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Greenhouse Gas Emissions and Price Elasticities of Transport Fuel Demand in Belgium

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GREENHOUSE GAS EMISSIONS AND PRICE ELASTICITIES OF TRANSPORT FUEL DEMAND IN BELGIUM

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By
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ABSTRACT/RESUMÉ

Greenhouse gas emissions and price elasticities of transport fuel demand in Belgium

Since 1990, Belgium has managed to bring down greenhouse gas emissions in most domains of economic activity. Road transport, as in many other countries, is a notable exception to this pattern: emissions have steadily increased, driven by an ever higher consumption of petrol and diesel. Even though the current overall performance will probably be sufficient to reach the reduction objectives of the Kyoto protocol, transport emissions thus need to be targeted in the future. One possible measure aimed at reducing them, an increase in fuel taxes, is examined in detail in this paper. The success of such a policy depends on the price elasticity of fuel demand, and therefore, the latter is estimated for Belgium and other European countries. The elasticities obtained are relatively small: in Belgium, for instance, a 10% increase in prices would cause consumption to fall by around 1.8% in the short-run and 2.3% in the medium run. Tax increases alone will thus certainly be insufficient for cutting emissions at this time horizon. Nevertheless, as a supporting measure in a more general reduction strategy, they could still yield substantial advantages. This Working Paper relates to the 2011 *OECD Economic Review of Belgium* (www.oecd.org/eco/surveys/Belgium).

JEL classification codes: Q42, Q48, Q58.

Keywords: Elasticity of fuel demand; Fuel taxes; Greenhouse Gas Emissions; Road transport; Belgium

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Émissions de gaz à effet de serre et élasticités-prix de la demande de carburants en Belgique

Depuis 1990, la Belgique a réussi à réduire ses émissions de gaz à effet de serre (GES) dans la plupart des domaines d'activité économique. Comme dans de nombreux autres pays, le transport routier constitue à cet égard une exception notable : ses émissions ont régulièrement augmenté, sous l'effet d'une consommation toujours croissante d'essence et de gazole. Même si les performances globales actuelles seront sans doute suffisantes pour atteindre les objectifs de réduction des émissions de GES du Protocole de Kyoto, un objectif doit donc être défini pour les futures émissions des transports. Une des mesures envisageables pour les faire diminuer, une hausse des taxes sur les carburants, est examinée de manière approfondie dans ce document. La réussite d'une telle mesure dépend de l'élasticité-prix de la demande de carburants, ce qui nous amène à estimer celle-ci pour la Belgique et d'autres pays européens. Les élasticités obtenues sont relativement modestes : en Belgique, par exemple, une hausse des prix de 10 % entraînerait un recul de la consommation de l'ordre de 1.8 % à court terme, et de 2.3 % à moyen terme. De simples augmentations des taxes seront donc certainement insuffisantes pour réduire les émissions à cet horizon. Néanmoins, en tant que mesures d'accompagnement s'inscrivant dans le cadre d'une stratégie plus générale de réduction des émissions de GES, elles pourraient avoir des retombées positives substantielles. Ce Document de travail se rapporte à l'*Étude économique de l'OCDE de la Belgique 2011* (www.oecd.org/eco/etudes/Belgique).

Classification Q42, Q48, Q58.

Mots clefs : Élasticité de la demande de carburants ; Taxes sur les carburants ; Émissions de gaz à effet de serre ; Transport sur route ; Belgique

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Greenhouse gas emissions and price elasticities of transport fuel demand in Belgium

By Tom Schmitz[1]

Introduction

In the Kyoto protocol, many OECD member states agreed to ambitious targets for the reduction of greenhouse gas (GHG) emissions. Today, Belgium is on track to fulfil these international obligations. Nevertheless, achievements remain fragile and are likely to be insufficient to meet more ambitious reduction goals, such as the EU's "20-20 plan" to reduce GHG emissions by at least 20% (with respect to 1990 levels) by 2020. On the whole, the energy intensity of the Belgian economy remains above OECD average, while the emission intensity is high in some important sectors (such as heavy industry or residential heating) but mitigated overall by the importance of nuclear energy. In particular, the emissions from road transport have increased over the past two decades whereas most other sectors managed to cut emissions. Consequently, road transport now already represents 20% of all GHG emissions, and needs to be a central part of every future emission reduction policy.

Emissions from road transport largely depend on the quantity of fuels used. Thus, in order to decrease them, fuel consumption has to be reduced. A large set of measures, such as tighter fuel economy standards for vehicles, road taxation, development of public transport and higher taxes on cars or transport fuels could possibly deliver this objective. This paper examines one such policy in detail: it assesses the impact of an increase in diesel and petrol taxes on the consumption of those two products by estimating the price elasticity of fuel demand. Assuming that supply is infinitely elastic, as can be deemed realistic for small countries, a tax increase is indeed directly and entirely transmitted to prices. Then, the change in quantities only depends on the price elasticity of demand[2].

Empirical estimations yield a short-run price elasticity of total fuel demand of around -0.18 for Belgium: thus, if prices increase by 10% from one year to another, fuel consumption will be reduced by around 1.8% in the same period. This price elasticity is relatively low compared to the ones found in the major review articles of the literature at the beginning of the 2000s, but higher than for most of the other eight European countries included in the analysis. In the medium-run, elasticity is somewhat higher, but still only reaches around -0.23. Thus, an increase in fuel taxes alone, even though its effect on fuel consumption is not negligible, is certainly insufficient for achieving a substantial reduction of GHG

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[1] The author is a Ph.D. candidate at Pompeu Fabra University, Barcelona, who served as a Consultant in the Economics Department of the OECD in summer 2010. The working paper is background material for Chapter 3 of the OECD's 2011 Survey of Belgium and benefited from comments by Tomasz Koźluk and Jens Høj. Special thanks go to Agnès Cavaciuti for statistical assistance and to Sylvie Ricordeau for editorial support.

[2] In practice, fuel prices vary because of changes either in the world oil price or in the national tax system. An overall price elasticity does not take these differences into account. Indeed, they are generally not meaningful for the consumer, except when there is the opportunity to buy fuel in a neighbouring country with lower taxes. On an aggregate level, such "fuel tourism" is found to be insignificant in Belgium (see Box 4) and therefore, price changes induced by taxes are assimilated to general price changes.

emissions from transport. However, as part of a more comprehensive strategy, this policy would still have many advantages: it would generate fiscal revenues that could finance other reduction policies, encourage transport innovation and (if mostly applied to diesel) reduce the tax disequilibrium between transport fuels.

The rest of the paper is organised as follows: Part 1 gives an overview of the performance of the Belgian economy regarding energy use and GHG emissions, with a special focus on road transport. Part 2 presents, after a brief literature survey, estimates for the price elasticity of fuel demand. Those are then used to analyze the impact of a price increase (induced by taxes) on the demand for road fuels.

Belgium has partly decoupled emissions and economic growth…

In 2007, at the time of the last official data submission to the United Nations Framework Convention on Climate Change (UNFCCC), Belgium had managed to cut GHG emissions by around 8% with respect to their 1990 levels. The impact of the global recession and the purchase of further emission rights by the federal government make it very likely that the reduction goal of 7.5% over the period 2008-2012 will be met (see Box 1 for more details). Nevertheless, further efforts have to be taken in order to prevent emissions from rising again and comply with more demanding reduction objectives.

Box 1. Belgium's progress towards the Kyoto goals

In 1990, Belgium had total GHG emissions of 143.2 Mt (Megatons) of CO_2-equivalent. Following the Kyoto protocol, the country engaged itself to reduce this figure by 7.5% for 2008-2012. As late as 2004, total emissions were still above the base year level, but the last official figures available for 2007 appeared to indicate that emission reductions in several sectors were sufficient for fulfilling the country's commitment: total emissions reached 131.3 Mt, a fall by 8.3% with respect to the base year.

This overall figure however concealed a climatic anomaly: the exceptionally warm winters of 2006 and 2007 (Belgian federal government, 2009) caused a large drop in emissions which made Belgium's performance in 2007 look better than what would be indicated by longer term trends. From 2005 to 2007, residential emissions (mostly due to heating) indeed fell from 22 to 19 Mt and the emissions of services (in which heating also plays a major role) were reduced from 31 to 27 Mt. Overall, these two reductions thus amounted to 7 Mt, *i.e.* 5% of base year emissions and 2/3 of the aspired Kyoto reduction. As climatic conditions were expected to normalize again, those reductions were judged unlikely to be sustained over the entire period 2008-2012. Accordingly, the 2009 projections of the federal government saw emissions rising again over the commitment period, and actually exceed the target by 3.6 Mt (European Commission, 2009). Thus, Belgium planned to use "flexible mechanisms" (purchases of emission rights or investments in foreign GHG reduction projects) in order to buy the right to 4.4 Mt of additional emissions and thereby ensure compliance with the Kyoto target.

It is unclear to which extent the global recession, which depressed economic activity and therefore GHG emissions, was already incorporated in those projections. This phenomenon may therefore help to keep emissions down, but on in any case, the figures above show that Belgium's structural achievements remain fragile and need to be put into perspective.

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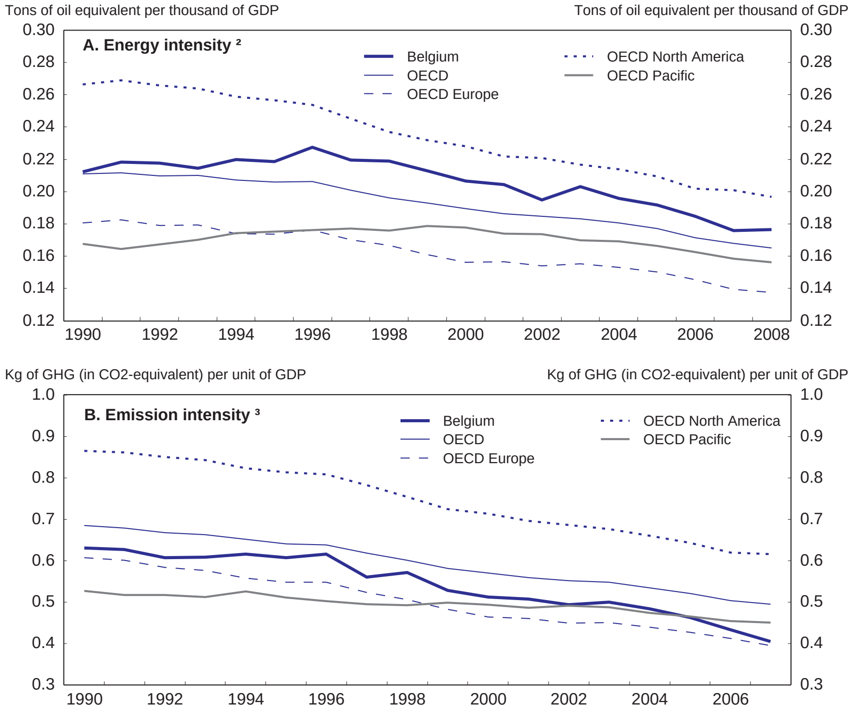
1. Objectives were differentiated at a regional level: Wallonia, a traditional industrial centre, had the highest reduction goals, and Brussels-Capital the lowest.

The main source of anthropogenic (man-made) GHG emissions is energy use. Therefore, both aggregates need to be jointly considered when analysing Belgium's emission profile. However, this does not imply a linear link between them, as emissions vary widely across energy sources: for instance, Belgium has managed in the last two decades to reduce emissions even though energy use increased, as the share of emission-intensive coal in the energy mix has been sharply diminished. Throughout economic sectors, the link between energy use and GHG emissions also differs substantially. It is weakest in agriculture, where methane and nitrous oxide emissions from livestock are far more important than CO_2

emissions from machines or vehicles. On the contrary, it is very strong in road transport, where almost all emissions come from the combustion of mineral fuels. Overall, Belgium has managed to decouple both its energy use and its GHG emissions from economic growth since 1990. Accordingly, the energy intensity and the emission intensity of GDP (defined respectively as Total Primary Energy Supply/GDP or Total GHG emissions/GDP) have been reduced by respectively 17% and 35%. These reductions are approximately in line with the average achievement in the OECD, although the latter is somewhat higher for energy and somewhat lower for emissions (see Figure 1). There is also a timing difference, as Belgian intensity reductions only started towards the end of the 1990s.

Figure 1. Energy and emission intensity of GDP [1]



1. OECD and OECD Europe exclude Hungary in 1990 and Slovakia in 1990 and 1991; OECD, OECD North America and OECD Pacific exclude Mexico and Korea. GDP is denominated in constant prices and in purchasing power parities (PPP) of 2000.
2. Energy use is measured by Total Primary Energy Supply (TPES).
3. GHG emissions are measured by total emissions excluding land use.

Source: UNFCCC Secretariat, OECD and IEA.

… but the country remains energy-intensive

Belgium’s energy intensity is high in absolute levels (see Figure 1). It has consistently remained above OECD average, and of the nineteen EU members belonging to the OECD, only three had a higher figure in 2008. On the contrary, emission intensity is below OECD average, and approximately in line with that of EU OECD members. The difference between the two figures is mostly due to the reliance on nuclear energy: in Belgium, this energy source, which emits only negligible amounts of GHG, represents around one fifth of total energy production and about half of all electricity production (in the OECD, these figures are only exceeded by France, Slovakia, Switzerland and Sweden), explaining the wedge between emissions and energy use.

The main target areas for a reduction strategy: road transport and the residential sector

Total GHG emissions, excluding land use changes, can be split into nine different emission sources[3]: Agriculture, Industry (excluding energy producers), Energy Industries, Services, Transport (excluding international aviation and maritime navigation), the residential sector, Waste, use of Solvents and "Other sources". Table 1 shows their respective share in total emissions for selected OECD countries, and Table 2 their emission reductions or increases between 1990 and 2007.

Table 1. **Share of GHG emissions by source (2007)**

	Agriculture	Industry	Energy Ind.	Services	Transport	Residential	Waste
Belgium	9%	31%	21%	4%	20%	14%	1%
Germany	6%	22%	42%	4%	16%	9%	1%
France	20%	22%	14%	5%	26%	11%	2%
Netherlands	13%	20%	33%	5%	17%	8%	3%
OECD[1]	8%	20%	35%	3%	23%	6%	3%
OECD EU	11%	21%	33%	3%	20%	9%	3%
OECD North America[2]	6%	17%	37%	3%	27%	5%	2%
OECD Pacific[3]	9%	28%	36%	5%	17%	4%	2%

1. Excluding Mexico and Korea.
2. Excluding Mexico.
3. Excluding Korea.

Source: UNFCCC Secretariat. The categories "Solvents" and "Other sources" have only a very small share of total emissions and are thus not shown.

Belgium's industry is the single most important emission source, representing almost one third of the country's total emissions. This share is clearly above OECD and OECD EU average (see Table 1). In turn, the mitigating influence of nuclear energy is again visible by the relatively low emission share of energy production. Transport (almost entirely made up of road transport) accounts for one fifth of total emissions – a share that has been increasing since 1990. Indeed, while Belgium achieved reductions in industry, agriculture and energy production, emissions from transport increased substantially. Only the less important service sector has progressed more (see Table 2).[4] This evolution is close the OECD EU average: European countries managed to reduce their overall emissions by cuts in all sectors, with the exception of transport. Outside Europe, however, emissions continued to increase, driven by transport and energy production.

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[3] Emissions submitted to the UNFCCC are organised according to the "Common Reporting Framework" established by the Intergovernmental Panel on Climate Change (IPCC). This methodology can be used to distinguish the cited nine emission sources. Their exact definitions are given in Appendix 1.

[4] These trends also explain the evolution of regional emissions: as planned, reductions have been largest in Wallonia, where industry is important, and emissions continued increasing in Brussels-Capital, where transport and services are decisive (Walloon regional government, 2008).

Table 2. **Evolution of GHG emissions by source (1990-2007)**

	Agriculture	Industry	Energy Ind.	Services	Transport	Residential	Waste	Total
Belgium	-15%	-18%	-12%	+29%	+26%	-7%	-68%	**-8%**
Germany	-21%	-25%	-10%	-45%	-7%	-34%	-72%	**-21%**
France	-12%	-18%	-6%	-1%	+15%	-1%	-17%	**-5%**
Netherlands	-18%	-23%	+23%	+37%	+35%	-18%	-53%	**-2%**
OECD[1]	-4%	-3%	+19%	-4%	+27%	-7%	-13%	**+9%**
OECD EU	-16%	-15%	-3%	-18%	+26%	-17%	-34%	**-7%**
OECD North America[2]	+9%	+4%	+26%	+4%	+29%	0%	-5%	**+18%**
OECD Pacific[3]	-3%	-4%	+42%	+6%	+18%	+11%	-14%	**+14%**

1. Excluding Mexico and Korea.
2. Excluding Mexico.
3. Excluding Korea.

Source: UNFCCC Secretariat. The categories “Solvents” and “Other sources” have only a very small share of total emissions and are thus not shown.

Industry and the residential sector maintain a high emission and energy intensity

The environmental performance of the main economic sectors can be assessed by calculating their emission intensity (*i.e.* by dividing their total emissions by their value added) or their energy intensity. This is possible for agriculture, industry, services and energy production[5] (see Table 3 for emission intensities). On the contrary, categories such as transport (which includes both professional and personal transport), waste or residential emissions do not have a value added in the strict sense, and therefore, their performance needs to be assessed in a different way[6].

In Belgium, emission intensity has fallen faster than actual emissions in all four sectors, indicating that economic activity is becoming less polluting. However, in agriculture and industry, Belgium remains among the countries with the highest emission intensity. For industry, this can be explained by the large share of particularly emission-intensive activities, such as the production of metals and chemicals[7], in the country’s industrial structure. Indeed, these two activities represent one fifth of all industrial value added, more than in any of the other European countries considered here. As they are also very energy-intensive (consuming almost two thirds of all final energy used in industry), the overall industrial sector is also characterised by a high energy intensity.

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[5] Statistical classifications for the split of total GHG emissions, final energy consumption and value added by sector differ, and therefore, correspondences between them need to be established. This has mainly been done by Eurostat: thus, energy and emission intensity statistics by economic sector are limited to European countries. The exact correspondences, as well as the numerical results for energy intensity, can be found in Appendix 1.

[6] As emissions from those sources cannot be allocated among economic sectors, it should be noted that emissions for the industry sector, for example, do not include GHG caused by transport, waste treatment or solvent use attached to industrial activities.

[7] In 2007, their respective emissions were 3 and 1.5 kg of CO_2-equivalent per thousand of value added, against an overall industrial average of 0.7 kg.

Table 3. **GHG emission intensity by economic sector (2007)**

	Agriculture		Industry		Energy Ind.		Services	
	GHG intensity	Change since 1995	GHG intensity	Change since 1995	GHG intensity	Change since 1995	GHG intensity	Change since 1995
Belgium	4.2	-20%	0.69	-40%	3.65	-21%	0.03	-25%
Germany	2.5	-19%	0.36	-24%	12.36	+16%	0.03	-47%
Denmark (2005)	4.4[2]	+7%	0.24	-19%	3.00	-55%	0.01	-33%
Spain	2.4	+5%	0.57	-13%	8.33	n. a.	0.02	n. a.
France[1]	3.0	-2%	0.41	-18%	2.63	-15%	0.03	-25%
Italy	1.6	-13%	0.41	-16%	6.08	+17%	0.03	+7%
Luxembourg (2006)	8.1	+50%	0.65	-50%	5.16	+9%	0.04	-42%
Netherlands	2.7	-29%	0.50	-36%	4.48	+11%	0.03	-28%
United Kingdom (2005)	3.5	-18%	0.34	-27%	4.30[3]	+6%	n. a.	n. a.

Absolute figures are given in kg of CO_2-equivalent per thousand of gross value added (in Euros and constant prices, reference year 2000).

1. All evolutions with respect to 1999.
2. Figures for 2007.
3. Estimate.

Source: UNFCCC Secretariat (Emission data) and Eurostat (Value added per sector).

In agriculture, energy and emission intensity are both high, but they cannot be linked directly. The high energy intensity of agriculture, which has not been reduced since 2000, may be due to the high occurrence of intensive agriculture in general, and more particularly, to the fact that farmers face low energy prices. For instance, they are exempted from fuel tax (OECD, 2008). Agricultural emissions are however not so much linked to this energy use, but largely made up of methane and nitrous oxide arising from the agricultural activities themselves. These types of emissions are pushed up in Belgium by intensive livestock farming in the north of the country. The observed reduction of emission intensity in this sector is thus mostly due to a reduction of the livestock (OECD, 2007)[8]. Finally, Belgium's emission intensity for energy production is low because of nuclear energy, and declining because of the decreasing use of coal. The emission intensity of services appears to be negligible in comparison to the other economic activities, and is relatively similar across most European countries.

Residential emissions, mostly caused by heating, cannot be analysed by comparing them to a value added. Putting them into perspective with the total population or the total living space in a country however gives an idea of emission "intensity". Both indicators deliver striking results for Belgium: relative emissions are far higher than in the rest of the OECD or in comparable European countries (see Table 4). Furthermore, apart from the effects of the warm winters of 2006 and 2007, there does not appear to be a downward tendency. This finding, which also holds for energy intensity, is probably linked to the poor energy performance of Belgian buildings (OECD, 2007).

To sum up, Belgium is characterised, with respect to other European countries, by an emission-intensive industrial sector, as well as by high household emissions. A dominant part of Belgian industrial emissions will fall under the European Union's Emission Trading Scheme, the cap-and-trade system that should guarantee reductions across the EU. A Belgian emission strategy will therefore need to address

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[8] In Belgium, the main sources of methane and nitrous oxide are cattle (enteric fermentation) and swine (manure management). According to the online database of the FAO, in 2008, cattle stocks were 2.5 million and swine stocks 6 million, down from respectively 3 and 7.5 million in 2000.

household emissions and the increasing problem of transport emissions, on a substantial rise during the last two decades. The latter evolution is described in greater detail in the next section.

Table 4. **Residential emission intensity**

	Residential emissions per capita (2007)	Residential emissions per square meter of useful floor area (2002)
Belgium	1786	62
Germany	1055	36
France	956	24
Netherlands	997	29
Spain	429	14
Italy	861	20
United Kingdom	1261	38
OECD[1]	900	n.a.
OECD EU	911	n.a.
OECD North America[2]	1163	n.a.
OECD Pacific[3]	474	n.a.

1. Excluding Mexico and Korea.
2. Excluding Mexico.
3. Excluding Korea.

Source: UNFCCC Secretariat and OECD. Emissions are expressed in kg of CO_2-equivalent.

The large increase of transport emissions will need to be contained

In road transport, energy use and GHG emissions are closely linked, reflecting the constant carbon content of fuel. Thus, there tends to be a direct and linear relationship between quantities consumed and emissions caused (EPA, 2005)[9]. For example, in Belgium, the amount of GHG emitted per ton of fuel consumed has remained more or less constant between 1990 and 2007 (around 3.1 tons for both petrol and diesel[10]). Accordingly, fuel consumption and emissions increased at the same rate (27%) during that period. This is a median position between countries with small increases or even reductions in fuel consumption (France, United Kingdom, Germany) and countries with high growth rates (such as the Netherlands or Spain), placing Belgium slightly below OECD and OECD EU average (see Table 5). The overall increase of fuel consumption conceals a long-run trend of diesel replacing petrol. This "dieselisation" is particularly striking in Belgium, where petrol consumption has stagnated in the 1980s, before decreasing, while diesel consumption has grown continuously. As a result, the diesel share exceeds 80% in 2007 and is highest among all countries considered. Outside Europe, diesel also often grew faster than petrol, but the latter remained dominant.

In the same period, total traffic (measured by total vehicle-km in a year) increased by 41% in Belgium. In particular, total distance driven by heavy and light trucks increased much faster than average: the latter was even multiplied by three. In neighbouring countries, traffic increases were somewhat lower (for example, by 30% in France and by 33% in the Netherlands) and while light and heavy duty vehicle

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[9] The carbon content could evolve, for example, if mineral fuels were replaced with electricity or hydrogen, or blended with biofuels. All those alternatives however remained of minor importance up to 2007, especially so in Belgium.

[10] Diesel, however, is denser than petrol, and therefore heavier: thus, while both fuels cause roughly the same emissions per ton, the emissions of one litre of diesel are higher than those of one litre of petrol.

traffic generally also expanded more than average, this was not quite as massive as in Belgium. Traffic increases exceeded the increase of fuel consumption because of technological progress (new cars consuming less by km driven) and dieselisation (diesel cars driving longer for each ton of fuel than their petrol equivalents)[11]. Accordingly, Belgium's emissions per vehicle-km have been reduced by 10% between 1990 and 2007.

These developments give a first idea of the emission "intensity" of transport. The latter is however affected by changes in the composition of traffic, as the increase in fuel-intensive heavy vehicles obscured part of the real improvements in fuel efficiency. To assess efficiency gains of vehicles precisely, emissions per vehicle-km by vehicle and engine type would have to be considered. However, these figures are not calculated everywhere and generally not comparable across countries. In Belgium, they are computed by three different regional agencies and according to three different methodologies, which makes aggregation or comparison problematic. On the other hand, the evolution of regional time series provides some ideas on efficiency. For example, in Flanders, they show that all vehicle classes (cars as well as light and heavy trucks) have improved their emission intensity by approximately 20%. This decrease is somewhat larger than the one suggested by the general figure of 10%, showing that the increasing share of trucks indeed probably set off part of the technological improvements.

Table 5. **Fuel consumption for road transport (1990-2007)**

	Diesel		Petrol		Total		Diesel/Petrol ratio	
	Consumption (2007)	Change since 1990	Consumption (2007)	Change since 1990	Consumption (2007)	Change since 1990	D/P ratio 1990	D/P ratio 2007
Belgium	6.5	+86%	1.4	-49%	7.9	+27%	1.3	4.6
Germany	26.4	+51%	21.1	-32%	47.5	-2%	0.6	1.3
Denmark	2.4	+73%	1.8	+16%	4.2	+43%	0.9	1.4
Spain	26.0	+189%	6.8	-16%	32.9	+92%	1.1	3.8
France	32.2	+89%	9.5	-47%	41.7	+19%	0.9	3.4
Italy	24.8	+61%	11.8	-8%	36.6	+29%	1.2	2.1
Luxembourg	1.7	+292%	0.4	+5%	2.1	+151%	1.0	3.9
Netherlands	6.7	+80%	4.3	+25%	11.0	+54%	1.1	1.6
United Kingdom	21.3	+100%	17.7	-27%	39.1	+12%	0.4	1.2
OECD	399.7	+84%	623.4	+18%	1023.1	+38%	0.4	0.6
OECD EU	186.3	+101%	98.4	-19%	284.8	+33%	0.8	1.9
OECD North America	152.0	+88%	450.3	+31%	602.3	+41%	0.2	0.3
OECD Pacific	48.1	+28%	67.1	+33%	115.2	+31%	0.7	0.7

Source: IEA. All figures are in megatons, and petrol and diesel include biofuels, with a special treatment in Germany (see Appendix 2). D/P stands for the ratio of diesel consumption to petrol consumption.

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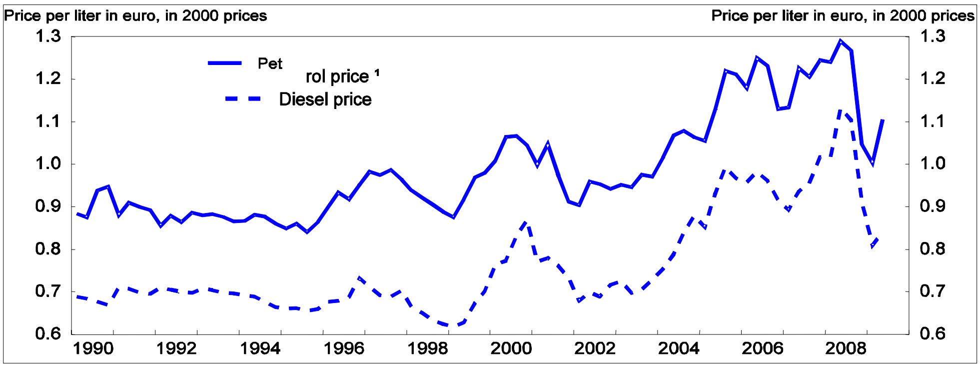
[11] Diesel cars have on average a 20–30% lower fuel economy (l/km) than petrol cars (Stead, 1999). However, diesel has a density of 0.86 kg/l and petrol a density of 0.74 kg/l (according to the IEA "*Energy prices and Taxes*" database). Thus, if fuel economy in l/km is 20% lower, fuel economy of diesel cars in kg/km is approximately 7% lower than that of petrol cars.

Fuel taxes sustained the shift to diesel

Fuel prices in Belgium, as in the surrounding countries, follow the evolution of the oil price: after being consistently low during the 1990s, they first experienced a temporary hike in 2001 and then a longer increase from the end of 2004, before falling because of the global recession (see Figure 2). As they both depend on the world oil market, petrol and diesel prices are heavily correlated. Nevertheless, diesel was consistently cheaper than petrol, a fact that also holds for most other European countries (with the exception of the United Kingdom and Spain), but is not necessarily true for other OECD members.

Figure 2. Prices for petrol and diesel in Belgium[1]



1. The petrol price refers to a quantity-weighted average of the prices of premium leaded petrol and premium unleaded petrol 95 RON.

Source: IEA.

Table 6 shows international nominal and real fuel prices, as well as the tax share in the total price. The latter is generally high for European countries and gives the State a large influence on the price level[12]. Indeed, taxes played an important role for the relative evolution of fuel prices. For instance, Belgian diesel prices were relatively high in Europe in 1990, but subsequent increases were relatively modest, smaller than those in all neighbouring countries. This reflects a falling tax share of the diesel price: from all European countries considered, Belgium's nominal diesel tax increased least between 1990 and 2007 (both in absolute and relative terms) and the tax share fell from an average position to one of the lowest. Petrol prices, in turn, were consistently high in Belgium, both in real and in nominal terms: in the direct neighbourhood, they are only exceeded by Dutch prices. The tax share on petrol is about average and has not evolved much.

Overall, the tax system on road fuels has favoured the shift to diesel[13]. The justification of this advantage is debatable. One kg of petrol creates the same quantity of GHG as one kg of diesel, but

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[12] In Belgium, control is even more direct through the mechanism of the "*contrat programme*", a long-term contract between the State and the Belgian Petrol Federation establishing a formula for maximal selling prices. Prices are updated on a daily basis and legally binding for all service stations. Additionally, a "positive" and a "negative" ratchet system ("*mécanisme du cliquet*"), created in 2003–04, is supposed to avoid too large prices changes by triggering an automatic move in excise taxes that offsets part of a large price increase or decrease.

[13] This is to some extent compensated by registration taxes, which are higher for vehicles with diesel engines. On the other hand, the tax break given to company cars (75% of their cost can be deducted as business expense) may have advantaged larger cars with diesel engines.

nevertheless, the latter was consistently and significantly cheaper over the last two decades[14]. Thus, if taxes should be neutral vis-à-vis emission sources, there is a case for rising diesel taxes. This principle is not generally applied throughout the economy: for instance, emitting one ton of CO_2-equivalent in metal production remains much cheaper than emitting it by using fuel for a motor vehicle[15], even though the environmental impact is the same. This indicates that increasing the price of industrial or residential emissions may actually be more cost-effective than a further increase in transport fuel taxes. Nevertheless, if Belgium wants to comply with ambitious reduction targets, the expansion of road transport in the last two decades necessarily needs to be addressed by some policy measure. A price increase of the major transport fuel is one of those: in order to assess it in greater detail and to compare it to other alternatives, its impact on demand, emissions and fiscal revenues in the short and medium run is estimated in the next part.

Table 6. **International fuel prices and taxes (per litre, in Euro)**

	Diesel						Petrol					
	1990			2009			1990			2009		
	Nominal	Real	Tax share	Nominal	Real	Tax share	Nominal	Real	Tax share	Nominal	Real	Tax share
Belgium	0.56	0.68	57%	1.02	0.85	52%	0.74	0.91	65%	1.32	1.09	63%
Germany	0.51	0.65	57%	1.08	0.93	60%	0.62	0.79	61%	1.27	1.07	67%
Denmark	0.33	0.41	n.a.	1.05	0.88	56%	0.74	0.92	69%[2]	1.28	1.10	64%
Spain	0.38	0.55	54%	0.91	0.70	50%	0.50	0.73	63%[2]	1.00	0.77	56%
France	0.52	0.62	63%	1.00	0.86	59%	0.81	0.96	74%	1.21	1.03	67%
Italy	0.50	0.73	66%	1.08	0.89	56%	0.76	1.10	75%	1.23	1.01	62%
Luxembourg	0.35	0.43	36%	0.85	0.69	49%	0.56	0.69	50%	1.03	0.85	58%
Netherlands	0.50	0.63	52%	1.00	0.83	58%	0.80	1.02	63%	1.34	1.11	69%
United Kingdom	0.57	0.74	59%	1.17	0.98	65%	0.61	0.80	61%	1.12	0.94	68%
Australia[1]	0.35	0.44	53%	0.75	0.58	37%	n.a.	n.a.	n.a.	0.72	0.55	39%
Canada[1]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	0.39	0.47	42%	0.60	0.50	33%
Japan[1]	n.a.	n.a.	n.a.	0.80	0.81	36%	0.66	0.71	48%	0.92	0.94	51%
United States[1]	0.25	0.32	28%	0.47	0.38	21%	0.24	0.32	27%	0.45	0.36	21%

Except when indicated otherwise, petrol prices and tax shares refer to a quantity-weighted average of the prices of premium leaded petrol and premium unleaded petrol 95 RON (for details, see Appendix 2). Real prices are obtained by deflating with the CPI (base year 2000).

1. Prices for regular unleaded petrol.
2. Figures refer to only to unleaded petrol.

Source: IEA, Allgemeiner Deutscher Automobil-Club (ADAC), Mineralölwirtschaftsverband.

Increasing fuel taxes to reduce GHG Emissions in road transport

The reaction of fuel consumption to price changes has been a major research topic over the last decades, given the great importance of transport for economic activity. In the 1970s and 1980s, most

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[14] The price advantage in litres (see Table 6) is even accentuated in kg by the fact that diesel is heavier than petrol (see above).

[15] On June 29th, 2010, EU emission allowances for industry were traded at 15.18 Euro per ton of CO_2 at the European Energy Exchange (EEX) in Leipzig. In contrast, Belgium's total taxes on one kg of diesel consumed by the transport industry (*i.e.*, excluding VAT) in 2009 were 0.41 Euro: with an emission factor of 3.1 tons of CO_2-equivalent per ton of fuel, this yields an implied tax of 132 Euro on the ton of CO_2.

studies were concerned with the impact of the oil price shocks in 1973–74 and 1978–79 and the dependence of OECD countries on imported oil, while later studies focus more on the possibilities to bring down GHG emissions by increasing fuel taxes. In theory, the impact of such a tax increase is simple to evaluate. In the basic microeconomic market model, presuming an infinitely elastic supply and an absence of leakage in the form of "fuel tourism", a tax increase is fully transmitted to prices and brings quantities down. The scope of this reduction only depends on the price elasticity of demand (see Box 2), and this elasticity also determines the consequences of the tax change for GHG emissions and fiscal revenues.

European countries are indeed using taxes on mineral fuels in order to bring emissions down. In Belgium, the creation of a special energy levy in 1993 (extended to diesel in 2003) and the "positive" ratchet mechanism (see above) point in that direction. However, the success of such a policy depends on the price elasticity of demand. It has often been argued that, as transport needs cannot be compressed, fuel demand is inelastic and almost does not react to prices. Plotting Belgium's total fuel consumption and the price of total fuel (Figure 4) does not completely confirm this. There has been a steady upward trend in consumption since 1970, which is likely to be related to rising income. Nevertheless, there seem to be some reactions to the oil price increases in the 1970s, in 1990–91, in 2001 and in 2005. Over the last forty years, a large number of econometric studies have tried to put numbers on this effect by estimating the price elasticity of fuel demand.

Box 2. Theoretical consequences of a tax increase on the road fuel market

On the market for road fuel, the consequences of a tax increase normally depend on the characteristics of both the demand and the supply curve, *i.e.*, on the price elasticity of demand and supply. However, on the international oil market, the demand of a small country such as Belgium will most likely not influence the price: thus, it is a common assumption[1] to suppose that on the national market for road fuels, supply is infinitely elastic (*i.e.*, the supply curve is horizontal). Therefore, a tax increase, shifting the supply curve upwards (from S_0 to S_1), is entirely transmitted to prices. The decrease in quantities (Q_0-Q_1) then only depends on the shape of the demand curve (see Figure 3).

Figure 3. **The impact of an increasing excise tax**

Arithmetically, supposing the demand function Q is sufficiently regular, the response of quantities to a small change in prices ΔP, starting from the equilibrium price P_0, is given by the Taylor expansion

$$Q(P_0 + \Delta P) = Q(P_0) + \Delta P * Q'(P_0) + o(\Delta P) \qquad (1)$$

Box 2. **Theoretical consequences of a tax increase on the road fuel market (*con't*)**

which then gives

$$\frac{Q(P_0+\Delta P)-Q(P_0)}{Q(P_0)} \approx \frac{\Delta P}{P_0} * \left(Q'(P_0) * \frac{P_0}{Q(P_0)}\right) = \frac{\Delta P}{P_0} * \varepsilon_P \quad (2)$$

In this equation, ε_P is the price elasticity of demand: when the price increases by 1%, demand will fall by $-\varepsilon_P$ %. It is then straightforward to assess the consequences of this fall for GHG emissions and for fiscal revenues[2].

This whole analysis supposes that there is only one market for road fuels, the Belgian one, and that consumers cannot buy fuel in neighbouring countries. This is of course a simplifying assumption, but in the empirical analysis, "fuel tourism" proves to be insignificant for Belgium on an aggregate level (see Box 4).

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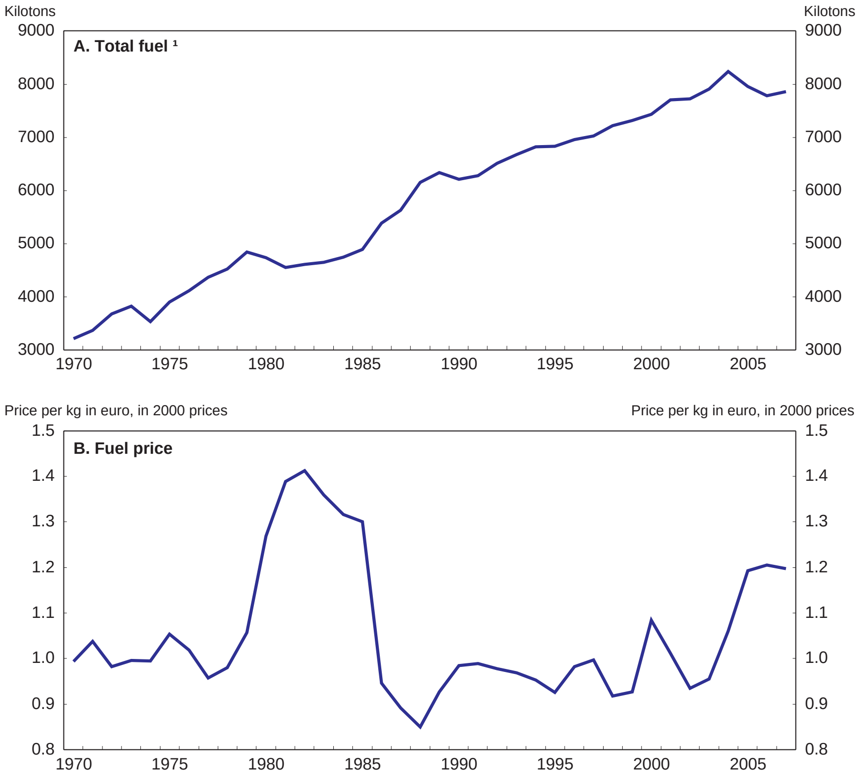
1. Wasserfallen and Güntensperger (1988) write that this assumption is sensible for a small economy (they consider Switzerland). More generally, Haughton (1998) argues that for petroleum products, "it is conventional (and usually reasonable) to assume that supply is infinitely elastic, particularly when annual data are being used".
2. For the latter, if taxes before the increase were t, the change in revenues is calculated as $((P_1-P_0)*Q_1) - (t*(Q_0-Q_1))$.

Figure 4. **Fuel consumption and prices in Belgium (1970-2007)**



1. The 'total fuel' aggregate is the sum of diesel and petrol consumption. Its price is calculated as a quantity-weighted average of the prices of the two (see Appendix 2).

Source: IEA.

The econometric literature yields a small, but significant price elasticity

In the basic microeconomic model presented above, demand depends on the fuel price and on income. However, a great number of other factors are potentially relevant, and therefore, most authors start by analysing the determinants of fuel demand, often considering the following accounting identity, established notably by Baltagi and Griffin (1983):

$$F = \frac{F}{KM} * \frac{KM}{C} * C \quad (3)$$

In this equation, F stands for the total level of fuel consumed during a given time span, KM for the total kilometres driven during the same period, and C for the total number of cars (or, more generally, of vehicles). [16] This decomposition allows analysing behaviour in a precise way, by decomposing the total price elasticity of fuel into three sub-elasticities measuring the response of fuel efficiency (KM/F), car utilisation (KM/C) and of the vehicle stock (C) to a change in prices. However, estimating the three different elasticities is often difficult. Thus, equation (3) is generally only used to get an idea about the determinants of fuel demand. All three variables depend, more or less directly, on the fuel price and on income, but there are also a great number of other determinants:

- Fuel efficiency (KM/F) is determined by technological progress, the composition of the vehicle fleet or driving styles.
- Car utilisation (KM/C) also depends on the number of cars per household and on the price of alternatives (such as rail transport, for instance).
- The stock of vehicles (C) furthermore depends on car prices and maintenance costs.

After deciding to include or to exclude those variables in their estimation, researchers generally consider a demand equation of the form

$$F_t = \beta_0 {P_t}^{\beta_1} {Y_t}^{\beta_2}$$

In this equation, F stands for the quantities of fuel consumed, P for the real price of fuel, and Y for real income (in this most basic model, no additional variables are used). When this model is log-linearised, it yields the econometric test equation[17]

$$f_t = \beta_0 + \beta_1 p_t + \beta_2 y_t + \varepsilon_t \quad (4)$$

This is often extended to a partial adjustment model, in order to capture long-run effects that build up over time:

$$f_t = \beta_0 + \beta_1 p_t + \beta_2 y_t + \beta_3 f_{t-1} + \varepsilon_t \quad (5)$$

Such a log-linear model has the advantage that elasticities are constant, and equal to the estimated coefficients: it is thus widely used in the literature. OLS or varieties of OLS constitute the principal estimation method. However, review articles, while finding that methodology influences results, have found no consistent pattern: there appears to be no method giving systematically higher or lower results (Hanly *et al.*, 2002).

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[16] The large majority of studies focuses on petrol, or on an aggregate of petrol and diesel, but only seldom on diesel alone. This is probably due to the focus of the literature on the United States, where petrol (gasoline) continues to dominate. The shift of diesel to petrol, and potential substitution issues, are thus only rarely modelled (for exceptions, see Chandrasiri, 2005, who uses a SUR methodology for joint estimation of petrol and diesel demand, or Pock, 2010).

[17] Small letters stand for the natural logarithms of the considered variables.

Some estimation issues: spurious regressions, simultaneity and demand shifts

The time series used for the estimation of the price elasticity of fuel demand are typically not stationary: for instance, Belgian fuel consumption is clearly drifting over time (see Figure 4). Therefore, estimation could yield "spurious regressions" with seemingly significant, but in fact meaningless results (Granger and Newbold, 1974). Indeed, when fuel quantities, fuel prices and income all have a unit root, OLS estimation of equation (4) gives consistent estimates only if those three variables are cointegrated.[18] In the presence of series with a unit root, econometric studies therefore have to test for the stationarity of the residuals from OLS estimation of equation (4), as is done in Bentzen (1994) or Hughes *et al.* (2006). Alternatively, the considered series need to be rendered stationary by estimating in first differences, as done by Wasserfallen and Güntensperger (1988).

Another major estimation issue is common to all demand estimations: simultaneity, *i.e.* a correlation between the price and the residual term, caused by the fact that quantities and prices are jointly determined on the market. However, when assuming an infinitely elastic supply, simultaneity is excluded from the start. This assumption can be challenged from a methodological viewpoint (see for example Kennan, 1989), but it appears to be fairly common in the literature, at least for small countries.[19] A related issue is the stability of demand. If the demand curve shifts over time because of variables that are not included in the analysis, it is not possible to estimate a single price elasticity. Some studies therefore test for breaks and argue that price elasticity evolved over time.

Main findings

The main findings of the literature are summarised in a number of major reviews, such as Espey (1998), Hanly *et al.* (2002) or Brons *et al.* (2008). Most studies find short-run price elasticities of around –0.3 and long-run elasticities of around –0.6: thus, fuel (or petrol) demand is considered to be inelastic, but not insensitive to prices. Hanly *et al.* derive two other stylized facts: *first*, long-run elasticity is higher than the short-run figure: effects build up over time rather than fading out. *Second*, when prices increase, fuel consumption is reduced more than distance driven: short and long-run elasticities for traffic are respectively –0.1 and –0.3. This gives some idea about the importance of the different effects regrouped in total price elasticity, as the remaining adjustment must be due to fuel efficiency.

Table 7. **Mean price elasticities from literature reviews**

	Espey (1998)	Hanly *et al.* (2002)	Brons *et al.* (2008)
Short-run price elasticity	-0.26	-0.25	-0.34
Long-run price elasticity	-0.58	-0.64	-0.84

In Belgium, estimates for short-run price elasticity, as calculated for instance by Sterner *et al.* (1994) or Baltagi and Griffin (1997) appear to be close to these averages, while long-run estimates fluctuate more. However, those specific studies are relatively old and do not consider the 1990s and the 2000s. Therefore, the next section estimates the price elasticity of fuel demand for Belgium and for eight other European countries.

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[18] The same is true for equation (5): Pesaran and Shin (1999) point out that an autoregressive distributed lag model (ARDL) of this type is only meaningful if the underlying variables are cointegrated.

[19] For the United States, where this assumption is more fragile, some studies rely on instrumental variable estimation (see for instance Hughes *et al.*, 2006 and Davis and Kilian, 2009).

Estimates of a price elasticity for Belgium and other European countries

Annual data for the period 1970–2007 have been gathered for nine European countries (Belgium, Germany, Denmark, Spain, France, Italy, Luxembourg, the Netherlands and the United Kingdom). The quantities of petrol and diesel used in road vehicles, as well as their real prices are taken from the International Energy Agency (IEA). The series for total fuel (F) is then defined as the sum of diesel and petrol consumed,[20] and the price (P) of this aggregate is a quantity-weighted average of diesel and petrol prices. Finally, real gross national income (Y) is taken from the OECD. A detailed description of the data used can be found in Appendix 2.

The simplest model of fuel demand, described by equation (4), is considered first. Most of the variables of the dataset appear to have unit roots (as illustrated for instance in Figure 4), and econometric testing confirms this: the augmented Dickey-Fuller (ADF) test cannot reject the null hypothesis of a unit root at the 5% level for almost all series. However, the Engle-Granger procedure shows that total fuel, the fuel price and national income are not cointegrated: the null hypothesis of no cointegration cannot be rejected in all countries except for Spain. Other cointegration tests confirm this finding, and adding a linear time trend to the test equation does not change it, except for the Netherlands (all results for the unit root and cointegration tests can be found in Appendix 3). Thus, there appears to be no consistent long-run relationship between the variables and estimating equation (4) in levels may yield a spurious result.[21]

Estimates of a short-term price elasticity from first difference equations

In the absence of cointegration, the model of equation (4) can be estimated in first differences, in order to capture short or medium-run relationships. The econometric test equation thus becomes:

$$\Delta f_t = \beta_0 + \beta_1 \Delta p_t + \beta_2 \Delta y_t + \varepsilon_t \quad (6)$$

First differences of the variables considered are indeed found to be stationary in most cases. For some countries (such as France and Germany) they are however only trend-stationary, as their fuel consumption has a marked U-shape.[22] The residuals of the first-difference regressions for those countries thus also have a trend. Accordingly, a linear trend is added in the estimation (*i.e.*, de-trending is provided) to make residuals stationary. Finally, dummies for the first oil price shock, in which the embargo of oil exporting countries caused a disruption in quantities that was disconnected from prices and incomes, are also included. The results for the three models are shown in Table 8. For most countries, they generally yield significant elasticity estimates with the expected signs (negative for prices, positive for income). Price elasticities are relatively low in comparison with previous studies, but not out of line with them. Belgium has, after Italy, one of the highest price elasticities of the considered countries, ranging around –0.18. The results thus confirm the inelastic nature of fuel demand: after a 10% increase in prices, fuel demand would decrease, all other things held equal, by approximately 1.8%.

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[20] As shown in Table 5, all countries included in the analysis have experienced a shift from petrol to diesel, which in fact began even before 1990. An estimation of diesel or petrol demand ignoring this shift will thus suffer from a strong omitted variable bias, even when a time trend or the price of the other fuel are included in the regression: for instance, regressing petrol consumption on income and the price of petrol often yields a negative income elasticity because petrol and income share a downward trend. In order to overcome such effects, the present analysis is conducted with respect to total fuel. For emissions, this mix of the two fuels is not problematic: series are expressed in kilotons, and the GHG emissions of one kiloton of petrol and one kiloton of diesel are roughly equal.

[21] This could be explained by an omitted variable bias or a behavioural shift that changed the parameters of the relationship. However, even for a shorter sample (1978–2007), the results remain identical.

[22] The full results of the stationarity tests are again shown in Appendix 3.

These estimates are short-term values, showing the reaction of quantities to a price change within a given year. However, as they influence long-term choices (purchase of a car, of a given car type, etc.) fuel prices are likely to have long-term impacts that are not captured by the model above. One way to estimate them would be to add lags of income or prices to the above equations. However, when limiting the number of lags for each variable to 2, this generally did not improve the model (judging by the Akaike Information Criterion) or produced insignificant estimates. Estimating the incidence of “leakage” to neighbouring countries and the impact of vehicle fuel economy on fuel demand also led to insignificant results, as shown in Boxes 3 and 4.

Table 8. Results of first-difference regressions

	Belgium			Germany			Denmark		
Dependent variable: Δf	**M_1**	**M_2**	**M_3**	**M_1**	**M_2**	**M_3**	**M_1**	**M_2**	**M_3**
c	0.02	0.01	0.03	0.00	0.00	0.03	0.02	0.01	0.01
Δp	-0.17**	-0.19***	-0.17***	-0.16***	-0.12**	-0.11**	-0.12	-0.18***	-0.18***
Δy	0.29	0.73***	0.66***	0.85***	1.01***	0.72***	0.63***	0.39**	0.40**
D1974		-0.12***	-0.13***		-0.02	-0.05**		-0.07***	-0.06**
D1975		0.12***	0.10***		0.07**	0.04*		0.10***	0.10***
t			-0.001**			-0.001***			0.0003
Observations	37	37	37	37	37	37	37	37	37
R^2	0.19	0.65	0.71	0.46	0.57	0.71	0.36	0.64	0.65
DW	2.19	1.66	2.06	1.69	1.50	2.11	1.76	1.28	1.30

	Spain			France			Italy		
Dependent variable: Δf	**M_1**	**M_2**	**M_3**	**M_1**	**M_2**	**M_3**	**M_1**	**M_2**	**M_3**
c	0.04	0.03	0.05	0.00	0.00	0.03	0.02	0.01	0.03
Δp	-0.19	-0.17	-0.10	-0.13**	-0.11*	-0.08*	-0.31***	-0.21***	-0.20***
Δy	0.23	0.53	0.95*	0.96***	1.03***	0.84***	0.48**	0.85***	0.57***
D1974					-0.01	-0.04**		-0.10***	-0.11***
D1975		0.14***	0.12**		0.03***	0.01		0.07***	0.04*
t			-0.002			-0.001***			-0.001***
Observations	33	33	33	37	37	37	37	37	37
R^2	0.11	0.31	0.36	0.60	0.63	0.80	0.47	0.74	0.79
DW	1.45	2.19	2.28	1.20**	1.20**	1.83	2.29	1.76	2.13

	Luxembourg			Netherlands			United Kingdom		
Dependent variable: Δf	**M_1**	**M_2**	**M_3**	**M_1**	**M_2**	**M_3**	**M_1**	**M_2**	**M_3**
c	0.05		0.07	0.02	0.01	0.02	0.01	0.01	0.03
Δp	-0.01		-0.01	-0.15**	-0.12*	-0.12*	-0.15***	-0.20***	-0.12**
Δy	0.22		0.21	0.48*	0.65**	0.65***	0.37***	0.28*	0.42***
D1974					-0.08***	-0.08***		-0.04*	-0.04**
D1975					0.07**	0.07**		0.03	-0.01
t			-0.001			-0.001			-0.001***
Observations	28		28	37	37	37	37	37	37
R^2	0.02		0.03	0.20	0.46	0.48	0.45	0.52	0.69
DW	0.98**		0.98**	1.99	1.97	2.04	1.59	1.48	2.13

***: significant at 1%, **: significant at 5%, *: significant at 10%. Standard errors are not adjusted, except for regressions where the Durbin-Watson (DW) statistic permitted to reject autocorrelation at 5% (in those equations, DW is marked with two stars, and Newey-West standard errors are used). For DW statistics in the inconclusive zone of the test, no adjustment was made.

The three models tested are

$$M_1: \quad \Delta f_t = \beta_0 + \beta_1 \Delta p_t + \beta_2 \Delta y_t + \varepsilon_t$$

$$M_2: \quad \Delta f_t = \beta_0 + \beta_1 \Delta p_t + \beta_2 \Delta y_t + \beta_3 D1974 + \beta_4 D1975 + \varepsilon_t$$

$$M_3: \quad \Delta f_t = \beta_0 + \beta_1 \Delta p_t + \beta_2 \Delta y_t + \beta_3 D1974 + \beta_4 D1975 + t + \varepsilon_t$$

D1974 and D1975 are the oil shock dummies. As equations are in first differences, two dummies are needed to account for the year 1974: one for the change from 1973 to 1974 (labelled D1974) and one for the change from 1974 to 1975 (labelled D1975).

Box 3. **The impact of vehicle fuel economy on fuel demand**

The absence of cointegration between total fuel quantities, the real fuel price and real income could be explained by an omitted variable bias. Among those, technological progress improving the fuel economy of vehicles could be potentially decisive[1]. Technological progress is however difficult to capture: any measure of the average fuel economy of the vehicle stock is necessarily endogenous, as it incorporates consumers' vehicle choices shaped by fuel prices and income. Two fuel economy variables are considered here: the average fuel economy of the vehicle fleet, *i.e.* the ratio between total fuel consumption and total vehicle-km driven, and the fuel economy of new cars as revealed by industry tests. The latter may be less affected by endogeneity (even though the indicator needs to be weighted by new car registrations, thereby reintroducing consumer choices), but covers only part of the vehicle fleet. However, both variables do not yield cointegration for Belgium when they are added to equation (4).[2]

The data on vehicle-km travelled however allows to calculate the price elasticity of the demand for distance travelled, by using vehicle-km (vkm) as the dependent variable and estimating the equation

$$\Delta vkm_t = \beta_0 + \beta_1 \Delta p_t + \beta_2 \Delta y_t + \varepsilon_t \quad (7)$$

The result is shown in Table 9. It confirms the findings of Hanly *et al.* (2002): the demand for vehicle-km is reduced less than the demand for road fuel after a price increase. In Belgium, almost half of the fuel quantity adjustment to higher prices in the short-run is therefore due to greater fuel efficiency, *i.e.*, more careful driving, less fuel-intensive journeys or switching to the most fuel-efficient vehicle in a household with several cars.

Table 9. **Price elasticity of the demand for vehicle-km**

Dependent variable	**Δvkm**
c	0.02
Δp	-0.09***
Δy	0.53***
Observations	37
R^2	0.39
DW	1.08

***: significant at 1%, **: significant at 5%, *: significant at 10%. Given the value of the DW statistic, Newey-West standard errors are used.

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1. Other variables, such as the total number of vehicles (which was used for example in Wasserfallen and Güntensperger, 1988) proved to be insignificant, in levels as well as in first differences.

2. The test was carried out with the Engle-Granger procedure, with and without an additional time trend. The variable for the fuel economy of new cars actually does not appear to have a unit root and therefore cannot be included in a single-equation cointegration analysis. When including it anyhow, cointegration tests yield contradictory results (the Engle-Granger test would conclude to cointegration, but the Phillips-Ouliaris and the Park Added Variables test would not) and the variable itself is insignificant.

Box 4. **The effects of fuel tourism in Belgium and the Netherlands**

Fuel tourism, *i.e.* filling up in other countries, can explain why a tax increase in one country may not have the same impact as a uniform oil price increase across a group of countries. An easy way to model this is to include a variable capturing the price difference between the considered country and its direct neighbours in the regression. This has been done for Belgium and the Netherlands, using an average of prices in border states, weighted by the population living in the regions next to the border (arrondissements for Belgium, provinces for the Netherlands). The estimated equation then becomes

$$\Delta f_t = \beta_0 + \beta_1 \Delta p_t + \beta_2 \Delta y_t + + \beta_3 \Delta \frac{p_t}{pa_t} + \varepsilon_t \quad (8)$$

where pa stands for the price abroad. However, this variable proves to be insignificant in Belgium and in the Netherlands, both for real and nominal prices.

Panel estimation

Instead of considering country-specific time series, the above dataset can also be transformed in an unbalanced panel, with 8 cross-sections and 38 observations for all countries except Spain (which has 34 observations).[23] According to econometric theory, panel estimation has several advantages over single-equation time series analysis: it increases the amount of information and thereby the efficiency of the estimates and it allows eliminating unobserved heterogeneity. In the case of fuel demand estimation in particular, Baltagi and Griffin (1997) argue that "using a root mean square error criterion, the efficiency gains from pooling appear to more than offset the biases due to intercountry heterogeneities [for the parameters to estimate]". Thus, even if the single-equation estimates shown above do not appear implausible and vary much less across countries than those of Baltagi and Griffin, there is a case for panel estimation[24].

Theoretically, the absence of cointegration between total fuel, real income and real fuel prices in most countries, as shown above, does not imply the absence of panel cointegration. Thus, the corresponding tests have been performed (all results can again be found in Appendix 3). The panel unit root tests indicate the presence of a unit root in the three relevant variables, but the Pedroni (1999) panel cointegration tests tend to reject cointegration. Therefore, the panel equivalents of equations (4) and (5) could yield spurious regressions, and the first differences of the relevant time series (which are found to be stationary) are again considered. Assuming fixed effects, the following equation is estimated:

$$\Delta f_{it} = \beta_0 + \beta_1 \Delta p_{it} + \beta_2 \Delta y_{it} + c_i + \varepsilon_{it} \quad (9)$$

This equation is estimated using the fixed effects estimator (*i.e.*, OLS estimation on the data transformed by a within transformation).[25] The results are shown in Table 10.

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[23] Luxembourg is excluded from the panel. Indeed, as the insignificant estimates from the single-country setting show, Luxembourg is highly atypical: a large part of its fuel demand is due to "fuel tourism" and depends more on the fuel price differential with neighbouring countries than on the Luxembourgish fuel price per se.

[24] In their regressions for individual countries, Baltagi and Griffin find for the period 1960–90 short-term price elasticities between –0.05 (United Kingdom) and –0.31 (Netherlands) for the eight countries of the present analysis. Their long-term elasticities range between –0.21 (United Kingdom) and –22 (France). The differences with the estimates shown in Table 8 could be due to estimation methods (notably, the use of first differences in the present analysis) or even to spurious regressions (as the drifts in the underlying data and the cointegration issue are not addressed).

[25] Note that even though the data are in first differences, the estimator used is not the first-difference estimator of equation (9). However, the latter yields almost identical results for price elasticity (in turn,

Table 10. **Results for fixed-effect panel estimation**

Dependent variable	**Δf**
c	0.01
Δp	-0.17***
Δy	0.51***
Observations	8 x 37[1]
R^2	0.32
DW	1.81

***: significant at 1%, **: significant at 5%, *: significant at 10%. The estimator used is the panel fixed effects estimator.
1. 37 observations for all countries, except for Spain (33).

With the exception of Italy, the price elasticities found in the single-country analysis were already relatively similar, between -0.12 and -0.20. It is therefore not surprising that panel estimation again yields a significant short-term price elasticity of comparable magnitude, estimated at -0.17. In contrary to Baltagi and Griffin (1997), single-country analysis thus performs relatively well in comparison with the panel. A possible explanation for this could be that the first-difference series used above already permitted to eliminate unobservable country-specific fixed effects in levels. In turn, the fixed effects in growth rates estimated for the panel appear to be relatively small for most countries (and in particular for Belgium), with the exception of Spain, having a consumption growth "surplus" of 2 percentage points per year.

Income elasticities also appeared to be relatively close across countries in the single-country analysis (see Table 8). To highlight the situation for price elasticity, it is possible to estimate an equation with common income elasticity, but country-specific price elasticities. This exercise reveals again that Belgium has a one of the highest price elasticities in international comparison, even if it remains close to the ones of the other countries, with the exception of Italy (see Table 11).

Lags of prices and income were generally found to be insignificant for individual countries (see above). However, adding lagged explanatory variables to the panel equation (9) improves estimation results. This difference can be explained by the greater efficiency of panel estimation. In particular, the significant lags show that the effects of price increases are not limited to the current year, and give an idea of their medium-run impact (see Table 12). Overall, medium-run price elasticity appears to be somewhat larger than the short-run figure: for the entire sample, it is estimated at -0.22 (the sum of the significant price variables in Table 12).

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coefficients for income appear to be different, which may be due to failure of the strong exogeneity assumption, *i.e.*, a correlation between income and the error term). Furthermore, the existence of a fixed effect is not incompatible with the fact that the data is expressed in first differences, because the fixed effect applies to growth rates and not to levels. Fixed effects are chosen over random effects as it cannot be excluded that individual unobserved factors affecting the growth rates of a country are correlated with explanatory variables.

Table 11. **Results for fixed-effect panel estimation with country-specific price elasticities**

Dependent variable	Δf
c	0.01
Δp (Belgium)	-0.17***
Δp (Germany)	-0.18***
Δp (Denmark)	-0.14*
Δp (Spain)	-0.16**
Δp (France)	-0.16**
Δp (Italy)	-0.31***
Δp (Netherlands)	-0.15**
Δp (United Kingdom)	-0.14**
Δy	0.52***
Observations	8 x 37[1]
R^2	0.33
DW	1.78

***: significant at 1%, **: significant at 5%, *: significant at 10%. The estimator used is the panel fixed effects estimator.

1. 37 observations for all countries, except for Spain (33).

Lags of prices and income were generally found to be insignificant for individual countries (see above). However, adding lagged explanatory variables to the panel equation (9) improves estimation results. This difference can be explained by the greater efficiency of panel estimation. In particular, the significant lags show that the effects of price increases are not limited to the current year, and give an idea of their medium-run impact (see Table 12). Overall, medium-run price elasticity appears to be somewhat larger than the short-run figure: for the entire sample, it is estimated at -0.22 (the sum of the significant price variables in Table 12).

Table 12. **Results for fixed-effect panel estimation with lags of the explanatory variables**

Dependent variable	Δf
c	0.01
Δp	-0.17***
$(\Delta p)_{-1}$	-0.05**
$(\Delta p)_{-2}$	-0.03
Δy	0.45***
$(\Delta y)_{-1}$	-0.08
$(\Delta y)_{-2}$	0.19**
Observations	8 x 37[1]
R^2	0.37
DW	2.22

***: significant at 1%, **: significant at 5%, *: significant at 10%. The estimator used is the panel fixed effects estimator. The model chosen minimises the Akaike Information criterion for all possible models allowing at most two lags of the explanatory variables.

1. 37 observations for all countries, except for Spain (33).

In the end, empirical estimations thus indicate that Belgium has a small, but significant short-run price elasticity of fuel demand, which is slightly higher than that of most other European countries. Panel estimation confirms this and also hints toward the existence of a somewhat larger medium-run price elasticity.

Assessment of the impact of an increase in fuel taxes

The empirical estimations above indicate that the short-term price elasticity of fuel demand in Belgium is around –0.18. Panel estimations show that in the medium-run, the reaction of quantities to prices is approximately 30% larger than in the short-run, which would imply a medium-run price elasticity of -0.23 for Belgium. These two figures permit to calculate the impact of different tax increases. Table 13 thus shows the changes in fuel consumption, GHG emissions and fiscal revenues when the government decides to trigger an increase in real prices of respectively 10, 20 and 30%, starting from the 2007 level.

Table 13. **Different scenarios for fuel tax increases in Belgium**

		Scenario 1	Scenario 2	Scenario 3
Real price increase		**10%**	**20%**	**30%**
Absolute increase in real taxes[1]		0.10 €/l	0.20 €/l	0.30 €/l
Final real price[1]		1.10 €/l	1.20 €/l	1.30 €/l
Decrease in fuel consumption	Short-run	140 Kt.	280 Kt.	420 Kt.
	Medium-run	180 Kt.	360 Kt.	540 Kt.
Emission reductions (in brackets: in percent of 2007 level)	Short-run	440 Kt. (-1.8%)	880 Kt. (-3.6%)	1320 Kt. (-5.4%)
	Medium-run	560 Kt. (-2.3%)	1120 Kt. (-4.6%)	1680 Kt. (-6.9%)
Additional real fiscal revenues (in brackets: in percent of real GDP in 2007)	Short-run	0.8 b. € (0.3%)	1.6 b. € (0.6%)	2.4 b. € (0.8%)
	Medium-run	0.8 b. € (0.3%)	1.6 b. € (0.5%)	2.3 b. € (0.8%)

Additional assumptions: All monetary figures are given in Euro, at 2000 prices. The emission factor of fuel is 3.1 tons of CO_2-equivalent per ton of fuel (see above). Real GDP is taken from the OECD "*National Accounts*" database.

1. As in all empirical calculations, quantities and prices were considered in kg for the calculations. However, to give more practical figures, the table indicates prices per litre. The real price of one litre of total fuel in 2007 was 1€, and 9398 l were sold.

This set of estimations indicates that in the short and medium-run, an increase in fuel taxes will only have a small effect on fuel demand and therefore on GHG emissions.[26] This effect is not negligible, but in a scenario where income and transport needs continue to grow, it will probably only be able to offset part of the increase in emissions. On the other hand, the limited decrease in fuel consumption also implies that the additional revenues collected by the state are large.[27] Further consequences, such as potential welfare losses of the overall economy due to higher transport costs cannot be assessed in this simple framework.

In sum, as the price elasticity of fuel demand is low, the Belgian government would need to trigger extremely steep price increases (far greater than the ones considered above) to bring down GHG emissions from transport in the immediate future. This is neither feasible nor desirable, and thus, a successful GHG reduction policy cannot be limited to an increase in fuel taxes. However, when embedded in a more comprehensive strategy, such a measure would not only contribute to the general effort, but also have several positive side-effects. First, it would generate high fiscal revenues, which could be used to finance

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[26] The impact of the different price increases calculated here is approximately in line with results obtained from a more general macroeconomic model (Logghe *et al.*, 2006).

[27] The fiscal revenues calculated here are only rough estimates, and their exact magnitude should be interpreted with care: while fuel tourism was found to be insignificant in the estimation above, this applied to a situation where price deviations between Belgium and other countries were not extraordinarily large. A unilateral Belgian price increase by 20 or 30% could change this situation and make fuel tourism a significant problem. Thus, some degree of European harmonisation for these measures would be desirable.

other reduction measures (targeting for example the emission-intensive industrial and residential sectors). Second, if tax increases were mostly applied to diesel, they would reduce the disequilibrium between the two major transport fuels and contribute to a more uniform taxation of GHG across emissions sources. Finally, by causing durably high fuel prices, additional taxes could encourage transport innovations. While the interaction of the latter with fuel prices is difficult to capture in an empirical study such as the above, it could be decisive for reducing fuel consumption in the long-run.

Bibliography

Badi Baltagi and James Griffin (1983), "*Gasoline demand in the OECD*", European Economic Review, No. 22, P.117–137.

Badi Baltagi and James Griffin (1997), "*Pooled estimators vs. their heterogeneous counterparts in the context of dynamic demand for gasoline*", Journal of Econometrics, Vol. 77, No. 2, P. 303–327.

Belgian federal government (2009), *"Cinquième communication nationale sur les changements climatiques, en vertu de la convention-cadre des Nations Unies sur le changement climatique"*, Service Public Fédéral Santé publique, Sécurité de la Chaîne alimentaire et Environnement, Brussels.

Jan Bentzen (1994), "*An empirical analysis of gasoline demand in Denmark using cointegration techniques*", Energy Economics, Vol. 16, No. 2, P. 139–143.

Martijn Brons, Peter Nijkamp, Eric Pels and Piet Rietveld (2008), "*A meta-analysis of the price elasticity of gasoline demand. A SUR approach*", Energy Economics, Vol. 30, No. 5, P. 2105-2122.

Sunil Chandrasiri (2005), "*Demand for road-fuel in a small developing economy: The case of Sri Lanka*", Energy Policy, Vol. 34, No. 14, P. 1833-1840.

Lucas Davis and Lutz Kilian, "*Estimating the effect of a gasoline tax on carbon emissions*", National Bureau of Economic Research Working Paper N. 14685, NBER, 43 P.

Robert Engle and Byung Sam Yoo (1987) "*Forecasting and testing in co-integrated systems*", Journal of Econometrics, Vol. 35, No. 1, P. 143-159.

Molly Espey (1998), "*Gasoline demand revisited: an international meta-analysis of elasticities*", Energy Economics, Vol. 20, No. 3, P. 273-295.

European Commission (2009), "*Progress towards achieving the Kyoto objectives*", Report from the Commission to the European Parliament and the Council, and Commission Staff Working Document accompanying the report, Brussels.

Eurostat (2009), "*Manual for Air Emissions Accounts*", Eurostat, Luxembourg.

Clive Granger and Paul Newbold (1974), "*Spurious regressions in Econometrics*", Journal of Econometrics, Vol.2, No.2, P. 111-120.

Luciano Gutierrez (2003), "*On the power of panel cointegration tests: a Monte Carlo comparison*", Economics Letters, Vol. 80, No. 1, P. 105-111.

Mark Hanly, Joyce Dargay and Phil Goodwin (2002), *"Review of Income and Price elasticities in the Demand for Road Traffic*", Economic and Social Research Council Transport Studies Unit publication 2002/13, University College London, 95 P.

Jonathan Haughton (1998), "*Estimating Demand Curves for Goods subject to Excise Taxes*", EAGER/PSGE-Excise Project, Methodological Note 2, USAID, 18 P.

Jonathan Hughes, Christopher Knittel and Daniel Sperling (2006), "*Evidence of a Shift in the Short-Run Price Elasticity of Gasoline Demand*", NBER Working Paper No. 12530, 33 P.

John Kennan (1989) "*Simultaneous Equations Bias in Disaggregated Econometric Models*", Review of Economic Studies, Vol. 56, No. 1, P. 151-156.

James MacKinnon (1996), "*Numerical Distribution Functions for Unit Root and Cointegration Tests*", Journal of Applied Econometrics, Vol. 11, No. 6, P. 601-618.

James MacKinnon (2010), "*Critical Values for Cointegration Tests*", Queen's Economics Department Working Paper No. 1227, Queen's University, Kingston, Ontario, 19 P.

OECD (2007), *"OECD Environmental Performance Reviews: Belgium"*, OECD, Paris.

OECD (2008), *"Environmental Performance of Agriculture in OECD countries since 1990"*, OECD, Paris.

Peter Pedroni (1999), "*Critical Values for Cointegration Tests in Heterogeneous Panels with Multiple Regressors*", Oxford Bulletin of Economics and Statistics, Vol. 61, P. 653–670.

M. Hashem Pesaran and Yongcheol Shin (1999), "*An autoregressive distributed lag modeling approach to cointegration analysis*", in Steinar Strøm (editor), "*Econometrics and Economic Theory in the 20th Century: The Ragnar Frisch Centennial Symposium*", Chapter 11, Cambridge University Press, Cambridge.

Markus Pock (2010), "*Gasoline and Diesel Demand in Europe: New Insights*", Energy Economics, Vol. 32, No. 1, P. 54-62.

Dominic Stead (1999), "*Relationships between transport emissions and travel patterns in Britain*", Transport Policy, Vol. 6, No.4, P. 247-258.

Thomas Sterner, Carol Dahl and Mikael Franzén (1994), "*Gasoline tax policy, carbon emissions and the global environment*", Journal of Transport Economics and Policy, Vol. 26, No. 2, P. 109-119.

United States Environmental Protection Agency (2005), "*Greenhouse Gas Emissions from a Typical Passenger Vehicle*", Emission Facts, US EPA, Washington, DC.

Steven Logghe, Bart van Herbruggen and Bruno van Zeebroeck (2006), "*Emissions of Road traffic in Belgium*", Report to the Fédération belge de l'automobile et du cycle (FEBIAC), Transport & Mobility Leuven, Leuven.

Martin Wagner and Jaroslava Hlouskova (2010) "*The Performance of Panel Cointegration Methods: Results from a Large Scale Simulation Study*", Econometric Review, Vol. 29, No. 2, P. 182-223.

Walloon Regional Government (2008), "*Environmental Outlook for Wallonia*", Service Public de Wallonie, Direction générale opérationnelle Agriculture, Ressources naturelles et Environnement, Jambes.

Wallon Regional Government (2010), "*Coût d'investissement d'une éolienne*", http://www.eolien.be/node/57

Walter Wasserfallen and Heinz Güntensperger (1988), "*Gasoline consumption and the stock of motor vehicles*", Energy Economics, Vol. 10, No. 4, P. 276-282.

World Wind Energy Association (2008), "*World Wind Energy Report*" World Wind Energy Association, Bonn.

Appendix 1: Correspondences for energy and GHG intensity

GHG intensity

The IPCC Common Reporting Framework, used to report GHG emissions, is not organized by economic sectors. Therefore, in order to allocate emissions to agriculture, industry, energy production and services, some assumptions had to be made. The according definitions of these sectors and their correspondences with economic sectors such as classified in the Eurostat "Statistical Classification of Economic Activities in the European Community" (NACE) are given in Table A1.1 below. Correspondences are based as far as possible on Eurostat information (Eurostat, 2009, Annex 1).

Table A1.1. **Correspondence between the GHG split and the NACE**

	Emission source (Common Reporting Format, IPCC)	**NACE Rev. 1.1. (Eurostat)**
Agriculture	1 A 4 c Agriculture/Forestry/Fishing (Emissions from Fuel combusted for these activities) + 4 Agriculture (Anthropogenic emissions from agriculture, excepting fuel (see above) and sewage)	A Agriculture + B Fishing
Industry	1 A 2 Manufacturing industries and construction. + 2 Industrial processes	CB Mining and Quarrying except energy producing materials + D Manufacturing - DF Manufacture of coke, refined petroleum products and nuclear fuel + F Construction
Energy industries	1 A 1 Energy industries + 1 B Fugitive Emissions from Fuels	CA Mining and Quarrying of Energy Producing Materials + E40 Electricity, gas, steam and hot water supply + DF Manufacture of coke, refined petroleum products and nuclear fuel
Services	1 A 4 a Commercial/Institutional	G Wholesale and Retail + H Hotels and Restaurants + I63 Supporting transport activities, travel agencies + I64 Post and telecommunications + J Financial Intermediation + K Real estate, Renting and Business + L Public Administration +M Education + N Health + O Other community and Personal Services - O 90 Sewage and Refuse disposal, Sanitation + P Activities of Households + Q Extra-territorial Organizations

The five remaining emission sources, “1 A 3 Transport” (emissions from fuels used for personal or professional transportation), “1 A 4 b Residential” (emissions from fuel combustion in households), “3 Solvent and other product use”, “6 Waste” and “1 A 5 Other” (Military use of fuels or non-specified) could not be allocated to the four economic sectors. They are therefore reported as standalone categories. On the NACE side, the activities related to transport (categories I60–I62), sewage and waste treatment (O90) and water collection and distribution (E41) are not allocated. Finally, for some specific subsectors of industry or energy producers, correspondences are listed below.

Table A1.2. **Detailed correspondence between the GHG split and the NACE for industry and energy production**

	Emission source (Common Reporting Format, IPCC)	**NACE Rev. 1.1. (Eurostat)**
Metal production	1.A.2.a. Iron and Steel + 1.A.2.b. Non-Ferrous Metals + 2.C. Industrial Processes, Metal production	DJ27 Manufacture of basic metals
Chemical industry	1.A.2.c. Chemicals + 2.B. Industrial Processes, Chemical Industry + 2.A.4. Industrial processes, Mineral Products, Soda Ash Production and Use	DG Manufacture of chemicals, chemical products and man-made fibres
Electricity and Heat	1.A.1.a Public electricity and heat production + 1.B.2.a Oil (Transport and Distribution) + 1.B.2.b Natural Gas (Transmission, distribution, ignoring emissions that actually occur in retail outlets (service stations))	E40 Electricity, gas, steam and hot water supply
Fuel production	1.A.1.b Petroleum refining + 1.A.1.c Manufacture of solid fuels and other energy industries (assuming none of these plants has become an independent electricity and heat producer) + 1.B.1. Fugitive emissions from Solid Fuels (excluding production of coke occurring in coke oven furnaces) + 1.B.2.a Oil (Exploration, Production, refining) + 1.B.2.b Natural gas (Production, Processing)	CA Mining and Quarrying of Energy Producing Materials + DF Manufacture of coke, refined petroleum products and nuclear fuel

Energy intensity

Final energy use (FEC) covers the energy consumption of all economic agents, with the exception of energy producers. Furthermore, it does not include the use of energy products for non-energy purposes (*e.g.*, the use of petroleum products in the chemical industry), as those are transformed rather than consumed. Although both energy use statistics and value added by sector are taken from the Eurostat online database, energy statistics are based on an IEA methodology, which splits up FEC among different sectors that do not necessarily correspond to the NACE. The correspondence between the two is generally given in the Eurostat “Concepts and definitions” (CODED) database, and if not, it can be assumed. Correspondences are shown in Table A1.2 below.

Table A1.3. **Correspondence between the FEC split and the NACE**

	Energy statistics (OECD/IEA)	**NACE Rev. 1.1. (Eurostat)**	**Correspondence source**
	102030 Agriculture	A Agriculture	assumed
	102020 Fisheries	B Fishing	assumed
Agriculture	**102030 + 102020**	**A + B**	
	101815 Chemical Industry	DG Manufacture of chemicals, chemical products and man-made fibres	CODED
	101845 Engineering and other metal industry	DJ28 Manufacture of fabricated metal products, except machinery and equipment + DK Man. of machinery and equipment n.e.c. + DL30 Man. of office machinery and computers + DL31 Man. of electrical machinery and apparatus n.e.c. + DL32 Man. of radio, television and communication equipment and apparatus + DM Man. of transport equipment	CODED
	101830 Food, drink & tobacco industry	DA Manufacture of food products; beverages and tobacco	CODED
	101810 Non-ferrous metal industry + 101805 Iron & steel industry	DJ27 Manufacture of basic metals	CODED
	101820 Non-metallic mineral products industry	DI Manufacture of other non-metallic mineral products	CODED
	101825 Ore extraction (except fuels) industry	CB Mining and quarrying except energy producing materials	CODED
	101850 Other non-classified industries	DD Manufacture of wood and wood products + DH Manufacture of rubber and plastic products + DL33 Man. of medical, precision and optical instruments, watches and clocks + DN Man. n.e.c. + F Construction	CODED
	101840 Paper and printing industry	DE Manufacture of pulp, paper and paper products; publishing and printing	CODED
	101835 Textile, leather & clothing industry	DB Manufacture of textiles and textile products + DC Man. of leather and leather products	CODED
Industry	**101805 + 101810 + 101815 + 101820 + 101825 + 101830 + 101835 + 101840 + 101845 + 101850**	**CB + D + F - DF**	
Services	**102035 Services + 102040 Other Sectors**	G Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods + H Hotels and restaurants + I63 Supporting and auxiliary transport activities; activities of travel agencies + I64 Post and telecommunications + J Financial intermediation + K Real estate, renting and business activities + L Public admin. and defence; compulsory social security + M Education + N Health and social work + O Other community, social, personal service activities + P Activities of households + Q Extra-territorial organizations and bodies	Assumed (according to CODED, 102035 corresponds to “Public Administration and services”)

This leaves unallocated, on the energy side, the categories “101900 Transport” and “102010 Households”, which constitute the two last categories of our split. On the NACE side, the value added by energy industries (contained in “CA Mining and Quarrying of Energy Producing Materials”, “E Electricity, gas, steam and water supply” and “DF Manufacture of coke, refined petroleum products and nuclear fuel”) and by transport industries (contained in categories I60 to I62) is left out.

With these definitions, the energy intensity of agriculture, services and industry can finally be calculated. Results for this exercise are shown in Table A1.4.

Table A1.4. **Energy intensity by economic sector (2007)**

	Agriculture		Industry		Services	
	Energy intensity	Change since 1995	Energy intensity	Change since 1995	Energy intensity	Change since 1995
Belgium	0.26	-36%	0.21	-30%	0.02	-12%
Germany	0.11	-12%	0.10	-20%	0.02	-32%
Denmark (2005)	0.31[2]	+16%	0.08	-18%	0.02	-17%
Spain	0.13	+23%	0.15	-11%	0.02	n. a.
France[1]	0.08	+1%	0.12	-18%	0.02	-10%
Italy	0.11	-5%	0.14	+1%	0.02	+25%
Luxembourg (2006)	0.29	+251%	0.27	-40%	0.01	-25%
Netherlands	0.40	-16%	0.17	-10%	0.03	-27%
United Kingdom (2005)	0.06	-30%	0.10	-10%	n.a.	n. a.

Absolute figures are given in tons of oil equivalent per thousand of gross value added (in Euros and constant prices, reference year 2000).

1. All evolutions with respect to 1999.
2. Figures for 2007.

Source: Eurostat.

Appendix 2: Further details on data sources

The quantities of petrol and diesel are taken from the 2009 edition of the IEA's "*Energy statistics*" database. They are given in kilotons, and correspond to the total amounts used in road vehicles, including agricultural and industrial highway use, but excluding use by the military, in stationary engines or by agricultural tractors not circulating on highways. Figures include the biodiesel or biopetrol blended with the mineral fuels: while those may change the carbon content of the fuel, the product remains essentially the same for the consumer, and a 5 or 10% fall in the mineral component of the fuel should not be interpreted as a fall in its demand.[28]

Diesel and petrol prices in national currency (including both excise tax and VAT) come from the "*Energy Prices and Taxes*" (Edition 3rd Quarter 2009) database of the IEA. Petrol prices are obtained from the basic data as an average of the prices of premium leaded petrol and premium unleaded petrol.[29] For the latter, European countries do not always offer the same varieties: some octane ratings can only be found in certain countries. Furthermore, statistics on the quantity split of petrol varieties do not always exist: thus, the IEA choice to regard premium unleaded petrol with 95 RON (available in all countries considered) as most representative for the overall unleaded petrol price is also adopted here. Diesel and petrol prices were converted to prices per kg, in order to be consistent with the quantity statistics.[30]

Price data for 1970–1977, which is not included in the "*Energy Prices and Taxes*" database, comes from an unpublished IEA dataset.[31] However, only industrial diesel prices were available for that period, the main difference between them and end-use prices being VAT. Therefore, VAT has been added back to those prices, using the standard rates of the respective countries, which in most cases are the appropriate ones for diesel.[32]

Data for gross national income in national currency was taken from the OECD's "*National Accounts of OECD Countries*" Database. Both income and prices were deflated with the Consumer Price Index (CPI, base year 2000), taken from the OECD "*Main Economic Indicators*", to obtain their real equivalents.

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[28] The case of pure biofuels is, however, different: just like Liquefied Petroleum Gas (LPG), they are a substitute to mineral fuels, and should not be added to them. Pure biofuels were however hardly ever sold in Europe during the considered time period. The only exception is Germany, where pure biodiesel (B100) had become relatively important. The IEA data do not distinguish pure and blended biofuels, but the exact amount of biodiesel mixed to mineral diesel is available from the Bundesamt für Wirtschaft und Ausfuhrkontrolle (BAFA), for 2005–07. For earlier years, the share of blended biodiesel in the total quantities of the fuel is assumed to be equal to the 2005 share (around 1/3).

[29] A split between internal market deliveries of leaded and unleaded petrol is taken from Eurostat. Deliveries of course do not exactly correspond to the actual use on the road, but deviations with respect to the IEA data are not large (generally smaller than 5% and always smaller than 10%), and for the purpose of the study, only the lead share is important: thus, these series are used to calculate a weighted average between the prices of leaded and unleaded fuel.

[30] Otherwise, when calculating the price of the total fuel aggregate, prices per litre would have to be weighted with quantities in kilotons, which would be inappropriate.

[31] For Luxembourg, no price data is available for that period. For Spain, the series start in 1974.

[32] For two countries, it was possible to be more precise: for Belgium, VAT rates on diesel were given by the Ministry of Finance. In Spain, VAT was only introduced in 1986. When a reduced rate was applied in 1978 (as it was the case in Italy), this reduced rate was used for the period following the last rate change in 1970–77.

Finally, the additional data used in Box 3 was taken from the Service Public Fédéral Mobilité et Transports (for the total vehicle-km travelled in one year) and from another unpublished IEA dataset (for the fuel economy of new vehicles).

Appendix 3: Unit roots, stationarity and cointegration

Unit root tests

Table A3.1 shows the results of ADF tests for the main variables used in the analysis. The test is carried out with the EViews software, and estimates the following equation

$$\Delta y_t = \alpha_0 + \alpha_1 t + \alpha_2 y_{t-1} + \sum_{i=1}^{k} \beta_i \Delta y_{t-1} + \varepsilon_t$$

The null hypothesis $\alpha_2 = 0$ (unit root) is then tested against $\alpha_2 < 0$. The number of lags included is automatically determined by the software using the Schwarz criterion, the maximum number of lags authorized being 9. The following table gives the t-statistic for α_2 and the significance level at which the null hypothesis of a unit root can be rejected, using the critical values given by MacKinnon (1996). The time trend in the test equation is not included for the price time series, which do not have an obvious trend over time.

Table A3.1. **Unit root tests**

Country	Variable	t-statistic	Country	Variable	t-statistic	Country	Variable	t-statistic
Belgium	f	-1.9680	Germany	f	0.0875	Denmark	f	-3.3346*
	p	-2.6407*		p	-1.2493		p	-1.8008
	y	-2.8374		y	-1.7474		y	-2.8584
Spain	f	-2.9438	France	f	-1.5080	Italy	f	-0.8379
	p	-1.5345		p	-1.6582		p	-3.2227**
	y	-2.8136		y	-2.9858		y	-1.8648
Luxembourg	f	-2.4789	Netherlands	f	-2.4176	United Kingdom	f	-0.7913
	p	-2.1054		p	-2.0517		p	-1.4888
	y	-3.2672*		y	-1.3126		y	-1.8254

*** Significant at 1%, ** Significant at 5%, * Significant at 1%. F stands for total fuel, P for the real price of total fuel, and Y for real income. Small letters denote natural logarithms.

Cointegration

Cointegration is tested according to the Engle-Granger procedure: for all countries where the three time series for total fuel, income and prices of total fuel appeared to have a unit root according to the ADF tests, the equation

$$f_t = \beta_0 + \beta_1 p_t + \beta_2 y_t + \varepsilon_t$$

is estimated by OLS, and the residuals from this equation are tested for a unit root with the ADF test, without time trend or constant. The appropriate critical values for the t-statistic are given by Engle and Yoo (1987) respectively by MacKinnon (2010). A necessary hypothesis for this is that real prices and real income are themselves not cointegrated, as this could generate more than one cointegrating vector and invalidate the test. Therefore, this relationship is tested first, with the same Engle–Granger procedure. The results for this preliminary test, shown in Table A3.2, allow us to proceed, and the final cointegration test statistics are shown in Table A3.3.

Table A3.2. **Cointegration test for income and the price of total fuel**

Country	t-statistic	Critical 5%-value (Engle and Yoo, 1987)	Critical 5%-value (MacKinnon, 2010)
Belgium	-0.12	-3.29	-3.50
Germany	-0.56	-3.29	-3.50
Denmark	-0.39	-3.29	-3.50
Spain	0.19	-3.29	-3.52
France	-0.80	-3.29	-3.50
Luxembourg	-0.54	-3.29	-3.55
Netherlands	-1.33	-3.29	-3.50
United Kingdom	-1.60	-3.29	-3.50

Remark: When adding a linear time trend to the cointegrating regression, the results do not change; cointegration is still always rejected at a 5% level.

Table A3.3. **Cointegration tests**

Country	t-statistic	Critical 5%-value (Engle and Yoo, 1987)	Critical 5%-value (MacKinnon, 2010)
Belgium	-1.55	-3.75	-3.97
Germany	-1.04	-3.75	-3.97
Denmark	-2.32	-3.75	-3.97
Spain	-5.22	-3.75	-4.00
France	-1.44	-3.75	-3.97
Luxembourg	-3.72	-3.75	-4.05
Netherlands	-2.58	-3.75	-3.97
United Kingdom	-1.53	-3.75	-3.97

The Engle-Granger procedure is sometimes criticized as performing poorly in small samples. Thus, to control the results, equation (4) was also estimated by fully modified OLS, and the Hansen Instability, the Park Added Variables and the Phillips–Ouliaris test were considered. Those three tests generally yield the same result than the Engle–Granger procedure. The only contradictions appear for Spain and Luxembourg, the countries in which the Engle–Granger test either found cointegration (Spain) or only narrowly rejected it (Luxembourg).

Adding a linear time trend to the above regression, the test statistics and critical values change as shown in Table A3.4. Cointegration is still rejected for most countries, with the exception of Spain and the Netherlands. Again, verification with a fully modified OLS estimation confirms those results: For Spain and the Netherlands, all four tests conclude towards cointegration (except Phillips–Ouliaris for the Netherlands). For the other countries, conclusions sometimes vary, but in general, there is thus only a very weak case for cointegration.

Table A3.4. Cointegration tests with a time trend

Country	t-statistic	Critical 5%-value (MacKinnon, 2010)
Belgium	-1.45	-4.44
Germany	-1.32	-4.44
Denmark	-3.72	-4.44
Spain	-4.89	-4.48
France	-1.09	-4.44
Luxembourg	-4.12	-4.55
Netherlands	-4.84	-4.44
United Kingdom	-4.09	-4.44

Stationarity tests for first differences

In order to test stationarity, a Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test is performed. For the variables for which the null hypothesis of stationarity could be rejected, trend–stationarity was tested by including a linear time trend in the test equation.

Table A3.5. **KPSS test for the stationarity of first differences**

Country	Variable	LM statistic for the null hypothesis of stationarity	LM statistic for the null hypothesis of trend-stationarity
Belgium	Δf	0.2829	
	Δp	0.0773	
	Δy	0.0927	
Germany	Δf	0.6697**	0.0787
	Δp	0.1308	
	Δy	0.2507	
Denmark	Δf	0.0595	
	Δp	0.1018	
	Δy	0.0809	
Spain	Δf	0.2439	
	Δp	0.1066	
	Δy	0.1075	
France	Δf	0.5782**	0.0980
	Δp	0.1528	
	Δy	0.2084	
Italy	Δf	0.5808**	0.1045
	Δp	0.1353	
	Δy	0.5570**	0.0449
Luxembourg	Δf	0.2402	
	Δp	0.1633	
	Δy	0.5000**	0.5000***
Netherlands	Δf	0.1140	
	Δp	0.1074	
	Δy	0.1211	
United Kingdom	Δf	0.3623*	0.0776
	Δp	0.3137	
	Δy	0.2761	

*** The null hypothesis is rejected at a 1% significance level, ** 5% significance level, * 10% significance level. The test was conducted with the standard EViews parameters (Bartlett Kernel, Newey-West bandwith). Small letters denote natural logarithms.

Panel tests

Panel unit root tests are often constructed in a similar manner to the corresponding tests on a single series. There are a large number of them, differing by the assumption of a common or an individual unit root process or by the test statistic used. Below, the five tests included in EViews are shown. As can be seen, they all point into the same direction, and the null hypothesis of a unit root can never be rejected at the 5% level.

Table A3.6. **Panel unit root tests**

	Common unit root process		Individual unit root process		
	Levin, Lin & Chu test	Breitung test	Im, Pesaran and Shin test	ADF-Fisher Chi-square	PP-Fisher Chi-square
Variable	Test statistic	Test statistic	Test statistic	Test statistic	Test statistic
f	1.44	2.85	1.45	12.45	13.97
p	-0.54		-1.40*	21.82	16.60
y	-0.19	-0.81	-0.20	14.95	13.30

All variables expressed in natural logarithms. *** The null hypothesis (existence of a unit root) is rejected at a 1% significance level, ** 5% significance level, * 10% significance level. The test was conducted with individual intercepts and trends for total fuel and income, and just with individual intercepts for the price of total fuel.

The most common panel cointegration tests are inspired from the Engle-Granger procedure. On this basis, Pedroni (1999) proposed seven test statistics for panel cointegration, which are shown below, with and without including a linear time trend in the test equation. Those tests provide mixed results, especially when including a linear trend. Simulation studies have also reached unequal conclusions: while Gutierrez (2003) finds that the rho-statistics have the highest power, Wagner and Hlouskova (2010) find that the ADF tests perform best. In Table A3.7, rho statistics are generally insignificant. The ADF tests, which are sometimes significant, depend heavily on the number of lags used in the test equation: if they are limited to one (as is the standard setting in EViews), they get insignificant, too. Overall, there is thus only weak evidence for panel cointegration.

Table A3.7. **Pedroni panel cointegration tests**

	Common AR coefficients				Individual AR coefficients		
	Panel v-Statistic	Panel rho-Statistic	Panel PP-Statistic	Panel ADF-Statistic	Group rho-Statistic	Group PP-Statistic	Group ADF-Statistic
Without a linear time trend.	0.88	-0.19	-1.78**	-1.57*	1.04	-0.24	0.17
	0.72 (weighted)	0.41 (weighted)	-0.22 (weighted)	0.19 (weighted)			
Including a linear time trend.	2.22**	-0.12	-1.65**	-1.72**	0.87	-0.65	-1.91**
	1.27 (weighted)	0.58 (weighted)	-0.18 (weighted)	-0.07 (weighted)			

*** The null hypothesis (no cointegration) is rejected at a 1% significance level, ** 5% significance level, * 10% significance level. The lag length for the tests is automatically selected using the Schwarz criterion.

Finally, panel unit root tests for first differences show that the existence of a unit root could clearly be rejected for all three underlying time series. It is thus safe to assume that they are stationary.

Table A3.8. **Panel unit root tests for first differences**

	Levin, Lin & Chu test	**Im, Pesaran and Shin test**	**ADF-Fisher Chi-square**	**PP-Fisher Chi-square**
Variable	**Test statistic**	**Test statistic**	**Test statistic**	**Test statistic**
Δf	-11.52***	-10.60***	127.41***	130.78***
Δp	-13.83***	-11.83***	143.82***	155.33***
Δy	-6.88***	-8.04***	92.78***	93.77***

*** The null hypothesis (existence of a unit root) is rejected at a 1% significance level, ** 5% significance level, * 10% significance level. The test was conducted with individual intercepts for all variables and without time trends (This is why the Breitung test, which requires a time trend, is excluded).

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