Transport and CO_2: Productivity Growth and Carbon Dioxide Emissions in the European Commercial Transport Industry

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Abstract

Transport activities account for more than 20% of the total annual carbon dioxide (CO_2) emissions in the EU27. While total CO_2 emissions decreased by around 7% from 1990 to 2008, transport related CO_2 emissions increased by around 24% (UNFCCC 2010). These figures emphasize the importance of transport related CO_2 emissions and their reduction to current climate protection efforts. In this context, this paper analyzes the productivity development of the European commercial transport sector under consideration of CO_2 abatement activities for the period between 1995 and 2006. We utilize a unique data set that combines environmental and economic information on an industry level. Using a directional distance function approach, we calculate a Malmquist-Luenberger productivity index that measures productivity change in the presence of environmental constraints such as air-pollution regulations. That is, the Malmquist-Luenberger productivity index improves if an increase in the desirable outputs is accompanied by a simultaneous decrease in the undesirable outputs. Or in other words, a reduction in emissions is not costless and thus negatively influences the production level of the desirable goods. Decomposing the index into its components, we analyse different sources of productivity change and compare the results to conventional productivity measures that ignore undesirable outputs.

Keywords: European transport industry, Carbon dioxide emissions, Productivity growth, Data envelopment analysis

JEL-Classification: L92, O47, Q53, Q 56

1. Introduction

International climate protection is widely recognized as one of the greatest global challenges of our time. As early as 1992, the international community of states agreed in the UN Framework Convention on Climate Change (UNFCCC) on the target of preventing further dangerous anthropogenic interference with the climate system. According to the Intergovernmental Panel on Climate Change (IPCC) the increase in average global temperature has to be limited to a maximum of 2° degree Celsius compared to the pre-industrial level in order to achieve this objective.[1] The Convention is complemented by the 1997 Kyoto Protocol under which 37 industrialized countries and the European Community have committed to reducing their collective greenhouse gas emissions by 5.2% against 1990 levels over the five-year period 2008-2012 (UNFCCC, 1997).[2]

Furthermore, to promote a post-2012 global climate regime, the EU made a unilateral commitment to reduce its collective greenhouse gas emissions to 20% below 1990 levels by 2020 in 2007. The EU offered to increase this reduction to 30% if other developed countries commit

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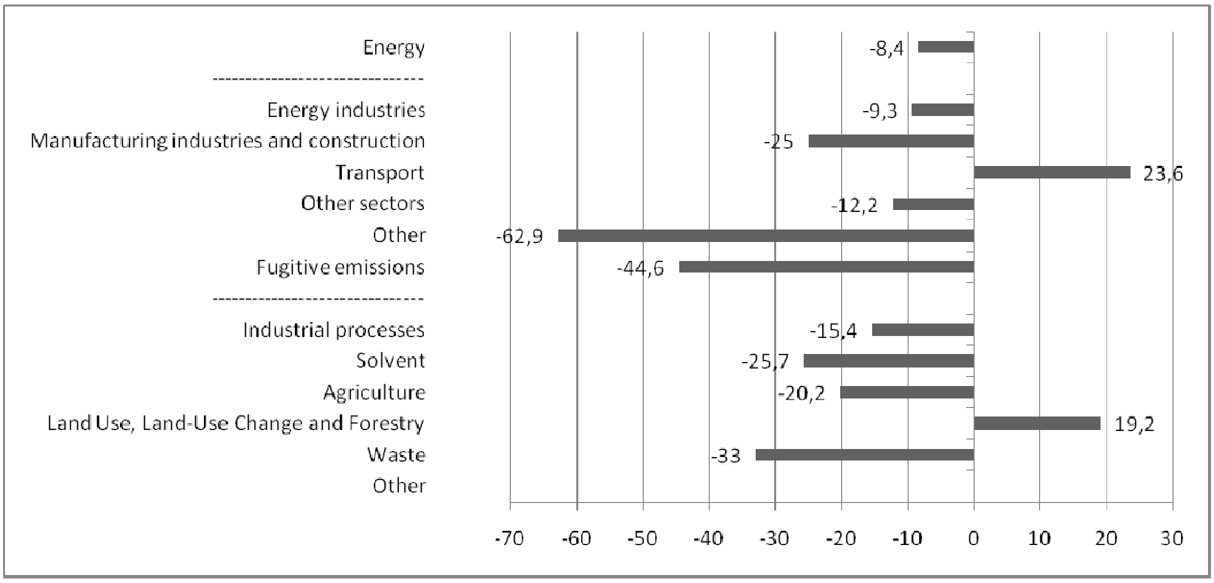
[1] The IPCC is an organisation established by the World Meteorological Organisation and the UN Environment Program to assess scientific, technical and socio-economic information relevant for the understanding of climate change, its potential impacts and options for adaptation and mitigation.

[2] Greenhouse gases covered by the Kyoto protocol include carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCs), perfluorcarbons (PFCs) and sulphur hexafluoride (SF6).

themselves to comparable reduction targets and more advanced developing countries to adequate targets in line with their abilities (European Communities, 2009). In 2005, the EU implemented the Emission Trading Scheme (ETS) to help EU Member States to achieve compliance with their commitments under the Kyoto Protocol.[3] The EU ETS is the first international trading system for CO_2 emissions in the world. It covers close to half of Europe´s emissions of CO_2 including in large part energy-intensive installations like combustion plants, iron and steel plant or factories making pulp and paper. Up to now households, agriculture, other industries and the transport sector are not included in the European trading system, which demands individual environmental regulations.[4]

CO_2 emissions from the transport sector attract the attention of both transport and climate change policy makers because of their significant share of overall emissions and their persistently strong growth, as illustrated in Table 1. The private and commercial transport sector accounts for nearly one-quarter (24.62% in 2008) of global energy-related CO_2 emissions.

Table 1: Change in GHG emissions from 1990 to 2008, %



Source: Calculations based on data from the UNFCCC.

At that the same time, projections for transport activity development show a consistent growth (see Table 2). The transport sector must increase their efforts and improve its environmental

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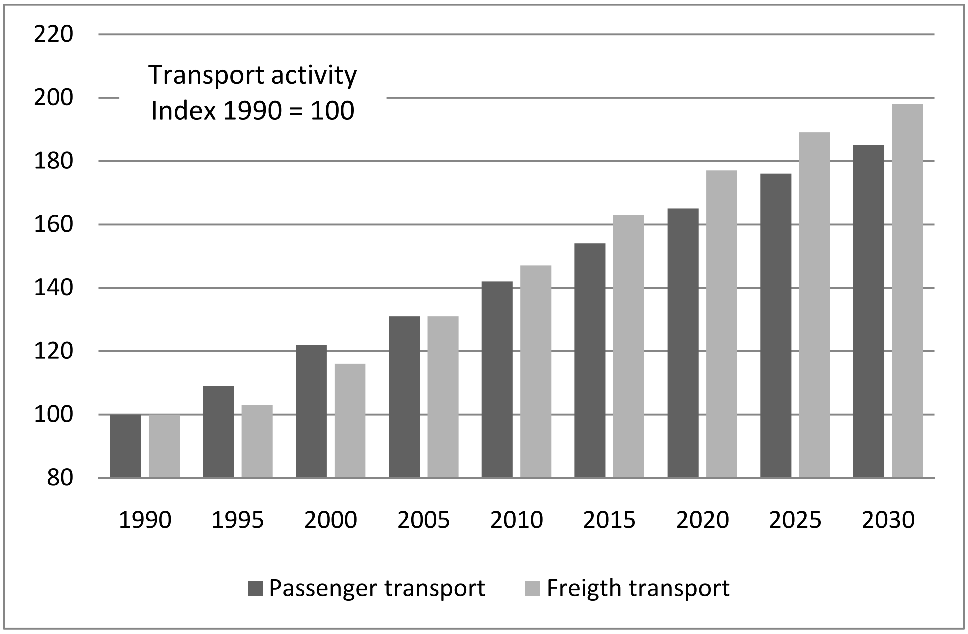
[3] Directive 2003/87/EC of the European Parliament and the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community.

[4] European Union has introduced legislation to include aviation in the EU emissions trading scheme (Directive 2008/101/EC).

performance to enable the EU to meet its overall emission reduction targets by 2020. The challenge is thus to promote a sustainable transport sector that meets environmental protection targets as well as economic requirements.

Table 2: Transport Activity Growth, 1990-2030



Source: Calculations based on data from "European Energy and Transport", 2007.

The described problem causes a great deal of attention to the effects of environmental regulations on economic growth among policy-makers and academia. Generally, environmental regulations result in a reallocation of input resources from the production of the marketable output to the use for emission abatement activities (Färe et al., 2001). Traditional measures of total factor productivity (TFP), e.g. Törnquist and Fischer indices, ignore the output of emission abatement activities (i.e. in this case reduced CO_2 emissions), because prices for environmentally hazardous by-products are typically not available. Productivity indices that ignore reductions in these undesirable outputs may yield biased measures of productivity growth.[5] Hence, the key feature of environmental regulations is the fact that the output of emission abatement activities are treated as the reduced level of emissions, that is, a reduction in bad output.

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[5] Throughout this paper, ´desirable` and ´good` output refers to the marketed good produced by the transport industry. ´Undesirable` and ´bad` output refers to CO_2 emissions, the environmentally hazardous by-product.

Chung et al. (1997) have developed a Malmquist-Luenberger (ML) productivity index that analyzes models for joint production of good and bad outputs and allows for the decomposition of productivity changes into two components, namely efficiency change and technical change. The advantage of this approach is that the data on quantities is ample, so that information on prices are not required. Chung et al. (1997) use the directional distance function approach to calculate the production relationship involving both desirable and undesirable outputs, while treating them asymmetrically. That is, the ML index credits the producer for simultaneously reducing the production of the bad outputs and increasing the production of the good outputs.

It also offers an alternative method to weight the relative importance of the bad output, which can be interpreted as if consumers have preferences for reducing bad outputs regardless of the actual damage resulting from theses emissions (Färe et al., 2001).

While the Malmquist productivity index has been widely used, only a limited number of empirical studies have applied the ML index to measure productivity growth in the presence of environmental constraints. These studies include Färe et al. (2001), Jeon and Sickles (2004), Yoruk and Zaim (2005) and Kumar (2006). The latter three studies focused on macro-level panel data. Jeon and Sickles (2004) and Yoruk and Zaim (2005) applied both Malmquist and ML indices to examine the impact on productivity growth due to the consideration of carbon dioxide in the former case and nitrogen oxide and organic water pollutant emissions in the latter one. Kumar (2006) employed only the ML index to analyse conventional and environmentally sensitive TFP. The study by Färe et al. (2001) belongs to the few empirical studies using micro-level panel data. They estimated the ML indices for the US state manufacturing sectors over the 1979-1986 period and found that average annual productivity growth was higher (3.6%) than if emissions were ignored (1.7%). The study by Wu and Wang (2007) developed an enlarged approach examining the causes of productivity change.

Using micro-level panel data, the objective of this paper is to measure productivity growth that explicitly accounts for the joint production of good and bad outputs, i.e. value added and CO_2 emissions, and compare these results to conventional measures that ignore bad outputs. Furthermore, this study looks into an industry sector which existing literature has hitherto not analysed, namely the commercial transport industry sector in 17 European countries for the period between 1995 and 2006.[6] This limitation emerges from difficulties in getting industry scale emission data as well as differences in classification of transport categories (e.g. road transport). Accordingly, the primary task of this study was to develop a database for the commercial transport industry. While general data sets like the UNFCCC greenhouse gas inventories do not differentiate between private and commercial transport emissions, we use a unique data set from Eurostat with industry level emission data.

The remainder of this paper is organized as follows: Section 2 applies the methodology and policy scenarios to the analysis of the sample. Section 3 describes the data and gives an overview about the statistical trends. The estimated results of productivity change, technical change and changes in technical efficiency are illustrated in Section 4. Section 5 presents our conclusions.

2. Methodology

To formally describe the model, assume that $x = (x_1, \dots, x_N) \in \mathbb{R}_+^N$ denotes a vector of inputs, $y = (y_1, \dots, y_M) \in \mathbb{R}_+^M$ denotes a vector of good outputs, and $b = (b_1, \dots, b_I) \in \mathbb{R}_+^I$ denotes a vector of bad outputs. The production technology can then be modelled as:

$$P(x) = \{(y, b) \colon x \text{ can produce } (y, b)\}, x \in \mathbb{R}_+^N, \tag{1}$$

where the output set $P(x)$ represents all the combinations of good and bad outputs (y, b) that can be produced using the input vector x. $P(x)$ is a convex and compact set and satisfies the standard properties of no free lunch, possibility of inaction, and strong or free disposability of inputs (see, e.g., Färe and Primont, 1995).

Further, in order to account for the joint production of good and bad outputs, we define three additional assumptions: First, we assume null-jointness of the output set[7]:

$$\text{if } (y, b) \in P(x) \text{ and } b = 0 \text{ then } y = 0. \tag{2}$$

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[6] For the transport sector there is a wide range of literature estimating costs for fuel economy measures but remarkably little agreement in the findings. In particular, there is debate whether the benefits of fuel economy measures (i.e. saved fuel) outweigh the costs (ECMT, 2007).

[7] The null-jointness assumption was first introduced by Shephard and Färe (1974)

That is, no good output can be produced without producing any bad outputs. Second, the good and the bad outputs are considered as being together weakly disposable[8]:

$$(y, b) \in P(x) \text{ and } 0 \leq \theta \leq 1 \text{ imply } (\theta y, \theta b) \in P(x). \tag{3}$$

This assumption states that a reduction of the bad outputs is not costless and negatively influences the production level of the good outputs. In other words, abatement activities require resources which otherwise could have been used to expand the amount of the good outputs. Finally, the good outputs are assumed to be strongly or freely disposable:

$$(y, b) \in P(x) \text{ and } y' \leq y \text{ imply } (y', b) \in P(x). \tag{4}$$

This assumptions implies that a reduction of the good outputs is feasible without a simultaneously reduction of the bad outputs. Further, together with Equation 3 it emphasizes the asymmetry between the good and the bad outputs insofar as good outputs are costlessly disposable but bad outputs are not.

A production technology that satisfies the above assumptions can be represented by a directional output distance function. Introduced by Chambers et al. (1996a, 1996b, 1998), it is formally defined on $P(x)$ as:

$$\vec{D}_o(x, y, b; g_y, g_b) = \sup \{\beta : (y, b) + (\beta g_y, \beta g_b) \in P(x)\}, \tag{5}$$

where $g = (g_y, g_b)$ and β, respectively, represent the direction and proportion in which the output vector (y, b) is scaled to reach the boundary of the output set $P(x)$. The directional output distance function value is bounded below by zero. A value equal to zero identifies the observed output vector as located on production possibilities frontier and, hence, as being technically efficient. Values greater than zero belong to output vectors within the frontier, indicating technical inefficiency.

We estimate three models of the directional output distance function with different output sets $P(x)$ and directional vectors $g = (g_y, g_b)$. In Model I, $\vec{D}_o(x, y, 0; y, 0)$, the bad outputs are excluded from the output set $P(x)$ and the directional vector is $g = (y, 0)$. This model completely ignores the

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[8] The concept of weak disposability was introduced by Shephard (1970).

harmfully characteristics of the bad outputs and solely seeks to increase the good outputs. In contrast, in Model II and III the bad outputs are a part of the output set $P(x)$. Choosing the same directional vector as in Model I, Model II, $\vec{D}_o(x, y, b; y, 0)$, seeks to increase the good outputs while the bad outputs are kept on their current level. Finally, in Model III, $\vec{D}_o(x, y, b; y, -b)$, the directional vector is $g = (y, -b)$. This model seeks to increase the good outputs and to decrease the bad outputs at the same time by the same amount.

The three directional output distance function models are illustrated in Figure 1. The left part of Figure 1 represents Model I, where $P(x)$ is the area of all feasible combinations of two good outputs, $y1$ and $y2$, that can be produced by the input vector x. Bad outputs are completely ignored and the model proportionally expands the original vector $(y1, y2)$ at point A along the direction $g = (g_{y1}, g_{y2})$ to the technically efficient output vector $(y1 + \beta g_{y1}, y2 + \beta g_{y1})$ at point B. The right part of Figure 1 represents Model II and III. Here, $P(x)$ is the area of all feasible combinations of one good output y and one bad output b that can be produced by the input vector x. While Model II uses the direction $g = (g_y, 0)$ to expand the original vector (y, b) at point A to the output vector $(y + \beta g_y, b)$ at point C, Model III uses the direction $g = (g_y, -g_b)$ and ends up at the output vector $(y + \beta g_y, b - \beta g_b)$ at point D.

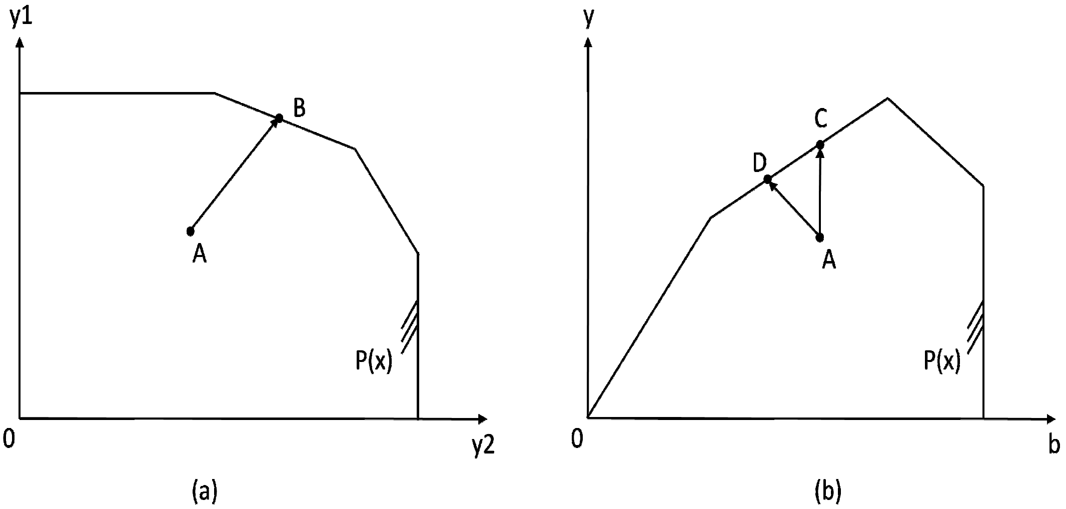

Figure 1: Directional output distance functions

The directional output distance functions can be estimated parametrically or non-parametrically. Following Färe et al. (2001), we opt for the latter and use data envelopment analysis (DEA). Given $t = 1, \dots, T$ time periods and $k = 1, \dots, K$ observations of inputs and outputs $\left(x^{k,t}, y^{k.t}, b^{k,t}\right)$, the following linear program has to be solved for each observation k' in each time period t:

$$
\begin{array}{lllll}
\vec{D}_o^t\left(x^{t,k'}, y^{t,k'}, b^{t,k'}; y^{t,k'}, -b^{t,k'}\right) = \max \beta & & & & \\
s.t. \quad \displaystyle\sum_{k=1}^{K} z_k^t\, y_{km}^t \geq (1+\beta) y_{k'm}^t\,, & m = 1, \dots, M, & & \text{(i)} & \\
\displaystyle\sum_{k=1}^{K} z_k^t\, b_{ki}^t = (1-\beta) b_{k'i}^t\,, & i = 1, \dots, I, & & \text{(ii)} & (6) \\
\displaystyle\sum_{k=1}^{K} z_k^t\, x_{kn}^t \leq x_{k'n}^t\,, & n = 1, \dots, N & & \text{(iii)} & \\
z_k^t \geq 0\,, & k = 1, \dots, K, & & \text{(iv)} &
\end{array}
$$

where z_k^t are intensity variables assigning a weight to each observation k when constructing the production possibilities frontier. The inequality constraints in (i) and (iii) state that observation k' does not produce more good outputs or uses fewer inputs than its efficient benchmark on the frontier. That is, good outputs and inputs are freely disposable. Further, together with the inequality constraints in (i), the strict equality constraints in (ii) impose weak disposability of the good and the bad outputs. Finally, the non-negativity constraints on the intensity variables in (iv) indicate that the production technology exhibits constant returns to scale (Chung et al., 1997). The solution to this program, the maximum value of β, shows at given inputs, how much the good and the bad outputs can be proportionally expanded and contracted relative to the efficient benchmark on the frontier.

In order to ensure that the program also satisfies the null-jointness assumption, the following restrictions on the bad outputs have to be added:

$$
\sum_{k=1}^{K} b_{ki}^t > 0, \quad i = 1, \dots, I, \tag{7}
$$

$$\sum_{i=1}^{I} b_{ki}^{t} > 0, \qquad k = 1, \dots, K. \tag{8}$$

The inequality constraints in (7) imply that each bad output is produced by at least one observation k, and the inequality constraints in (8) state that each observation k produces at least one bad output. If for observation k' all bad outputs are equal to zero $\left(b_{k'i}^{t} = 0, i = 1, \dots, I\right)$, these restrictions imply that all intensity variables in (6) are zero $(z_k^t = 0, k = 1, \dots, K)$, which in turn implies that all good outputs must be zero $\left(y_{k'm}^{t} = 0, m = 1, \dots, M\right)$. Hence, null-jointness is guaranteed (Färe et al. 2001).

Taken together, the linear program in (6) and the restrictions in (7) and (8) represent Model III of which Model I and II are special cases. For Model I, the equality constraints in (ii) and the restrictions (7) and (8) are dropped, while for Model III the equality constraints in (ii) are replaced with the equality constraints: $\sum_{k=1}^{K} z_k^t\, b_{ki}^t = b_{k'i}^t\, , i = 1, \dots, I$. Hence, the maximum value of β for Model II and III shows at given inputs, how much the good outputs can be expanded relative to the efficient benchmark on the frontier while the former completely ignores any bad outputs and the latter holds the bad outputs constant.

In order to measure the model-specific productivity change we use the Malmquist-Luenberger (ML) productivity index as introduced by Chung et al. (1997). Compared to the standard Malmquist productivity index (Malmquist, 1953), the ML productivity index allows to measure productivity change in a situation where bad outputs are jointly produced with good outputs.

To calculate the ML productivity index we need to specify four directional distance functions for each model: two functions where the observations under consideration and the reference technology are from the same period, $\vec{D}_o^t\left(x^t, y^t, b^t; g_y^t, g_b^t\right)$ and $\vec{D}_o^{t+1}\left(x^{t+1}, y^{t+1}, b^{t+1}; g_y^{t+1}, g_b^{t+1}\right)$, and two functions where the observations under consideration and the reference technology are from different periods, $\vec{D}_o^t\left(x^{t+1}, y^{t+1}, b^{t+1}; g_y^{t+1}, g_b^{t+1}\right)$ and $\vec{D}_o^{t+1}\left(x^t, y^t, b^t; g_y^t, g_b^t\right)$. Abbreviating the functions with $\vec{D}_o^t(t)$, $\vec{D}_o^{t+1}(t+1)$, $\vec{D}_o^t(t+1)$ and $\vec{D}_o^{t+1}(t)$, respectively, the ML index of productivity change between period t and $t+1$ can be defined as:

$$ML_t^{t+1} = \left[\frac{\left[1 + \vec{D}_o^t(t)\right]}{\left[1 + \vec{D}_o^t(t+1)\right]} \times \frac{\left[1 + \vec{D}_o^{t+1}(t)\right]}{\left[1 + \vec{D}_o^{t+1}(t+1)\right]}\right]^{\frac{1}{2}}. \tag{9}$$

A value equal to unity indicates no productivity change. A value less than unity indicates a productivity decrease and a value greater than unity indicates a productivity increase. Further, the ML index can be decomposed into an efficiency change component $MLEFF_t^{t+1}$ and a technical change component $MLTECH_t^{t+1}$. That is,

$$ML_t^{t+1} = MLEFF_t^{t+1} \times MLTECH_t^{t+1}, \tag{10}$$

where

$$MLEFF_t^{t+1} = \frac{\left[1 + \vec{D}_o^t(t)\right]}{\left[1 + \vec{D}_o^{t+1}(t+1)\right]}, \tag{11}$$

and

$$MLTECH_t^{t+1} = \left[\frac{\left[1 + \vec{D}_o^{t+1}(t)\right]}{\left[1 + \vec{D}_o^t(t)\right]} \times \frac{\left[1 + \vec{D}_o^{t+1}(t+1)\right]}{\left[1 + \vec{D}_o^t(t+1)\right]}\right]^{\frac{1}{2}}. \tag{12}$$

$MLEFF_t^{t+1}$ captures the change in the distance of the observations to their respective frontiers. A value equal to unity indicates no change. A value less than unity indicates an increase in the distance and hence an efficiency decrease. Finally, a value greater than unity indicates a decrease in the distance and hence an efficiency increase.

A shift of the frontier is captured by $MLTECH_t^{t+1}$. A value equal to unity indicates no shift and hence no technical change. A value less than unity indicates a shift towards fewer good outputs and more bad outputs and hence technical regress. Finally, a value greater than unity indicates a shift towards more good outputs and fewer bad outputs and hence technical progress.

3. Data

Our analysis is based on industry level panel data of 17 countries, 16 member states of the European Union and Norway for the period 1995-2006.[9] The commercial transport sectors´ annual time-series of the input quantities, as well as the variables of good and bad outputs are classified according to the third revision of the International Standard Industrial Classification (ISIC) listed in Table 3.[10] For our calculations we use totalised quantities for the industry categories I60 to I63, while I64 "post and telecommunications" was excluded.

Table 3: Transport sector classification

I - Transport, storage and communications
60 - Land transport; transport via pipelines
61 - Water transport
62 - Air transport
63 - Supporting and auxiliary transport activities; activities of travel agencies
64 - Post and telecommunications

Our input variables are intermediate inputs, capital stock and number of employees. Value added is considered as proxy of the desirable or good output and CO_2 emissions as proxy of the undesirable or bad output.

The raw data series, which are mainly drawn from the Structural Analysis Database (STAN) of the OECD,[11] are all measured in local currency units at current prices except employees and CO_2 emissions, which are measured in numbers and tons, respectively. A few data series from STAN, which report missing values, are replaced by those of the EU KLEMS project on Productivity in the European Union.[12]

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[9] Norway participates in the European Union's single market via the European Economic Area (EEA) agreement (EFTA country). This makes Norway a highly integrated member of most sectors of the EU internal market.

[10] ISIC Rev. 3 is compatible with the NACE Rev. 1 classification used by EU member countries.

[11] Directorate for Science, Technology and Industry (Organisation for Economic Co-operation and Development, OECD)

[12] This project is funded by the European Commission, Research Directorate General as part of the 6th Framework Programme, Priority 8, "Policy Support and Anticipating Scientific and Technological Needs". Purpose is to create a database on productivity by industry for EU member states with a breakdown into contributions from capital (K), labour (L), energy (E), materials (M) and service inputs (S).

GDP deflators from the OECD database are used to transform these series into constant prices based on the year 2000.[13] The local currency measures are converted, for cross-country comparison, to an international common unit using purchasing power parities (PPPs) also collected from the OECD database.[14] To generate the capital stock we use the standard perpetual inventory method (PIM) under a uniform 5% depreciation rate.[15] That is

$$K_{i,t} = K_{i,t-1} - \delta K_{i,t-1} + I_{i,t} = (1-\delta)K_{i,t-1} + I_{i,t}\ , \tag{13}$$

where $K_{i,t}$ is capital stock of sector i at period t, $I_{i,t}$ is gross fixed capital formation/investment and δ is the rate of depreciation (assumed constant over time). Following Hall and Jones (1999), the initial capital stock series is calculated with the following formula:

$$K_0 = \frac{I_0}{\delta + g_I}, \tag{14}$$

where K_0 is the initial capital stock. Here, I_0 is the level of gross fixed capital formation in the initial period, g_I is the rate of growth in gross fixed capital formation, and δ again represents depreciation. The number of employees is used as labour input, which is not adjusted for changing quality or know-how due to lack of consistent data.

Data on CO_2 emissions (measured in thousands of tons) are from a unique industrial level data set provided by Eurostat, the statistical office of the European Union. Emission data for private and commercial transport are in general only available inseparably. We apply the “Air Emissions Accounts” data set that yield to comply with the ISI-Classification for the first time. Consequently, the emission data are in some cases presented in a different way than in traditional emissions statistics such as UNFCCC greenhouse gas inventories and the IPCC (Intergovernmental Panel on Climate Change) statistics. The data set includes only national economic activities rather than activities on the national territory. This means that particularly emissions by national economic units abroad are included in the accounts under the industry earning the value added from these activities. Also, emissions are allocated to the different industries i.e. transport emissions due to own account transport

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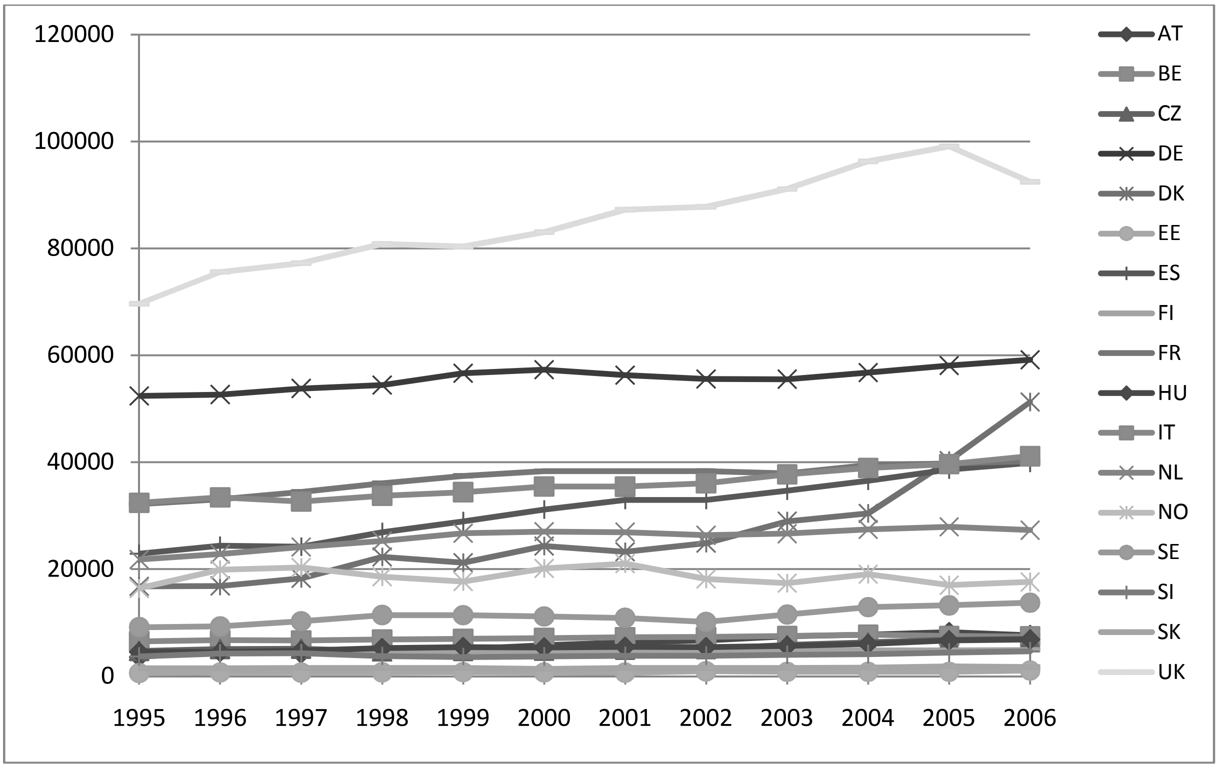
[13] We had to use the overall annual GDP deflator (base 2000 = 100) due to incomplete industry-specific deflators for our in- and output variables from STAN database.

[14] The PPPs in national currency per US dollar for GDP are given in the National Accounts.

[15] The depreciation rate is a country average value according to diverse sources like Abadir (2001) or Görzig (2007).

activities are attributed to the total emissions for the industry responsible.[16] The data set is based on a survey in 2008 and distinguishes between the transport industry categories I60 to I63.[17] Table 4 summarises the trend in CO_2 emissions for our sample over the 1995-2006 time period.

Table 4: Trend in CO_2 emissions (in thousand tons) 1995 - 2006



Note: The country codes represent in turn Austria (AT), Belgium (BE), Czech Republic (CZ), Germany (DE), Denmark (DK), Estonia (EE), Spain (ES), Finland (FI), France (FR), Hungary (HU), Italy (IT), Netherlands (NL), Norway (NO), Sweden (SE), Slovenia (SI), Slovakia (SK) and United Kingdom (UK).

The descriptive statistics of all variables used in this study are presented in Table 5, bringing into focus the diversity and heterogeneity of the European countries. During the 1995-2006 period a group of five countries belonging to the EU15 states, namely Germany, United Kingdom, Italy, France and Spain, display the highest values for all five variables of the sample. Exceptions are Denmark with remarkably high CO_2 emissions in addition to the Netherlands and Norway, which follow the big five with relatively high values for capital stock and intermediate input, as well as CO_2 emissions.

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[16] For detailed information see the “Manual for Air Emission Accounts” from Eurostat (2009) and the publication “Nameas for air emissions – Results of pilot studies” from the European Communities (2001).

[17] France makes an exception including I64 in I63. Because the value of CO_2 emissions from the classification group I64 “post and telecommunications” is comparatively low, effects on our results are neglectable.

While the United Kingdom had the maximum value of CO_2 emissions (in 1995: 69,643 thousand tons and in 2006: 92,436 thousand tons) for the whole period, Estonia displays the lowest with 567 thousand tons CO_2 emissions in 1995 and 1,059 thousand tons in 2006. As mentioned before, Denmark has to be singled out due to the exceptionally high increase of average annual growth at about 11.29% for the whole period.

Table 5: Descriptive statistics of the sample

Variable	Unit	Mean	SD	Min	Max
Capital Stock	million int. US$	88685	89970	2176	377129
Employees	number in thousands	388	401	32	1498
Intermediate Input	million int. US$	32154	33729	1691	138971
Value Added	million int. US$	23579	24528	921	89631
CO_2 Emissions	tons in thousands	21320	22436	567	99081

Before focussing on our results, it is informative to look a bit closer at the pattern of our variables. Table 6 shows the annual average growth rates of desirable and undesirable output, inputs and emission intensity over the entire 1995-2006 period. The emission intensities are measured as the ratio of carbon dioxide emissions to economic output, here value added. Average growth rates of the desirable output, i.e. value added and the undesirable output, i.e. CO_2 emissions amount to a total of 1.73% per year and 3.55%, respectively. Germany, France and Finland had the highest average annual growth in value added (4.70%, 3.99% and 3.83%, respectively), while value added in Hungary and Slovakia decreased over the study period. CO_2 emissions have increased for all 17 countries with average annual growth rates ranging between 1% and 11%. Finland, Germany and Norway had the lowest average annual growth in emissions, all less than 1.20%. Average growth rates of capital stock, employees and intermediate input were at 5.74%, 1.02% and 4.34% per year; most countries have increased these inputs. Emission intensity shows a 2.11% growth rate in total. During the study period, only five countries, i.e. Belgium, Germany, Finland, France and the Netherlands have decreased their emission intensities while most countries have increased CO_2 emissions per value added. Presenting two contrarian examples, Germany´s emission intensity is decreasing despite a simultaneous increase of value added. The significant increase in average growth rates of economic output is accompanied by a less intense increase in CO_2 emissions. In contrast, Denmark's emission intensity is rapidly increasing even though growth rates of value added have been decreasing.

Table 6: Average annual growth rates of outputs, inputs and CO_2 intensity

Country	Value added	CO_2 emission	Capital stock	Employees	Intermed. input	CO_2 intensity
AT	2.02%	7.93%	7.55%	0.91%	8.87%	6.14%
BE	2.26%	1.20%	3.79%	1.01%	4.48%	-0.87%
CZ	0.70%	3.80%	7.41%	-0.03%	2.82%	3.80%
DE	4.70%	1.12%	5.60%	0.47%	5.89%	-3.38%
DK	2.27%	11.29%	2.78%	0.60%	8.30%	9.44%
EE	2.75%	6.90%	6.75%	0.18%	5.53%	5.21%
ES	2.71%	5.22%	11.06%	4.54%	5.04%	2.55%
FI	3.83%	1.10%	4.90%	1.49%	4.59%	-2.62%
FR	3.99%	2.05%	4.05%	1.49%	5.65%	-1.79%
HU	-3.15%	3.93%	-1.11%	0.02%	-1.72%	7.79%
IT	0.71%	2.20%	3.38%	2.72%	2.92%	1.58%
NL	2.37%	2.09%	0.66%	1.35%	4.38%	-0.15%
NO	0.89%	1.16%	1.90%	1.13%	2.35%	0.27%
SE	3.11%	3.98%	5.55%	0.57%	4.47%	0.82%
SI	0.63%	2.37%	12.07%	0.28%	2.23%	1.85%
SK	-2.31%	1.40%	12.71%	-1.12%	3.72%	4.38%
UK	1.88%	2.68%	8.53%	1.64%	4.33%	0.81%
Total	1,73%	3,55%	5,74%	1,02%	4,34%	2,11%

Note: The country codes are the same as in Table 4.

The patterns of CO_2 emissions and emission intensities from the commercial transport industry that are shown in Table 6 are affected by numerous factors, including technical change, economical growth as well as changes in the modal split (Färe et al., 2001). Reductions in emissions are realized through technical progress that, in a direct way, positively affects abatement or indirectly advances the good to bad output ratio. Furthermore, recessions, respectively declines in economical growth can cause emissions reductions. Conversely, general economic growth would result in an increase of the good and bad output if not accompanied by technical progress. For instance, the continuous strong increase in Denmark´s CO_2 emissions (see Table 4) may be founded in the extensive above average growth – in comparison to the other European industrialised countries – in the time period between 1994 to 2007. Finally, a change in modal split can affect the level of emissions in both directions, considering that different means of transportation yield different CO_2 levels.

4. Results

The results of our estimations are presented in Table 7, 8 and 9. Table 7 shows the estimates of the average annual productivity change over the period 1995-2005. All models suggest that average annual productivity decreased over the observed period. The decrease varies from -2,24% in Model I, which completely ignores CO_2 emissions, to -1,44% in Model III, which credits reductions in CO_2 emissions. Furthermore, Table 8 and 9, which report the average annual technical change and the average annual efficiency change, respectively, show that this development is mainly due to technical regress. While across all models average annual efficiency change decreases by less than 1%, technical regress varies from 1.96% in Model I to 1.21% in Model III.

Table 7: Average annual productivity growth, 1995-2005

Country	Model I	Model II	Model III
Austria	0.9510	0.9672	0.9847
Belgium	1.0138	1.0213	1.0108
Czech Republic	0.9599	0.9868	0.9900
Denmark	1.0098	n.a.	n.a.
Germany	0.9961	1.0062	1.0155
Estonia	0.9535	0.9561	0.9642
Finland	1.0034	0.9984	0.9893
France	0.9954	1.0037	1.0022
Hungary	0.9883	0.9923	0.9780
Italy	0.9865	0.9885	0.9896
Netherlands	1.0096	0.9958	1.0058
Norway	0.9962	0.9873	0.9745[b]
Slovakia	0.8765	0.9205	0.9328
Slovenia	0.9436	n.a.	n.a.
Spain	0.9562	0.9576	0.9692
Sweden	1.0002	1.0003	0.9919
United Kingdom	0.9596	0.9002	n.a.
Mean[a]	0.9776	0.9844	0.9856

Notes: [a]For the countries for which a value in Model III is announced. [b]Norway for 1996-2005.

On the country-level, all models show a high variation in the productivity development. The lowest value is observed for Slovakia in Model I indicating a annual average productivity decrease of -12,34% when CO_2 emissions are ignored. The highest value is shown for Belgium in Model II suggesting an increase of annual average productivity of 2.13% when CO_2 emissions are held constant.

Comparing the results of Model I with the results of Model II and III, reveals that the majority of the countries undertake CO_2 abatement activities In contrast to Model I –which completely ignores CO_2 emissions and thus all abatement activities – Model II and III reward these countries for their efforts and hence show a higher productivity index than Model I.

Table 8: Average annual technical change, 1995-2005

Country	Model I	Model II	Model III
Austria	0.9890	1.0072	1.0038
Belgium	0.9978	1.0050	1.0017
Czech Republic	0.9735	0.9896	0.9921
Denmark	1.0011	n.a.	n.a.
Germany	0.9744	0.9812	0.9997
Estonia	0.9162	0.9134	0.9335
Finland	1.0034	0.9984	0.9893
France	0.9749	0.9811	0.9878
Hungary	0.9754	0.9724	0.9759
Italy	0.9956	0.9971	0.9986
Netherlands	1.0159	1.0119	1.0140
Norway	1.0012	1.0145	1.0061[b]
Slovakia	0.9201	0.9331	0.9392
Slovenia	0.9691	n.a.	n.a.
Spain	0.9951	0.9973	0.9970
Sweden	0.9927	0.9934	0.9924
United Kingdom	0.9596	0.9002	n.a.
Mean[a]	0.9804	0.9854	0.9879

Notes: [a]For the countries for which a value in Model III is announced. [b]Norway for 1996-2005.

However, despite the increasing productivity indexes from Model I to Model III we only find a positive development of productivity for four countries in Model III., namely for Belgium, Germany, France and the Netherlands. As shown in Table 6, for these countries the average growth rate of value added exceeds the average growth rate of CO_2 emissions. Hence, these countries were able to achieve a growth in good output with a lower CO_2 intensity. All other countries show a decrease in average productivity in Model III and a corresponding increase in their CO_2 intensity. The only exception is

Finland. Despite a decrease in its CO_2 intensity, a negative productivity development is observed in Model III.

Table 9: Average annual efficiency change, 1995-2005

Country	Model I	Model II	Model III
Austria	0.9617	0.9604	0.9809
Belgium	1.0168	1.0173	1.0095
Czech Republic	0.9861	0.9959	0.9975
Denmark	1.0101	1.0000	1.0402
Germany	1.0224	1.0257	1.0159
Estonia	1.0443	1.0470	1.0352
Finland	1.0000	1.0000	1.0000
France	1.0211	1.0234	1.0150
Hungary	1.0135	1.0207	1.0024
Italy	0.9911	0.9916	0.9912
Netherlands	0.9938	0.9845	0.9926
Norway	0.9953	0.9736	0.9717
Slovakia	0.9535	0.9878	0.9936
Slovenia	0.9741	0.9838	0.9603
Spain	0.9613	0.9608	0.9722
Sweden	1.0081	1.0074	0.9998
United Kingdom	1.0000	1.0000	1.0000
Mean	0.9973	0.9988	0.9987

5. Conclusions

In this paper we analyzed the productivity growth of the commercial transport industry in 16 member states of the European Union and Norway for the period 1995-2006. Using a directional distance function approach, we calculated three versions of the Malmquist-Luenberger productivity index that allows accounting for the joint production of good and bad outputs. While our first model completely ignores the bad output, i.e. CO_2 emissions, and solely seeks to increase the good output, i.e. value added, the second and the third model give credits to observations that increase value added at a constant or at a reduced level of CO_2 emissions.

Up to now, our preliminary results suggest that independent of the model the average annual productivity decreased over the observed period. This development is mainly due to technical regress.

Furthermore, the lower productivity values observed for a majority of the countries in Model I compared to the values in Model II and III indicate that in the presence of CO_2 abatement activities a model that completely ignores these activities, i.e. our Model I, provides biased measures of productivity. Finally, as expected, we found a positive development of productivity in Model III only for countries with a decreasing CO_2-intensity.

Future research plans include the investigation of factors that can explain the observed high variation in the productivity development between countries, the identification of innovators that shift the frontier over time as well as the application of a bootstrap procedure to allow a statistical interpretation of the index numbers.

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