian economy in the period 1995 to 2010.

We divide the sample period in the subperiods 1995 to 2000, 2000 to 2005, and 2005 to 2010. Our results indicate that the main driver in the first two subperiods is the change in final demand level and in the last subperiod changes in the structure of intermediate demand, mainly in the electricity production. In the subperiod from 1995 to 2000 the intensity effect and the structural effect were slightly absorbing the emission increase. A pattern changed in the subperiod from 2000 to 2005 where all factors are responsible for some increase in GHG emission. In the last period, we observe a better performance in terms of emission intensity, but still have positive emission growth for the whole economy. Final demand is strongly driven by the production of export goods. In the structural linkage of the economy, trade integration had a negative effect on emissions due to an overweight of outsourcing compared to insourcing, a pattern which reversed in the last subperiod. Production of electricity is the main driver of increasing GHG emissions in the Austrian economy. For the first two subperiods it was closely followed by land transport, however, this service strongly improved in the last period, leading to a moderate negative balance over the whole time interval under consideration.

In general, it becomes obvious, that economic growth has so far not decoupled from the use of electricity and the efficiency gains are not yet sufficient to offset the demand effect. Therefore, future policy should aim at both, improvement of technology and reduction of carbon intensive demand. The overall performance of the Austrian economy with respect to GHG emissions has to be strongly improved compared to the period under consideration in order to achieve the emission targets of the Paris Agreement. Policy must further aim at improving the GHG balance of electricity. The pattern revealed in our study shows, that technological improvements have not offset the higher demand for electricity.

The scope of domestic policy in changing demand patterns is rather small, especially as exported goods play an important role in increasing emissions. Therefore, it is questionable whether European countries should focus on the production-based emissions as it is currently the case in the emission targets of the European Union. Small open economies can only influence own production, not the consumption patterns in other countries. As both, improvements in production technology and reduction of demand for emission intensive goods might be necessary, a consumption-based approach should be adopted as well.

These policy actions would improve competitiveness defined as the ability of a country to achieve Beyond GDP goals and would be in line with a high-road strategy for high-income countries suggested in by Aiginger and Vogel (2015). A high-road strategy in this sense includes inter alia environmental ambition. This requires, in particular, shifting technical progress toward resource and energy saving, reducing subsidies for fossil energy and encouraging renewable energy.

Future research should focus on more details at the reasons of sector specific fluctuations. For instance, one surprising result in our analysis is, that services of land transport performed quite poor in the second period with respect to emissions intensity but improved considerably in the last period. Another important field of research would be the adoption of a consumption-based accounting in the framework of a HDSA.

References

Aiginger, K., Vogel., J., 2015. Competitiveness: from a misleading concept to a strategy supporting Beyond GDP goals, Competitiveness Review 25(5), 497–523 (https://doi.org/10.1108/CR-06-2015-0052)

Almon, C., 2000. Product-to-Product Tables via Product-Technology with No Negative Flows. Economic Systems Research 12 (1), 27–43 (https://doi.org/10.1080/095353100111263)

Chang, N., Lahr, M. L., 2016. Changes in chinas production-source co2 emissions: insights from structural decomposition analysis and linkage analysis. Economic Systems Research 28(2), 224–242 (https://doi.org/10.1080/09535314.2016.1172476)

Croner, D., Frankovic, I., 2018. A Structural Decomposition Analysis of Global and National Energy Intensity Trends. The Energy Journal 39(2), 103–122 (https://doi.org/10.5547/01956574.39.2.dcro)

Dietzenbacher, E., Hoen, A.R., 1998. Deflation of input-output tables from the user's point of view: A heuristic approach, Review of Income and Wealth 44(1), 111–122 (https://doi.org/10.1111/j.1475-4991.1998.tb00255.x)

Guevara, Z., Rodrigues, J. F. D., 2016. Structural transitions and energy use: A decomposition analysis of Portugal. Economic Systems Research 28(2), 202–223 (https://doi.org/10.1080/09535314.2016.1157456)

Hoekstra, R., Michel, B., Suh., S., 2016. The emission cost of international sourcing: Using structural decomposition analysis to calculate the contribution of international sourcing to CO2-emission growth. Economic Systems Research 28(2), 151–167 (https://doi.org/10.1080/09535314.2016.1166099)

Kaltenegger, O., Löschel, A., Pothen, F., 2018. The Effect of Globalisation on Energy Footprints: Disentangling the Links of Global Value Chains. Energy Economics, in print (https://doi.org/10.1016/j.eneco.2018.01.008)

Koller, W., Stehrer, R., 2010. Trade integration, outsourcing and employment in Austria: A decomposition approach. Economic System Research 22(3), 237–261 (https://doi.org/10.1080/09535314.2010.493504)

Lenzen, M., 2016. Structural analyses of energy use and carbon emissions – an overview. Economic Systems Research 28(2), 119–132 (https://doi.org/10.1080/09535314.2016.1170991)

Malik, A., Lan, J., 2016. The role of outsourcing in driving global carbon emissions. Economic Systems Research 28(2), 168–182 (http://dx.doi.org/10.1080/09535314.2016.1172475)

Pasurka, C., 2008. Perspectives on pollution abatement and competitiveness: Theory, data, and analyses. Review of Environmental Economics and Policy 2(2), 194–218 (https://doi.org/10.1093/reep/ren009)

Peters, G. P., 2008. From production-based to consumption-based national emission inventories. Ecological Economics 65, 13–23 (https://doi.org/10.1016/j.ecolecon.2007.10.014)

Porter, M. E., van der Linde, C., 1995. Towards a new conception of the environment-competitiveness relationship. The Journal of Economic Perspectives 9(4), 97–118 (https://doi.org/10.1257/jep.9.4.97)

UNFCCC (2012). Report of the conference of the parties on its seventeenth session, held in Durban from 28 November to 11 December 2011 addendum. Part two: Action taken by the conference of the parties at its seventeenth session (https://unfccc.int/resource/docs/2011/cop17/eng/09a01.pdf)

Voigt, S., Cian, E. D., Schymura, M., Verdolini, E., 2014. Energy intensity developments in 40 major economies: Structural change or technology improvement? Energy Economics 41, 47–62 (https://doi.org/10.1016/j.eneco.2013.10.015)

Wiedmann, T., Lenzen, M., Turner, K., Barett, J., 2007. Examining the global environmental impact of regional consumption activities – Part2: Review of input-output models for the assessment of environmental impacts embodied in trade. Ecological Economics 69, 211–222 (https://doi.org/10.1016/j.ecolecon.2006.12.003)

Xu, Y., Dietzenbacher, E., 2014. A structural decomposition analysis of the emissions embodied in trade. Ecological Economics 101, 10–20 (https://doi.org/10.1016/j.ecolecon.2014.02.015)

Appendix

This appendix provides some background and more details concerning the construction of the input-output tables deflated to a common price basis, i.e. prices of 1995. In its core, the approach follows the one of Dietzenbacher and Hoen (1998) and has been devised in a similar form for the preparation of deflated input-output tables in previous work by Koller and Stehrer (2010). It is based on the construction of sectoral price index vectors that are applied in the deflation process. Apart from sectoral price indices for domestic output and for imports, different price indices were used for different use categories (intermediate input use, final consumption, fixed capital formation, exports). All price information employed has been taken from the official Austrian national accounts. The procedure proceeded top-down and involved the application of biproportional fitting algorithm (RAS) in order to ascertain the validity of the horizontal balance equation. However, the vertical balance equation was not considered in the procedure since deflation of value added or its components was not an aim of the procedure. It has to be admitted that the procedure is of approximative nature for many reasons, one of them beeing that original price information is available only in the form of previous year prices.

The deflation procedure can be characterized by the following steps:

1. Calculation of vectors of sectoral price indices for domestic output and imports, based on volumes and nominal values from national accounts
2. Construction of a 2 times 4 table of aggregated price indices for four different use categories and separated for domestic and imported origin. This step involves RAS to make sure the restictions given by known margins are met.
3. Disaggregating price information for all 8 use categories to construct sectoral price indices.
4. Provisional deflation of the input-output table using the 8 different price indices.
5. Application of a proportional correction to each row of the input-output table to make sure that the sum over all uses of commodity i equals total output or, respectively, total imports of commodity i.

Furthermore, the data procedure involved also the reclassification of the input-output table for the year 2010 from the ÖCPA 2008 to the ÖCPA 2003 classification, based on bridge matrices provided by Statistics Austria. It should be noted, that for the 2010 input-output table the reclassification procedure was applied after deflating it to the price basis of 2005 but before deflating from prices of 2005 to prices of 1995.