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Essays on motor fuel taxation and price dynamics in the European Union

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ESSAYS ON MOTOR FUEL TAXATION AND PRICE DYNAMICS

IN THE EUROPEAN UNION

BY

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In loving memory of a person who always encouraged learning, my grandmother, Nanai Zaynab Enikeeva. She used to say that every day brings a new discovery that should not be missed.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

ESSAYS ON MOTOR FUEL TAXATION AND PRICE DYNAMICS IN THE EUROPEAN UNION

by

Aliya Sassi

University of New Hampshire, December, 2012

When the economic literature refers to characteristics of the motor fuel market in the EU, one has to be cautious in comparing indicators across time and space because of the ongoing enlargement of the Union. This dissertation contributes to a limited empirical literature on motor fuel fiscal competition and discussions on fuel tourism and fiscal policy coordination in Europe. The first essay provides an overview of the EU market from 1994 to 2010 for four major motor fuels and its evolution at every stage of EU expansion. It examines changes in the characteristics and taxation rates of the EU *representative* member-country and shows that the EU countries decreased their motor fuel excise taxes, but increased VAT taxes.

There has been an ongoing dialogue in the EU about tax harmonization because fuel taxes impact prices of other goods as well as economic and environmental policies across Europe. Prior empirical literature on motor fuel convergence either ignores newer

member states or was published before data for some of those states was available. The second essay empirically tests for club convergence in prices and taxes for four motor fuels used by the EU. It treats older and newer member states separately and also distinguishes between Eurozone and non-Eurozone countries. By analyzing these categories of countries separately, it attempts to obtain a more accurate picture of fuel tax and price convergence and finds some evidence for the emergence of market segmentation. The methodology allows for non-linearity of data, an important feature of prices.

By building upon the theoretical literature on fiscal federalism, the third essay empirically examines how political, economic, environmental and geographical factors influence taxes on motor fuels in the EU. It uses 2004-2010 data and spatial modeling techniques and finds that a 10% increase in the motor fuel excise tax by neighbors results in an up to 6% excise tax increase by an EU country. Countries in the EU also positively respond to VAT tax changes by their neighbors, meaning that national governments recognize mobility of tax bases for both motor fuels excise taxes and VAT taxes.

ESSAY 1: 1994 – 2010 ENLARGEMENT OF THE EU AND THE EUROPEAN MARKET FOR MOTOR FUELS

1.1. INTRODUCTION

Essay I of this dissertation provides a historical discussion of the motor fuel market in the European Union (EU) between 1994 and 2010. It compares differences in economic and transport related characteristics of a typical member country since the EU creation in 1993. Chapters 1.6.1 - 1.6.4 look at a few stages of the EU enlargement and their impact on the formation of taxation policies and real prices for four major motor fuels in the Common European Market.

The contributions of this essay to the literature are threefold. Firstly, the paper compares the evolution of motor fuel consumer prices, producer prices, and taxes between older and newer member states, as well as between the Eurozone and non-Eurozone countries. To date, prior literature on motor fuels in the EU analyzed only the data for the older member countries and for fewer motor fuel types. This paper looks at the EU and its taxation structure as a larger, more complex system because of its historical enlargement to the east.

Secondly, prior studies often compared tax shares among the EU member states, which do not serve as best indicators of the tax dynamics between countries. This is because an increase or a drop of tax share in a consumer price may be caused by two factors: a change in a motor fuel producer price or a change in total taxes, or by any combination of the two. In addition, changes in total tax level for motor fuels depend on both value added tax (VAT), a percent tax, and a lump-sum excise tax. This gives an additional complexity to the European motor fuel tax system because different EU members may have different incentives for shifting between these two types of taxes.

Lastly, this paper recognizes that one of the common characteristics of the national taxation structures in the EU is that member states practice double-taxing of motor fuels. The VAT tax, an ad-valorem percentage tax, is typically levied *after* the excise tax, a specific lump-sum amount tax, as well as all local taxes have been added to the producer price, which results in an additional tax premium. Since the compositions of the excise and the VAT taxes differ among the EU members, the dynamics of total motor fuel taxes also differ. Prior literature typically ignores double-taxation of motor fuels in the EU and pays attention mostly to differences in excise taxes among members. Nevertheless, our data show that in 2004-2010, real values of these additional tax premiums in the EU were ranging from €0.056-0.115 per one liter of unleaded gasoline and €0.045-0.083 for diesel.

This paper uses the newest weekly data for 1994-2010 for four major motor fuels from the EU Oil Bulletin published by the European Commission (see Appendix 1.A for data description). The results are useful for contributing to a historical dialogue about the Common European Market for motor fuels and to the discussions surrounding tax harmonization processes in the EU.

1.2. THE ENLARGEMENT OF THE EU, ITS TRANSPORT AND MOTOR FUEL POLICIES

The origin of the European Union goes back to the Treaty of Rome in 1957, when six European countries with relatively similar economic statuses decided to form the European Economic Community, or the EEC (Table 1). Thirty six years later, in 1993, twelve European countries formally established The European Union, or the EU (EU-12). Since then, the Union has experienced a few stages of enlargement: in 1995, 2004, and 2007. The largest expansion happened in 2004, when ten Central and Eastern European countries joined the Union. The twenty five countries that formed the EU before its last expansion in 2007 are typically known as the EU-25. Currently, the EU unites twenty seven member countries (EU-27). For the purposes of this essay, the twelve countries that formed the EU in 1993 and the three countries that joined it in 1995 are referred to as older member states (OMS). The twelve countries that joined the EU in 2004 are referred to as newer member states (NMS). In addition to OMS and NMS, the EU can be divided into the Eurozone and non-Eurozone countries. Differences in motor fuel taxation and prices between OMS and NMS, as well as between the Eurozone and non-Eurozone groups will be examined later in this essay.

Once a country joins the EU, it becomes a part of the common European Internal Market zone that unites the EU member countries. Today, the EU consists of members that are diverse not only geographically, but also culturally and economically. Seventeen[1]

[1] As of January 1, 2012. Sixteen countries were the Eurozone members at the time of this study.

out of twenty seven EU members also share a common monetary policy as well as a common currency – the Euro. Despite the existence of common policies and goals among the EU members, national-level control over taxation is still considered to be a symbol of sovereignty for most European countries, e.g. (Ring, 2008). Although a part of the larger union, each member country still determines its own national bundle of taxation, budgetary, and energy policies[2]. It became a general practice, therefore, that the European Commission implements tax floors on certain goods including motor fuels, leaving it to the individual EU members to establish national taxation structures and tax levels.

Governments rely on tax revenues to fulfill their budgetary obligations, so tax revenues, including motor fuel tax revenues, are important to them. In the EU, revenues from indirect taxes, such as VAT and excise taxes, on average account for about 14% of the GDP and between 30-55% of total tax revenues. At the same time, revenues from motor fuel excise taxes account for about 1.5-2% of GDP and 4-5% of total tax revenues (Eurostat, 2011). Macroeconomic impact of taxing motor fuels is far more outreaching than taxing other goods. This is because transportation costs are imbedded in the price of most consumption goods and services, and taxes levied on motor fuels in the EU account for a greater share of final consumer price than in the U.S.

In addition to contributing to budget revenues, motor fuel taxes are also corrective taxes. Pigou (1932) was the first to propose that gasoline taxes help reduce externalities associated with motor fuel consumption, such as vehicle-related emissions. Gasoline taxes, therefore, reduce gasoline consumption towards a socially optimal level; this is

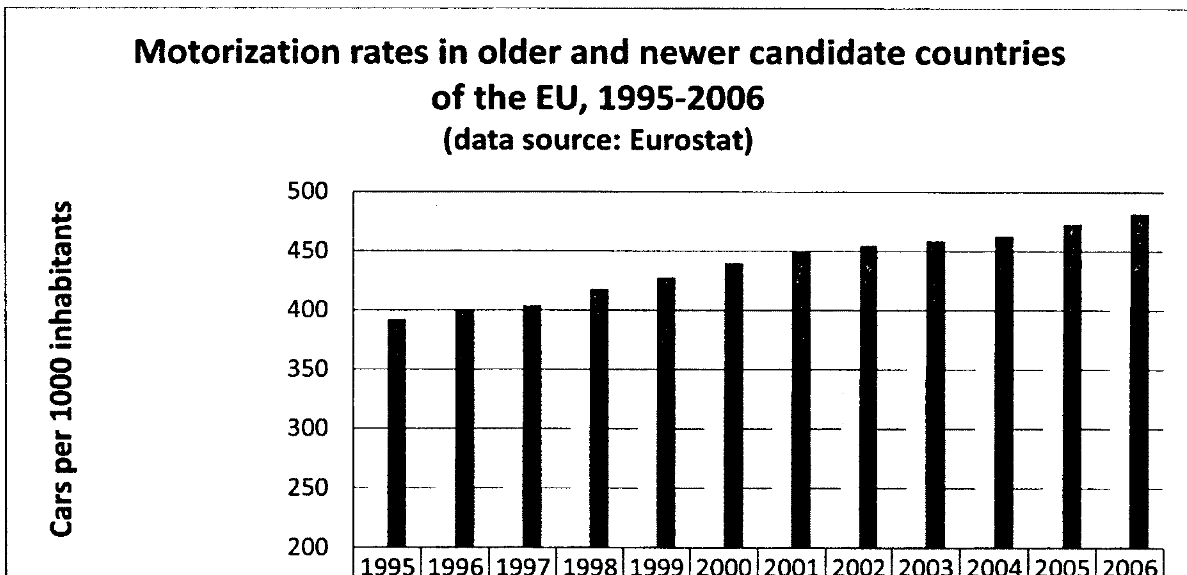
[2] In March 2012, however, by signing a Fiscal Compact Treaty, all members of the EU except for the U.K. and the Czech Republic agreed upon collectively tightening fiscal measures starting 2013 (Council of the European Union (CEU), 2012).

known as a Pigouvian role of taxes. Taxes remain the major policy tools in addressing emissions from road transport (see Appendix 1.B), and revenues from these taxes in the EU are not typically earmarked for road projects like in the U.S. (Newbery & Santos, 1999). The extent to which each national government employs them for either correction of market externalities or revenue generation plays an important role in fuel tax dynamics in all of Europe. In spite of taxation policies in place, since 1990, emissions from the transportation sector in the EU-27 have increased by approximately 21% (Eurostat, 2011, pp. 138-139). At the same time, emissions from all other sectors of the economy have decreased.

Changes of the EU as a Union also played an important role in explaining these tax dynamics. Table 2 shows that characteristics of the EU have significantly changed since its creation, both because of its enlargement and because of changes within individual countries. Its total population has increased from roughly 186 million people in 1957 (then EEC), to 350 million in 1993, and to 501 million in 2010. With every stage of the enlargement, the characteristics of what is typically referred to as the EU *representative* member country (RMC) have also changed. Between 1993 and 2007, the average population of a RMC has dropped from 29 million to 18 million, suggesting that smaller, relatively less populated countries have joined the union during this period.

At the same time, mean per capita GDP of a typical RMC citizen has increased by about 20%: from $23,777 in 1993 to $27,232 in 2007 (in $2005, Table 2). Since 1957 when the first European community – the EEC – was created, mean real GDP per capita had increased roughly 2.6 times by 2007 (Table 2). Table 2 shows that these dramatic economic improvements occurred because of ongoing growth in the average growth rate of GDP as well as greater trade openness. These factors also played a crucial role in changes related to transport and fuel consumption in every EU member country. The inland freight volume of the union has nearly doubled between the time of its formation in 1993 and the last enlargement in 2007: a jump from 833.9 to 1,719.9 billion T-km respectively (Table 2). During the same period, the annual inland passenger volume for private cars had also increased by roughly 1,400 billion passenger-km. The overall stock of passenger cars in the EU grew from 145.4 million vehicles in 1993 to 219.7 million in 2007. Although, on average, the number of new passenger vehicle registrations had decreased from 880 to 592 thousand cars per year per RMC, per capita motorization rates showed a steady growth in both OMS as well as NMS.

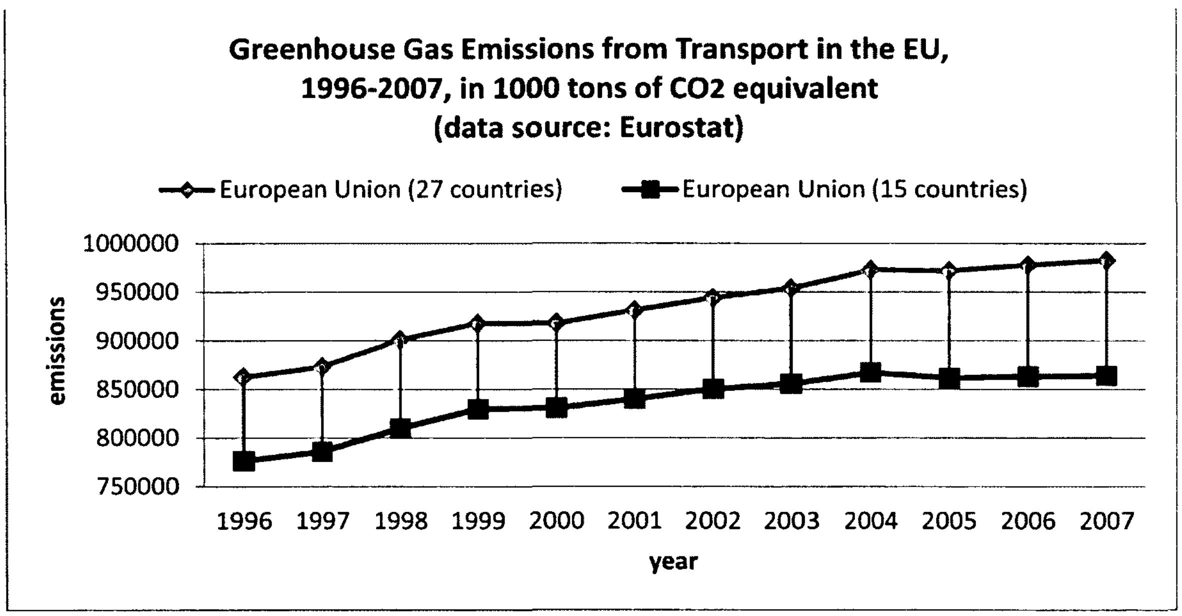
Figure 1.



	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
NMS (newer members, candidates)	267	275	295	305	317	328	332	342	353	365	382	404
■ EU-15 (older members)	392	401	404	418	428	440	449	455	459	463	473	482

Figure 1 displays motorizations rates in OMS and NMS groups, or the average number of cars per 1000 inhabitants. The gap in the motorization rate between the older and the (future) newer members of the EU has been steadily decreasing since the 1990s (Figure 1). With the exception of 2001, the motorization rates for ten countries that eventually became NMS have been growing faster than the motorization rates for the fifteen OMS. What this means is that on average, residents in NMS have been acquiring vehicles at much higher rates than those in OMS, e.g. (Eurostat, 2009a, pp. 39-40). In short, by 2007, a RMC became better off economically, had higher levels of motor fuel consumption and fewer new passenger cars registered every year, even though motorization rates rose.

Figure 2.



Changes in the EU have also resulted in a decrease in the overall European volume of greenhouse gas (GHG) emissions, e.g. (European Environment Agency (EEA), 2009, p. 23), but in an increase of emissions from transport (Eurostat, 2009c, p. 143). In 1993, the twelve original EU members released about 871 million tons of GHG emissions from transport (in CO_2 equivalent), and in 2007 the twenty seven EU members of the expanded Union generated 1,298 million tons (Table 2). Thus, by 2007 a RMC produced on average fewer emissions from transport. Figure 2 shows that, starting in 2004, the emissions reduction efforts were especially evident for the fifteen original members that were able to stabilize their GHG emissions from transport. After 2004, the increase in emissions from transport was primarily due to higher contributions of NMS countries (Figure 2).

The efforts to reduce overall GHG emissions in Europe have been mostly successful when directed at other sectors of the economy, but not in regard to the transportation sector (Eurostat, 2009c, p. 143). Emissions from transport in the EU grew in spite of the fact that producer prices and VAT taxes on all motor fuels had increased between 1994 and 2010 (Table 4). A reduction of real excise taxes on these fuels by 14-18% during this period may have played a part in an increase of emissions from transport. Nevertheless, real consumer prices on unleaded petrol and diesel motor fuels increased by 12-25% during this period (Table 4), while nominal prices were up by 68-88% respectively (Table 5). This is why it is important to examine a relationship between European motor fuel prices and taxes: these factors are major policy taxes for economic activity related to passenger transport in the EU.

1.3. MOTOR FUEL CONSUMPTION IN THE EU

Out of four types of motor fuels discussed in this dissertation – unleaded gasoline, leaded gasoline, automotive gas oil (diesel), and liquefied petroleum gas (LPG) fuel – diesel is the most popular motor fuel in the EU. About 209,059 kilotons of oil equivalent of this fuel is consumed in the EU annually, accounting for roughly 70% of all motor fuel consumption (Figure 3). Diesel fuel typically powers larger vehicles that form the EU freight fleet and plays an important role in facilitation of European trade.

Both diesel and unleaded Euro-super-95 gasoline remain popular fuel choices among passenger car owners. Figure 3 shows that in 2010, consumption of unleaded Euro-super-95 gasoline in the EU accounted for roughly 30% of total motor fuel consumption. In addition, over half of passenger cars in the EU were petrol-driven (Eurostat, 2009c, p. 93). Nevertheless, according to Eurostat, by the late 2000s, the share of diesel-powered passenger cars in the EU has increased, surpassing in some countries a 50% benchmark, for example, in Belgium (59%) or Austria (55%).

Although this dissertation also discusses historical data for leaded gasoline, this fuel was phased out from the EU market by the mid-2000s (Löfgren & Hammar, 2000). Since January 2000, the EU has prohibited sales of leaded gasoline on its territory due to its harmful impact on human health and the environment. Leaded gasoline used to be particularly popular in Eastern and Central Europe, and many NMS continued using it until they joined the EU in 2004. In the past, this fuel was a cheaper alternative to a cleaner unleaded Euro-super-95 gasoline.

Figure 3.

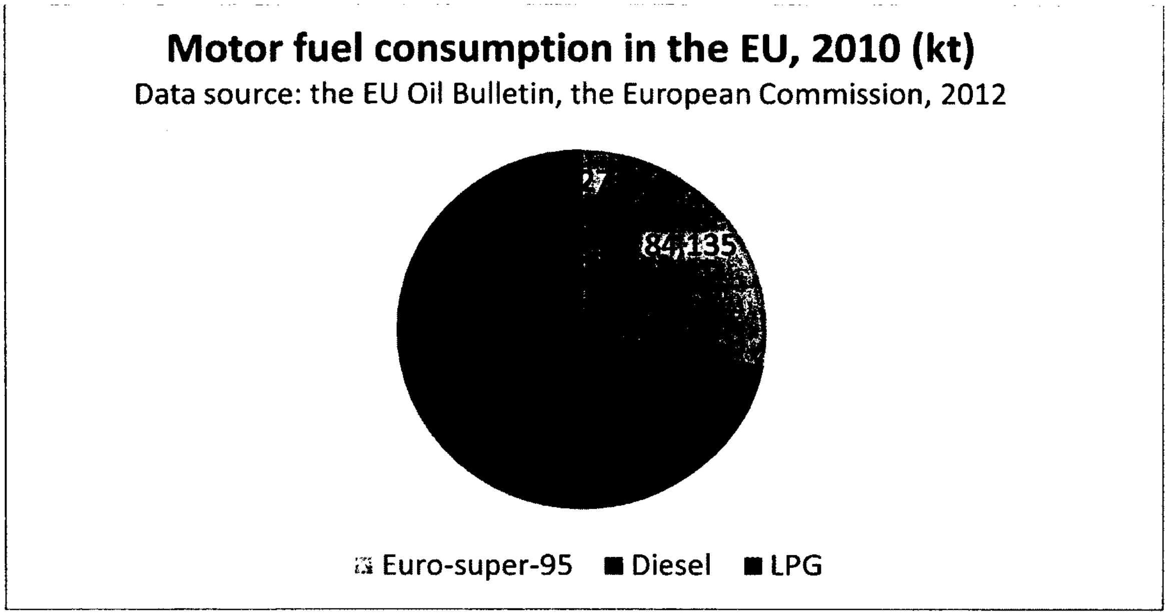


Figure 3 shows that in 2010 consumption of liquefied petroleum gas (LPG) was equal to 4,527 kiloton of oil equivalent; it was much lower than consumption of diesel and unleaded gasoline. Liquefied petroleum gas accounted for only 2% of the EU total motor fuel consumption, in part due to lower energy content of this fuel compared to unleaded gasoline and diesel. In addition, in order to use LPG, vehicles must have an internal combustion engine instead of a spark ignition engine. Compared to environmental characteristics of other motor fuels, LPG has an advantage because it produces lower amount of particulates. Currently, this fuel is being consumed in limited amounts in the EU countries in part because of inconvenience to consumers: the EU has a relatively poor network of LPG refueling stations.

Finally, it is worth noting that these motor fuels are not substitutes in the short run. Each fuel type requires a different engine specification, so the consumer can switch from one fuel type to another only in the long run, by either acquiring a new or modifying the existing vehicle.

1.4. THE STRUCTURE OF GASOLINE TAXES IN THE EU

Although this paper focuses on motor fuels, the general discussion in this sub-chapter can be applied towards other cases when several taxes are levied together on the same good, such as so-called 'sin' goods; for example, motor fuel, cigarettes, alcohol, etc. The key points here are to examine the two types of taxes levied on motor fuels in the EU, the VAT and the excise tax, and to discuss the varied perceptions of fairness that are typically associated with double taxation.

There are two major motor fuel taxes that the EU motor fuel consumers pay: an ad valorem type (VAT) and a lump-sum type (excise) tax. Both types are taxes on consumption, with national governments receiving the entire revenues and sellers acting as facilitators of intermediate tax accounting and collection.

The VAT, or the value added tax, is an ad-valorem type tax that is proportional to the price. It is levied in the form of a percentage on the volume of purchase. From the end consumer's point of view, a VAT levied on most goods, including motor fuels, in the EU is the same as a conventional retail sales tax in the U.S. The main difference between a VAT and a conventional retail sales tax is that the latter is only levied when a good is sold to the end user, while the former, VAT, is paid upon every sales transaction. Yet, with appropriate accounting and paperwork, non-end users, namely sellers and manufacturers, can deduct VAT previously paid by them on inputs, so the tax is only applied to the 'value added' during the last stage of production.

By contrast, excise taxes are product-specific; they are typically levied to partially discourage consumption of so-called 'sin' goods that create negative externalities, such as motor fuels, alcohol and cigarettes. These lump-sum taxes are levied in a form of a fixed monetary amount per unit sold or volume purchased. The motor fuel excise taxes in the EU are set as a fixed lump-sum per 1000 liters of fuel, for example, €359 per 1000 liters of unleaded Euro-super-95. As a result, the impact on a consumer price from changes in taxes or producer prices is not straightforward: ad-valorem type taxes may magnify changes triggered by shocks on production side, while lump-sum taxes are sensitive to inflation and require constant revisions to maintain their real values (e.g. England, 2009).

In order to address European environmental objectives, EU legislation sets the following minimum rates on fuel excise taxes: €421, €359, €330, and €125 per 1000 liters of leaded, unleaded, diesel, and LPG fuels respectively (CEU, 2003, Council Directive 2003/96/EC, Annex I). Current EU legislation also requires a standard minimum VAT rate of 15% on most goods, including motor fuels (CEU, 2006, Council Directive 2006/112/EC, Article 97). Both legislations allowed certain exceptions. For example, Luxembourg levied a lower VAT rate of 12% on unleaded gasoline from 1994 to 2004. Portugal is another EU member that had lower VAT rates of 5% and 12% on diesel between 1994 and 1996 (CEC, 1977, Council Directive 77/388/EEC[3]). Although the EU countries are not bound to a VAT tax ceiling, in 1996 they came to a collective agreement to make "every effort" not to exceed a 25% VAT benchmark.[4] It is challenging for the EU as a union to make changes to its fuel tax floors because such

[3] with subsequent amendments.

[4] European Parliament Fact Sheets. 3.4.5. Value added tax (VAT). http://www.europarl.europa.eu/factsheets/3_4_5_en.htm

decisions require unanimous voting by the EU members (CEU, 2003, Council Directive 2003/96/EC, Article 29). This limits flexibility of indirect taxation, impacting tax coordination processes in the EU. The unanimity rule was challenged in 2003 by a proposal to replace it with majority voting, but the change was not agreed upon by the members, which is just another example of tax revisions being a politically challenging task.

From the economists' perspective, "the number of times the item is taxed is economically meaningless", because economists are typically concerned only with the total tax level (Gale & Slemrod, 2001, p.624). Moreover, economists would argue that even in the imperfectly competitive motor fuel market, both VAT and excise taxes on motor fuel will have similar impacts on price. This is because there are no significant quality differences in motor fuels sold under the same name across the EU countries; for example, in unleaded gasoline Euro-super-95. By contrast, a common excise tax on cigarettes eliminates relative price differences across brands of different quality, reducing the effect of anti-smoking policy and making the VAT tax more attractive to policymakers (Cnossen, 2006). Under either the VAT or excise tax on motor fuel, therefore, national governments would obtain the same effect of motor fuel consumption discouragement, but they may also encounter voters' disagreement with the fairness of a smaller excise tax. This is because a smaller motor fuel excise tax in lieu of a higher general VAT tax may create a perception among the general public that vehicle users do not pay for pollution that they produce.

A higher reliance on VAT tax also forces national governments to tax domestic fuel producers more heavily because the biggest portion of the value added is typically created at home during the refinery stage of motor fuel production. In addition, the volatile nature of the world oil price in combination with higher reliance on VAT (per cent) causes final motor fuel consumer prices to fluctuate at an even wider range, resulting in both greater uncertainty among producers and macroeconomic instability (England, 2009). If motor fuel producers and consumer prices do not move in sync, it can impact cyclical market changes. Hence, from the policymakers' perspective, the choice between the VAT and the excise tax is dictated by a combination of factors, from economic factors to the variety of views on tax fairness among voters.

In setting tax levels, policymakers also often face claims by the opposing side that may portray tax-setting in an unfavorable light (see Gale & Slemrod, 2001, for discussion). One of the arguments that may arise when two types of taxes are levied on the product at the same time (an ad valorem tax and a lump-sum tax) is the case of double taxation. Yet, those who often bear a heavier portion of the tax burden might find such taxation schemes unfair. Double taxation has already been a hot topic for debate in other areas of economic policy, for example, taxing dividends is often portrayed as unfair. This is because corporations pay income taxes on profits before distributing a portion of their after-tax profits to shareholders, who are then obligated to pay personal taxes on their dividends (e.g. Rosen, 2005, p.433). In this context, it is important to briefly discuss who pays a higher share of the tax burden and how gasoline excise tax incidence is different than the incidence, for example, of the cigarette excise tax.

Typically, when taxes are being levied, both producers and consumers take on some of the burden. The shares of these burdens are determined by differences in elasticities of demand and supply, that is, by differences in percentage reactions to a one per cent change in price. For both cigarettes and motor fuels, demand is less elastic than supply, so the tax burden is shifted towards consumers (e.g. Alm, et al., 2009; Chernic & Reschovsky, 1997; England, 2007; Cnossen & Smart, 2005). This is because consumers cannot always easily give up smoking or substitute one type of motor fuel for another, at least in the short run. For example, Chouinard and Perloff (2004) show that in the U.S., elasticity of supply is greater in states that sell less gasoline, and that consumers in small states pay a higher share of gasoline tax burden than those in large states. This is because for cigarettes, consumers are the ones primarily involved in cigarette 'smuggling,' but for gasoline, wholesalers are the ones moving motor fuel across borders (e.g. Lovenheim, 2008).

Since the EU consumers are specifically concerned with the fairness of the motor fuel tax (Hammar & Jagers, 2007), the way in which taxes are levied on motor fuels in Europe is worth closer examination. Double taxing of vehicle motor fuel exists in the EU because the VAT is levied on the volume of the purchase after the lump-sum excise tax has been added. Equation 1 shows that in the EU, a consumer pays the following price per one liter of motor fuel[5]:

$$P^C = (P^P + T + L)(1 + VAT)\,, \tag{1}$$

where P^C and P^P denote consumer and producer prices respectively (in €), T is the excise tax (in €), L is a combination of other local unit taxes (in €) and VAT represents the value

[5] This simplified equation intends to demonstrate the structure of the motor fuel taxes in the EU. Under the assumption of perfectly elastic supply, it also represents the supply curve. In the long run, this assumption seems reasonable. In the short run, however, both supply and demand are inelastic, but demand is arguably less elastic than supply because motor fuels have no close substitutes. Appendix D provides an additional discussion for a more complex case of inelastic supply. Also see Chouinard and Perloff (2004) who show that in the U.S., for example, the state gasoline tax falls almost entirely on consumers, not wholesalers.

added tax (in %). Since local lump-sum taxes L are typically small compared to other taxes, I omit them and re-write Equation 1 for a single liter purchase (Equation 2):

$$P^C = P^P(1 + VAT) + T(1 + VAT) \tag{2}$$

The last term of Equation 2 shows that, in addition to producer price, the VAT tax base includes lump-sum taxes. The EU data on motor fuels show that these additional tax premiums $(T \cdot VAT)$ varied across member countries and were relatively large. For example, in 2004-2010, these tax premiums reached, on average, €0.085 per one liter of unleaded gasoline and €0.064 for diesel (see Appendix 1.C, Figures 9-10). Next, by total differentiation of Equation 2 with respect to time I obtain Equation 3:

$$\frac{dP^C}{dt} = \frac{dP^P}{dt}(1 + VAT) + P^P\frac{dVAT}{dt} + \frac{dT}{dt} + \left(T\frac{dVAT}{dt} + VAT\frac{dT}{dt}\right) \tag{3}$$

The first term on the right hand side of Equation 3 suggests that an increase in producer price for motor fuel causes both consumer price and the VAT tax revenue from one liter of fuel to increase. The second and the third terms on the right hand side of Equation 3 mean that any change in either VAT or excise tax rates impacts the consumer price. The last two terms in the brackets on the right hand side of Equation 3 suggest that any change in one tax on motor fuel further magnifies the impact of another tax on consumer price.

In sum, any changes in either the excise tax or the VAT tax introduce additional shocks to producers and consumers. Because of the perception of fairness, these shocks, as well as the choice between the two types of taxes, may be more meaningful than has been previously assumed by studies that only include the excise taxes in their framework (e.g. Dreher & Kreiger, 2008). Additional tax burdens from double-taxing in the EU are most likely to be passed on to motor fuel consumers because the elasticity of demand is lower than the elasticity of supply (e.g. Chouinard & Perloff, 2004; Pock, 2010). This is why it is worth examining motor fuel taxation patterns in the EU: it allows for more meaningful motor fuel price and tax comparisons across the EU members.

1.5. OPTIMAL TAXATION AND THE DOUBLE DIVIDEND OF THE MOTOR FUEL EXCISE TAX

Economic literature on optimal taxation discussing the distortionary impact of taxes deals with the optimal choice of type and rate of the tax. Frank Ramsey (1927) suggested that governments should set tax rates in such a way that marginal deadweight losses of different taxation policies are equalized. According to Ramsey's inverse elasticity rule, unless the labor supply is inelastic, necessities, such as gasoline, should be taxed more heavily than luxuries (Ramsey, 1927, p.58). The Ramsey rule is often critiqued on the grounds of key assumptions, implementability, and fairness (see Selim, 2007 for a comprehensive summary). Nan (1995), for example, shows that under the Clinton administration, petroleum and energy products were taxed at rates higher than Ramsey's excess burden minimizing rates in part because the rule ignores government budgets.

Minimizing total excess burden is not the only goal in choosing the tax rate; motor fuel excise taxes also reduce motor fuel consumption to a socially optimal level by reducing externalities associated with fuel consumption (Pigou, 1932). Ramsey (1927, p.47) specifically states that he excludes the Pigouvian feature of the tax from his assessment of the tax burden. Yet, while motor fuels' excise taxes are environmental (Pigouvian) taxes by nature, internalizing externalities is not the only gain associated with this tax policy. This is because environmental taxes impact prices on goods and services and distort both consumers' choices and the labor market.

During the last couple of decades, debates about "green tax reforms" emphasized important interaction between new environmental policies and existing taxation policies in place (Pearce, 1991; Rotemberg & Woodford, 1994; Oates, 1995; Ballard et al., 2005, among others). These debates are based on the so-called 'double dividend' literature that suggests that Pigouvian taxes can be used not only to reduce pollution levels, but also to reduce existing distortionary non-environmental taxes, for example, income, labor, or sales taxes, resulting in a 'double dividend' (Sandmo, 1975; Terkla, 1984). That is, an increasingly popular idea among policymakers is the idea behind the double dividend: to tax "bads" instead of "goods" (Pigou, 1932) by "swapping" environmental taxes for non-environmental distortive taxes (Glouder, 1995; 1998).

In addition to the Pigouvian effect of reduced externalities, there are two other effects of every tax policy that a policymaker must consider: a revenue-recycling effect and a tax-interaction effect (Parry, 1995; Glouder, 1995). The revenue-recycling effect suggests that environmental tax revenues may be recycled to reduce gross distortionary costs of taxation policies. The tax-interaction effect works in the opposite direction than the revenue-recycling effect; it suggests that reduced rates of pre-existing distortionary taxes will not necessarily fully offset the non-environmental distortions created by the new environmental tax. Just like other taxes, environmental taxes, such as motor fuel excise taxes, alter the pattern of economic activity. They raise the cost of production and magnify distortions generated by pre-existing taxes on factors of production (capital and labor), creating a tax-interaction effect (Bovenberg & de Mooij, 1994b). The tax-interaction effect is also found to be of a greater magnitude in a second best policy setting (e.g. Glouder, 1998), the point relevant to taxation of motor fuels.

Glouder (1995) distinguishes between a weak and a strong version of the double dividend. A *weak* double dividend is associated with welfare improvement for the case when recycling environmental tax revenues via distortionary tax cuts results in cost savings, compared to the case when these revenues are returned in a lump-sum fashion (e.g. Metcalf et al., 2004; Babiker et al., 2003). A *strong* double dividend refers to revenue-neutral tax substitution with zero or negative gross cost of tax policy changes (Bovenberg & de Mooij, 1994a, 1994b).

Empirical studies of the double dividend typically use computational general equilibrium models and provide mixed findings, but generally find some support for the double dividend of the gasoline excise tax. For example, Gloom et al. (2008) find that increasing gasoline and fuel taxes in the U.S. and recycling revenues to reduce capital income taxes lead to welfare gains from both an increased consumption and an improvement in environmental quality. Van Heerden et al. (2006) find a positive double dividend effect of gasoline consumption taxes in South Africa, for the case when tax revenues are recycled to either reduce VAT taxes or food prices. Their results also suggest that recycling gasoline tax revenues to reduce food prices also leads to a GDP increase. Bovenberg and Glouder (1997) evaluate an increase in U.S. federal gasoline taxes for the revenue-neutral case, with revenues being devoted to a reduction in income taxes. According to Bovenberg and Glouder (1997), although this policy produces a tax-shifting effect away from the over-taxed factor of production (capital) towards the under-taxed factor (labor), while gross costs of the policy are reduced, they remain positive.

To summarize, when implementing environmental policy, a policymaker has to take into consideration interdependence of various tax policies because of the interacting goals of these policies. On one hand, 'green' gasoline excise taxes affect consumers and producers both directly and indirectly. These taxes also have a regressive effect on low-income population, including both vehicle drivers as well as non-drivers that consume goods with high embedded transportation costs. On the other hand, gasoline excise taxes increase welfare because of both the Pigouvian effect and the revenue-recycling effect; but they may also partially decrease welfare because of the tax-interaction effect. By further increasing the existing motor fuel excise taxes, the EU national governments may consider exploring the double dividend side of this tax by lowering, for example, a distortive VAT consumption tax.

1.6. MOTOR FUEL PRICES AND TAXES IN 1994-2010

1.6.1. A General Overview of Real Price Dynamics in the EU

The EU is a good example for analyzing motor fuel prices and taxation patterns in both the short and long runs. In Europe, unlike the U.S., taxation is a primary policy tool for reducing GHG emissions from transport, which results in overall higher levels of motor fuel taxes and greater variation in tax rates among countries. Between 1994 and 2010, the EU average real prices for motor fuels increased between 2% and 25% (Table 4),[6] depending on the fuel type.

Producer prices and, more importantly, changes in the price of oil, were key elements in determining the behavior of consumer prices (Figures 4-5). From 1994 to 2010 real consumer prices on two major motor fuels, such as unleaded fuel and diesel fuel, had increased by an average of €173-€199, or by 12-25%. During the same period, producer prices on these fuels had increased by an average of €113-€192, which corresponds to an increase of 62-76% in producer price (Table 4). During this period, the price of oil was largely influenced by global geopolitical events, including the 2004 enlargement of the EU. For example, the growing oil prices in 2003-2008 may be explained by a rapid global economic expansion, which was met by a stagnant supply. In addition, geopolitical and speculative factors also played some role on this oil price growth (e.g. Kesicki, 2010; Turner, et al., 2011; Coleman, 2012). A subsequent

[6] Monthly consumer price indices (CPI) from the UNECE Statistical Division database are used here to convert tax and price data into real values. See Appendix E for addition discussion.

Figure 4.

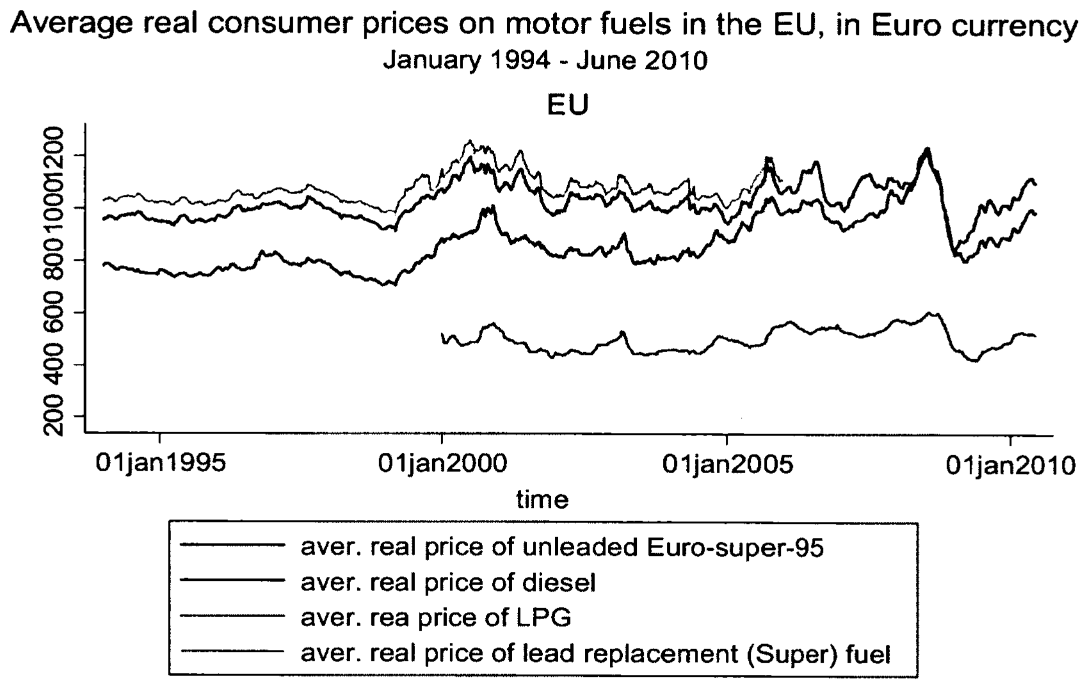
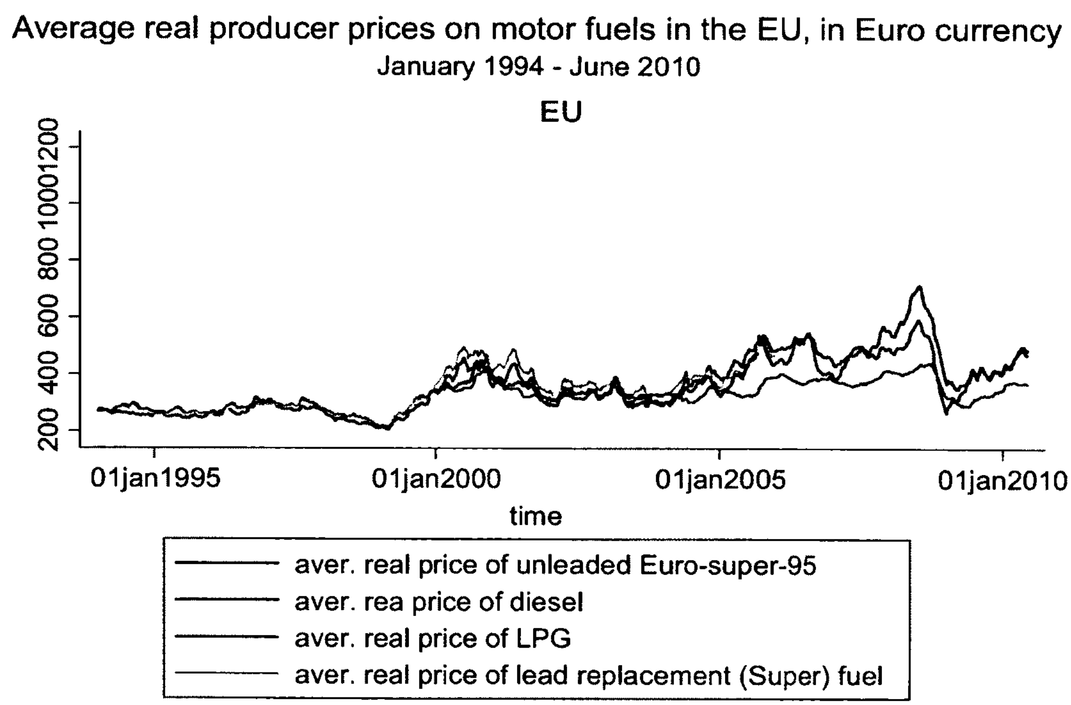


Figure 5.



sharp drop of motor fuel prices in the EU in the late 2000s may be explained by the global financial crisis of 2008 and the slow recovery, including an economic downturn in the EU.

Over time, however, real consumer prices on motor fuels can only be partially explained by producer price levels and dynamics. Until 2004, real producer prices were roughly equal among different motor fuel types, suggesting that taxes and their composition were also major components of motor fuel price analysis. Figures 4 and 5 show that tax differences introduced price differences between different types of motor fuels. Although from 1994 to 2010 both producer and consumer prices on motor fuels increased, the average levels and compositions of taxes on motor fuels for a typical EU country also changed.

Prior studies of motor fuel taxes in the EU often concentrated on tax shares (taxes as percentages of final consumer prices of fuel), which do not necessarily accurately reflect the real extent of tax burden and taxation dynamics (e.g. Dreher & Krieger, 2008, 2010). This is because any combination of the two factors may impact the change of motor fuel tax shares over time: producer prices and tax rates. All else constant, tax share in a consumer price may drop solely because of an increase in producer price. In the EU, depending on the motor fuel type, both factors played a role in tax share changes (Table 4). Furthermore, tax share calculations normally focus on just the excise tax.

To conclude, in spite of the fact that in 2004 the EU grew and took over more diverse and economically weaker countries, motor fuel taxing behavior became much more similar across the enlarged Union (EU-27), especially for VAT taxes (Table 4). In addition, although total level of taxes on unleaded gasoline have decreased by about 8.7%, it appears that on average, the EU member countries did not display strong "race-to-the-bottom" type tax setting behavior. They rather moved towards an overall decrease in their excise taxes, but an increase of VAT taxes on vehicle motor fuels. This is despite of greater volatility of the oil price and motor fuel producer prices than in the mid-1990s, and the fact that VAT tax is a percent tax that intensifies such volatility of producer prices. The movement away from a lump-sum excise tax towards an ad-valorem VAT tax suggests that the EU national governments were willing to rely more on volatile but potentially higher tax revenues than in the mid-1990s. Thus, such a move away from excise taxes towards VAT taxes is not surprising, since the price of oil had been primarily growing during the analyzed period. In addition, reduction of excise taxes in the EU may also indirectly suggest some degree of fiscal competition among member states in terms of setting their motor fuel excise taxes.

1.6.2. Motor Fuel Taxes and Prices in OMS versus NMS

The biggest expansion of the EU occurred in 2004, when ten countries from Eastern and Central Europe joined the Union. Because of Soviet-type inherited models of industrial organization, transport infrastructures, and environmental regulations, these NMS were less economically advanced and had poorer environmental quality than OMS (e.g. Carmin & VanDeveer, 2005). Upon their membership in 2004, NMS were obligated to adopt the entire legislative and regulatory body of the EU, the *acquis communautaire*, including the common environmental regulatory framework. In practice, however, their political will and ability to implement these environmental policies remained questionable (e.g. Schreurs, 2005; Pavlinek & Pickles, 2005). Because of the *acquis* and because in the 2000s tax harmonization was at the forefront of the EU policy arena, it is worth examining motor fuel price and tax dynamics in NMS separately from OMS.

Since 2004 when NMS joined the EU, it was expected that these countries would raise and harmonize their taxation policies with the existing EU members, and that motor fuel prices in NMS would reflect the pricing situation on the Internal European Market. Such harmonization process was impacted by two factors. Firstly, compared to OMS, almost all NMS were facing higher motorization growth rates (Eurostat, 2009a, p. 39-40); higher motor fuel taxes could have slowed down the economic activity. Secondly, while under the Kyoto Protocol OMS committed to sharing the burden of reducing EU emissions in 2008-2012 (CEU, 2002, Council Decision 2002/358/EC), NMS were facing individual, non-shared emission reduction targets. This is because the Kyoto Protocol was ratified in 2004, before NMS joined the EU. For most NMS, such emission reduction targets were not a concern and provided rather a comfortable safety net in case a country decided to significantly increase its emission level. With the exception of Slovenia, actual emissions in NMS countries were considerably lower than their set Kyoto targets (e.g. Eurostat, 2009b, p. 18). In addition, Cyprus and Malta did not face any Kyoto targets at all.

Between 2004 and 2010, real consumer prices for unleaded gasoline in NMS countries were, on average, about 24-30% lower than in OMS countries. For diesel, this difference increased from 12% to 21%. By 2010, these differences corresponded to €280 per 1000 liters for unleaded gasoline and €182 for diesel respectively (Table 6). Surprisingly, differences in motor fuel producer prices between OMS and NMS groups were relatively small compared to differences in motor fuel consumer prices. For example, in 2010, average differences in real producer prices for Euro-super-95 gasoline and diesel fuel were about 13-14%. Taxation, hence, rather than producer price differences, played a major role in a consumer price gap between these two groups, OMS and NMS. For example, the real tax burden of unleaded gasoline was, on average, 45-47% higher in OMS than in NMS, or by €225-228 per 1000 liters. For diesel, this difference was also substantial, 27-28% or €109-121 per 1000 liters of diesel (Table 6).

Compared to other motor fuels, LPG fuel was roughly half as expensive. The average difference in real consumer prices between OMS and NMS groups was also smaller for LPG than for other fuels (Table 6). By 2010, this difference corresponded to about €0.097 per one liter of LPG fuel, or 20%, up from 6% in 2004. Because LPG fuel is considered to be environmentally cleaner, taxes on LPG fuel were much lower than taxes on other motor fuels. Yet, unlike the situation for other motor fuels, total taxes on LPG were slightly higher in the NMS group (Table 6). Although this taxation gap between NMS and OMS had decreased in the late 2000s, on average, higher producer prices in OMS outweighed the impact of higher taxes in NMS for this fuel. As a result, despite higher taxes, LPG fuel was cheaper on the territories of newer members of the Union.

Real consumer prices on LPG were especially high in France and Bulgaria and low in Belgium and Luxembourg. High LPG consumer prices in France were driven by the highest LPG producer prices in Europe. Bulgaria was a special case, a country that possessed both high taxes and high producer prices on LPG fuel. As a result, the most expensive LPG fuel in the EU was in Bulgaria. Low LPG prices in Belgium and Luxembourg can be explained by low taxes.

1.6.3. Policy 'Leaders,' 'Fence-sitters' and 'Foot-draggers'

The environmental policy literature suggests that there were behavioral differences among the national governments in their approaches to environmental policy, for example, between northern and southern European countries (e.g. Pavlinek & Pickles, 2005). In addition, differences in approaches to environmental taxation existed not only between OMS and NMS groups, but also among the OMS themselves. Denmark, the Netherlands and Germany, along with Austria, Finland and Sweden, were often referred to as 'leaders' or 'pace-setters' in shaping the EU environmental regulation (e.g. Liefferink & Andersen, 1998). By contrast, Portugal, Greece and Spain were known as 'laggards' or 'foot-draggers,' because they often acted as reluctant environmental policy-takers in the EU (Börzel, 2005). These terms tend to refer more broadly to countries' personality types in setting environmental policy.

In relation to motor fuels, the OMS data for 1994-2010 show that some 'leaders' ('pace-setters') like Denmark, the Netherlands, and Finland had the highest real consumer prices on unleaded gasoline; other 'leaders' like Sweden and Germany – on diesel. These OMS, along with the U.K. had traditionally kept their motor fuel taxes among the highest in the EU.

The U.K. is an interesting case on its own. Britain was typically referred to as a 'fence-sitter' in European environmental policy, a country that either takes an indifferent position, or switches its behavior from a 'laggard' to an occasional 'pace-setter' (e.g. Börzel, 2005). In relation to motor fuels, however, the U.K. had been known as a definite 'leader' in part, perhaps, due to natural geographical barriers to cross-border motor fuel shopping. Starting in the late 1990s, the U.K. earned its reputation for its high prices on all types of motor fuel, primarily because of much tighter motor fuel taxation policies than in other EU countries, especially for diesel. In some years, total taxes paid on unleaded gasoline were over 80% of the final consumer price (Smith, 2000). By the end of the 2000s, nevertheless, British prices on motor fuels became more moderate and harmonized with the rest of the EU, due, in part, to a temporary decrease of VAT rates and fuel tax freezes.

Starting in 2000, the U.K. suffered from a series of large protests against high motor fuel prices that were driven by high taxes. Many protesters were conservative farmers and truck drivers; in 2000, for example, they blocked access to fuel refineries and eventually caused temporary shortages of gasoline at fueling stations (e.g. The Economist, 2000; 2012). Nevertheless, protests gained some public support, and the British government agreed to revise and freeze fuel excise tax rates. Protests continued for almost a decade, and in 2011, the government promised to implement a flexible taxation stabilizing scheme (e.g. Hotter, 2011).

Most environmental policy 'pace-setters' displayed their typical policy-setting personalities in relation to motor fuel taxation, but not all 'foot-draggers' did the same. Just like with other environmental policies, with motor fuel taxation policies, Spain remained a 'laggard' while Portugal did not. The data show that in 1993-2010 Portugal, for example, paid close attention to its motor fuel taxation policies and adjusted its excise taxes more often than any other EU member: 52 times for unleaded gasoline and 35 times for diesel.

Greece also remained a 'laggard' up until the financial crisis of the late 2000s. After keeping motor fuel taxes low for years, Greece sharply increased them to address budgetary needs rather than environmental concerns. A sharp increase of motor fuel taxes led to a steep jump in motor fuel consumer prices, with Greek motor fuel prices quickly becoming among the highest in the EU. These policies, however, don't imply that Greece switched its policy-setting personality from a 'laggard' to a 'leader.' It is rather consistent with the economic literature that originated in works by Ramsey (1927): at a time of fiscal difficulties, countries often increase their indirect taxes on consumption goods, including motor fuel excise taxes, rather than taxes on income and savings. By doing so, governments encourage work rather than leisure (e.g. Selim, 2007).

Although a typical environmental policy 'fence-sitter,' Luxembourg was one of the two biggest 'foot-draggers,' or 'laggards,' in motor fuel taxation. Both Luxemburg and Spain, traditionally maintained their motor fuel taxes low, especially compared to other OMS. As a consequence, Luxembourg and Spain traditionally had some of the lowest real consumer prices on unleaded and diesel fuels among OMS. Their motor fuel prices and taxes were more consistent with NMS levels than OMS levels. This may also be the reason why, by the late 2000s, Luxembourg and Spain continued to be absolute leaders in per capita greenhouse gas emissions in the EU (EEA, 2009, p.27).

Because of the common environmental commitments, before and immediately after the 2004 expansion of the Union, there was a concern that NMS would join the 'laggards' and offset the progressive nature of the EU environmental policy (VanDeveer & Carmin, 2005). Most NMS entered the EU in 2004 with relatively modest taxation rates. Some of them became new 'leaders,' at least among NMS, while others did, indeed, remain 'laggards.'

On the one hand, by the end of 2000s many newer members made efforts to harmonize their motor fuel taxes with OMS levels. For example, during the late 2000s Malta and the Baltic countries, such as Estonia and Lithuania, raised their taxes on unleaded gasoline and diesel. Similarly, Slovenia, a country that already had relatively high taxes on diesel compared to other NMS, also raised them to levels more consistent with diesel tax levels of OMS. Lithuania was the only country that drastically raised its LPG taxes by increasing both the VAT tax rates and more than doubling its LPG excise tax rates. With the exception of Slovenia, harmonization efforts of these NMS cannot be directly attributed to compliance with their 2008-2012 Kyoto emission targets. This is because in 2009, the average emissions in Estonia and Lithuania were already below their individual Kyoto targets; Malta had no assigned targets at all (EEA, 2009, p.71-73). Nevertheless, all of these motor fuel policy changes had occurred in the late 2000s, that is, at the time of financial crisis. These policy changes, hence, may be partially attributed to countries' addressing their budgetary needs, rather than to environmental political pressures from the rest of the EU.

On the other hand, some NMS joined the motor fuel policy 'laggards' group. Cyprus, for example, remained known as one European country with some of the lowest taxes. Consequently, in 2004-2010, real consumer prices for both unleaded petrol and diesel in Cyprus were low. The fact that Cyprus did not face any Kyoto emission reduction targets may help explain low motor fuel taxes and why Cyprus was among few EU members with per capita growth in emissions (EEA, 2009, p.27). Between 1990 and

2007, transport-related emissions in Cyprus nearly tripled (EEA, 2010, p.15). Finally, in the late 2000s, some NMS entered the Eurozone. This new membership introduced an opportunity to reexamine their national motor fuel taxes.

1.6.4. Motor Fuel Taxes and Prices in the Eurozone versus Non-Eurozone Countries

The Eurozone, the zone of a common currency – the Euro, originated in 1999 as a single monetary union between eleven EU members. In 2001, Greece also joined the Eurozone; Slovenia, Slovakia, Cyprus and Malta joined it in the late 2000s. By non-Eurozone, this paper refers to the EU members that were a part of the EU between 1999 and 2010, but not a part of the Eurozone (Table 1).

The data show that between 1999 and 2010, real consumer prices on leaded, unleaded and diesel motor fuels were, on average, different between the Eurozone and non-Eurozone groups (e.g. Figure 6). Since real motor fuel producer prices in these two sets of countries were roughly the same, differences in taxes, hence, once again help explain this consumer price disparity. For leaded and unleaded gasoline, average tax and, consequently, consumer price differences remained large even after 2004, about €100-180 per 1000 liters.

For diesel, however, tax and real consumer prices difference became negligible after 2004, at least until the late 2000s (Figure 7). For LPG fuel, taxes in non-Eurozone countries were on average slightly higher than in the Eurozone both before and after 2004. Yet, the real consumer prices on LPG were, on average, higher in the Eurozone because of higher producer prices in this group.

Figure 6.

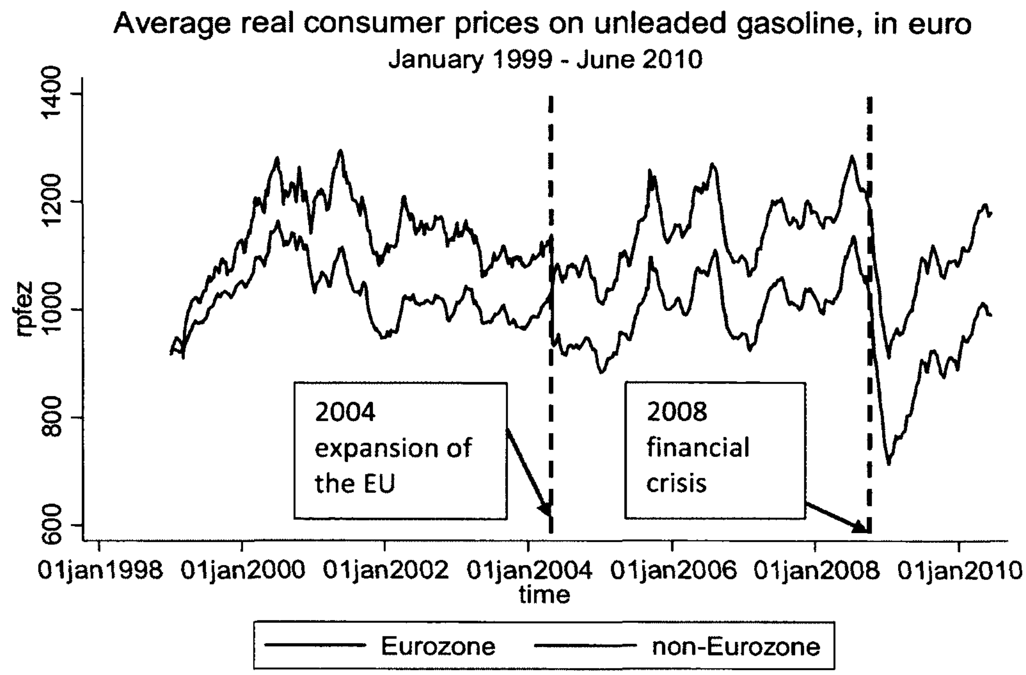
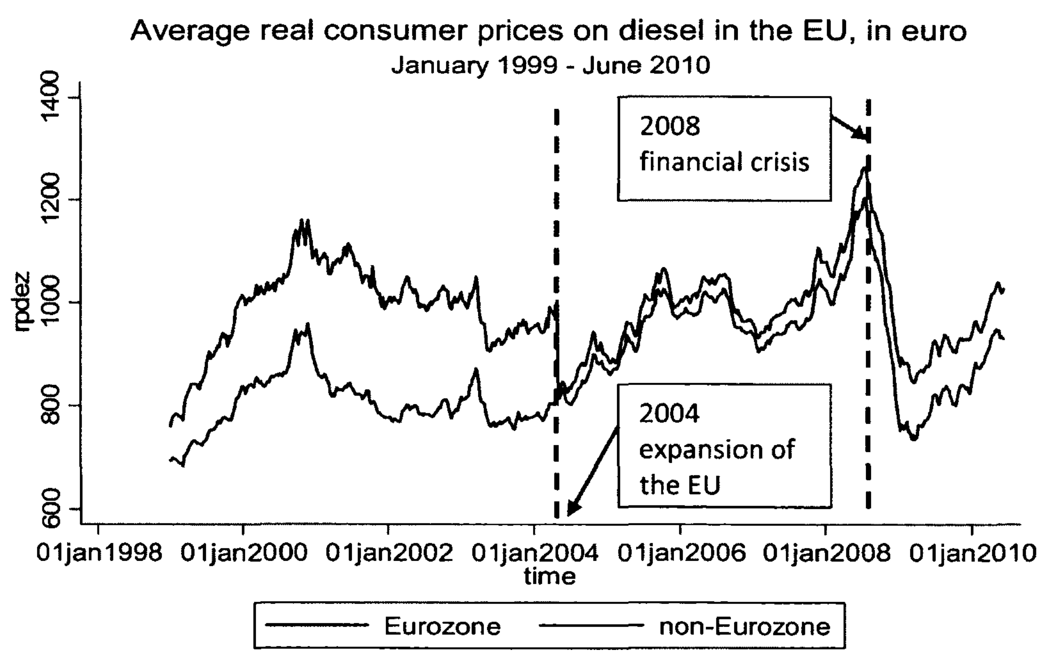


Figure 7.



There were a few major reasons for these differences in motor fuel taxation between the Eurozone and non-Eurozone. Firstly, at any point in time, the Eurozone countries possessed different economic characteristics than non-Eurozone countries. Before the 2004 enlargement of the EU, the non-Eurozone group consisted of the economically superior Scandinavian countries and the U.K., countries that were known as 'leaders' in motor fuel taxation. Then, in 2004, the average consumer prices on motor fuels in the non-Eurozone group experienced a sharp drop (Figures 6-7). After the 2004 EU enlargement, most countries in the new, enlarged non-Eurozone group were from the economically weaker Eastern and Central Europe (Table 1).

Secondly, inflation may have played an important role in motor fuel policy design for these two groups. National excise tax rates are sensitive to inflation because they are established in a form of fixed lump-sum amounts in national currency. The inflation rate in the Eurozone has been low because of its conservative approach to a common monetary policy. By contrast, inflation and reliability of real excise tax revenues may have been a concern in countries that joined the non-Eurozone group after 2004. Unless excise taxes were adjusted frequently, like in Slovenia and Hungary, the fixed nominal amount of the motor fuel excise tax made the corresponding tax revenues vulnerable to inflation (e.g. England, 2009). Also, frequent adjustment of motor fuel excise taxes is often a politically challenging task. For some new members of the Eurozone, however, switching to the euro currency gave an opportunity to reevaluate motor fuel excise tax policies. For example, Slovakia, after joining the Eurozone in 2009, altogether canceled its excise tax rates on LPG fuel.

Lastly, consumer prices in the Eurozone countries were displayed in the same currency, allowing for easy comparison among its members. Discounting other factors, non-Eurozone consumers did not always possess perfect information about exchange rates, inflation rates, and fuel prices in neighboring countries to make similarity comparisons at the time of their purchase. Under these circumstances of incomplete information in non-Eurozone countries, pressures on national governments from their citizens regarding motor fuel policies could have been weaker than in the Eurozone. Diesel fuel prices in 2004-2009 were the exception because on average there were no significant price differences between the Eurozone and non-Eurozone. This may indirectly suggest that NMS countries were under pressure to reduce diesel fuel tourism that is typically caused by truck drivers, who are highly mobile across national borders and compare prices more frequently.

CONCLUSION

Between the early 1990s and 2010, the motor fuel market in the EU went through a series of drastic changes. A variety of factors influenced these transformations – from the EU enlargement, to the creation of the Eurozone, to dramatic changes in both production costs and tax structures of individual member countries. By looking at OMS and NMS as well as at the Eurozone and non-Eurozone countries as separate but related groups, this essay provides a better picture of the EU motor fuel market of the 1990s-2000s. Nobody has gathered this information in a single paper before, especially for the newer EU member-countries. This is exactly where this essay fits in the literature. I believe it is important for the European Commission policymakers and other stakeholders to understand the complexity of the EU transformations and their impact on motor fuel market and tax-setting behaviors of both newer and older member-countries.

After the creation of Eurozone in 1999, average producer prices on motor fuels were nearly identical between the Eurozone and non-Eurozone countries, with the exception of LPG fuel. Tax levels, however, were higher in the non-Eurozone group. After the largest expansion of the EU in 2004, differences in taxation between OMS and NMS introduced substantial differences in real consumer prices between these groups. When NMS countries joined the EU in 2004, they also changed the composition of the non-Eurozone group. If, before 2004, average consumer prices on leaded, unleaded and diesel fuels were, on average, lower in the Eurozone, after 2004 the situation had reversed. This was because the ten newer members were primarily from Eastern and

Central Europe; they were weaker economically and had lower motor fuel taxes than OMS countries. At the same time, real producer prices remained almost identical between the OMS and NMS during the entire period of 2004-2010. The data also show that while motor fuel tax shares in the EU, on average, decreased, it happened primarily due to raising producer prices and higher oil prices.

In order to guide the motor fuel internal market in the EU, the European Commission imposed tax floor policies (e.g. CEU, 2003, Council Directive 2003/96/EC). Following these guidelines, the member states were free in setting their own national motor fuel policies. In setting environmental policies, different OMS traditionally were known for their different policy setting personalities as either 'leaders,' 'fence-sitters,' or 'laggards.' This paper shows that in taxing motor fuels, OMS also assumed the corresponding personalities, except for the U.K. that became a 'leader.' For example, some OMS traditionally kept their motor fuel taxes either low, like Spain, or high, like the Netherlands. Newer states also assumed similar personalities as either 'laggards' or 'leaders,' at least among NMS. The analysis also reveals that for some NMS 'leaders,' changes in motor fuel policies could be attributed to adapting to the financial crisis of the late 2000s, rather than to addressing environmental concerns such as transport emissions.

One of the key takeaways of this essay is that an important outcome of the EU transformation, in real terms, is that the EU members were slowly switching from lump-sum motor fuel excise taxes to ad valorem VAT taxes. That is, they were shifting the tax burden away from polluters towards the general public, which partially explains why the EU transportation sector was the only sector of the economy that experienced an absolute increase in exhaust emissions.

Overall, this essay lays the groundwork for studying the unified internal market for motor fuel in the EU and whether long-term prices and tax policies will become more homogeneous over time. The question remains, however, about the long-term outcome of these transformations in the EU and how members' individual policy-setting personalities reacted to these changes. This question can be answered only empirically. Understanding how these tax-policy setting personalities of individual member states interact with each other in a complex system like the EU is critical for predicting both short-term and long-term motor fuel price outcomes.

One testable hypothesis for future research is that, based on findings about differences in NMSs' tax policy-setting personalities, at least some NMS will harmonize their taxes on motor fuels with OMS in the long run. It is possible, given that motor fuel differences in producer prices remain small, tax-setting behaviors will drive fiscal harmonization efforts as well as transport emission reduction efforts in the EU both in the short and the long run. Another hypothesis worth testing is whether differences and similarities in socio-economic factors, for example, between the EU members that are neighbors, serve as additional factors that shape a country's tax-setting personality. These questions will be researched in the next two essays of this dissertation.

Table 1. Year of Entry to the European Community, the EU, and the Eurozone

<table>
<tr><th>Country</th><th>Code</th><th>Year Joined</th><th>OMS vs. NMS</th><th>Euro-zone Since</th><th colspan="5">The EU Enlargement Timeline</th></tr>
<tr><td>Belgium</td><td>BE</td><td>1957</td><td>OMS</td><td>1999</td><td rowspan="6">Treaty of Rome (1957) established the European Economic Community (EEC), and later the European Community (EC) in 1967</td><td rowspan="12">Maastricht Treaty (1993). The EU is formed (EU-12)</td><td rowspan="15">The first enlarge ment of the EU (1995). The EU-15 is formed</td><td rowspan="25">The biggest enlarge ment of the EU (2004). This group of countries is referred to as EU-25</td><td rowspan="27">EU-27</td></tr>
<tr><td>France</td><td>FR</td><td>1957</td><td>OMS</td><td>1999</td></tr>
<tr><td>Germany</td><td>DE</td><td>1957</td><td>OMS</td><td>1999</td></tr>
<tr><td>Italy</td><td>IT</td><td>1957</td><td>OMS</td><td>1999</td></tr>
<tr><td>Luxembourg</td><td>LU</td><td>1957</td><td>OMS</td><td>1999</td></tr>
<tr><td>Netherlands</td><td>NL</td><td>1957</td><td>OMS</td><td>1999</td></tr>
<tr><td>Denmark</td><td>DK</td><td>1973</td><td>OMS</td><td>-</td><td rowspan="21"></td></tr>
<tr><td>Ireland</td><td>IE</td><td>1973</td><td>OMS</td><td>1999</td></tr>
<tr><td>The U.K.</td><td>UK</td><td>1973</td><td>OMS</td><td>-</td></tr>
<tr><td>Greece</td><td>EL</td><td>1981</td><td>OMS</td><td>2001</td></tr>
<tr><td>Portugal</td><td>PT</td><td>1986</td><td>OMS</td><td>1999</td></tr>
<tr><td>Spain</td><td>ES</td><td>1986</td><td>OMS</td><td>1999</td></tr>
<tr><td>Austria</td><td>AU</td><td>1995</td><td>OMS</td><td>1999</td><td rowspan="15"></td></tr>
<tr><td>Finland</td><td>FI</td><td>1995</td><td>OMS</td><td>1999</td></tr>
<tr><td>Sweden</td><td>SE</td><td>1995</td><td>OMS</td><td>-</td></tr>
<tr><td>Cyprus</td><td>CY</td><td>2004</td><td>NWS</td><td>2008</td><td rowspan="12"></td></tr>
<tr><td>Czech Republic</td><td>CZ</td><td>2004</td><td>NMS</td><td>-</td></tr>
<tr><td>Estonia</td><td>EE</td><td>2004</td><td>NMS</td><td>2011</td></tr>
<tr><td>Hungary</td><td>HU</td><td>2004</td><td>NMS</td><td>-</td></tr>
<tr><td>Latvia</td><td>LV</td><td>2004</td><td>NMS</td><td>-</td></tr>
<tr><td>Lithuania</td><td>LT</td><td>2004</td><td>NMS</td><td>-</td></tr>
<tr><td>Malta</td><td>MT</td><td>2004</td><td>NMS</td><td>2008</td></tr>
<tr><td>Poland</td><td>PL</td><td>2004</td><td>NMS</td><td>-</td></tr>
<tr><td>Slovakia</td><td>SK</td><td>2004</td><td>NMS</td><td>2009</td></tr>
<tr><td>Slovenia</td><td>SI</td><td>2004</td><td>NMS</td><td>2007</td></tr>
<tr><td>Bulgaria</td><td>BG</td><td>2007</td><td>NMS</td><td>-</td><td rowspan="2"></td></tr>
<tr><td>Romania</td><td>RO</td><td>2007</td><td>NMS</td><td>-</td></tr>
</table>

Table 2. The European Union and Community in 1957-2010[7]

Year	1957	1993	1995	2004	2007	2010
Name of the Union	**EEC**	**EU-12**	**EU-15**	**EU-25**	**EU-27**	**EU-27**
Number of Members	6	12	15	25	27	27
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Population[8]						
Total population	185,677,260	349,858,760	374,239,930	458,349,900	490,393,880	501,103,425
Mean population	30,946,210	29,154,900	24,949,330	18,334,000	18,162,740	18,559,386
St. dev. population	28,134,590	28,050,200	26,636,290	23,710,680	23,017,100	23,442,236
Max population	71,019,070	81,132,270	81,653,700	82,424,610	82,401,000	81,802,257
Min population	308,450	398,080	409,700	396,850	401,880	412,970
GDP per Capita, $2005						
Mean GDP per capita	10,477.27	23,777.01	24,904.65	25,548.11	27,232.00	na
St. dev. GDP per capita	3,936.60	8,576.84	7,727.89	11,741.76	13,308.92	na
Max GPD per capita	16,974.68	48,633.00	49,863.74	68,390.36	77,783.50	na
Min GDP per capita	6,802.39	15,280.04	16,131.11	10,908.69	9,313.56	na
GDP Growth Rate Among Members, % in $2005						
Mean growth rate	3.24	-0.73	3.11	3.72	4.73	na
St. dev. growth rate	2.09	1.89	2.53	2.21	2.58	na
Max growth rate	5.87	3.02	10.89	8.61	10.36	na
Min growth rate	1.04	-2.52	-0.30	0.09	1.35	na
Openness, % in $2005						
Mean openness	49.81	71.56	75.17	109.32	120.60	na
St. dev. openness	50.29	51.68	48.91	53.23	55.34	na
Max openness	134.47	205.53	218.23	287.04	301.41	na
Min openness	12.68	32.55	38.61	51.95	55.18	na

[7] Source of data on population, GDP per capita, GDP growth rate, and openness for 1957-2007: Alan Heston, Robert Summers and Bettina Aten, Penn World Table Version 6.3, Center for International Comparisons of Production, Income and Prices at the University of Pennsylvania, August 2009.

[8] Source of population 2010 data: Eurostat online database.

Table 2. (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
Motorization Rate, Cars per 1000 Inhabitants[9]						
Average motorization rate	na	368.33	390.33	430.33	442.83	na
St.dev. motorization rate	na	114.51	100.10	103.84	108.42	na
Max motorization rate	na	552.00	571.00	657.00	676.00	na
Min motorization rate	na	188.00	208.00	222.00	164.00	na
GHG Emissions from Transport, Million tons CO2 Equivalent[10]	na	871.38	946.32	1,229.19	1,297.57	na
Average GHG emissions	na	72.62	63.09	49.17	48.06	na
St.dev. GHG emissions	na	65.42	62.77	62.04	60.69	na
Max GHG emissions	na	198.59	199.18	199.83	188.85	na
Min GHG emissions	na	4.05	4.10	2.77	3.27	na
Inland Freight, Million T-km[11]	na	833,946.00	1,016,944.00	1,471,730.00	1,719,875.00	na
Mean freight	na	69,495.50	67,796.27	63,988.26	68,795.00	na
St.dev. freight	na	74,296.41	78,859.20	84,213.44	93,783.42	na
Max freight	na	211,622.00	237,515.00	303,744.00	343,439.00	na
Min freight	na	484.00	530.00	580.00	587.00	na

[9] Source: Eurostat database. For 2004, data on motorization rates are not available for Denmark, Malta, Greece, Portugal. For 2007, data is not available for Malta, Greece and Portugal.

[10] Data source: EEA.

[11] Data source: OECD statistical database. For 2004 and 2007, data for Cyprus and Malta are not available.

Table 2. (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
Inland Passenger Ttransport (Private Cars), Million P-km[12]	na	3,043,866.00	3,401,321.00	4,300,919.00	4,445,164.00	na
Mean passenger transport	na	304,386.60	283,443.42	238,939.94	246,953.56	na
St.dev. passenger transport	na	289,772.21	295,100.79	292,462.01	296,177.15	na
Max passenger transport	na	729,500.00	815,300.00	868,700.00	868,000.00	na
Min passenger transport	na	21,656.00	25,781.00	22,042.00	24,355.00	na
New Passenger Car Registration[13]	na	10,562,929	11,805,067	10,989,204	14,198,226	na
Mean registration	na	880,244.08	787,004.47	578,379.16	591,592.75	na
St.dev. registration	na	999,644.65	985,881.88	954,721.99	851,219.72	na
Max registration	na	3,194,204.00	3,314,061.00	3,266,826.00	3,148,163.00	na
Min registration	na	29,927.00	28,806.00	16,514.00	6,223.00	na
Stock of Passenger Cars[14]	na	145,353,064	160,174,996	210,136,292	219,729,733	
Mean stock	na	12,112,755.33	10,678,333.07	8,755,678.83	8,789,189.32	na
St.dev. stock	na	13,198,491.07	12,699,833.95	12,674,289.66	12,331,261.39	na
Max stock	na	38,772,000.00	40,404,294.00	45,376,000.00	41,184,000.00	na
Min stock	na	217,754.00	231,666.00	204,949.00	273,784.00	na

[12] Data source: OECD statistical database. Note, that data are not available for Ireland and Luxembourg in 1993, 1995, 2004, and 2007; Austria in 1995 and 2004; Cyprus, Estonia, Latvia, and Malta in 2004 and 2007; Bulgaria and Romania in 2007.

[13] Data source: UNECE database. Note, that data are not available for Greece, Italy, and Portugal in 2004 and 2007; Luxembourg, Malta, and Spain in 2004.

[14] Data source: UNECE database. Note, that data are not available for Portugal in 2004 and 2007; Greece in 2007.

Table 3. Table of Abbreviations

Abbreviation	Description
EEC	European Economic Community
EU	The European Union
EU-12	The twelve original members of the European Union
EU-27	The European Union as of 2007
EU-25	The European Union as of 2004
OMS, or EU-15	The twelve countries that formed the EU in 1993 and the three countries that joined the EU in 1995 are referred to as *older member states*
NMS	The twelve countries that joined the EU in 2004 are referred to as *newer member states*
EZ-12	The Eurozone group, consists the 11 original Eurozone countries and Greece
RMS	*Representative member country* of the EU
VAT	*Value added tax* - an ad valorem type tax; it is levied in the form of %
LPG	Liquid petroleum gas
UK	The United Kingdom (Great Brittan)
GHG	Greenhouse gas emissions
CPI	Consumer price index
ETS	Emission Trading Scheme
CEU	The Council of the European Union
CEC	The Council of the European Community
EEA	European Environment Agency

Table 4. Mean *Real* Prices and Taxes per 1000 Liters of Motor Fuel in the EU between 1994 and 2010 (standard deviation in parenthesis)

Time Period	**1994**	**1995**	**2004**	**2007**	**2010**	**Change 1994 - 2004**	**Change 2004-2010**	**Change 1994-2010**
EU Members	***EU-12***	***EU-15***	***EU-25***	***EU-27***	***EU-27***			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Unleaded Euro-super-95								
Consumer price on unleaded petrol, Euros	966.08 (103.96)	951.83 (86.23)	1004.43 (149.24)	1085.43 (177.28)	1079.13 (178.22)	*3.97%*	*7.44%*	*11.70%*
Producer price on unleaded petrol, Euros	280.34 (38.84)	267.22 (37.01)	361.24 (40.54)	462.21 (53.67)	453.14 (52.11)	*28.86%*	*25.44%*	*61.64%*
Excise tax, unleaded petrol, euros	538.93 (82.68)	532.81 (69.98)	479.41 (129.20)	443.86 (127.21)	443.78 (112.35)	*-11.04%*	*-7.43%*	*-17.66%*
VAT tax, unleaded petrol, %	17.93 (3.22)	18.99 (3.40)	19.35 (3.08)	19.48 (2.43)	20.00 (2.50)	1.42	0.65	2.07
Tax share, unleaded petrol, %	70.78 (4.26)	71.80 (3.94)	63.18 (7.14)	56.60 (6.75)	57.41 (4.96)	-7.60	-5.77	-13.37
Total taxes per 1000 liters, Euros	685.75 (96.92)	684.61 (82.53)	643.19 (156.37)	623.23 (160.61)	625.99 (144.57)	*-6.21%*	*-2.67%*	*-8.71%*
Observations	*576*	*735*	*1,094*	*1,225*	*594*			
n	*12*	*15*	*25*	*25*	*27*			
T	*48*	*49*	*44*	*49*	*22*			
Diesel								
Consumer price on diesel	764.14 (86.86)	748.05 (72.56)	852.60 (125.98)	976.52 (126.85)	955.91 (128.34)	*11.58%*	*12.12%*	*25.10%*
Producer price on diesel	263.55 (36.95)	253.88 (40.92)	363.14 (44.84)	484.76 (47.39)	462.21 (52.67)	*37.79%*	*27.28%*	*75.38%*
Excise tax, diesel	388.19 (50.63)	377.97 (45.44)	349.85 (102.51)	331.37 (93.76)	332.27 (78.19)	*-9.88%*	*-5.03%*	*-14.41%*
VAT tax, diesel, %	17.26 (4.62)	18.39 (4.67)	19.49 (2.79)	19.48 (2.43)	20.01 (2.50)	2.23	0.52	2.75
Tax share, diesel, %	65.45 (3.34)	66.09 (3.84)	56.79 (6.39)	49.82 (5.84)	51.28 (4.74)	-8.66	-5.51	-14.17
Total taxes per 1000 liters, Euros	500.59 (65.97)	494.17 (54.10)	489.47 (121.94)	491.76 (115.57)	493.70 (99.85)	*-2.22%*	*0.86%*	*-1.38%*
Observations	*576*	*735*	*1,094*	*1,225*	*594*			
n	*12*	*15*	*25*	*25*	*27*			
T	*48*	*49*	*44*	*49*	*22*			

Table 4. (continued)

Time Period	1994	1995	2004	2007	2010	Change 1994 - 2004	Change 2004-2010	Change 1994-2010
EU Members	*EU-12*	*EU-15*	*EU-25*	*EU-27*	*EU-27*			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
LPG Fuel								
Consumer price on LPG	na	na	473.45 (71.05)	532.79 (71.35)	523.74 (92.67)	na	*10.62%*	na
Producer price on LPG	na	na	328.60 (54.60)	378.27 (64.31)	370.48 (80.71)	na	*12.74%*	na
Excise tax, LPG	na	na	71.19 (38.79)	71.27 (32.69)	68.69 (36.42)	na	*-3.51%*	na
VAT tax, LPG, %	na	na	18.30 (4.12)	18.48 (3.51)	19.31 (3.65)	na	1.01	na
Tax share, LPG, %	na	na	30.26 (8.52)	29.06 (7.34)	29.46 (8.56)	na	-0.80	na
Total taxes per 1000 liters, Euros	na	na	144.85 (50.39)	154.52 (41.55)	153.26 (47.12)	na	*5.81%*	na
Observations	*0*	*0*	*642*	*784*	*396*			
n	*0*	*0*	*16*	*16*	*18*			
T	*0*	*0*	*40*	*49*	*22*			
Lead Replacement (Super) Fuel								
Consumer price on leaded petrol	1035.66 (107.40)	1021.49 (89.87)	1056.85 (182.45)	na	na	*2.05%*	na	na
Producer price on leaded petrol	274.40 (35.90)	261.99 (35.40)	384.96 (56.83)	na	na	*40.29%*	na	na
Excise tax, leaded petrol	602.44 (93.06)	600.85 (78.54)	507.04 (142.65)	na	na	*-15.84%*	na	na
VAT tax, leaded petrol, %	18.18 (2.84)	18.41 (2.74)	18.25 (1.10)	na	na	0.07	na	na
Tax share, leaded petrol, %	73.29 (4.02)	74.21 (3.83)	62.84 (6.47)	na	na	-10.45	na	na
Total taxes per 1000 liters, Euros	761.25 (104.84)	759.50 (90.25)	671.89 (170.02)	na	na	*-11.74%*	na	na
Observations	*576*	*588*	*436*	*0*	*0*			
n	*12*	*12*	*11*	*0*	*0*			
T	*48*	*49*	*40*	*0*	*0*			

Table 5. Mean *Nominal* Prices and Taxes per 1000 Liters of Motor Fuel in the EU between 1994 and 2010 (standard deviation in parenthesis)

Time Period	**1994**	**1995**	**2004**	**2007**	**2010**	**% Change 1994 - 2004**	**% Change 2004-2010**	**% Change 1994-2010**
EU Members	***EU-12***	***EU-15***	***EU-25***	***EU-27***	***EU-27***			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Unleaded Euro-super-95								
Consumer price on unleaded petrol	736.09 (79.60)	767.24 (88.53)	984.08 (150.48)	1150.68 (169.54)	1234.42 (143.41)	*33.69%*	*25.44%*	*67.70%*
Producer price on unleaded petrol	212.52 (21.12)	214.45 (27.70)	353.76 (40.42)	491.18 (55.20)	520.51 (42.63)	*66.46%*	*47.14%*	*144.92 %*
Excise tax, unleaded petrol	411.75 (71.38)	430.05 (68.29)	469.79 (127.86)	469.52 (127.81)	505.34 (104.69)	*14.10%*	*7.57%*	*22.73%*
VAT tax, unleaded petrol, %	17.93 (3.22)	18.99 (3.40)	19.35 (3.08)	19.48 (2.43)	20.01 (2.50)	*7.92%*	*3.41%*	*11.60%*
Tax share, unleaded petrol, %	70.78 (4.26)	71.80 (3.94)	63.18 (7.14)	56.60 (6.75)	57.41 (4.96)	*-10.74%*	*-9.13%*	*-18.89%*
Observations	*576*	*735*	*1,094*	*1,225*	*594*			
n	*12*	*15*	*25*	*25*	*27*			
T	*48*	*49*	*44*	*49*	*22*			
Diesel								
Consumer price on diesel	582.29 (64.39)	602.89 (71.55)	835.19 (125.81)	1037.00 (128.23)	1096.37 (104.28)	*43.43%*	*31.27%*	*88.29%*
Producer price on diesel	200.44 (24.65)	204.77 (37.65)	355.72 (45.40)	515.39 (51.25)	531.14 (45.31)	*77.47%*	*49.31%*	*164.99 %*
Excise tax, diesel	295.96 (39.34)	303.89 (36.00)	342.66 (100.41)	351.44 (97.99)	379.95 (77.51)	*15.78%*	*10.88%*	*28.38%*
VAT tax, diesel, %	17.26 (4.62)	18.39 (4.67)	19.49 (2.79)	19.48 (2.43)	20.01 (2.50)	*12.92%*	*2.67%*	*15.93%*
Tax share, diesel, %	65.45 (3.34)	66.09 (3.84)	56.79 (6.39)	49.82 (5.84)	51.28 (4.74)	*-13.23%*	*-9.70%*	*-21.65%*
Observations	*576*	*735*	*1,094*	*1,225*	*594*			
n	*12*	*15*	*25*	*25*	*27*			
T	*48*	*49*	*44*	*49*	*22*			

Table 5. (continued)

Time Period	1994	1995	2004	2007	2010	% Change 1994 - 2004	% Change 2004-2010	% Change 1995-2010
EU Members	*EU-12*	*EU-15*	*EU-25*	*EU-27*	*EU-27*			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
LPG Fuel								
Consumer price on LPG	na	na	463.15 (71.07)	568.50 (70.32)	613.30 (103.59)	na	*32.42%*	na
Producer price on LPG	na	na	321.48 (54.44)	403.22 (63.31)	431.45 (80.09)	na	*34.21%*	na
Excise tax, LPG	na	na	69.84 (38.25)	76.48 (35.45)	82.41 (46.83)	na	*18.00%*	na
VAT tax, LPG, %	na	na	18.29 (4.12)	18.48 (3.51)	19.31 (3.65)	na	*5.58%*	na
Tax share, LPG, %	na	na	30.26 (8.52)	29.06 (7.34)	29.46 (8.56)	na	*-2.64%*	na
Observations	*0*	*0*	*642*	*784*	*396*			
n	*0*	*0*	*16*	*16*	*18*			
T	*0*	*0*	*40*	*49*	*22*			
Lead Replacement (Super) Fuel								
Consumer price on leaded petrol	789.75 (87.96)	806.41 (94.21)	1031.49 (184.00)	na	na	*30.61%*	na	na
Producer price on leaded petrol	208.43 (22.36)	205.78 (24.84)	375.64 (57.43)	na	na	*80.22%*	na	na
Excise tax, leaded petrol	460.19 (79.43)	475.41 (79.24)	494.94 (141.04)	na	na	*7.55%*	na	na
VAT tax, leaded petrol, %	18.18 (2.84)	18.41 (2.74)	18.25 (1.10)	na	na	*0.39%*	na	na
Tax share, leaded petrol, %	73.29 (4.02)	74.21 (3.83)	62.84 (6.47)	na	na	*-14.26%*	na	na
Observations	*576*	*588*	*436*	*0*	*0*			
n	*12*	*12*	*11*	*0*	*0*			
T	*48*	*49*	*40*	*0*	*0*			

Table 6. Real Motor Fuel Price and Tax Differences between OMS and NMS, 2004-2010

	2004				2010				2004-2010 Growth	
	OMS	NMS	Absolute Difference	% Difference	OMS	NMS	Absolute Difference	% Difference	OMS	NMS
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Unleaded Gasoline										
Consumer price, €	1066.99	858.34	208.65	24%	1,203.63	923.51	280.12	30%	136.64	65.17
Producer price, €	355.12	374.78	-19.66	-5%	477.52	422.67	54.85	13%	122.40	47.89
Total tax level, €	711.86	483.57	228.29	47%	726.11	500.84	225.27	45%	14.25	17.27
Excise tax, €	538.78	348.51	190.27	55%	530.64	339.89	190.75	56%	-8.15	-8.62
VAT, %	19.67	19.20	0.47	2%	20.07	20.00	0.07	0%	0.40	0.80
Diesel										
Consumer price, €	881.18	784.78	96.40	12%	1,036.87	854.72	182.15	21%	155.69	69.94
Producer price, €	358.71	372.22	-13.51	-4%	489.36	428.27	61.09	14%	130.65	56.05
Total tax level, €	522.47	412.55	109.92	27%	547.50	426.45	121.05	28%	25.03	13.90
Excise tax, €	379.62	288.78	90.84	31%	377.08	276.53	100.55	36%	-2.54	-12.25
VAT, %	18.17	19.20	-1.03	-5%	20.07	20.00	0.07	0%	1.90	0.80
LPG										
Consumer price, €	482.95	456.84	26.11	6%	577.76	480.53	97.23	20%	94.81	23.69
Producer price, €	350.47	294.91	55.56	19%	432.28	321.05	111.23	35%	81.81	26.14
Total tax level, €	132.49	161.93	-29.44	-18%	145.48	159.48	-14.00	-9%	12.99	-2.45
Excise tax, €	80.16	69.05	11.11	16%	70.78	62.77	8.01	13%	-9.38	-6.27
VAT, %	19.21	19.20	0.01	0%	19.31	20.00	-0.69	-3%	0.10	0.80

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APPENDICES

APPENDIX 1.A

THE DATA AND SUMMARY STATISTICS

The weekly data for 27 EU members for the total period of January 3, 1994 - June 7, 2010 are from the EU Oil Bulletin published by the European Commission. The dataset is in the form of unbalanced panel; it includes pre-tax and tax-inclusive prices, value-added tax (VAT) rates, excise tax rates and exchange rates. The data are for four types of motor vehicle fuels: unleaded petrol (Euro-super-95), automotive gas oil (diesel), liquefied petroleum gas (LPG) motor fuel and lead replacement (Super) petrol. The maximum number of weeks for diesel and unleaded gasoline is 858. For the LPG fuel, the data is available only for 2000-2010, and for lead replacement fuel the data is for 1994 - 2005.

The original data comes in two separate data files. All prices and excise tax levels are converted to euro. Monthly consumer price indices (CPI) from the UNECE Statistical Division database help converting data into real values. For Ireland, from 1994-1996, additional CPI data is provided by the Central Statistics Office of Ireland. In order to match weekly prices, monthly CPI indices are transformed into weekly indices using the geometric mean formula for weekly growth rates. The tax level for each motor fuel is approximated as a difference between real consumer and producer prices.

Table 7 provides summary statistics of this unbalanced data sample. It shows that from 1994-2010, real mean consumer prices were equal to €1034 per 1000 liters of unleaded Euro-super-95 and €888 for diesel. Real mean producer prices were €375 and €387 respectively. During this period, real consumer and real producer prices on both Euro-super-95 and on diesel experienced high price variation. For diesel, deviations from the mean price were, on average, higher within countries than between countries. Price volatility of both fuels seemed to have been driven by countries' ongoing internal volatility on the production side. In addition, during the analyzed period, there were large differences in both types of taxes between the EU members.

For both Euro-super-95 and diesel fuel, mean VAT tax rates were roughly the same (19.3%), but mean excise taxes for unleaded fuel (€491) were much higher than for diesel (€355). For Euro-super-95, these mean excise taxes varied at a greater standard deviation rate of €126 than for diesel (€101). As a result, mean shares of total taxes in a consumer price accounted for 63% for Euro-super-95 and 57% for diesel. By contrast to price variation, tax shares on all types of fuel varied slightly more between the EU members than within a given country, with an average deviation in tax shares of roughly 9%.

The data on LPG fuel are only available for fewer countries and shorter time periods; it starts in 2000. During 2000-2010, real mean consumer price on LPG fuel was much lower (€509) and more stable than for other types of motor fuels. At the same time, real mean producer price on LPG (€359) was only slightly lower than producer prices on other fuels. Tax levels on LPG were also much lower than for other types of motor fuels. Average VAT tax rate for LPG was equal to 18.3%, and mean excise tax rate was €70 per 1000 liters, which was 5-7 times lower than for diesel and unleaded gasoline. This is why, on average, taxes accounted for only 29% of the consumer price for LPG, or roughly two times lower than for other motor fuels.

Data on lead replacement (Super) petrol is also only available for fewer countries and shorter time periods; it ends in 2005. Between 1994 and 2005, real mean consumer price of leaded gasoline was equal to €1074 per 1000 liters, which is roughly three times higher than the producer price of €332 (Table 3). These mean levels of Super fuel were almost identical to corresponding values for unleaded Euro-super-95 fuel, and were only slightly above the price of diesel. During the same time period, mean excise tax for lead replacement gasoline was the highest among all motor fuels (€576). Average VAT tax rate for this fuel was 18.2%, or well above the tax floor. For lead replacement petrol, relatively high excise taxes and their frequent changes may be explained by the members' efforts to phase this fuel out from the market.

Table 7. Summary Statistics: Real Prices and Taxes on Motor Fuels in the EU

Variable	Mean	Std. Dev.	Min	Max	Observations
(1)	(2)	(3)	(4)	(5)	(6)
Unleaded: 1994-2010					
rprice overall	1034.65	163.33	531.67	1692.53	N = 15197 n = 27
between		138.65	720.88	1251.01	
within		109.77	640.06	1476.16	
rpf0 overall	375.19	96.28	157.90	793.21	N = 15197 n = 27
between		46.64	314.37	529.25	
within		87.68	173.41	773.79	
rexcisef overall	491.09	125.71	208.04	946.48	N = 15197 n = 27
between		130.50	246.10	674.28	
within		47.84	283.54	763.28	
fuel95vat overall	19.32	2.99	12.00	25.00	N = 15197 n = 27
between		2.65	13.00	25.00	
within		0.80	16.91	22.35	
share_f95 overall	63.40	8.86	39.63	85.95	N = 15197 n = 27
between		8.08	46.50	72.89	
within		5.40	45.40	79.24	
Diesel: 1994 - 2010					
rpdiesel overall	887.58	167.82	508.57	1615.58	N = 15197 n = 27
between		99.37	722.31	1194.96	
within		134.96	467.18	1407.62	
rpd0 overall	387.92	117.30	154.77	828.11	N = 15197 n = 27
between		51.00	327.26	513.12	
within		109.09	176.22	833.19	
rexcised overall	355.19	101.09	177.18	946.48	N = 15197 n = 27
between		92.98	207.29	674.69	
within		39.64	141.47	626.98	
dieselvat overall	19.32	3.06	5.00	25.00	N = 15197 n = 27
between		2.54	15.00	25.00	
within		1.35	7.81	23.81	
share_diesel overall	56.58	8.81	33.17	86.17	N = 15197 n = 27
between		7.10	41.52	71.45	
within		6.13	37.92	72.41	
LPG Fuel: 2000-2010					
rplpg overall	508.87	87.71	314.86	838.45	N = 6429 n = 18
between		72.41	404.59	662.14	
within		58.90	280.34	805.74	
rplpg0 overall	359.45	69.49	160.94	571.02	N = 6429 n = 18
between		52.72	245.15	456.14	
within		49.49	170.81	609.89	

Table 7. (continued)

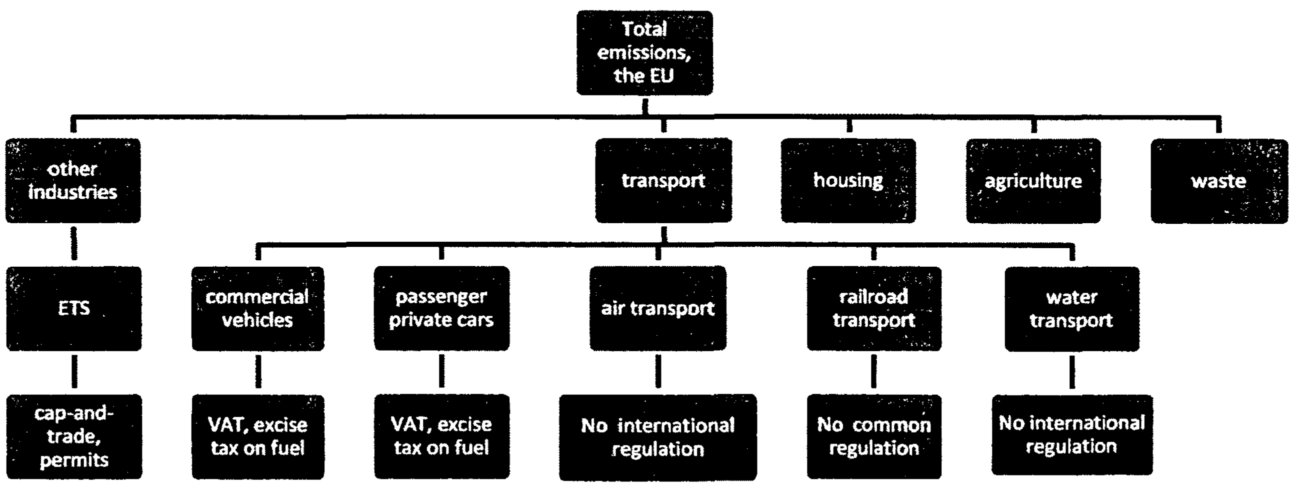
Variable	Mean	Std. Dev.	Min	Max	Observations
(1)	(2)	(3)	(4)	(5)	(6)
rexciselpg overall	70.37	38.76	0	170.88	N = 6429 n = 18
between		33.97	0	145.57	
within		16.19	-6.81	124.57	
lpgvat overall	18.29	3.99	6.00	25.00	N = 6429 n = 18
between		3.48	6.00	22.15	
within		0.79	15.41	21.14	
share_lpg overall	29.17	8.31	14.57	53.66	N = 6429 n = 18
between		7.13	17.35	41.78	
within		3.57	14.29	48.65	
Leaded (Super) Fuel: 1994 - 2005					
rpsuper overall	1073.93	158.71	742.65	1666.04	N = 5412 n = 17
between		144.92	798.42	1310.74	
within		92.48	708.59	1514.28	
rps0 overall	331.92	90.32	157.05	685.83	N = 5412 n = 17
between		56.58	242.65	468.07	
within		77.99	182.44	633.15	
rexcises overall	575.57	131.06	318.79	986.80	N = 5412 n = 17
between		130.53	349.84	755.63	
within		69.34	352.25	860.38	
supervat overall	18.21	2.26	12.00	25.00	N = 5412 n = 17
between		2.64	13.89	25.00	
within		0.66	16.32	21.59	
share_super overall	68.80	8.22	44.90	86.56	N = 5412 n = 17
between		7.29	52.31	76.63	
within		6.00	48.04	82.81	

APPENDIX 1.B

GHG EMISSIONS SECTORS IN THE EU

Figure 8 shows a scheme of major EU policies that target GHG emissions in major emitting industries. With the exception of transport, housing, agriculture and waste industries, GHG emissions are regulated through the Emission Trading System (ETS). ETS is the cap-and-trade type emission permit market. It is worth noticing that the VAT tax and the excise tax on fuel remain major policy tools in the EU in addressing social costs from transport.[15]

Figure 8. Major GHG Policies in the EU and the Place of Motor Fuel Taxation in the European Policy Approach



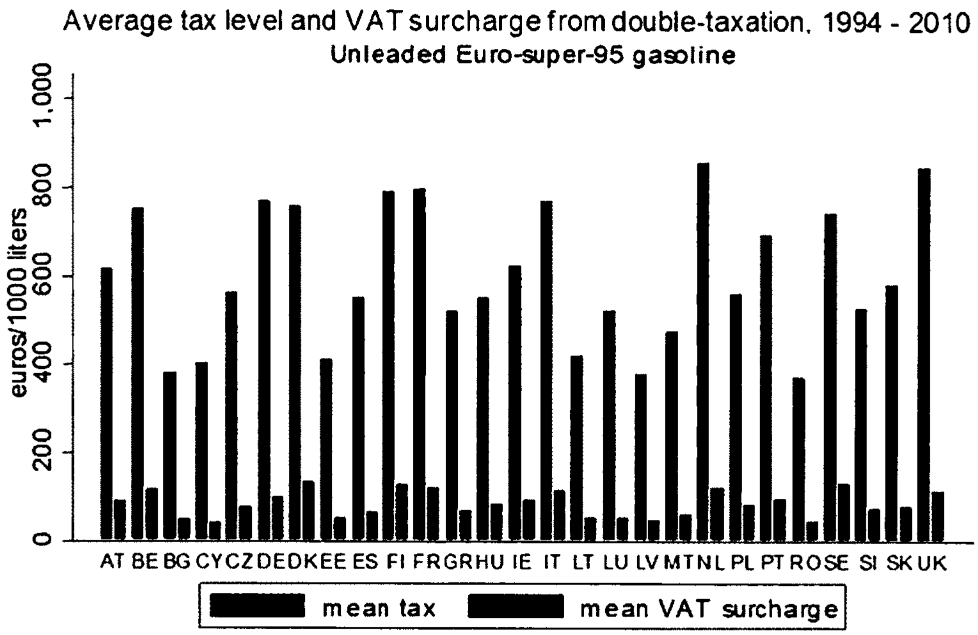
[15] For additional discussion see TERM 26 EEA 31. 2006 (EEA, 2006)

APPENDIX 1.C

Table 8. Average Real Tax Premiums on Unleaded Gasoline and Diesel, 2004-2010

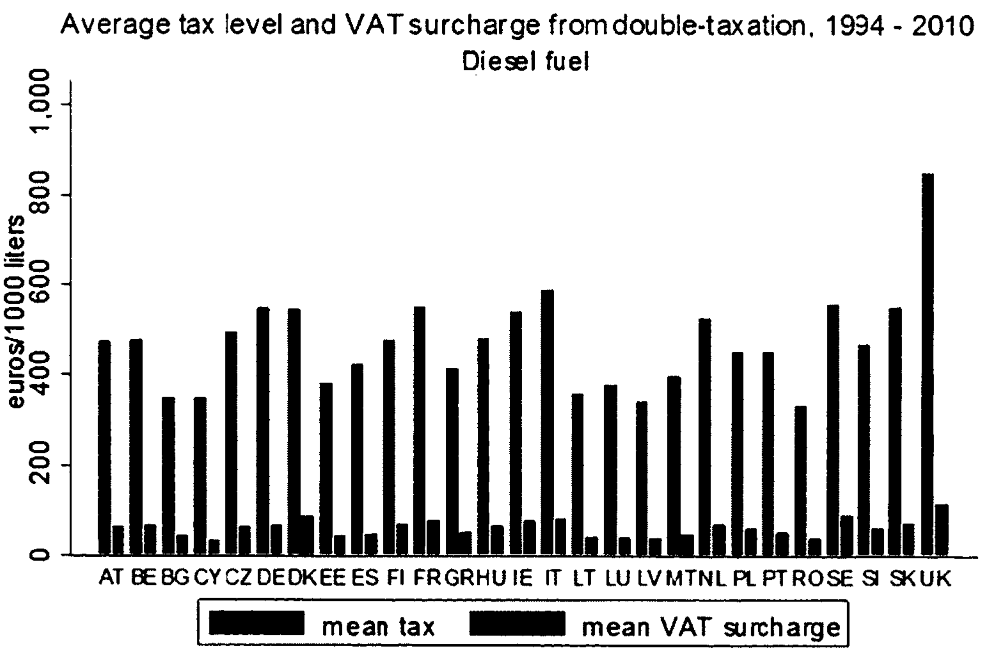
ID	**Unleaded Gasoline**	**Diesel**
AT	87.27	67.86
BE	119.75	68.23
BG	52.56	46.04
CY	42.94	35.17
CZ	77.24	64.99
DE	111.33	80.01
DK	132.26	89.43
EE	53.13	46.97
ES	60.92	45.98
FI	126.74	69.77
FR	113.80	80.43
GR	60.70	48.85
HU	83.10	68.47
IE	91.92	75.33
IT	108.61	80.23
LT	54.16	43.36
LU	62.95	40.68
LV	48.46	41.55
MT	60.93	48.78
NL	125.52	72.42
PL	84.19	62.78
PT	109.03	66.69
RO	46.76	39.39
SE	130.17	97.28
SI	74.30	63.18
SK	80.34	74.03
UK	109.10	109.10
mean	***85.49***	***63.96***
st.dev.	***29.20***	***18.90***
min	***42.94***	***35.17***
max	***132.26***	***109.10***

Figure 9.



Data source The EU Oil Bulletin, the European Commission

Figure 10.



Data source: The EU Oil Bulletin, the European Commission

APPENDIX 1.D

EXCESS TAX BURDEN OF MOTOR FUEL TAXES IN THE EU

The classical textbook version typically portrays the concept of excess burden using compensated demand curves and a single tax (e.g. Rosen, 2005, p.314-315). Following similar model, for simplicity, assume that the compensated demand curve can be depictured as a straight line and that marginal cost of one liter of motor fuel in the EU is constant. Under these assumptions, the supply curve becomes the horizontal line S at price P (Figure 11). Consumer surplus APH is the area between the price and the demand curve. Then, the excess burden from a single VAT tax on motor fuel is the area of triangle ABC, which is equivalent to:

$$R_{ABC} = \frac{1}{2}\Delta P \cdot \Delta Q \qquad \text{(d.1)}$$

Under a single tax, the difference between gross and net price is equal to

$$\Delta P_{BC} = (P(1 + VAT) - P) = P \cdot VAT \qquad \text{(d.2)}$$

where P is price before tax and is the VAT is the percentage rate of the Value Added Tax. Given that by definition the value of compensated price elasticity of demand (η) is:

$$\eta = \frac{\Delta Q}{\Delta P}\frac{P}{Q} \;, \qquad \text{(d.3)}$$

from Equation (d.3), change in quantity demanded can be written as

$$\Delta Q = \frac{\eta Q \Delta P}{P} \qquad \text{(d.4)}$$

Using Equations (d.2) and (d.4), Equation (d.1) becomes:

$$R_{ABC} = \frac{1}{2}(P(1 + VAT) - P) \cdot \Delta Q = \frac{1}{2}P \cdot VAT \cdot \frac{\eta Q \Delta P}{P} = \frac{VAT \eta Q \Delta P}{2} \qquad \text{(d.5)}$$

or, using (d.2), the area of triangle ABC is

$$R_{ABC} = \frac{\eta Q P (VAT)^2}{2} \qquad \text{(d.6)}$$

Now, suppose that instead of a single tax, two taxes are levied on this motor fuel, the VAT tax and the excise tax T (Figure 11). The new consumer surplus is depictured as the area AHI. The excess burden from both the excise and the VAT taxes on motor fuel increases to the area of triangle ADE. Simple algebra helps estimate the area of the new triangle ADE using Equation (d.1):

$$R_{ADE} = \frac{1}{2}\big((P + T)(1 + VAT) - P\big) \cdot \Delta Q \qquad \text{(d.7)}$$

With two taxes, the change in price can be estimated by Equation (d.8):

$$\Delta P_{ADE} = \big((P + T)(1 + VAT) - P\big) = P \cdot VAT + T \cdot VAT + T \qquad \text{(d.8)}$$

Then, using Equation (d.8), Equation (d.7) can be re-written as Equation (d.9):

$$R_{ADE} = \frac{1}{2}\left((P+T)(1+VAT)-P\right)\frac{\eta Q \Delta P_{ADE}}{P} = \frac{\eta Q}{2P}(P \cdot VAT + T \cdot VAT + T)^2 \tag{d.9}$$

Using Equation (d.6), the formula for excess burden[16] becomes Equation (d.10):

$$R_{ADE} = \frac{\eta Q (VAT)^2}{2} + \frac{\eta QTVAT}{P} + \frac{\eta QT^2}{2P} = R_{ABC} + \frac{\eta QTVAT}{P} + \frac{\eta QT^2}{2P} \tag{d.10}$$

Equation (d.10) shows that in addition to excess burdens of the VAT and excise taxes, an extra burden arises from interaction between these two taxes. This additional excess burden is captured by the second term on the right hand side $\left(\frac{\eta QTVAT}{P}\right)$ of Equation (d.10).

The above discussion of excess tax burden, however, does not account for the substitution effects between the motor fuel excise tax and VAT. A new excise tax T shifts the supply upward from S' to S" and results in environmental improvement. Figure 11 pictures this environmental improvement with area of the rectangle EFHC = $T(Q_1 - Q_2)$. Then, the welfare gain of the excise tax is EFC= $T(Q_1 - Q_2)/2$. Following the earlier discussion of the double dividend literature[17] (chapter 1.5), the EU national governments may choose to increase the environmental excise taxes and to decrease the distortionary VAT, while keeping the overall tax level the same. Then, the supply curve shifts S' downward and the area of the triangle EFHC becomes bigger. This leads to a bigger welfare gain of the Pigouvian tax from bigger emission reductions. Such policy will reduce some of VAT distortions; this is because the tax burden will be shifted away from the general public (non-polluters) towards motor fuel consumers (polluters). Thus, the substitution between the motor fuel excise tax and the VAT increases fairness.

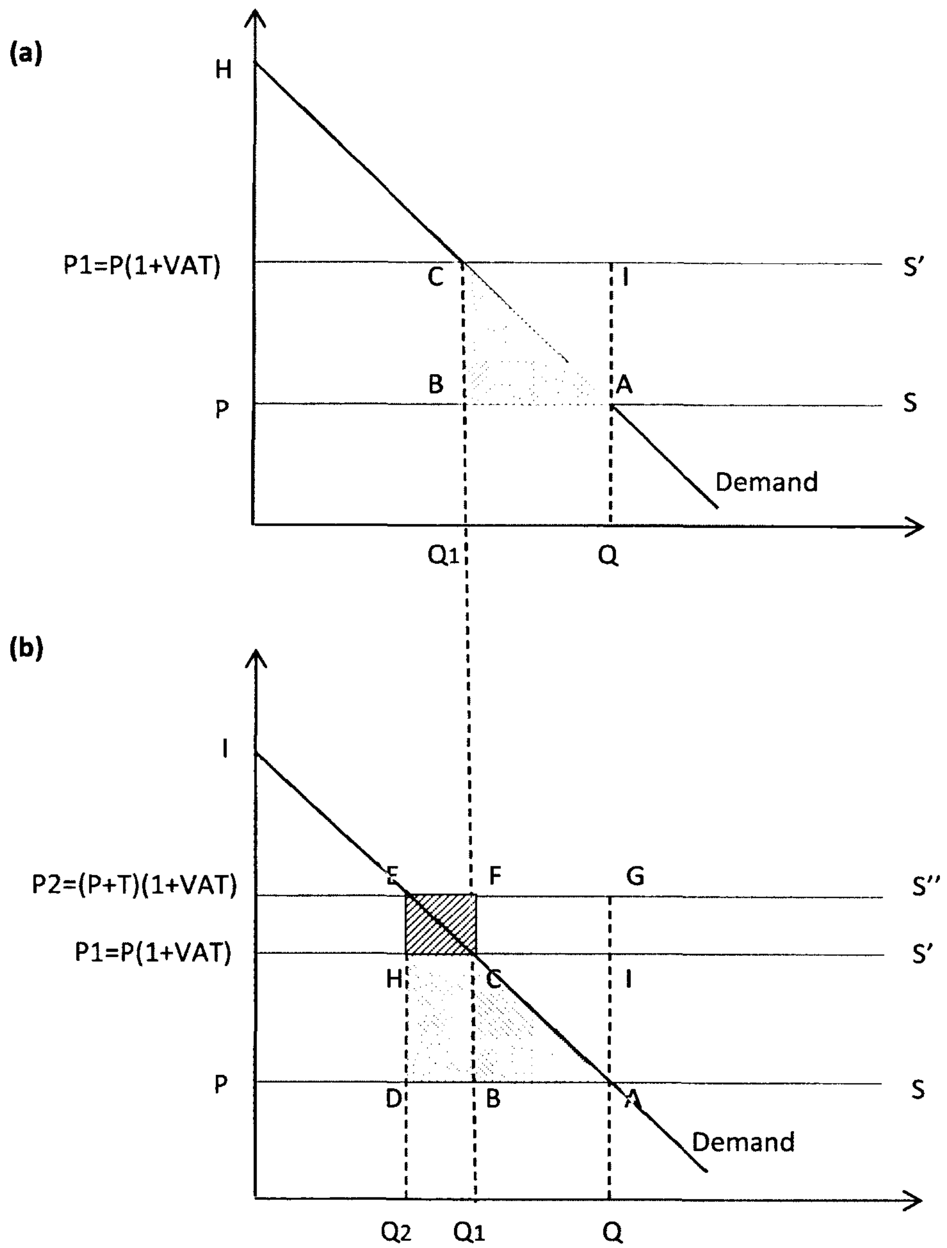
[16] When the supply curve is upward sloping, the formula for excess burden becomes

$$\left(\frac{Q(VAT)^2}{2} + \frac{QTVAT}{P} + \frac{QT^2}{2P}\right)\left(\frac{1}{\eta} + \frac{1}{\varepsilon}\right)^{-1}$$

where ε is the elasticity of supply. As ε approaches infinity, this expression becomes equation (d.10).

[17] In this simple, partial equilibrium set-up, the tax-interaction effect of the double dividend cannot be evaluated and, therefore, is ignored.

Figure 11. Excess Burden of VAT and Excise Taxes on Motor Fuels



APPEDIX 1.E

TAX CHANGES IN THE EU

Seven Stages of Motor Fuel Price Dynamics

The behavior of real motor fuel consumer and producer prices on leaded, unleaded and diesel fuel between 1994 and 2010 in the EU can be informally separated into seven stages (Figures 4-5). During the first stage between 1994 and 1999 and the fourth stage between 2002 and 2004, real prices for motor fuels were relatively stable, with a slight price drop in the late 1990s. A significant price growth occurred during the second stage between 1999 and 2000, which was followed by a gradual price drop during the third stage in 2001-2002. After the relative stability of the mid-2000s, motor fuel consumer prices again began to consistently but erratically increase in 2004-2008 (the fifth stage), primarily due to corresponding behavior of producer prices in the 2000s. In 2008, motor fuel consumer price collapsed (the sixth stage), and the final, seventh stage, of price growth began in the late 2008-2009.

As a result of these transformations, between 1994 and 2010 in the EU, both real and nominal producer and consumer prices for motor fuels have, on average, increased (Tables 4 and 5). For example, in 1994, the average real consumer prices for motor fuels were approximately €966 per 1000 liters of unleaded petrol and €764 for diesel. By 2010, these prices reached roughly €1079 and €956 respectively (Table 4, Figure 4), reflecting increases of 12% and 25%. While fewer data and shorter time periods are available for lead replacement (Super) fuel, its average real consumer price had slightly risen from €1036 in 1994 to €1057 in 2004, or by 2% (Table 5, Figure 4). The LPG data are also only available for fewer years, for the period 2000-2010. At the beginning of the 2000s, LPG fuel was much cheaper than other motor fuels, but its real consumer prices also increased: from €473 in 2000 to €524 in 2010, or by 11% (Table 4, Figure 4).

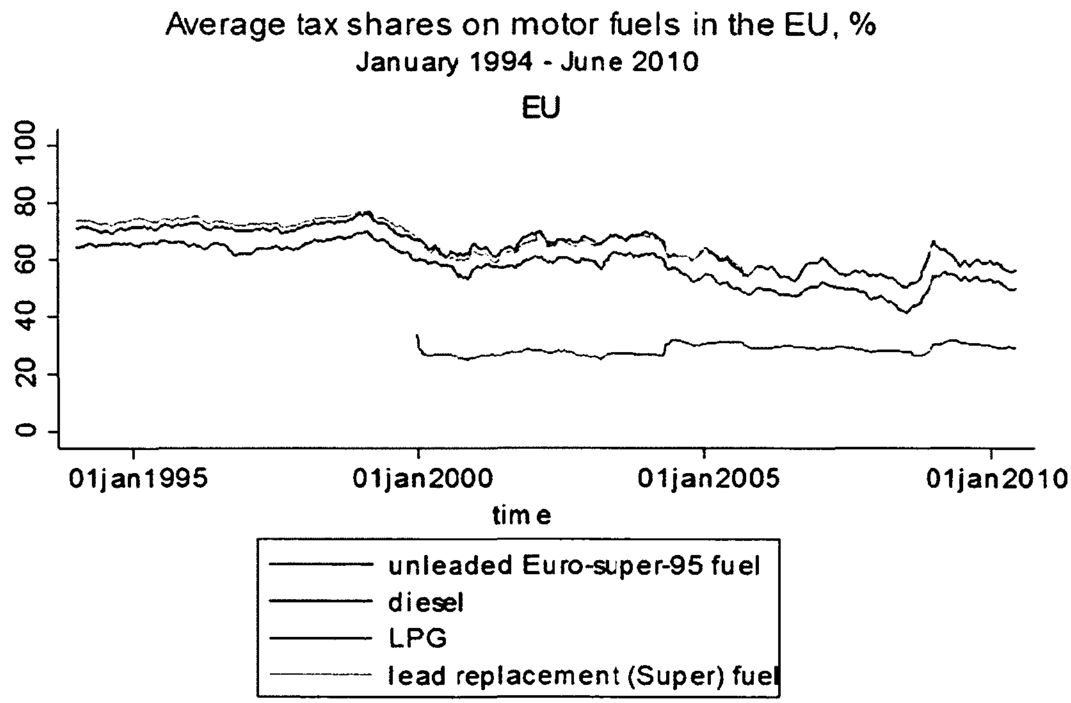
Before 2004, producer prices were almost identical across different fuel types (Figure 5). After the largest expansion of the EU in 2004, these prices began to slowly diverge among different motor fuels, especially the price of LPG fuel. In 1994, the average real producer prices were in a benchmark of €280 for Euro-super-95 and €263 for diesel per 1000 liters. By 2010, these prices increased 62% and 76% respectively, and were equal to €453 for unleaded gasoline and €462 for diesel (Table 4, Figure 5).

Data for lead replacement gasoline is available for fewer countries and years, but shows a similar pattern. Between 1994 and 2004, real producer prices on leaded fuel have increased from €274 to €385, or by 40%, and were roughly equal to producer prices on other major types of motor fuels at that time (Table 4). By the middle of 2010, the average real producer price for LPG had reached €370 – a level about 20% lower than for diesel and unleaded fuel (Table 4). Lower taxes, however, were the major reason why the average LPG consumer prices in the EU remained almost twice lower than prices on other motor fuels. Similarly, for other motor fuels, the dynamics of consumer prices were defined by movements in producer prices, but large level differences in consumer prices between fuels were defined by differences in taxes between these fuel types.

Motor Fuel Taxes in the EU: Tax Share in a Consumer Final Price

Figure 12 shows that between 1994 and 2010 in the EU, tax shares in consumer prices of motor fuels mirrored all stages of changes on the production side: as motor fuel producer prices were constantly rising since 1999, tax shares were shrinking (Figures 5, 12). During this period, the average tax shares decreased by approximately 14% for diesel and unleaded gasoline (Table 4).

Figure 12.



By the summer of 2010, the average tax share in the final consumer price of unleaded Euro-super-95 dropped to below 60%; for diesel it dropped below 52% (Table 4, Figure 5). These numbers were down from roughly 70% and 65% respectively in the mid-1990s. For lead replacement fuel, the tax share mirrored changes for unleaded fuel in 1994-2004. By contrast, the average tax share of LPG fuel remained relatively stable at a level of about 30% in 2000-2010 (Table 4, Figure 12), and decreased only slightly due to smaller change in an average LPG producer price.

These changes in tax shares for unleaded Euro-super-95 fuel and for lead replacement gasoline were triggered by both an increase in producer price and a decrease in taxes during this period. For example, between 2010 and 1994, the total real amount of taxes (both excise and VAT) per 1000 liters of unleaded fuel had decreased by about 8.7% (Table 4). For diesel, the total real amount of taxes remained roughly the same as in in the mid-1990, suggesting that an increase in producer prices alone accounted for a tax share drop for this fuel. Finally, total taxes on LPG fuel had increased by about 6% in 2004-2010, meaning that both factors played an important role in LPG tax share dynamic, but producer prices grew slightly faster.

In regard to tax composition, two types of major changes in taxing motor fuels happened in the EU in 1994-2010. Firstly, on average, the EU members were partially shifting from motor fuel excise taxes to VAT taxes. Secondly, the variation in both VAT and excise tax rates among the EU member countries became smaller by 2010, especially for the VAT tax. During 1994-2010 the average VAT tax rate levied on motor fuels in the EU had increased from 18% to 20% for unleaded gasoline and from 17% to 20% on diesel (Table 4). In the mid-1990s, these average VAT rates among EU-15 countries varied by 3-5% from the mean, but by 2010, this variation across members in the enlarged EU-27 became tighter. Real excise tax rates on motor fuels steadily decreased in 1994-2010; they fell by €56 for diesel and €95 for unleaded gasoline, or a 15-18% drop (Table 4). Even for lead replacement gasoline, real excise taxes had decreased by €95 in 1994-2004. In 2004, when newer member states joined the Union, variation in excise tax rates became relatively large among the EU members, but it also decreased by 2010.

ESSAY 2: CLUB CONVERGENCE IN THE EU: AN EMPIRICAL ANALYSIS OF MOTOR FUEL PRICES AND TAXES

2.1. INTRODUCTION AND MOTIVATION

Taxing motor fuels differs from taxing other consumption goods. It has a macroeconomic impact because transportation costs are typically embedded in the price of most other goods and services. There is also the second, environmental, aspect of motor fuel taxes: they facilitate a reduction of externalities associated with motor fuel consumption (Pigou, 1932). Ryan et al. (2009), for example, show that taxes are a more powerful tool for reducing CO_2 emissions from new vehicles than voluntary agreements by automobile manufacturers.

Analyzing national approaches to motor fuel taxation in Europe contributes to a broader discussion of fiscal dis-harmonization among the EU member countries. Since the creation of the Eurozone in 1999 and the largest expansion of the EU in 2004, there has been surprisingly little discussion in the literature of the role played by differences in national fiscal policies. Moreover, countries that joined the EU in 2004 were from Central and Eastern Europe; they were weaker economically and, as a result, required aggressive government borrowing and spending in order to grow their economies. It is possible that the divide in fiscal policies and budgets made the EU more vulnerable to risks, and triggered the frustrating struggles of the early 2010s. When the Eurozone countries delegated control over their monetary policies, they implicitly assumed that economic and financial risks would be shared among the Eurozone members. It is not surprising that, in a setting where monetary policies are harmonized in some countries (the Eurozone) and disharmonized in others (non-Eurozone countries), and fiscal policies are set by the EU members sovereignly, the euro grows weaker and the Common Market becomes unstable. Although this paper focuses on motor fuels, in a broader sense the latest crisis has revealed tensions between the setting of national fiscal policies and the operation of a common monetary union.

In the EU, differences in motor fuel tax rates among member states remain large, and this contributes to fuel price differences among member states (e.g. Newbery, 2005; Rietveld & Woudenberg, 2005). For example, my data show that from 1994-2010 total taxes on unleaded gasoline and diesel fuel accounted, on average, for 57-63% of the final price and varied across members by roughly 7-8%. According to the European Treaty, tax differences are typically considered to be barriers to a smooth operation of the Common European Market. Given such wide tax variation, the question remains whether national economies are moving toward the Union goals of social, environmental, and economic homogeneity among the EU members and the highly competitive European Common Market. In this context, an analysis of long-run behavior as well as the relationship between consumer prices, producer prices, and taxes would shed more light on fiscal harmonization and on the long-run feasibility of a common, highly competitive market for motor fuels in the EU.

This study looks at two forms of convergence, tax convergence and price convergence, which may occur separately from one another because of different underlying forces behind them. The concept of convergence implies a gradual and eventual reduction of level differences either among all economic units or among units within sub-groups (clubs). In other words, convergence of motor fuel prices among the EU members implies that motor fuel prices across the EU move towards a common price level; divergence and club convergence suggest that the market is segmented. If motor fuel prices converge, the EU as a whole would benefit from a smoother, non-distortive operation of the Common Market for motor fuels. On the other hand, price divergence among the EU members suggests the presence of market frictions such as large differences in taxation policies, market power, transportation costs, etc.

For taxes, convergence implies that national governments in the EU harmonized their total motor fuel taxation levels among each other. Under this scenario, national governments give up some control over addressing social costs associated with motor fuel consumption, such as local noise, air pollution from exhaust emissions, road congestion, traffic fatalities, etc. If motor fuel tax levels do not converge in the long run, it implies that sovereign governments maintain control over their national fuel tax systems, even with the Common Market. Given that local pollution and other social costs like congestion vary among the EU members, a disharmonized tax scenario helps national governments to address transport related social costs more efficiently. This is why examining tax convergence in the EU is important: it adds to the discussions of environmental conditions and motor fuel price dynamics in the entire EU region.

Despite its importance, the literature on motor fuel price dynamics and tax convergence in the EU remains limited. Studies of motor fuel prices in the EU are also typically limited to a single country analysis (e.g. Asplund et al., 2000), and only a few authors attempt to examine motor fuel price adjustments in a multi-country framework (e.g. Wlazlowski et al., 2009). While the economic literature on motor fuel taxes pays attention to environmental and climate change policies in the EU (e.g. Sterner, 2007, 2010; Schreurs, Selin & VanDeveer, 2009) and to cross-border fuel shopping (e.g. Leal et al., 2009; Banfi et al., 2005), the long-run state of motor fuel taxation – an important factor for relevant policy analysis – remains underexplored. This is in spite of findings that higher taxes reduce demand for motor fuel (Sterner, 2007) and for new cars (Ryan et al., 2009). Oates (2001a) suggests that, in general, the literature on tax harmonization and fiscal competition is large but exceedingly theoretical. In regard to motor fuels in particular, even the recent studies of price and tax convergence in the EU include only older member states (e.g. Robinson, 2007; Dreher & Krieger, 2008, 2010; Bilgili, 2010). Some of their findings, therefore, have limited relevance to policy implications in the EU as a whole.

In order to address these shortcomings, this paper asks whether there has been convergence or divergence in motor fuel taxes and prices among the EU members at different stages since 1994. For the purpose of this essay, the twelve countries that formed the EU and the three countries that joined it in 1995 are referred to as older member states (OMS). The twelve countries that joined the EU after 1995 are referred to as newer member states (NMS).

The first contribution of this paper to the body of economic research on motor fuels is that it adds to the limited empirical literature on fiscal competition and tax harmonization (e.g. England, 2007; Lockwood & Migali, 2009; Rietveld et al., 2001; Wildasin, 2006). Secondly, by including both OMS and NMS, the paper takes into consideration data from after the largest EU expansion. It also separates the Eurozone from non-Eurozone countries. This separation on its own provides an interesting insight into how national motor fuel markets and national policies are interrelated in the EU. Finally, I show that after the largest expansion of the EU in 2004, motor fuel markets have not been completely integrated, even in the absence of trade restrictions. To achieve this in a more effective way than previous studies, I use a newer club convergence methodology developed by Phillips and Sul (2007) and extend the analysis to four types of motor fuels: unleaded gasoline, automotive gas oil (diesel), liquid petroleum gas (LPG) and lead replacement fuel. The essay also adds to the empirical literature on the Law of One Price (LOP) and international price convergence (e.g. Funke & Koske, 2008; Goldberg & Verboven, 2005; Egger, Gruber & Pfaffermayr, 2009).

2.2. LITERATURE REVIEW ON FUEL PRICE AND TAX CONVERGENCE

Convergence in motor fuel taxes and convergence in motor fuel prices result from different driving forces. The theory of the Law of One Price (LOP) predicts that in competitive markets and in the absence of market frictions, consumer prices on identical commodities expressed in the common currency should eventually equalize among countries because of arbitrage opportunities (e.g. Isard, 1978; Ardeni, 1989; Baffes, 1991). The underlying assumptions of the LOP are that there are no trade restrictions and that transportation costs are negligible. Then, according to LOP, if motor fuel taxes converge and production costs remain small in the EU, motor fuel consumer prices should also converge because of the commonality of the European market.

Rietveld and Woudenberg (2005) suggest that variation in production costs of fuels among most countries is typically small; it plays little role in explaining variation in consumer prices on motor fuels. Production costs are better at explaining levels rather than variation of motor fuel consumer prices (e.g. Wlazlowski et al., 2009; Dreher & Krieger, 2008, 2010). Since producers in all countries face a nearly identical price of crude oil in spot markets, variation in producer prices among countries can be entirely attributed to the differences in refining capacities, costs of production, or differences in market power of local gasoline producers (e.g. Rietveld et al., 2001). Taxes, however, remain an important factor in explaining motor fuel price variation among economic units, including members of the EU (e.g. Newbery, 2005; Rietveld & Woudenberg, 2005; Rietveld et al., 2001). Nevertheless, Dreher and Krieger (2010) show that for OMS the convergence in consumer prices of diesel is driven by the convergence of producer prices rather than by tax convergence.

Tax convergence or divergence, unlike price convergence, is mainly driven by broadly defined political forces (e.g. Ilzkovitz, et al., 2007) and the stringency of environmental policies (e.g. European Commission, 2011) both at the national level and the EU level. According to fiscal competition literature (e.g. Oates & Schwab, 1988; Wilson 1999; Oates, 2001a, 2001b; Rork, 2003; Giuliodori & Beetsma, 2008), neighboring states may fiscally compete with one another. In addition, the theory of yardstick competition suggests that voters may pressure their governments to reduce the tax burden, especially during the pre-election period (Besley & Case, 1995). Voters pay attention to consumer prices on motor fuels, as well as price differences, because the topic is being discussed frequently in the media (e.g. Löfgren & Nordblom, 2010). Thus, national motor fuel tax policies and changes to these policies may influence and be influenced by not only fuel prices within a given country, but also in neighboring regions. In the long run, the interrelation of policies may lead to convergence.

Historically, this general urgency for commonality and unification of Europe is a legacy of the fall of the Berlin Wall in 1989 (e.g. Carmin & VanDeveer, 2005). European nations aimed to reduce tariffs, support multinational corporations, connect transportation infrastructures, etc. They also worked towards enlarging the EU and expanding economic zones, including the zone of common visa requirements, the zone of common currency, etc. Moreover, during the 1990s and 2000s, there has been additional pressure on the EU members to comply with common climate change goals and to revise national emission policies (e.g. the Council of European Communities, 2003; European Commission, 2001, 2008, 2010).[18] These efforts resulted in calls for further harmonization of taxation structures among the members (e.g. Ilzkovitz et al., 2007; Newbery, 2005; the Council of European Communities, 1992a, 1992b; the European Commission, 2007, 2011).

A growing literature on fuel price convergence and tax convergence provides limited agreement on whether fuel consumer prices converge among European countries, and what the role of taxes is in this process. Bentzen (2003) uses data from 1978-2002 and finds only weak evidence that petroleum prices, when expressed in a common currency, converge among European OECD countries, but not among all OECD members. Without formally testing for it, Bentzen (2003) attributes such convergence to tax harmonization processes in the EU. Wlazlowski et al. (2009) analyze fuel price dynamics among OMS and suggest that consumers react to low fuel prices in neighboring countries by travelling across borders to take advantage of these opportunities. Dreher and Krieger (2008, 2010) use the nominal data for OMS from 1994-2004 and a panel unit root test developed by Levin, Lin and Chu (2002). They examine if the LOP holds for consumer and producer prices of unleaded petrol and diesel fuel and also emphasize the role of consumer arbitrage (fuel tourism) in these convergence processes. Dreher and Krieger (2008, 2010) find a relatively fast convergence in consumer prices on diesel and unleaded fuel among OMS, which they also partially attribute to consumer arbitrage, at least for diesel. Their results show rapid producer price convergence and slower fuel tax convergence among OMS.

To the best of my knowledge, there have been only two published papers that empirically test motor fuel *tax* convergence. Bilgili (2010) utilizes quarterly data from

[18] A more recent proposal is to tax fuels and electricity according to their (1) energy content , or (2) alternatively, respective CO_2 content (European Commission, COM 169/3, 2011)

1979-2008 for twelve out of fifteen OMS for light fuel oil and automotive diesel fuels and the Lagrange Multiplier unit root test. He finds mixed evidence of tax convergence in the EU: taxes for household automotive diesel converge in nine out of twelve countries, but diverge for Germany, Luxembourg, and the U.K.. Dreher and Krieger (2010) find some support for tax convergence in both value added taxes (VAT) and the excise taxes as well as in tax shares among OMS, but not for convergence in absolute tax levels.

There are also a number of recent studies on the LOP of natural gas prices in the EU that generally conclude that these prices converge within the European region or sub-regions (e.g. Siliverstovs et al., 2005; Asche et al., 2002; Robinson, 2007, Neumann et al., 2006; Panagiotidis & Rutledge, 2007). These findings on natural gas convergence are not surprising because of fixed contracts rigidity (Rosendahl & Sagen, 2009). Transportation costs within Europe are lower for natural gas because it is transported by pipeline. This is not the case for motor fuels because they are harder to transport long distances, especially if countries have natural geographical barriers. Thus, the relative rather than the absolute LOP may hold for motor fuel prices in the EU, as some segmentation of markets is possible even within the Union.

In sum, prior studies of motor fuels often rely on unit root tests that ignore the fact that individual time series in the panel may have non-linear behavior. This is in spite of the fact that gasoline prices can be stickier downwards than upwards (e.g. Asplund et al., 2000) and that governments also may display non-linear fiscal behavior (e.g. Chortareas, Kapetanios & Uctum, 2008). Choi and Moh (2007) show that, even if the time series in the panel are sufficiently long and persistence is not an issue, standard unit root tests suffer from low power and become biased towards non-rejecting a unit root if analyzed series follow non-linear dynamics. Traditional panel unit root tests also tend to suffer from several limitations and weaknesses such as occasional failure to account for cross-sectional dependence, difficulty interpreting a null hypothesis, assuming a linear model specification, etc. (see Choi, 2004 for discussion). Thus, some of the studies described earlier rely on empirical techniques that might be improved using a variety of newer empirical tools for panel analysis, including a non-linear approach to modeling convergence by Phillips and Sul (2007). This paper reconciles the existing findings and uses a newer empirical approach to inquire about motor fuel price and tax convergence patterns in the enlarged EU.

2.3. MODELING CONVERGENCE OF MOTOR FUEL PRICES AND TAXES

My empirical analysis relies on a methodological approach proposed by Phillips and Sul (2007). I test for convergence in balanced panels through identification of convergence clubs (see Appendix 2.A). A notable advantage of this method is that it captures nonlinear transition mechanisms. Given the ample empirical evidence on the nonlinearity of relative prices in the PPP literature (e.g. Taylor, 2001; Taylor & Taylor, 2004; Kilic, 2009; Norman, 2010 among others), this feature is appealing in my analysis. Another feature of this methodological approach is that it allows for individual heterogeneity of units within a panel, without pre-selecting club members or imposing specific assumptions about trend stationarity or stochastic non-stationarity of the dependent variable. The method also allows for transitional dynamics, that is, for convergence testing regardless of whether economies are initially in a state of transition or near steady state equilibrium. It deals directly with individual heterogeneity, addresses autocorrelation concerns, and produces results that are easy to interpret. Since motor fuel prices and taxes for individual countries take a wide range of values over the period 1994-2010 and possibly have different convergence paths, this methodological approach is appropriate to test for fuel price and tax convergence.

2.3.1. Empirical Model

Time enters my model in a non-linear fashion as the following. Let y_{it} denote the dependent variable (either tax level or price of motor fuel) in country i at time t, where $i = 1, 2, \dots, N$; $t = 1, 2, \dots, T$. The dependent variable in my model can be decomposed into two components (Equation 4):

$$y_{it} = g_{it} + \varphi_{it}, \tag{4}$$

where g_{it} represents systematic components, which include common components of cross-sectional dependence in a panel, and φ_{it} captures transitory components. Under this specification, the framework can take a form of a linear or a non-linear process, either stationary or not. In a more general setting, the model takes a nonlinear form (Equation 5):

$$y_{it} = \delta_{it} Y_t, \quad \text{for all } i \text{ and } t, \text{ where} \tag{5}$$

$$\delta_{it} = \frac{(g_{it} + \varphi_{it})}{Y_t} \tag{6}$$

where Y_t is a common component and δ_{it} (Equation 6) is a time varying idiosyncratic component. That is, δ_{it} measures economic distance between a common panel trend Y_t and a country's individual value of y_{it} at time t (Equation 5). In the case of fuel taxation, Y_t stands for a common tax trend in the entire EU, while δ_{it} depicts a relative share of a single country's tax level in common tax trend Y_t in the EU at time t. In the case of price convergence, Y_t stands for a common price trend in the EU, and δ_{it} represent a relative share of a single country's influence on the EU price at time t. A semi-parametric form of the economic distance component ensures its convergence to a constant over time for all $\propto \geq 0$ (Equation 7):

$$\delta_{it} = \delta_i + \sigma_{it}\,\xi_{it} = \delta_i + \frac{\sigma_i}{L(t)\,t^{\propto}}\,\xi_{it} \qquad t \geq 1, \qquad \sigma_i > 0, \qquad \text{for all } i \tag{7}$$

In Equation 7, δ_i and σ_i represent constants, the error term ξ_{it} is iid N(0, 1) and weakly dependent over time via slowly varying time function $L(t)$, such that $\lim_{t \to \infty} L(t) = \infty$. Under a semi-parametric specification, δ_{it} converges to δ_i for all non-negative values decay rate of $\propto$. Parameter δ_{it} in Equation 5 plays an important role in analyzing convergence within a panel. For example, for any given country i, if δ_{it} converges to a constant (δ_i), this implies that prices (taxes) among a few countries may eventually converge to a steady state, if for each country Equation 8 holds:

$$\text{plim}_{k \to \infty} \delta_{it+k} = \delta \qquad \text{iff} \;\; \delta_i = \delta \;\; \text{and} \quad \propto \geq 0 \tag{8}$$

Unlike other conventional convergence methods, this method does not require pre-specification of the nature of the trend or linearity of the time path of the economic distance δ_{it}. Note that in my model (Equation 8), both Y_t and y_{it} may follow either deterministic or stochastic trend. This is one of the attractive features of this convergence modeling approach. At the same time, the path of the trajectory parameter δ_{it} of every individual country i in the EU determines if convergence within a panel will occur in the long-term.

According to Equation 8, for motor fuel taxes (prices) to converge among countries in the same panel, a common component (g_{it}) shall dominate transitory components of individual heterogeneity (φ_{it}). If an individual country's heterogeneity dominates over a common trend in the EU, these members will follow their own paths, resulting in divergence of fuel taxes or prices. Such specification allows for temporary transitional periods, when economic distance between any two EU countries temporarily diverges $\left(\delta_{it} \neq \delta_{jt}\right)$. Equations 5, 8 and 9 imply that a *relative* long-run equilibrium exists between, for example, countries i and j if:

$$\lim_{k \to \infty} \frac{y_{it+k}}{y_{jt+k}} = 1 \qquad \text{for all } i \text{ and } j \tag{9}$$

In order to empirically examine long run behavior I first remove business cycle components (K_{it}) from the data prior to the analysis. Phillips and Sul (2007) show that a removal of cyclical components improves power of their test for finite samples. This transforms Equation 5 into Equation 10:

$$y_{it} = \delta_{it} Y_t + K_{it} \qquad \text{for all } i \text{ and } t, \tag{10}$$

where K_{it} is a business cycle effect. To smooth out a non-linear representation of European fuel price and tax data, I employ the widely used Hodrick and Prescott (1997) filtering technique. I employ this procedure prior to conducting club convergence analysis for every sub-sample in order to remove the cyclical trend from the data. This filter can be used with sorter time series; it is also popular for its convenience: it does not require pre-specification of the nature of the common trend Y_t. The smoothing parameter of the filter (λ) is typically chosen based on data frequency; in my application of weekly data $\lambda = 6400$.

2.3.2. The Log t-Test

Both motor fuel tax convergence and price convergence can be examined by estimating the transition parameter δ_{it} and testing whether it converges to a constant. Because of the over-parameterization issue, the transition parameter δ_{it} in Equation 5 cannot be estimated directly. I, therefore, introduce h_{it} – a *relative transition coefficient* that measures δ_{it} in relation to a panel average (Equation 11). Figures 13-34 (Appendix 2.B) display relative taxes and prices by fuel type, or relative transition curves (h_{it}). For every EU member state these figures portray country series relative to the EU average, and suggest that countries in the EU often follow their individual time paths to convergence.

$$h_{it} = \frac{y_{it}}{N^{-1}\sum_{i=1}^{N} y_{it}} = \frac{\delta_{it}}{N^{-1}\sum_{i=1}^{N} \delta_{it}} \tag{11}$$

Phillips and Sul (2007) offer a specific 3-step procedure and the log t-Test that determines if the cross sectional variance (H_t) of the relative transition parameter h_{it} converges to zero as time approaches infinity (Equation 12):

$$H_t = \frac{1}{N}\sum_{i=1}^{N}(h_{it} - 1)^2 \rightarrow 0 \quad \text{as} \quad t \rightarrow \infty\,, \tag{12}$$

where H_t is the variance of the relative transition parameter h_{it}. The condition stated in Equation 8 implies that δ_{it} converges to δ. The null hypothesis of convergence for a given number of countries N, therefore, tests if $h_{it} \rightarrow 1, H_t \rightarrow 0,$ as $t \rightarrow \infty$ (Equations 12-14). Thus, the hypotheses of the log t-Test are:

$$\mathcal{H}_0\colon \delta_i = \delta \; and \; \propto \geq 0 \tag{13}$$

$$\mathcal{H}_A\colon \delta_i \neq \delta \;\; \text{for all } i \quad \text{or} \quad \propto < 0 \tag{14}$$

The null hypothesis of the test is that real motor fuel series will converge among each other (Equation 13). In the case that the null hypothesis is not rejected for the entire sample, this outcome is denoted hereafter as *global convergence*. Only under specific restrictions on $\propto$ and $L(t)$, does global convergence imply absolute convergence (or zero level differences in the long run) among the panel series (e.g. Apergis et al., 2010). If individual decay rates in Equation 7 are negative ($\propto < 0$), the economic distance will not converge. This forms the alternative hypothesis of non-convergence of the log t-Test (Equation 14). Rejection of the null hypothesis still allows for the possibility of convergence in some subgroups of the panel; rejection only implies that at least one country behaves differently from the panel average. Even if the null hypothesis of global convergence is rejected for the entire sample, countries may still converge in sub-groups (clubs). These clubs can be identified using the four-step clustering algorithm described in Appendix 2.B. This algorithm is based on sorting countries into subgroups and log t-Test repetition. In contrast to the relative convergence, under club convergence each club may have its own non-stationary time-path, and clubs may diverge from one other.

The first step of the log t-Test for convergence requires constructing a cross-sectional variance ratio (H_1/H_t) by using Equations 11-12. As a second step, I test the null hypothesis of convergence by running an OLS regression with robust covariance matrix (Equation 15):

$$\log\left(\frac{H_1}{H_t}\right) - 2\log L(t) = \hat{a} + \hat{b}\log t + \hat{u}_t\,, \tag{15}$$

for $t = rT, rT+1, \ldots, T$ with $r > 0$. In Equation 15, the time varying function $L(t) = \log(t)$, and parameter $\hat{b} = 2\,\hat{\alpha}$, where $\hat{\alpha}$ is the estimate of decay rate α under null hypothesis. Phillips and Sul (2007) use Monte Carlo simulations and show that setting parameter $r \in [0.2, 0.3]$ ensures stronger test results and helps eliminating the initial effect; I use $r = 0.3$, as recommended by them for both satisfactory size and power. The third step of the *log t-Test* requires a one-sided t-test for $\alpha \geq 0$, using $\hat{b}$ and heteroskedasticity and autocorrelation consistent standard error. That is, if $t_{\hat{b}} < -1.65$, the null hypothesis of convergence is rejected at the 5% level.

The difference between the asymptotic cointegration approach and the traditional cointegration is as follows (also see Phillips & Sul, 2007, p.1778-1779). Using Equation 5, the difference between variable y_t for two EU countries A and B can be presented as Equation 16:

$$y_{At} - y_{Bt} = (\delta_{At} - \delta_{Bt})Y_t \tag{16}$$

Typically, if the common panel trend Y_t is non-stationary and the relative distances are not equal to one another ($\delta_{At} \neq \delta_{Bt}$), then the two series y_{At} and y_{Bt} are not considered to be cointegrated. According to Equation 8, however, as $t \to \infty$, relative distances converge to the same common δ, in which case y_{At} and y_{Bt} may be thought of as asymptotically cointegrated. Yet, if the speed of convergence in the common panel trend Y_t is faster than the speed of convergence of the relative economic distances (δ_{it}), conventional tests may not always disclose the asymptotic cointegration. This is why they construct their test in relative terms, as a ratio, instead of a linear difference. Equation 9 ensures that when series are cointegrated, their ratio converges to a constant or, in a case of deterministic trend, to a random variable.

The approach described here, however, has several limitations. First, the log t-Test is an asymptotic test and its properties greatly depend on the number of time periods (T) in the panel. Like any asymptotic test, it does not solve the common problem of low T. Second, this algorithm is sensitive to the order in which countries are initially sorted when one conducts a search for clubs. This critique does not apply to the global test because in that case the order does not matter. As new members join the club, the club-average also changes. According to steps 2 to 4 of the clustering algorithm (see Appendix 2.A), every new member is compared to the *current* club average. In this situation, the member joined last is compared to a different club-average than the member admitted before him. Lastly, the approach requires a balanced sample, which, depending on data availability, may further limit the number of time periods T in a panel.

2.4. DATA

The weekly data on nominal prices and taxes for four types of motor fuels are extracted from the EU Oil Bulletin published by the European Commission database.[19] The data are for unleaded petrol (Euro-super-95), automotive gas oil (diesel), liquefied petroleum gas (LPG) and lead replacement petrol (Super). To date, only a part of this data and only for OMS has been previously used in the literature (e.g. Wlazlowski, et al., 2009; Dreher & Krieger, 2008, 2010).

All prices and excise taxes are converted into real values with daily euro exchange rates and a monthly consumer price index (CPI) for the period 1994-2010 from the UNECE Statistical Division database. Monthly CPI indices are transformed to match weekly price levels by constructing weekly series of CPI price deflators, using the geometric mean formula to calculate the average weekly CPI growth rates and between months. The listed monthly CPI was assigned to week one. Price index for week two was obtained as a product of the CPI for week one, multiplied by the weekly CPI growth rate. Price index for week three is the product of the CPI for week two, multiplied by the weekly CPI growth rate, etc.

The tax level for each product is estimated as a combination of excise and value added taxes for any given motor fuel. All price and tax level data is then transformed into natural logs. Because Bulgaria and Romania joined the EU in 2008, these two countries are excluded from the panel in order to maximize the number of total time periods. The remaining members of the EU are denoted as EU-25. Also, in order to maximize the

[19] Updated data are periodically published at : http://ec.europa.eu/energy/observatory/oil/bulletin_en.htm

number of time periods, only the original countries that formed the Eurozone and Greece are included in the Eurozone group (EZ-12). The data is divided into thirteen separate sub-samples and each of them is balanced with no gaps according to availability of observations (Table 9). Table 10 displays summary statistics for each balanced sample (see Essay 1, Appendix 1.A, of this dissertation for discussion).

The statistical analysis is conducted using the STATA 11 software package. First, I test for a presence of *global* and club convergence in the EU for all four motor fuels. Second, the EU members are separated into OMS or NMS, and convergence is determined within these subsets of countries. Next, the analysis is repeated for the Eurozone. Convergence test results are summarized in Table 11.

2.5. EMPIRICAL ANALYSIS AND RESULTS

2.5.1. Convergence Results for Unleaded Euro-super-95 Fuel

I find a presence of global convergence in taxes, but not in consumer prices on unleaded gasoline in the EU. This conclusion follows because, for taxes, the t-statistic ($t = -0.96$) of the left-tailed log t-Test is only slightly above the threshold level of $t = -1.65$ (Table 11, Figure 13). By contrast, for consumer prices the t-statistic of global convergence ($t = -12.00$) is below the threshold level (Tables 11-12). Following the club convergence algorithm described in Appendix 2.A, I find three clubs for Euro-super-95 consumer prices, which implies that this market in the EU is segmented (Figures 14-16). In addition, consumer prices on this gasoline in Latvia and Poland do not converge to any of the three club averages, or between each other (Tables 11-12). To further investigate the relationship between prices and taxes in the EU clubs, I repeat the analysis using producer prices for unleaded Euro-super-95 gasoline. Like consumer prices, producer prices for unleaded gasoline converge in clubs rather than globally (Figure 17), which follows from the t-statistic of the global log t-Test ($t = -15.23$) being below the threshold level (Tables 11-12).

The first consumer price convergence club for Euro-super-95 consists of most OMS, except for Luxembourg and Spain, and three NMS, Slovakia, the Czech Republic, and Malta (Table 11, Figure 14). This is not surprising, given the high praise for strong economic performances and GDP growth in the 2000s in such NMS as Slovakia, the Czech Republic, and Malta. In addition, Slovakia and the Czech Republic are among the leaders of the EU auto industry and geographical neighbors with each other as well as with at least one other OMS. For these three NMS, approaches to motor fuel taxing may have also played a role in convergence with other OMS. Relative transition curves for taxes in Slovakia and Czech Republic show that in 2004, total taxes on unleaded gasoline were lower than in the rest of the EU, but by 2010 they had risen to the EU average (Figure 13). Malta also increased its taxes in 2009, but the relative transition curve for its Euro-super-95 taxes remained below the EU average (Figure 13). It is worth noting that, compared to other EU members, Malta had unusual transition paths for producer and, as a consequence, for consumer relative prices (Figures 14 and 17). The erratic nature of Maltese producer prices may be due to its location on an island and by the fact that it imports all of its gasoline.

The second consumer price club for Euro-super-95 includes Estonia, Lithuania, Luxembourg and Spain (Table 11, Figure 15). It is unexpected that such dissimilar OMS like Spain and Luxembourg converge with NMS like Lithuania and Estonia. One possible explanation is a gradual reduction for motor fuel taxes in Spain and Luxembourg, depicted by the transition curves on Figure 13, which possibly contributed to their diverging price paths from the rest of OMS. It is, however, expected that Estonia and Lithuania are in one club because they have similar political and economic histories and belong to the same geographical area. Estonia, Latvia, and Lithuania are somewhat isolated from the rest of the EU, and all are former Baltic USSR Republics. Nevertheless, in contrast to Latvia, total tax levels on unleaded gasoline in both Lithuania and Estonia are much more similar to the rest of the EU than in neighboring Latvia. In addition, Lithuania and Estonia form one producer price club with Hungary. This club is unexpected, given that these three NMS are not immediate neighbors and differ somewhat in terms of their gasoline production. One thing in common is that Lithuania, Estonia, and Hungary have remained non-Eurozone countries since they joined the EU in 2004.

The third consumer price club for unleaded gasoline includes Hungary and the island of Cyprus, countries that are both NMS since 2004 (Table 11, Figure 16). This club is unexpected because Hungary and Cyprus do not share any geographical borders, and are dissimilar in terms of population and passenger car fleet. One factor that may partially explain this market segment is that Hungary and Cyprus belong to the same tax club for Euro-super-95 among NMS. Their relative transition curves indicate that while the difference in total taxes between Hungary and Cyprus remains large, both countries gradually decrease their total taxes on unleaded gasoline compared to the rest of the EU (Table 11, Figure 13). Thus, a similar trend in taxation rather than production may be the reason for consumer gasoline price convergence between them.

For consumer prices on Euro-super-95, Latvian and Polish disintegration may be driven by a combination of factors such as their size, geographical location, NMS status, or it may be that gasoline producers in these countries have greater market power. Poland is the biggest NMS in terms of its geographical size. Unlike in Luxembourg, for example, a majority of Polish consumers are less likely to cross national borders to purchase unleaded gasoline. This can be seen when I restrict the analysis to just NMS: Polish consumer prices for Euro-super-95 converge with prices in Lithuania, Estonia, Hungary and Cyprus, that is, with non-neighboring NMS (Figure 19).

An analysis of producer prices and taxes sheds more light on the Euro-super-95 market in Latvia and Poland. My test results indicate that producer prices in Latvia, Poland, and the U.K. do not converge either among each other or with any of the existing club averages. It is not surprising that producer prices in the U.K. do not converge with the rest of the EU because the U.K. is the major oil producer in Europe. However, for Latvia and Poland, producer price non-convergence is one reason why consumer prices follow their own, non-converging path (Figure 20). As for taxes, Latvian tax levels remain among the lowest in the EU and are closer to those of Cyprus (Figure 18). Thus, given that Latvia does not refine its own gasoline, a non-convergence of Latvian Euro-super-95 consumer prices with the rest of the EU or with any other NMS seems to be driven by its exports of gasoline and by low, non-converging taxation.

It is worth noting that a few other countries had interesting transition paths in the EU. Figures 13 and 14 show that Greece was a country with relatively low consumer prices on unleaded gasoline, until it sharply increased its taxes and, consequently, consumer prices on Euro-super-95 in 2010. That is, as the economic literature predicts (e.g. Rork, 2003), at the time of economic hardship, Greece increased its indirect (excise) taxes, followed by a value added tax increase as well.

In summary, my findings on club convergence for unleaded Euro-super-95 gasoline lend little support to the LOP. It implies that national markets for this fuel in the EU are integrated into several regional markets instead of one common European market. My results also suggest that differences in consumer price convergence paths among the EU-25 countries stem from convergence differences in production prices rather than taxes, although relative taxes remain an important component of this dynamic. OMS, but not NMS, tend to converge in taxes and prices to their group averages. For the twelve original Eurozone members (EZ-12), taxes and prices on unleaded gasoline also seem to converge among members (Table 11). The empirical evidence of this convergence, however, appears to be slightly stronger for OMS than the Eurozone group, especially for taxes. Among NMS, Latvia and Poland are the two countries that have loose integration with the rest of the EU market for unleaded gasoline. In addition, there is one producer club which is an anomaly among my data: that of Austria, Sweden, and Slovenia. While producer prices converge among these three countries, they are part of a much larger consumer price club. This is surprising because while Austria and Slovenia are geographical neighbors, Sweden is not; and while Austria and Sweden are OMS, Slovenia is a NMS country.

2.5.2. Convergence Results for Diesel Fuel

My test results indicate that while diesel taxes converge in most of the EU-25 countries, except for Cyprus and Latvia, neither consumer or producer prices converge (Table 11, Figures 23-35). The situation with the diesel market seems to be similar to the unleaded gasoline market: differences in producer price paths drive differences in consumer price convergence. The majority of EU-25 countries form the first price convergence club (Table 11, Figure 22), indicating that the diesel market among the rest of the EU members is somewhat integrated. The largest consumer price club for diesel fuel has more members than the largest club for Euro-super-95. It consists of all of the OMS, except for Luxembourg, and six NMS: Slovakia, the Czech Republic, Malta, Slovenia, Poland and Estonia. Thus, with the exception of Hungary and two Baltic NMS, diesel consumer prices in the entire Central and Eastern Europe converge with diesel prices in Western Europe. This outcome may be a result of higher mobility of diesel consumers (truck drivers) across national borders as well as harmonized diesel taxes in the EU.

Hungary, Cyprus, and Luxembourg form a second separate diesel consumer price club (Figure 23). As described in the previous section, Hungary and Cyprus, both NMS, also formed a separate consumer price club for unleaded gasoline. Luxembourg, however, is an OMS and is an unexpected member of this diesel club. It is not unusual that two geographical neighbors in the Eastern Baltics, such as Latvia and Lithuania form the last consumer price club for diesel (Table 11, Figure 24). Their fossil fuels are exported from Russia, and the primary users of diesel, the truck drivers on international routes to Europe, may exert an additional pressure for emergence of this separate diesel market from the rest of the EU.

There is also strong evidence of convergence in diesel producer prices, and consumer prices among OMS and among the EZ-12, but not in the entire EU-25 (Table 11). For the entire NMS group, I do not find any evidence of convergence in either diesel consumer or producer prices. This might suggest that some of the NMS have already integrated with the European Common Market for diesel, or are on their way to doing so. For instance, diesel consumer prices in Slovakia and Malta display individual, non-converging behavior among NMS, but converge with many OMS (Table 11). For Malta, like for its unleaded gasoline, an erratic consumer price path may be explained by wide swings of producer prices compared to the EU average, which is reflected in its relative transition curve for diesel producer prices (Figure 25).

For some countries, relative transition curves for total taxes and prices for diesel are worth describing. Compared to the other EU members, the diesel tax levels have increased in Greece, Malta, Latvia, Estonia, Slovenia and Ireland, but decreased in Hungary and Slovakia between 2004 and 2010 (Figure 21). In these countries, diesel consumer prices reflected the corresponding tax change. For example, Greece, which used to have lower taxes and hence lower consumer prices for diesel than the EU average, sharply raised its taxes on diesel in the late 2000s when it had a serious fiscal budget problem. Also, by the late 2000s, relative producer prices for diesel in Hungary and the Eastern Baltic countries began to increasingly diverge from the rest of the EU (Figure 25). My test results show that Hungary and Estonia already form a single producer price convergence club in the EU and among NMS (Table 11). This is surprising given that Hungary and Estonia are not geographical neighbors.

The U.K. has the most interesting relative transition curves for diesel fuel among the EU-25 as well as among OMS. Diesel consumer prices in the U.K. first sharply rose in the late 1990s and then somewhat dropped between the early 2000s and 2008 (Figure 22) as a result of a series of large protests against high motor fuel taxes, while still remaining relatively high compared to the rest of the EU. British diesel taxes followed a similar pattern but remained the highest in the EU, which explains the path of diesel consumer prices (Figure 21). Similar to unleaded fuel, this outcome for diesel in the U.K. can be explained by some of the lowest producer prices in the EU, given the fact that the U.K. is one of the largest oil exporters in Europe.

2.5.3. Convergence Results for LPG and Lead Replacement (Super) Fuels

In contrast to diesel and unleaded gasoline, LPG data is available for fewer countries during a shorter time span because it is a much smaller market than the market for unleaded gasoline or diesel. LPG results indicate that there is no *global* convergence in consumer prices, producer prices, or taxes among the sixteen analyzed EU members. For LPG, taxes converge into two clubs and producer prices converge into three clubs or do not converge at all (Table 11, Figures 26, 28).

Two separate consumer price clubs exist among the sixteen countries with available data, mainly due to non-harmonization of LPG taxes and producer prices (Table 11). Some OMS, such as France, Portugal, Italy, Germany, and the Netherlands form the first LPG price club (Figure 27). These countries are similar economically and are among the oldest EU founders. These five countries are also a part of a larger LPG tax club and, with the exception of Italy, a larger producer price club. The remaining eleven EU members for which the data is available, form the second consumer price club that consists of both OMS and NMS (Table 11, Figure 27). This outcome may be driven by long term differences in production costs and taxes for LPG fuel in the EU. There is strong evidence of two tax convergence clubs for LPG fuel (Table 11, Figure 26). The first, a low tax club, includes Spain, Belgium, Luxembourg, and Slovakia. This first tax club is surprising because there are no obvious similarities between these countries, except for Belgium and Luxembourg being neighbors. The remaining twelve EU members, both OMS and NMS, form the second LPG tax club.

In contrast to unleaded gasoline and diesel fuel, findings for LPG indicate that taxes on this fuel are not harmonized in the EU. While accounting for only about 2% of the overall EU motor fuel market, the LPG market is relatively small. Yet, there are typically some political costs associated with disharmonized tax scenarios. For countries where LPG consumers are highly mobile across borders and taxes are high, some producers would have to assume a larger share of the tax burden and could be forced to shut down, lay off employees, or migrate to countries with lower tax rates, causing social and political tensions (see Banfi, et al., 2005; Dreher & Krieger, 2008, 2010 for discussions). In contrast, under the harmonized tax scenario, like the situation with diesel and unleaded gasoline in the EU, national governments face other issues, such as lesser flexibility in addressing local transport-related social costs.

As for lead replacement (Super) gasoline, data limitations restrict my focus to only two different subsets of six countries each, for the periods 1994-2001 and 2000-2005. Moreover, this fuel was officially banned in the EU starting 2000, and in the early 2000s, the EU countries were slowly phasing it out from the market. Using data for the period of 1994-2001, consumer prices on leaded gasoline in France, Italy, Belgium and Ireland converge in a single club (Table 11, Figure 30). Consumer prices on this fuel in Spain and Greece form the second convergence club – an unexpected pairing because, despite that these countries are both OMS and in southern Europe, they are geographically distant from one another (Figure 30). On the other hand, both countries are known for their low taxation rates on motor fuels among OMS (Figure 29). This two club outcome for prices on leaded fuel can be partially explained by differences in convergence paths of taxes among these six OMS countries; my test results show that their producer prices globally converge (Table 11, Figure 31). During the period of 1994-2001, taxes on Super fuel in France, Italy, Spain, and Greece followed their own, non-converging path (Figure 29). Belgium and Ireland, on the other hand, showed relative tax convergence and, joined by France and Italy, consumer price convergence.

Meanwhile, a different picture emerges from the 2000-2005 data subset for lead replacement (Super) fuel. Producer prices on this gasoline in the Netherlands, Portugal, Spain, Greece, France and the U.K. indicate strong global convergence (Table 11, Figure 34). Test results also show weak evidence of global convergence in taxes among these OMS countries (Table 11). With the exception of the Netherlands, consumer prices for Super gasoline also converge in a single club in this group (Figure 33). Thus, convergence for Super fuel occurs in a much smoother fashion based on the data from the 2000s compared to the late 1990s, in part due to stronger tax harmonization. In sum, in the early-mid 2000s, taxes and prices on lead replacement petrol became more similar among OMS and also became higher than in the late 1990s, which may reflect a common effort to phase out this fuel from the European market at that time (e.g. Löfgren & Hammar, 2000).

2.6. CONCLUSION AND POLICY DISCUSSION

In light of the ongoing EU enlargement, the findings of this paper can contribute to dialogues on motor fuel market integration, policy convergence, 'fuel tourism' and fiscal harmonization among the EU members. Since I account for countries' heterogeneity and non-linear transition mechanisms, the findings are also useful for designing more precise policies related to motor fuels and greenhouse gas emissions from transport in Europe. These policies include the upcoming revision of the National Emission Ceiling Directive 2001/81/EC (The Council of European Communities, 2001) and a proposed Directive that recommends setting tax floors based on the CO_2 content of each fuel (The European Commission, 2011).

Nevertheless, it is worth noting that my test results of the club convergence analysis could be fragile, mainly due to the small sample properties of the Phillips-Sul method. One has to keep these limitations in mind when assessing the findings of this paper. Although they could be the best available in the literature, they are nonetheless subject to future challenge and could be reversed.

That being said, unlike the prior literature on motor fuels, this paper shows that in the EU, the market for motor fuels remains segmented. For the two major motor fuels in the EU, unleaded gasoline and diesel, I find some support of the Law of One Price (LOP) for OMS and the EZ-12 groups, but not for NMS or for the EU as a whole. My results for OMS are consistent with the findings by Dreher and Krieger (2008, 2010), who use nominal data for the period 1994-2004, but do not include NMS in their study. I show, however, that in contrast to OMS countries, NMS do not form a motor fuel club among each other. The results also indicate that in the long run, motor fuel markets in some NMS - Hungary, Cyprus, and the Eastern Baltic countries, for example - may not become integrated with the rest of the EU motor fuel market. I also find that the LOP does not hold for LPG fuel, a much smaller European fuel market, either among the sixteen EU members for which data is available, or among OMS and NMS groups.

One of the key takeaways from my findings is that in order to reduce motor fuel market segmentation in the EU, individual governments should ensure a highly competitive environment for motor fuel producers. This is because such long-term segmentation is driven more by behavior of producer prices than by taxes. For unleaded gasoline and diesel, I do not find global convergence in consumer or producer prices among the EU-25, but I find it in taxes. Producer prices converge in the OMS and the EZ-12 groups, except for diesel producer prices in Ireland, Luxembourg, and the Netherlands in the EZ-12 group. Nevertheless, for the EU as a whole, the persistence of clubs in real producer prices indicates that the markets for motor fuels are far from the spot market condition, and that relative differences in production prices may remain among sub-groups in the long run.

As for taxes, my results suggest that in the 1990s-2000s in the EU, in the presence of the statutory tax floor measures (CEU, 2003), unenforced tax ceiling measures (25% VAT), and members' individual environmental policy measures, taxes for two major motor fuels began harmonizing. For diesel fuel and unleaded gasoline, total taxes are harmonized among the entire EU, but this harmonization is rather fragile. This fragility is consistent with limited flexibility of indirect taxation due to the unanimity rule required in voting to approve any changes to the EU tax floor legislation by the member-countries. This fragility may also be driven by socio-economic differences of the EU members as well as by differences in national-level externalities associated with road transport. Taxes on diesel and unleaded gasoline in OMS and in the EZ-12 converge to their group averages, but taxes among NMS do not converge. Since these taxes globally converge in the entire EU, my results suggest that some but not all NMS countries are less actively involved in the process of tax harmonization with the OMS and the EZ-12.

The aims of the Union are to encourage free competition, to smooth the operation of the European Common Market, to better integrate NMS, and to reduce overall GHG emissions (e.g. Council of European Communities, 2003; the European Commission, 2001, 2008, 2010; Eurostat, 2009a, 2009b). Given these goals, my findings suggest that the European Commission should consider further narrowing the tax gap among the EU members. Harmonized motor fuel taxes typically help to reduce fuel tourism and to stabilize the stream of tax revenues to national governments. In a competitive setting, under harmonized taxes, mobile consumers lose incentives to strategically purchase fuel abroad. If taxes are to become even more harmonized, the EU has a strong foundation for a non-distortive operation of the Common Market for motor fuels, but needs to ensure that the European market is competitive. At times of financial hardship, however, national governments often rely on raising gasoline taxes, such as excise taxes on motor fuels (Rork, 2003). Thus, it is important to understand that as time progresses, tax convergence among the EU countries may become more fragile or even result in a disharmonized tax scenario if the current economic crisis in Europe progresses.

When it comes to environmental policy, fuel tax harmonization may be viewed as an unspoken agreement between countries to tax motor fuels at a common CO_2 benchmark level. In climate change policy debates, policymakers are often concerned with forecasting CO_2 emissions. Forecasting and simulation models are frequently used in preparing such environmental policy proposals and predicting its outcomes. Both motor fuel prices and taxes serve as key variables in these simulation studies (e.g. England, 2007), including studies of emissions from transport in the EU (e.g. Abrel, 2010). Recent studies emphasize the importance of testing for club convergence because the assumption of cross-country convergence/divergence in CO_2 emissions is often embedded in simulation models (for discussion see Panopoulou & Pantelidis, 2009). With taxes being the primary policy tool for reducing emissions from transport in the EU, my findings on motor fuel price convergence and tax harmonization are of crucial interest to such policy assessments.

In this light, one current policy proposal, 'Amending Directive 2003/96/EC Restructuring the Community framework for the taxation of energy products and electricity,' help national governments to address both the environmental goals and the budgetary goals (the European Commission, 2011). This proposed policy recommends imposing tax floors based on the CO_2 content of each fuel, which may strengthen the EU tax harmonization. The proposed policy is also in line with emission reduction commitments up to 2020 (the European Commission, 2010), and should make motor fuel tax policies more consistent with the climate related goals of the EU. National governments may also benefit from supporting this unit emission based taxation scheme; they are typically confronted with the local social costs of transport, such as increasing emissions. The new scheme allows them to tax fuels in a manner more consistent with the European Emission Trading Scheme.

Finally, in a broader sense, the findings of this essay are also relevant to the current fiscal policy dialogs in Europe and origination of the European Fiscal Union: in 2012, the EU members (except for the Czech Republic and the U.K.) signed the Fiscal Stability Treaty (CEU, 2012). By using the newly available data for motor fuels as an example, this essay provides some insights that twenty seven diverse countries, both older and newer members of the Union, fiscally coordinate some of their taxation decisions even in the absence of formal policy.

Some studies, however, find that EU members also form clubs in their per capita GDP, meaning that in the long run inequality among EU members will remain (e.g. Apergis et al., 2010). The big picture consequence of the 2012 EU fiscal consolidation is that in the presence of per capita GDP disparity, tax harmonization suggested by my results implies a real income disparity across EU members. Then, the income-adjusted tax burden on drivers in the relatively poorer EU countries (e.g. NMS) will be much higher compared to the burden on drivers in richer EU countries (e.g. Germany, Denmark). In this setting, it becomes likely for the European Commission to form a central authority that would be responsible for making transfer payments from rich to poor EU members. The issue, however, will be to determine the exact size of these transfer payments and the least distortive way of recycling revenues from these payments by the receiving governments.

As an extension of this essay, it is important to assess the role of tax competition among neighboring states and the rest of the EU members. In addition, as it is discussed in the previous section, countries in some clubs seem dissimilar in terms of their geographic locations, economic factors, and the lengths of their EU membership. The next essay sheds more light on the factors that influence price and tax dynamics in the short run, and on the continuous integration of NMS into the European Common Market for motor fuels.

Table 9. Balanced Data Samples for Club Convergence Analysis of Fuel Prices and Tax Levels in the EU

Balanced Sample Number	Fuel Type	Sample Period		Number of Countries	Number of Time Periods	Included Countries
		Beginning	End			
1	Unleaded Euro-95	1/2/1995	6/7/2010	15	758 (806)	OMS
2	Unleaded Euro-95	6/7/2004	6/7/2010	25	297 (314)	EU-25
3	Diesel	1/2/1995	6/7/2010	15	758 (806)	OMS
4	Diesel	6/7/2004	6/7/2010	25	297 (314)	EU-25
5	LPG	7/26/2004	6/7/2010	16	290 (309)	BE, CZ, DE, EE, ES, FR, HU, IT, LT, LU, LV, NL, PL, PT, SI, SK
6	Leaded Super	1/03/1994	6/4/2001	6	362 (388)	BE, ES, FR, GR, IE, IT
7	Leaded Super	1/03/2000	8/8/2005	6	278 (293)	ES, FR, GR, NL, PT, UK
8	Unleaded Euro-95	6/07/2004	6/7/2010	10	297 (314)	NMS, except BG and RO
9	Diesel	6/14/2004	6/7/2010	10	296 (313)	NMS, except BG and RO
10	Unleaded Euro-95	1/1/2001	6/7/2010	12	465 (493)	EZ-12
11	Diesel	1/1/2001	6/7/2010	12	465 (493)	EZ-12
12	LPG	7/26/2004	6/7/2010	8	290 (307)	FR, PT, NL, ES, BE, DE, LU, IT
13	LPG	7/26/2004	6/7/2010	8	290 (307)	SK, SI, CZ, HU, PL, LT, EE, LV

Table 10. Summary Statistics, Balanced Samples 1 – 13 (real data)

Variable	Mean	Std. Dev.	Min	Max	Observations
	(1)	(2)	(3)	(4)	(5)
Data set 1, Euro-95					*N=11370, n=15, T=758*
price950	365.46	95.82	157.90	793.21	
price951	1074.74	154.28	699.75	1692.53	
fuel95vat	19.45	3.17	12.00	25.00	
fuel95excise	533.06	104.03	285.44	946.48	
Tax level share	65.99	7.38	44.31	85.95	
Data set 2, Euro-95					*N=7425, n=25, T=297*
price950	441.15	77.87	201.03	793.21	
price951	1063.95	180.31	535.92	1692.53	
fuel95vat	19.51	2.61	12.00	25.00	
fuel95excise	448.07	121.79	208.04	732.17	
Tax level share	57.99	7.08	39.63	76.74	
Data set 3, Diesel					*N=11370, n=15, T=758*
pdiesel0	374.25	116.94	154.77	828.11	
pdiesel1	896.29	177.49	508.57	1615.58	
Diesel vat	19.45	3.17	12.00	25.00	
Diesel excise	374.74	102.69	236.26	946.48	
Tax level share	58.59	8.05	36.29	86.17	
Data set 4, Diesel					*N=7425, n=25, T=297*
pdiesel0	478.28	88.43	263.06	828.11	
pdiesel1	972.38	148.84	586.51	1479.99	
Diesel vat	19.51	2.61	12.00	25.00	
Diesel excise	334.64	88.17	177.18	732.17	
Tax level share	50.63	6.35	33.17	73.39	
Data set 5, LPG					*N=4640, n=16, T=290*
plpg0	367.02	72.60	160.94	517.02	
plpg1	519.74	82.37	314.86	750.08	
lpg vat	19.12	2.04	12.00	25.00	
lpg excise	71.02	35.12	0.00	159.01	
Tax level share	29.49	8.13	14.57	53.66	
Data set 6, Super					*N=2172, n=6, T=362*
super0	306.23	76.28	157.05	528.29	
super1	1069.07	116.15	779.59	1353.52	
super vat	19.20	1.84	15.00	21.00	
super excise	589.64	88.21	375.46	747.31	
Tax level share	71.31	6.40	52.98	85.03	
Data set 7, Super					*N=1668, n=6, T=278*
super0	394.77	77.21	240.66	603.33	
super1	1141.63	186.67	791.20	1666.04	
super vat	18.02	1.23	16.00	21.00	
super excise	570.68	162.98	318.79	986.80	
Tax level share	64.66	8.14	44.90	79.35	

Table 10. (continued)

	(1)	(2)	(3)	(4)	(5)
Data set 8, Euro-95 NMS					*N=2970, n=10, T=297*
price950	431.87	78.60	201.03	674.44	
price951	920.80	122.21	535.92	1343.38	
fuel95vat	19.05	2.13	15.00	25.00	
fuel95excise	342.33	62.49	208.04	475.62	
Tax level share	53.11	5.81	39.63	68.91	
Data set 9, Diesel NMS					*N=2960, n=10, T=296*
pdiesel0	463.78	86.20	263.06	772.82	
pdiesel1	891.74	124.86	586.51	1346.17	
Diesel vat	19.05	2.13	15.00	25.00	
Diesel excise	285.99	57.77	177.18	427.09	
Tax level share	48.04	5.73	33.17	62.76	
Data set 10, Euro-95 EZ-12					*N=5580, n=12, T=465*
price950	413.57	86.37	203.51	793.21	
price951	1099.10	158.27	732.13	1692.53	
fuel95vat	18.95	2.35	12.00	22.00	
fuel95excise	508.44	105.20	285.44	684.76	
Tax level share	62.20	6.69	44.31	79.54	
Data set 11, Diesel EZ-12					*N=5580, n=12, T=465*
pdiesel0	434.51	106.94	239.63	828.11	
pdiesel1	927.55	144.84	616.02	1413.49	
Diesel vat	18.95	2.35	12.00	22.00	
Diesel excise	342.82	59.50	236.26	487.97	
Tax level share	53.52	6.23	36.29	71.51	
Data set 12, LPG OMS					*N=2320, n=8, T=290*
plpg0	407.32	58.48	275.15	571.02	
plpg1	549.47	80.08	345.03	750.08	
lpg vat	18.56	2.16	12.00	21.00	
lpg excise	59.95	37.61	0.00	159.01	
Tax level share	25.44	7.27	14.57	45.98	
Data set 13, LPG NMS					*N=2320, n=8, T=290*
plpg0	326.71	62.22	160.94	495.59	
plpg1	490.02	73.42	314.86	711.78	
lpg vat	19.69	1.74	18.00	25.00	
lpg excise	82.09	28.41	0.00	132.86	
Tax level share	33.53	6.82	15.97	53.66	

Table 11. Club Convergence Results (t-statistics in parenthesis)[20]

Time Period	Number of Countries	Fuel Type	Prices or Tax Levels	Global Convergence Test $\hat{b}\,(t-stat)$	Convergence Club Classification	
					Group Membership	$\hat{b}\,(t-stat)$
(1)	(2)	(3)	(4)	(5)	(6)	(7)
2004-2010	25	Euro-95	tax levels	-0.029 (-0.97)	1st club: EU-25	-0.029 (-0.97)
2004-2010	25	Euro-95	consumer prices	-0.438 (-12.00)*	1st club: NL, DK, DE, BE, FI, GR, PT, SE, IT, IE, FR, UK, SK, AT, MT, CZ, SI 2nd club: LU, ES, LT, EE 3rd club: HU, CY No club: PL, LV	0.013(0.25) 0.153 (1.61) 1.368 (4.55) -0.551(-4.32)*
2004-2010	25	Euro-95	producer prices	-1.072 (-15.23)*	1st club: DK, MT, IT, BE, PT, FI, NL, IE, CY, ES, DE, LU, FR, SK, CZ, GR 2nd club: AT, SE, SI 3rd club: LT, EE, HU No club: UK, PL, LV	0.025 (0.26) 0.378 (1.69) 0.778 (2.90) -1.903 (-10.81)*
1995-2010	15 OMS	Euro-95	tax levels	0.310 (12.36)	1st club: all OMS	0.310 (12.36)
1995-2010	15 OMS	Euro-95	consumer prices	0.219 (9.76)	1st club: all OMS	0.219 (9.76)
1995-2010	15 OMS	Euro-95	producer prices	0.722 (10.99)	1st club: all OMS	0.722 (10.99)
2004-2010	10 NMS	Euro-95	tax levels	-0.368 (-5.55)*	1st club: CZ, SI, MT, PL, LT, EE 2nd club: HU, LV, CY No club: SK	0.591 (4.85) 0.434 (3.37) -
2004-2010	10 NMS	Euro-95	consumer prices	-0.852 (-10.48)*	1st club: CZ, SI 2nd club: PL, LT, HU, CY, EE No club: SK, MT, LV	0.558 (1.07) 1.051 (5.85) -1.346 (-18.08)*
2004-2010	10 NMS	Euro-95	producer prices	-0.903 (-9.85)*	1st club: MT, CY, SK, CZ, PL, SI 2nd club: LT, EE, HU No club: LV	0.014 (0.11) 0.778 (2.90) -
2001-2010	12 EZ	Euro-95	tax levels	0.002 (0.10)	1st club: EZ-12	0.002 (0.10)

[20] An asterisk (*) indicates rejection of null hypothesis of convergence at 5% level.

Table 11. (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
2001-2010	12 EZ	Euro-95	consumer prices	-0.087 (-2.95)*	1st club: NL, DK, BE, FI, GR, PT, IT, IE, FR, AT, LU No club: ES	0.035 (1.03) -
2001-2010	12 EZ	Euro-95	producer prices	0.559 (7.57)	1st club: EZ-12	0.559 (7.57)
2004-2010	25	Diesel	tax levels	-0.102 (-4.63)*	1st club: EU-25 (except CY and LV) No club: CY, LV	0.083 (2.60) -2.074 (-4.65)*
2004-2010	25	Diesel	consumer prices	-0.540 (-22.51)*	1st club: UK, SE, IE, DE, IT, DK, GR, NL, BE, PT, CZ, FR, FI, AT, SI, SK, ES, MT, PL, EE 2nd club: LU, HU, CY 3rd club: LT, LV	0.029 (0.86) 1.066 (6.14) -0.096(-0.17)
2004-2010	25	Diesel	producer prices	-1.771 (-30.79)*	1st club: PT, IT, FI, GR, DK 2nd club: SE, DE, CY, NL, LU, CZ, FR, AT, MT 3rd club: HU, EE No club: BE, IE, ES, SK, PL, UK, SI, LT, LV	0.341 (2.11) 0.243 (1.93) 0.070 (0.13) -2.638(-24.47)*
1995-2010	15 OMS	Diesel	tax levels	0.592 (26.87)	1st club: all OMS	0.592 (26.87)
1995-2010	15 OMS	Diesel	consumer prices	1.412 (52.97)	1st club: all OMS	1.412 (52.97)
1995-2010	15 OMS	Diesel	producer prices	0.983 (16.64)	1st club: all OMS	0.983 (16.64)
2004-2010	10 NMS	Diesel	tax levels	-0.582 (-13.06)*	1st club: CZ, SI, EE, MT, HU, PL No club: SK, LV, LT, CY	0.178 (2.28) -0.539(-5.69)*
2004-2010	10 NMS	Diesel	consumer prices	-1.105 (-16.23)*	1st club: CZ, SI 2nd club: PL, EE, HU, CY, LT No club: SK, MT, LV	1.861 (5.17) 0.462 (3.52) -1.197(-10.35)*
2004-2010	10 NMS	Diesel	producer prices	-1.379 (-15.45)*	1st club: PL, MT, SI, LT 2nd club: HU, EE No club: CY, CZ, SK, LV	0.031 (0.18) 0.065 (0.12) -2.527(-24.37)*
2001-2010	12 EZ	Diesel	tax levels	0.088 (8.31)	1st club: EZ-12	0.088 (8.31)

Table 11. (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
2001-2010	12 EZ	Diesel	consumer prices	0.243 (7.91)	1st club: EZ-12	0.243 (7.91)
2001-2010	12 EZ	Diesel	producer prices	-0.253 (-3.33)*	1st club: PT, IT, FI, GR, BE, ES, DE, FR, AT No club: IE, NL, LU	0.038 (0.42) -0.730 (-2.83)*
2004-2010	16	LPG	tax levels	-0.729 (-31.54)*	1st club: ES, BE, LU, SK 2nd club: IT, LT, NL, DE, PL, HU, FR, SI, LV, PT, CZ, EE	1.895 (19.06) 0.276 (8.59)
2004-2010	16	LPG	consumer prices	-0.743 (-15.65)*	1st club: FR, NL, PT, IT, DE 2nd club: SI, ES, EE, BE, CZ, HU, LU, PL, LT, SK, LV	0.112 (2.02) 0.030 (0.49)
2004-2010	16	LPG	producer prices	-1.023 (-15.63)*	1st Club: FR, PT, NL, ES, SI, BE, DE, LU 2nd club: EE, SK, HU 3rd club: LT, LV No club: IT, CZ, PL	0.041 (0.63) 0.042 (0.37) 3.023 (12.29) -0.991(-5.62)*
2004-2010	8 OMS	LPG	tax levels	-0.355 (-15.18)*	1st club: IT, NL, DE, FR, PT 2nd club: ES, BE, LU	0.477 (14.46) 0.527 (9.09)
2004-2010	8 OMS	LPG	consumer prices	-0.352 (-5.65)*	1st club: FR, NL, PT, IT, DE 2nd club: ES, BE, LU	0.112 (2.02) 2.307 (16.19)
2004-2010	8 OMS	LPG	producer prices	-0.206 (-3.45)*	1st Club: FR, PT, NL, ES, BE, DE, LU No club: IT	0.071 (1.09) -
2004-2010	8 NMS	LPG	tax levels	-2.028 (-46.74)*	1st club: LT, PL, HU, SI, LV, CZ, EE: No club: SK	0.105 (1.90) -
2004-2010	8 NMS	LPG	consumer prices	-0.248 (-3.61)*	1st club: EE, CZ, HU, PL, LT, SK, LV No club: SI	0.219 (3.12) -
2004-2010	8 NMS	LPG	producer prices	-0.954 (-12.32)*	1st Club: EE, SK, HU 2nd club: LT, LV No club: SI, CZ, PL	0.042 (0.37) 3.023 (12.29) -1.414(-9.32)*

Table 11. (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
1994-2001	6	Super	tax levels	-1.135 (-81.88)*	1st club: BE, IE No club: FR, IT, ES, GR	3.930 (14.88) -1.251(-88.60)*
1994-2001	6	Super	consumer prices	-1.078 (-23.98)*	1st club: FR, IT, BE, IE 2nd club: ES, GR	0.597 (6.64) -0.081(-0.43)
1994-2001	6	Super	producer prices	1.154 (10.83)	1st Club: IE, BE, ES, GR, IT, FR No club: -	1.154(10.83) -
2000-2005	6	Super	tax levels	-0.006 (-0.19)	1st club: NL, UK, FR, PT, ES, GR No club: -	-0.006 (-0.19) -
2000-2005	6	Super	consumer prices	-0.098 (-3.35)*	1st club: UK, FR, PT, ES, GR No club: NL	0.169 (4.53) -
2000-2005	6	Super	producer prices	0.866 (12.50)	1st Club: NL, PT, ES, GR, FR, UK No club: -	0.866(12.50) -

Table 12. Club Convergence in Real Consumer Prices on Euro-Super-95 Fuel among the EU-25

Last T order (Step1)	ID	t-value								Club
		Step 2	**Step 3**	**Step 2**	**Step 3**	**Step 2**	**Step 2**	**Step 3**	**Step 2**	
1	NL	Base	Core							S1
2	DK	**6.89**	Core							S1
3	DE	5.91	5.91							S1
4	BE	1.93	1.93							S1
5	FI	2.32	2.32							S1
6	GR	3.22	3.22							S1
7	PT	3.20	3.20							S1
8	SE	2.54	2.54							S1
9	IT	2.50	2.50							S1
10	IE	3.53	3.53							S1
11	FR	3.49	3.49							S1
12	UK	2.41	2.41							S1
13	SK	3.24	3.24							S1
14	AT	2.04	2.04							S1
15	MT	1.53	1.53							S1
16	CZ	0.54	0.54							S1
17	LU	-1.33	-1.33	Base	Core					S2
18	ES	-2.24	-0.60	**6.67**	Core					S2
19	SI		(0.013) 0.25	-	-					S1
20	PL		-3.44	-3.14	-3.14	Base			Base	-
21	LT		-1.31		1.96	-			-	S2
22	HU		-5.62		-0.84	-4.89	Base	Core	-	S3
23	CY		-5.23		-2.82		(1.368) **4.55**	Core	-	S3
24	EE		-1.18		(0.153) 1.61	-	-	-	-	S2
25	LV		-8.91		-8.11		-3.97	-3.97	(-0.551) -4.32	-

Global convergence: -0.438 (-12.00)*

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APPENDICES

APPENDIX 2.A

CLUSTERING ALGORITHM

To test for convergence in subgroups, I use a clustering algorithm that follows Phillips and Sul (2007). This clustering algorithm allows identification of such clusters and the number of these subgroups:

Last Observation Ordering: Order N countries according to the last observation in a panel, from the highest to the lowest.

Core Group Formation: based on step 1 select k highest countries and form a subgroup G_k with $k = 2, 3, \ldots, N$. Next, run the log t-Test for convergence within each subgroup and choose the size (k^*) of the core group – the club – according to the following rule of the maximized t_k:

$$k^* = \arg\max_k \{t_k\} \quad subject\ to \quad \min\{t_k\} > -1.65. \qquad (13)$$

Sieve for Club Membership: Following step 2, all remaining countries are tested one at a time on whether to be included in this core group (club). Following a conservative choice, the new country is included in a club only if the t-statistic is positive. The procedure is repeated until the formation of the first convergence club is completed.

Stopping Rule: All remaining countries that are not selected in a core club in step (3) are combined in a new complement subgroup. The log t-Test is conducted over this subgroup to determine whether this cluster of countries would converge among each other, resulting in only two convergent clubs in a panel. If not, the algorithm procedure is repeated until all clubs in a panel are determined. The remaining countries display divergence behavior.

To provide a better understanding of how Phillips and Sul's (2007) method is used to determine convergence clubs, the following is the detailed explanation of how I determined consumer price clubs for unleaded Euro-super-95 fuel. For consumer prices on unleaded gasoline, the log t-Test rejects the null hypothesis of global convergence among the EU-25 ($t = -12.00$), so the possibility of club convergence is investigated (Table 3). According to the guideline suggested by Phillips and Sul (2007), panel series first have to be reordered based on the highest, most recent observation, June 7, 2010. Based on step 1 of the algorithm, the Netherlands had the highest level of consumer prices on Euro-super-95 fuel on that date, so it is denoted as the base country in the ordering (Table 4).

Following step 2 of the algorithm, I perform the log t-Test by adding one country at a time to the base and calculating a t-statistic. This process continues until the t-statistic becomes lower than the threshold level of $t = -1.65$. For example, when Denmark is added to the Netherlands, the t-statistic is $(t = 6.89)$, so Denmark is added to the subgroup of potential core countries. When Germany is added to the first two countries, the new t-statistic $(t = 5.91)$ is higher than the threshold, so Germany joins the subgroup and the next country – Belgium – is evaluated, etc. After adding Spain, the t-statistic $(t = -2.24)$ becomes lower than the threshold, so I stop pre-selecting countries for the first club. In this pre-selected subgroup, the highest t-statistic is for the first two EU members listed in Table 4 $(t_k = 6.89;\ k = \{1, 2\})$, which implies that the core group for consumer prices consists of the Netherlands and Denmark.

Next, according to step 3 of the algorithm, countries are added to the core group one by one and a new t-statistic is printed. For the first sixteen countries in Table 4, these t-statistics are positive; all of these countries become the members of the first club. Because Luxembourg has a negative t-statistic $(t = -1.33)$, it is not included in this club. When Spain is added to the sixteen members of the first club, its t-statistic is also negative $(t = -0.60)$, and Spain does not become a new member. Slovenia is the last country with a positive t-statistic $(t = 0.25)$ and becomes the seventeenth member of the first club. When the remaining countries are added one by one to the existing seventeen members, the individual t-statistics for all of them are negative. Thus, none of these countries becomes the eighteenth member of the first club.

For a complement group, or the remaining eight countries that are not selected to the first club, the log t-Test rejects the null hypothesis of convergence of consumer prices $(t = -4.19)$. Because a complement subgroup does not form the second club, step 4 of the algorithm suggests repeating the club clustering procedure for these countries until all clubs are identified.

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APPENDIX 2.B

RELATIVE TRANSITION PATHS OF MOTOR FUEL PRICES AND TAXES IN THE EU (h_t)

Figure 13.

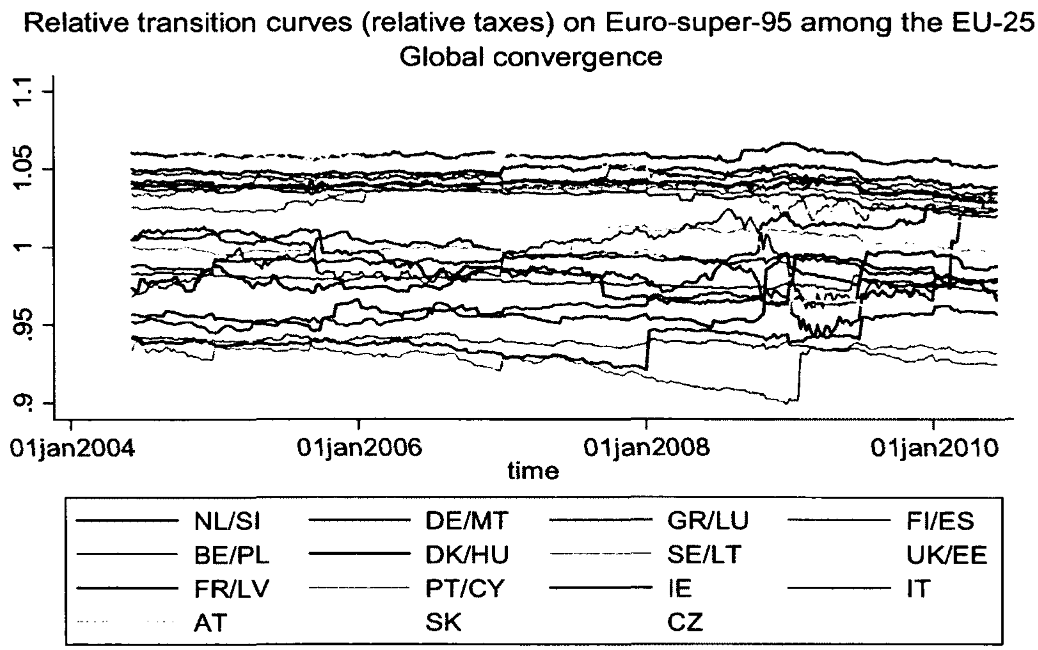


Figure 14.

Club 1 among the EU-25: unleaded Euro-super-95 fuel
Relative transition curves (relative consumer prices)

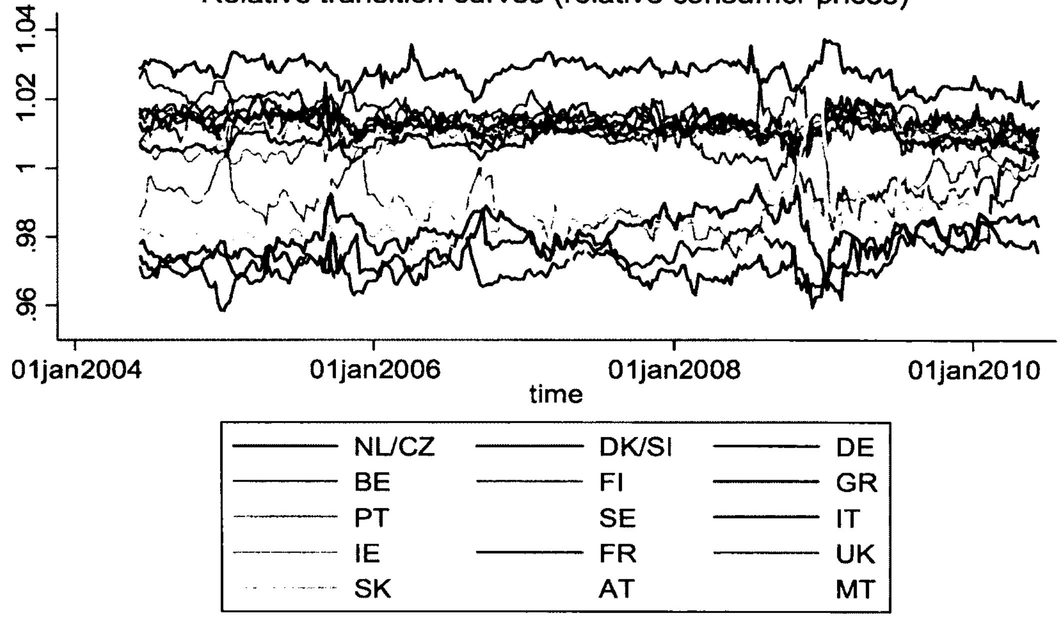


Figure 15.

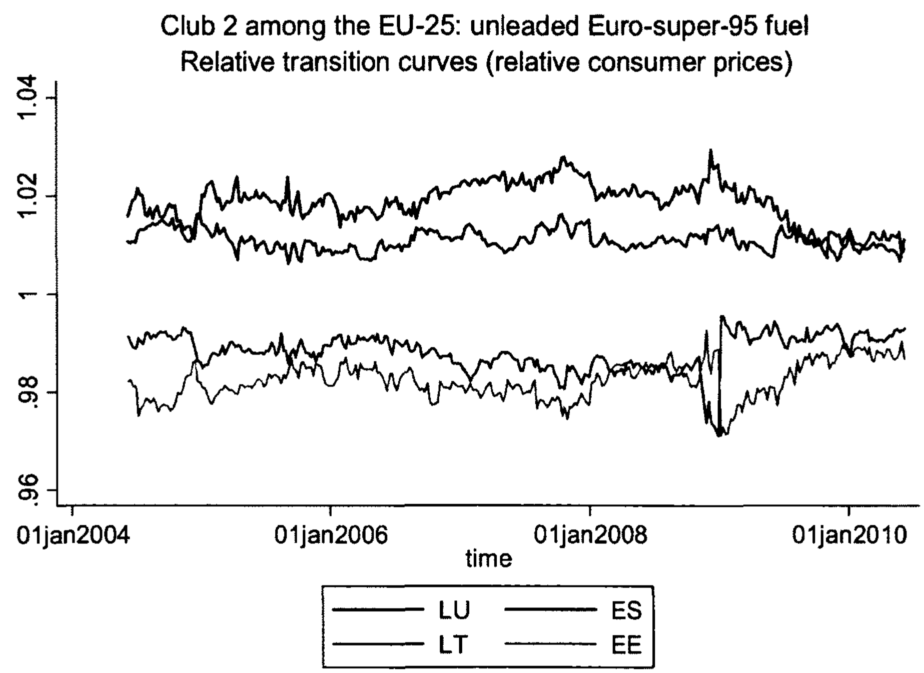


Figure 16.

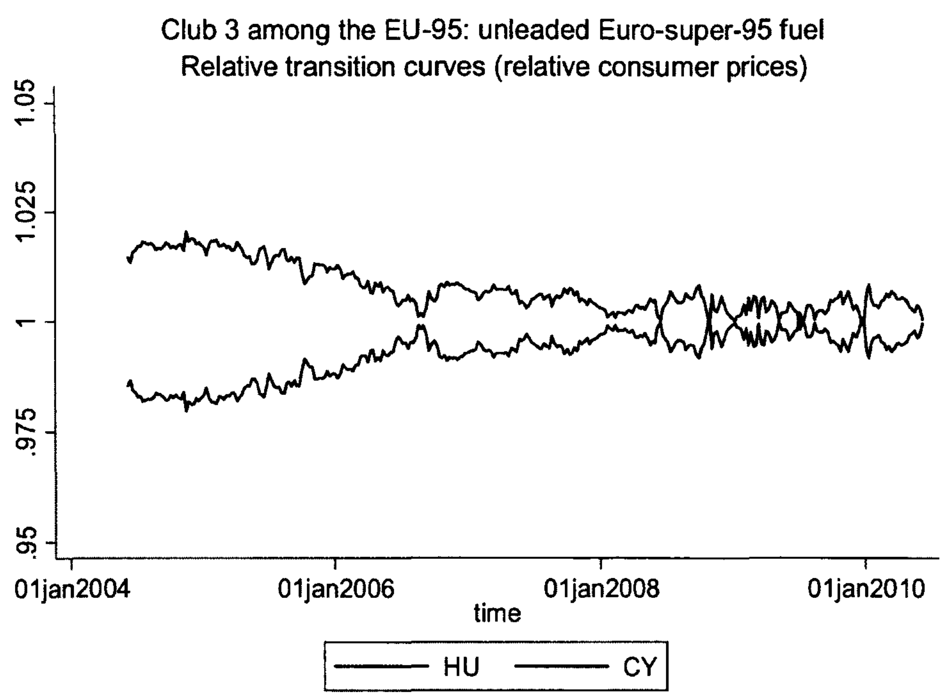


Figure 17.

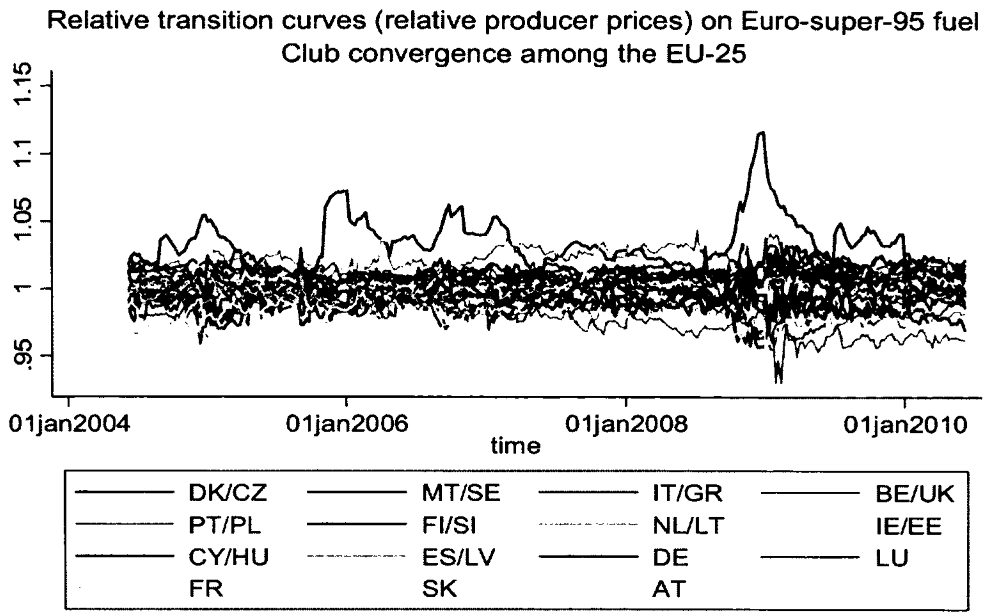


Figure 18.

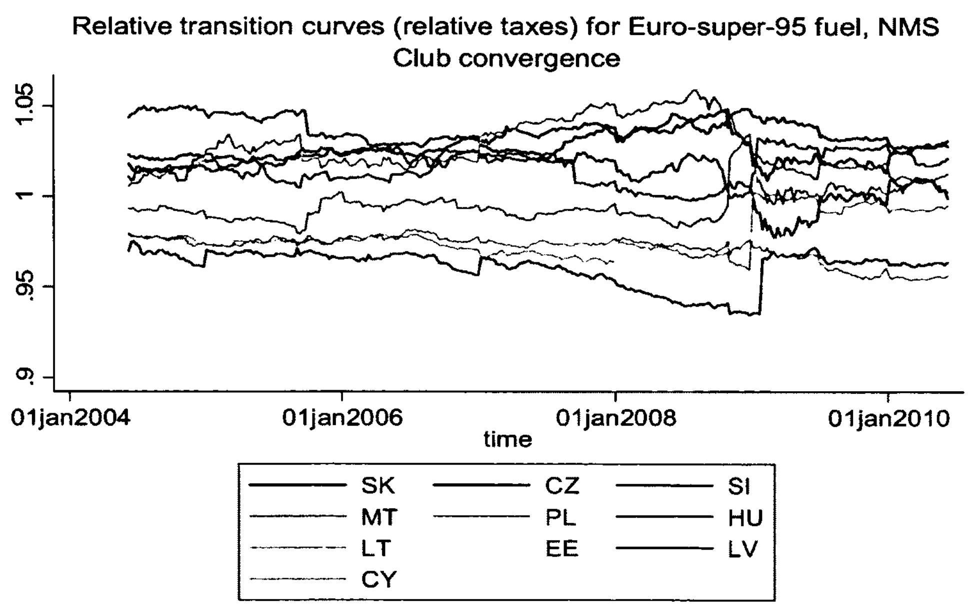


Figure 19.

Relative transition curves (relative consumer prices) for Euro-super-95, NMS Club convergence

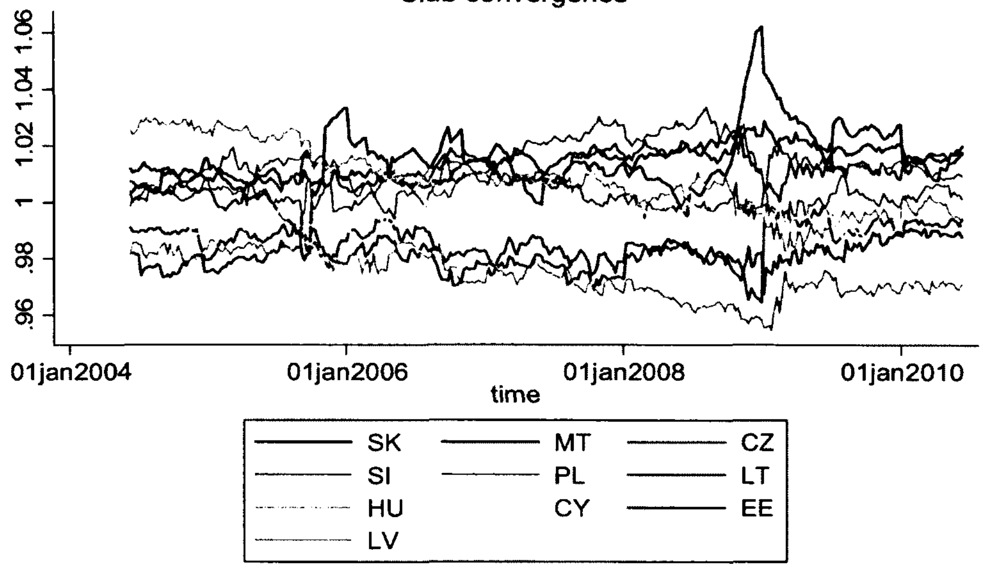


Figure 20.

Relative transition curves (relative producer prices) for Euro-super-95, NMS Club convergence

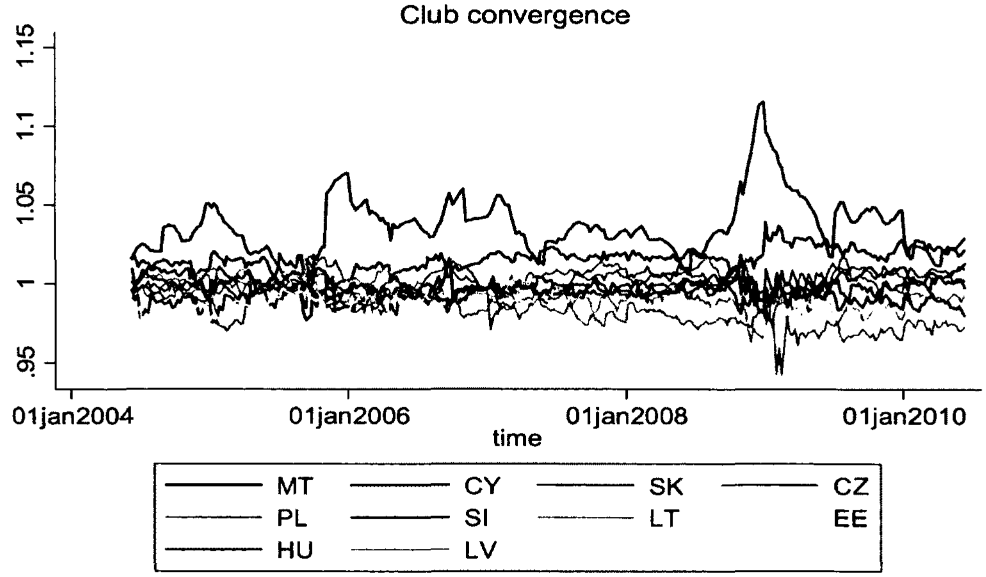


Figure 21.

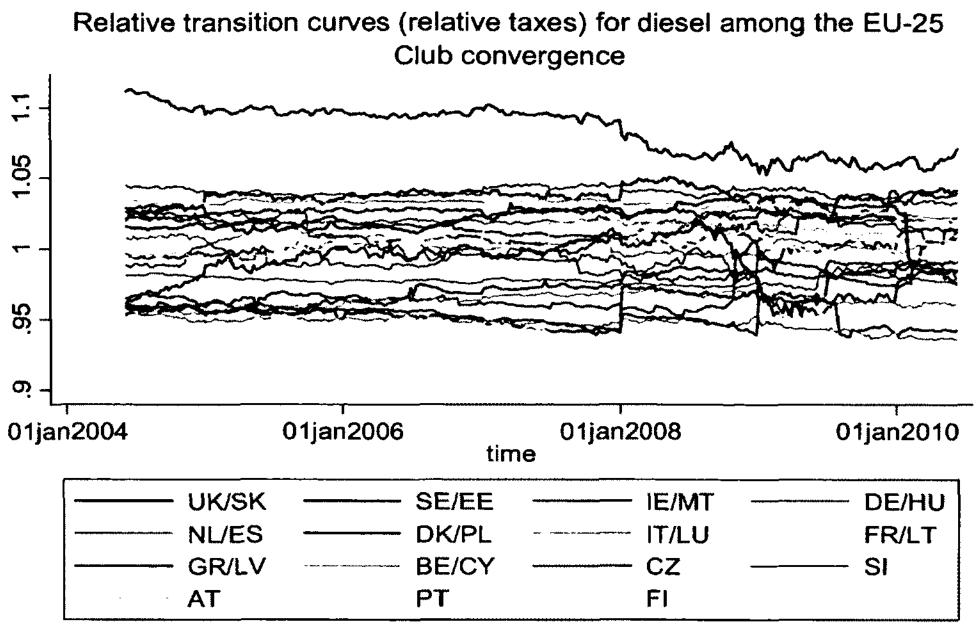


Figure 22.

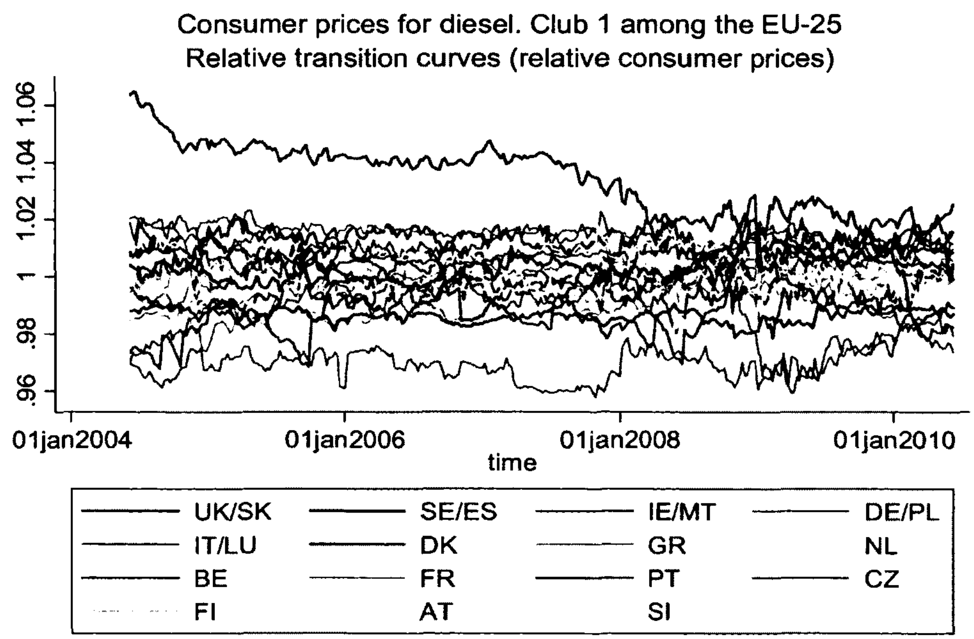


Figure 23.

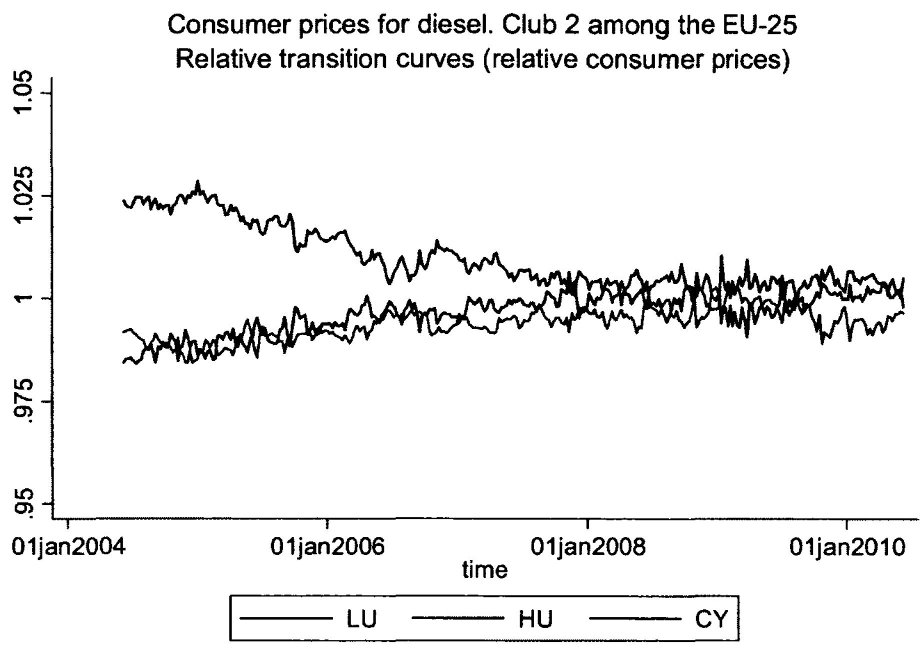


Figure 24.

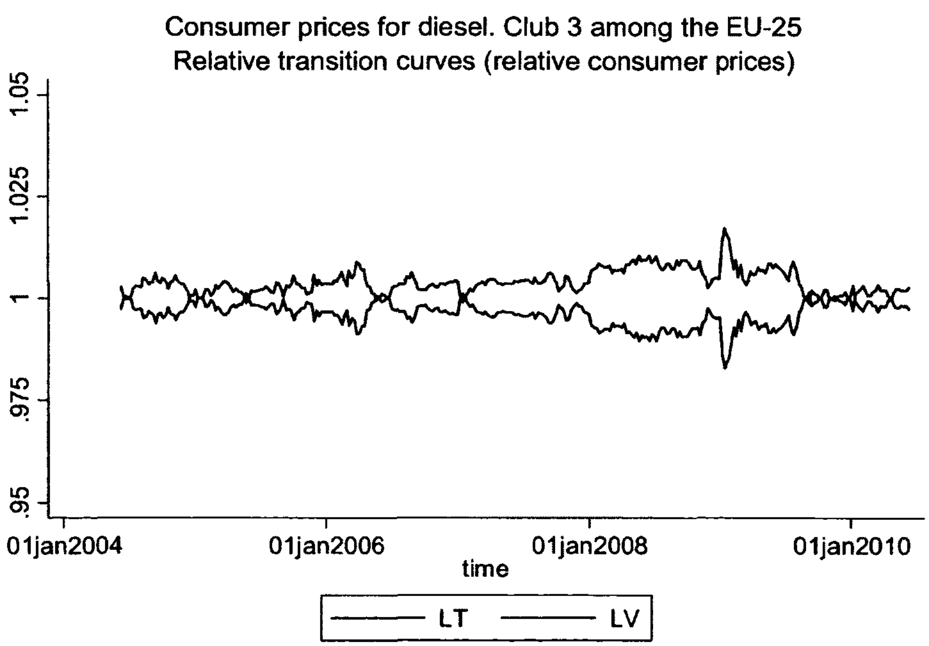


Figure 25.

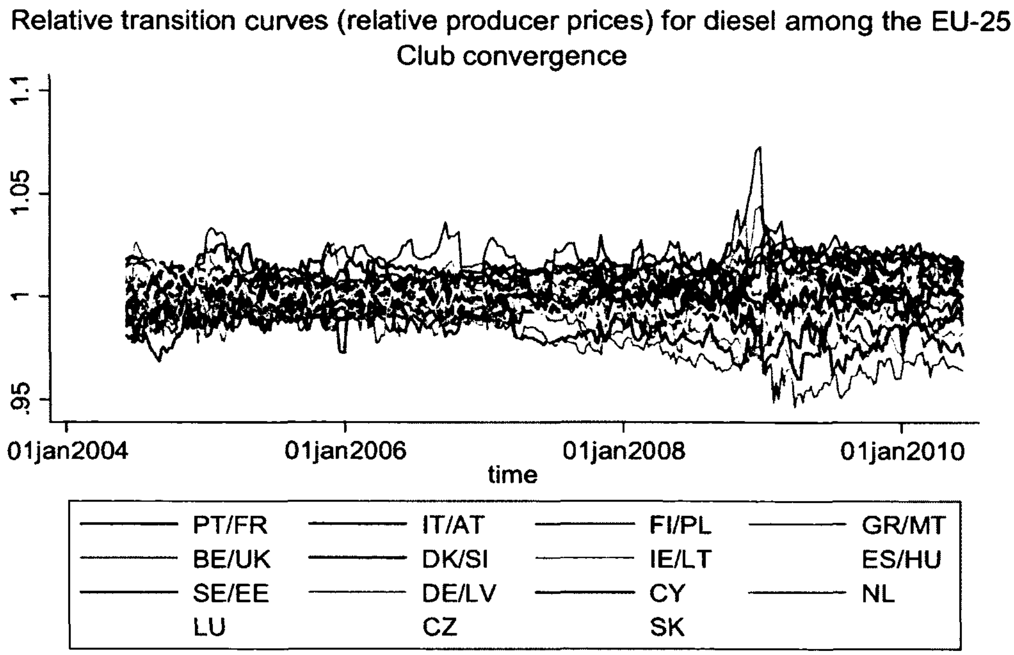
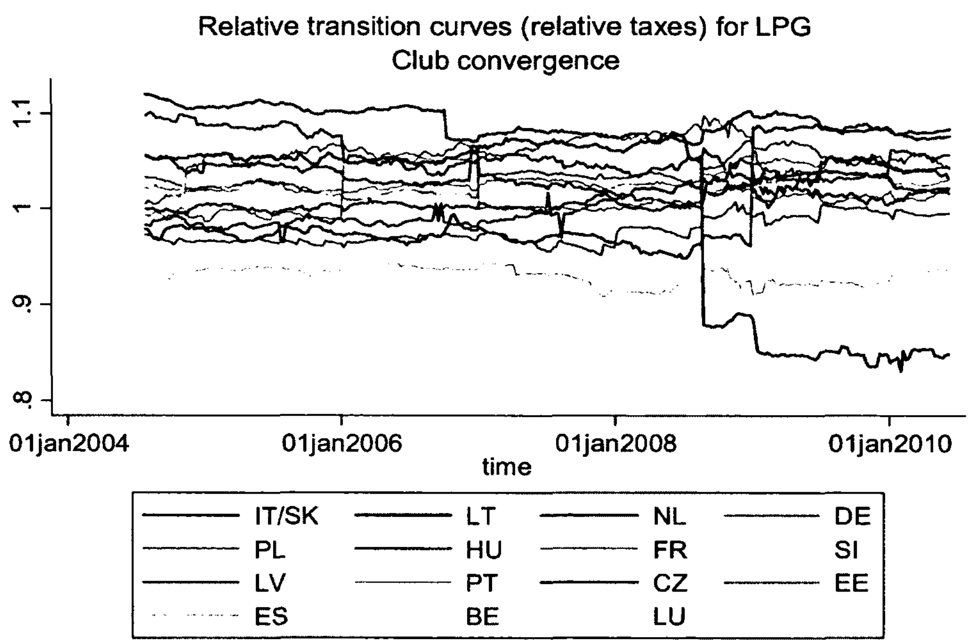


Figure 26.



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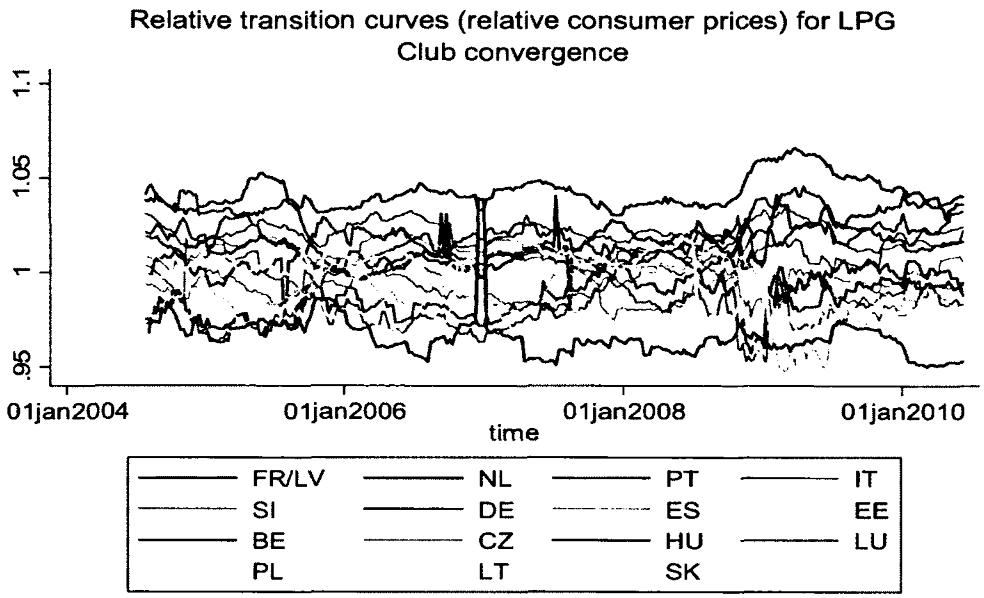


Figure 28.

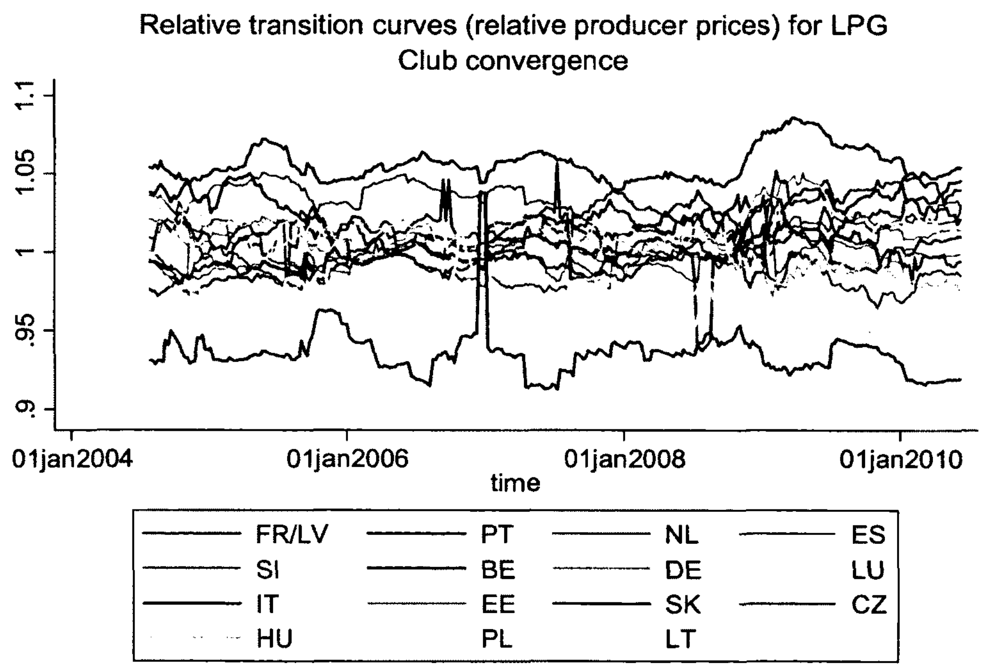


Figure 29.

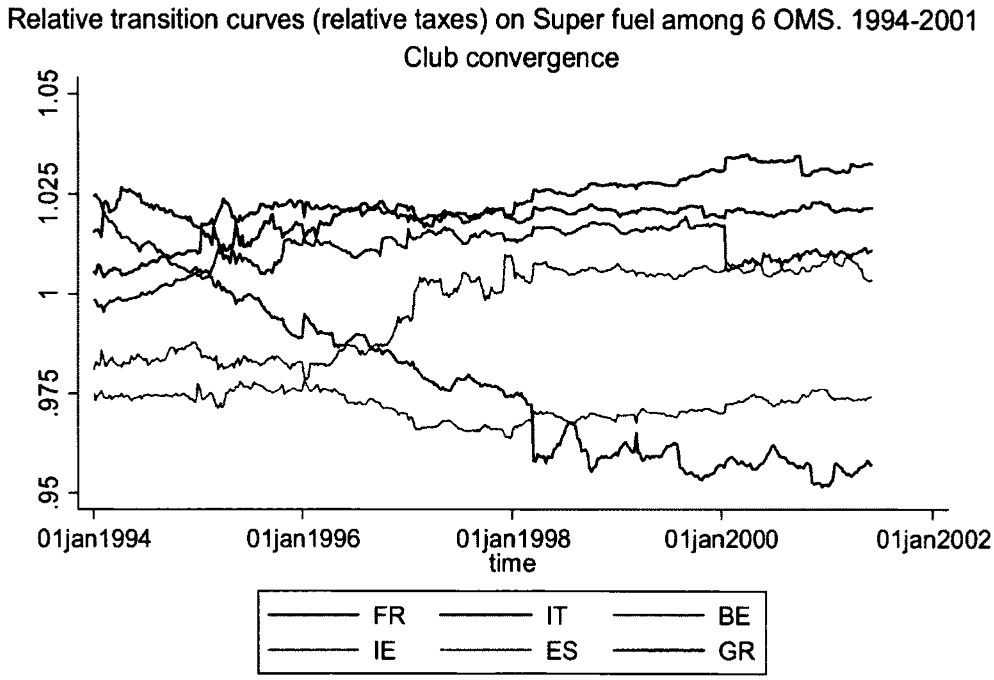


Figure 30.

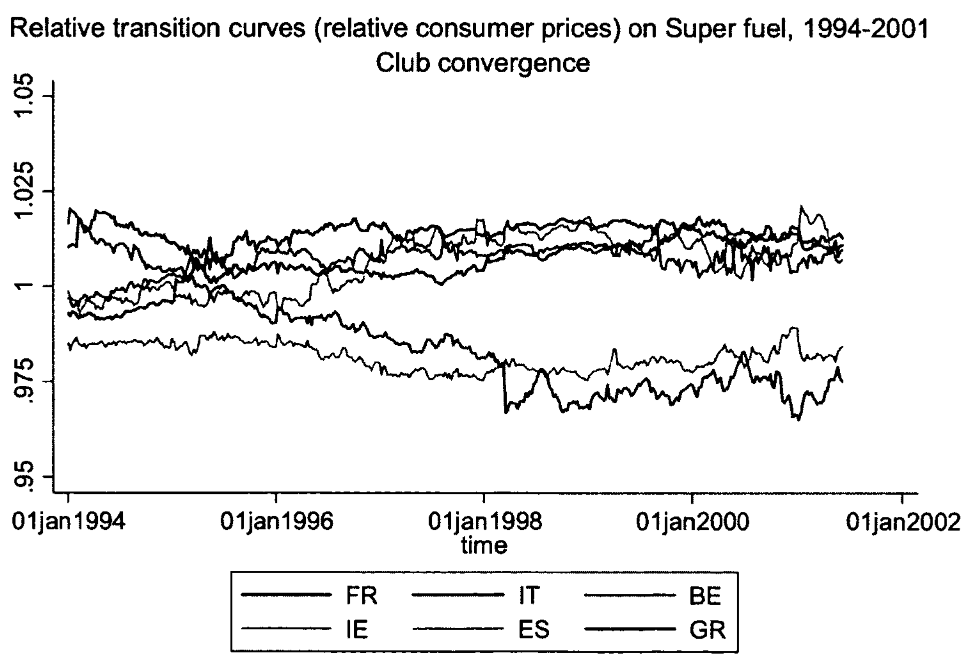


Figure 31.

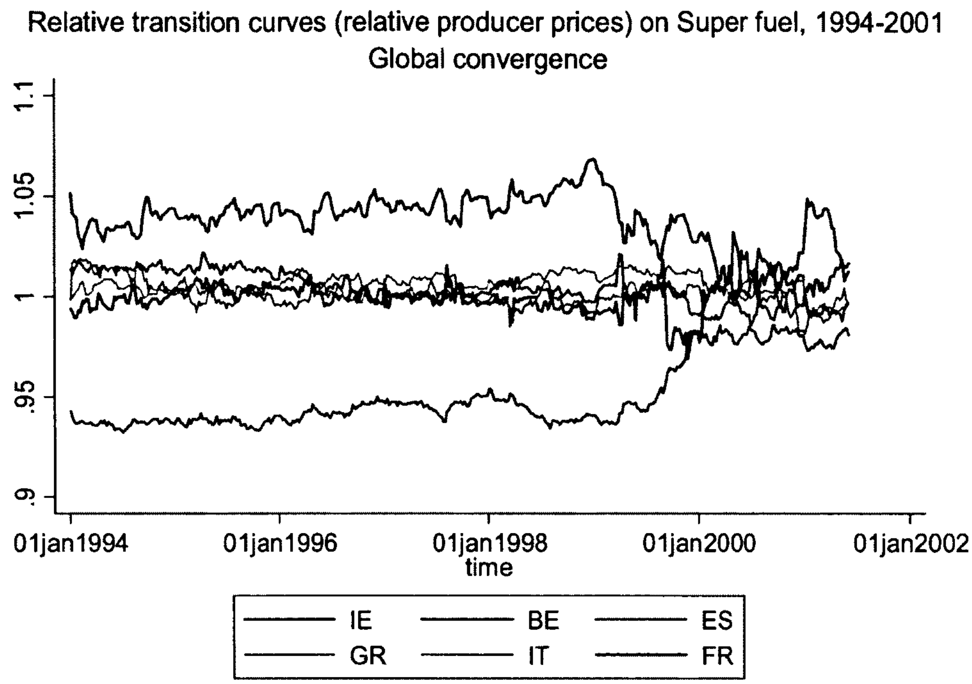


Figure 32.

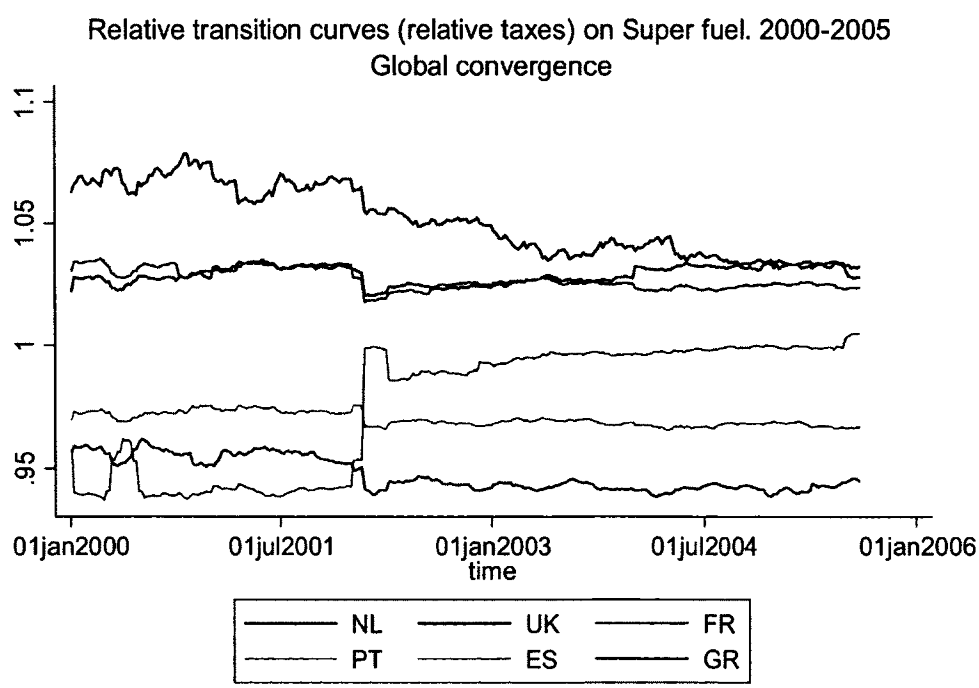


Figure 33.

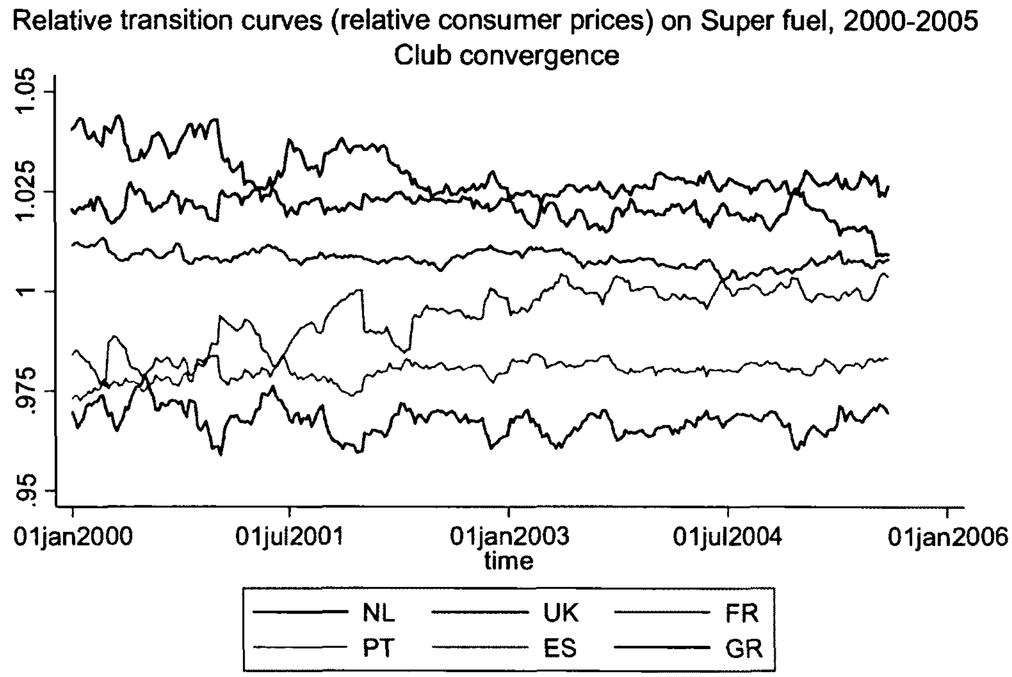
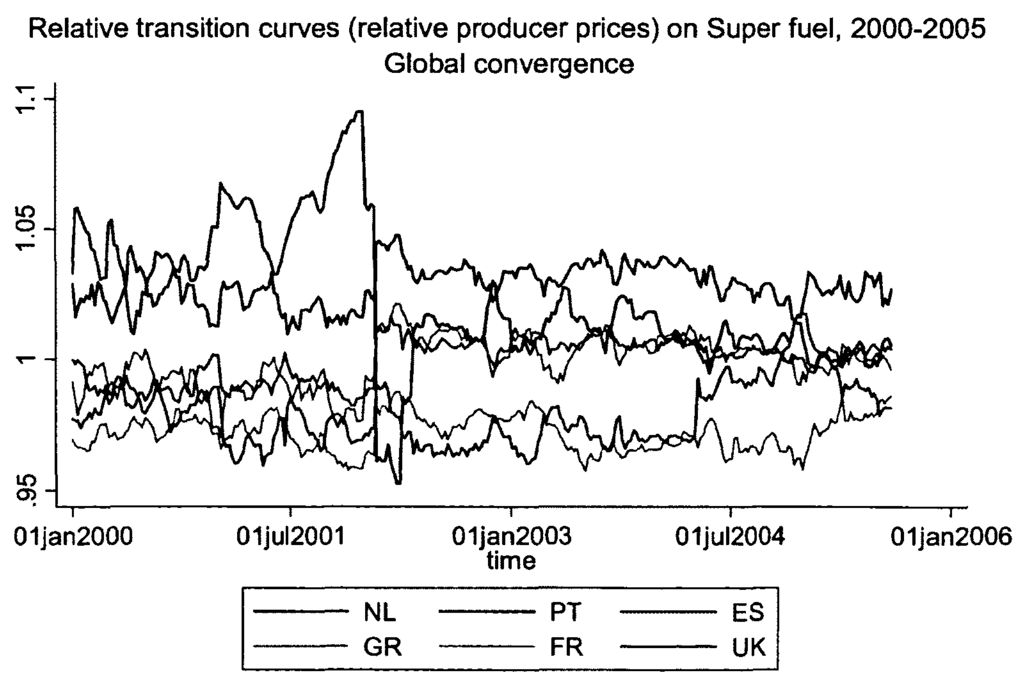


Figure 34.



ESSAY 3: IS THERE MOTOR FUEL FISCAL COMPETITION IN THE EUROPEAN UNION?

3.1. INTRODUCTION AND MOTIVATION

This paper examines how political, economic, and geographic factors influence motor fuel tax setting behaviors among members of the EU, and whether or not these behaviors are strategic. The major question it addresses is how individual countries that are integrated in a single union respond in the short run to changes in motor fuel tax rates of neighboring countries. By contrast to previous economic literature on motor fuel taxation, this paper recognizes the united, inter-related, but fiscally-competitive setting of the EU and the dual role of motor fuel taxes. It contributes to a limited empirical literature on fiscal competition in the EU and to a complex discussion of motor fuel tax and emission reduction decisions of the national governments.

In addition to a country's traditional budget constraints, every EU country faces both the emission targets and pressure from EU peers to reduce greenhouse gas emissions (GHG). This peer pressure can be roughly identified as the difference between a country's emission targets and its actual emissions. In this situation, are some European countries more willing to match an increase in fuel tax rates rather than a decrease?

Drawing from prior studies on motor fuel tax matching in the U.S. (e.g. Rork, 2003), I argue that the overall pattern of fuel tax matching is different in Europe. On the one hand, the absolute level of gasoline prices is much higher in Europe than it is in the U.S. due to a higher share of fuel taxes in the final price of fuel. Therefore, it might be more difficult for European politicians to argue in favor of a further increase in fuel tax rates. On the other hand, some of the EU countries have high representation of green parties in their governments, and will be more willing either to initiate or to match an increase of a fuel tax. The ways in which the EU members respond to changes in the fuel taxation of their neighbors may not be the same in terms of reasons, direction and/or magnitude when compared to interconnectivity of responses among other regional governments like the states in the U.S. The goal of this paper is to empirically test if they behave differently, in comparison to how the U.S. states interact with each other when neighbors' fuel taxes change.

The proposed research question is particularly important to address for a few reasons. First of all, this question is current given increasing globalization and the emergence of new types of economic unions between countries. Historically, the integration of separate countries in one union is not a new practice; nevertheless, the EU is the first example of a number of independent countries voluntarily forming a union and a Common Internal Market. These types of unions may be replicated in the future, for example, among some former USSR members. In the case of the EU, the origination of the Internal Market took place after the Treaty of Rome was ratified in 1957. Later, with the Single European Act of 1986, a group of European countries agreed upon a single internal market and free circulation of people, capital, goods, and services between member states. One of the major goals of the EU community, as it is outlined by the European Treaty, is to ensure that taxation differences between member states do not distort the smooth functioning of the Common European Market.[21] These distortions are facilitated by mobility of individuals across borders, and may lead to uneven pressures on producers in different countries because of tax inequality.

[21] See the consolidated version of the Treaty Establishing the European Community, Articles 3, 90, and 93 (Treaty on European Union, 2002).

The second reason is that the EU represents a good example for analyzing fuel taxes. In Europe, unlike the U.S., fuel taxation is chosen as a primary policy tool for reducing emissions, which results in an overall higher level of fuel tax rates. Instead of heavy reliance on taxes, the U.S. primarily controls emissions from its transport sector by utilizing the CAFÉ emission standards for newly-manufactured vehicles. In the EU, member states share common values and treaties, and sixteen out of twenty seven members even share a common monetary policy. With such close integration, a single member country's decisions are bounded by common policies and peer pressure from other members. In addition, each EU member state faces a limited choice of policy instruments, leaving taxation as one of the fewer 'sovereign' policy tools still available to them. Therefore, countries in the newly integrated Europe make their decisions based not only on sovereign interests, but also are forced to consider the consequences of their own policies on neighbors and other union members.

The third reason for analyzing fuel taxation, in particular, is that vehicle fuel taxes are different from other types of taxes. One can argue that the objective of taxing vehicle fuels in particular is somewhat different from taxing other goods in general. Today, taxing vehicle fuels plays an important role in reducing emissions and other vehicle-related externalities, in addition to its original historical purpose of generating tax revenues for the government to finance road construction and maintenance projects.

The fourth reason for examining fuel taxation in the EU is because it is a current leader in addressing global environmental concerns, especially when it comes to reducing GHG emissions (e.g. Schreurs, Selin & VanDeveer, 2009, p.3). Common environmental goals force the EU members to consider peer pressure from their neighbors when making taxation policy decisions. Thus, commitments of the EU members to control exhaust emissions are tougher than they are among states in the U.S.

Finally, given some concerns with the consequences of possible 'fuel tourism' and 'fuel havens' in Europe, it is important to determine whether the EU members behave in a similar manner to the states in the U.S. when it comes to motor fuel taxation.[22] Because of the open borders among the EU nations, fuel consumers in the EU often include both residents and non-residents of a home country, and changes in fuel taxes may result in 'fuel tourism' and cross-border fuel shopping. Changes in fuel tax rates in one country create a response in its fuel tax base. As a result, vehicle emissions may be higher because consumers change their routine routes to purchase fuel due to motor fuel tax and, consequently, price changes. In the 2000s, the European Commission began to be concerned with this 'fuel tourism' issue and, as a result, they put pressure on the EU members to further coordinate their tax structures.

In sum, tax setting behavior is primarily driven by political rather than market forces. It also greatly depends on the degree of mobility of the motor fuel tax base. This paper intends to examine how a combination of these factors shapes fiscal competition among the EU members.

[22] For example, Jos Dings, the Director of Transport and Environment of the EU, raises his concerns in regards to Luxembourg by calling it a 'fuel haven'. He states that in Luxembourg fuel taxes are low and per capita fuel sales are roughly 5-10 times higher than in its neighboring countries. Available on-line: http://www.europeanvoice.com/article/imported/fuel-tax-havens-/68453.aspx

3.2. LITRATURE REVIEW

3.2.1. Fiscal Federalism, Mobility, and Taxing of Motor Fuels

In public economics, the decisions regarding how to provide local public goods efficiently and how much to tax depend on the structure of fiscal authority, the degree of decentralization, and the mobility of tax bases. In addition to being neighbors and individual nations, the EU members are also united in a single union with a common central authority: the European Parliament and the European Commission. The classical theory of fiscal federalism (e.g. Musgrave, 1959, 1965; Oates, 1968, 1972, 1991) suggests that while greater centralization helps to improve coordination of fiscal decisions, decentralization leads to more efficiency in addressing local needs.

The origin of the fiscal competition discussion, i.e. when governments compete for mobile resources among themselves to increase tax revenues, can be traced back to works by Tiebout (1956) and Oates (1972). Tiebout's (1956) "sorting model" allows households to move to a selected location based on their sorting of alternatives. Subsequently, these alternatives are a result of their demand for local public goods. Oates (2008) argues that, according to his famous Decentralization Theorem (Oates, 1972), efficiency gains from a decentralized provision exist regardless of individuals' mobility, but for Tiebout sorting these gains are enhanced by such mobility. The literature on fiscal competition, hence, argues that taxation decisions among neighboring states, municipalities, and provinces are typically interconnected because tax bases are mobile in their nature. This interconnection creates an incentive for governments to compete for mobile resources (e.g. Wildasin, 2006; Wilson, 1999). Thus, tax competition between neighbors, especially in the presence of greater mobility in their tax bases, may lead to more coordinated taxes on motor fuels in the EU.

In more recent literature on fiscal federalism, Oates (2005, 2008) distinguishes its two directions: the so-called 'second generation theory of fiscal federalism' and the 'political economy approach' to the public sector. The 'second generation theory of fiscal federalism' has a game-theory framework and can be traced to Kornai's (1979) concept of 'soft budget constraint.' Because the constraint is 'soft,' local public authorities might feel insured by higher levels of government in the case of serious financial troubles; therefore, they lose an incentive to act fiscally responsibly (e.g. Qian & Roland, 1998; Rodden, et al., 2003). Based on this type of fiscal federalism, aggressive tax competition in motor fuel taxes may occur in the EU and also may lead to a race-to-the-bottom. The degree of tax base mobility is also not very important to local fiscal authorities because of their loose incentives for responsible fiscal discipline.

The second alternative development in the fiscal federalism is the 'political economy approach' to multi-level governance: this is when public officials can potentially lose reelections if voters disagree with their rent-seeking behavior (e.g. Besley & Coate, 2003; Lockwood, 2006). In this setting, local governments are believed to have their own objectives and fiscal behavior motives. They may engage in either competition or strategic tax-setting, especially under greater decentralization (e.g. Oates, 2001a, 2001b; Brueckner, 2003, 2004).

One example of the 'political economy' fiscal federalism is the yardstick competition model (Besley & Case, 1995). The yardstick competition model suggests that in light of imperfect information voters compare domestic policies to similar policies of their neighbors. This outcome implies that neighbors' policies serve as a benchmark (yardstick) for comparison during elections. Voters may be more sensitive to motor fuel tax changes than tax changes in other goods because fuel prices may serve as strong signals to voters. In the long run, this may result in harmonization of motor fuel tax rates among neighbors if voters are sensitive enough to motor fuel tax differences.

In addition to theoretical fiscal competition literature, there is growing empirical support for responses to tax changes between neighbors. Case, Rosen and Hines (1993), for example, formalize the theoretical framework of governments' interdependence and use the U.S. data from 1970-1985 to find evidence of fiscal interdependence among the U.S. states. Rork (2003), uses the U.S. data from 1967-1996, and shows that if the tax has a mobile base, such as a motor fuel tax, an increase in a tax rate by a neighbor is typically matched by an increase in a tax rate by a home state. Rietveld and Woudenberg (2005) use 1998 data for 32 European countries and find that geographically smaller EU nations are more aggressive than larger ones in lowering their gasoline and diesel taxes. Although there are no specific EU studies on race-to-the-bottom in taxes on motor fuel, there are some empirical studies of fiscal competition in other taxes in the EU. Lockwood and Migali (2009), for example, show that the creation of the single internal market in 1993 significantly increased fiscal competition in excise taxes for alcohol and cigarettes among the original EU-12[23] countries. Van der Hoek (2003) compares tax structures in the EU-15 for the period 1965-2000 and finds no evidence of race-to-the-bottom in capital taxes. As noted by Oates (2001b, p.137), however, the race-to-the-bottom outcome is simply

[23] EU-12 typically refers to the 12 original EU member states; EU-15 are the 15 members that formed the EU before 2004, and EU-27 are the 27 member countries after the 2007expansion of the Union.

one of suboptimal Nash equilibriums of fiscal competition. In sum, these empirical studies suggests interdependence of motor fuel tax setting behavior among neighbors, at least in the short term, which may eventually lead to tax harmonization.

3.2.2. Fiscal Competition and Its Outcomes: Forces Leading to Motor Fuel Tax Coordination

According to the European Commission, the difference in tax systems among the member states is one of the major reasons for the inefficient, unsmooth functioning of the Internal Market: 'The existence of 25 different tax systems creates barriers to the mobility of factors and thus to the full implementation of the Internal Market' (Ilzkovitz et al., 2007, p. 13). This is why the long-term outcome of fiscal competition, motor fuel tax harmonization, is desirable by the European Commission (Newbery, 2005a). Nevertheless, greater fiscal competition in the EU may drive motor fuel tax rates to their minimal level. By setting tax floors on motor fuels, the European Commission regulates this lowest tax level and establishes a minimum benchmark towards which taxes may or may not converge (CEU, 2003).

A researcher's view on the outcomes of fiscal competition in the EU depends on his/her perspective on fiscal federalism, discussed in the previous section. On the one hand, under strong centralization, the pressure to harmonize motor fuel taxes among the EU members and, at the same time, keep them relatively high is also strong. On the other hand, under the 'political economy' view and the race-to-the-bottom principle, fiscal competition between neighbors should drive tax rates to the lowest possible level.

Both of the above outcomes also depend on an individual's mobility. Higher mobility of a tax base should lead to the following: higher tax competition among neighboring EU member countries, lower motor fuel tax rates, a decrease of motor fuel tax revenues in total tax revenues, weaker reliance on motor fuel excise taxes over time. Rork (2003), for example, shows in the U.S., the share of revenues from motor fuel taxes in states budgets have declined over time. Although there may be many reasons for this, one possible explanation is that the American motor fuel consumer tax base may be relatively mobile.

Under some degree of tax base mobility in the EU, changes in fuel tax rates create a response by the tax base (which includes both residents and non-residents of the home country): 'fuel tourism' and cross-border shopping. There are two types of consumers that can contribute to fuel tourism and, as a result, to higher exhaust emissions: truck drivers and local consumers who live along country borders and engage in cross-border shopping. Truck drivers travel long distances, cross European national borders, and may strategically change their routes to refuel. 'Fuel tourism' is typically associated in the policy literature with the first type of consumers, while economic literature refers to both types of consumers as 'fuel tourists.'

Eurostat indicates that consumers of unleaded gasoline are primarily private vehicle owners, while consumers of diesel are primarily road transport businesses (Eurostat, Panorama of Transport, 2009). Commercial truck drivers have different fueling incentives than private car owners, resulting in different purchasing behavior. Because of higher mobility, truck drivers are more price-elastic and consumer price convergence is expected to be faster for diesel than for other types of motor fuels (e.g. Dreher and

Krieger, 2010). Accordingly, stronger tax and price harmonization for diesel fuel is also expected because of added pressures on low-tax countries to eliminate motor fuel 'tax havens.'

Empirical literature on the topic of fuel tourism is rather limited.[24] Banfi et al. (2005) find some evidence of fuel tourism along borders in Switzerland from 1985-1997. Leal et al. (2009) find some evidence of cross-border motor fuel shopping as a response to price changes among regions in Spain. Wlazlowski et al. (2009) also provide evidence of 'fuel tourism' in the EU by investigating European price dynamics with the vector error correction model to account for asymmetry in price transmission. Rietveld et al. (2001) examine fueling behavior of Dutch auto-owners based on 1997 survey data. They find that, for an average driver, a tradeoff between price difference and distance traveled is €0.005 per kilometer. Their survey also indicates that 30% of Dutch residents who live along the border with Germany will cross-border shop for fuel if the price difference is 0.05€ per liter. Moreover, Rietveld et al. (2001) find that 5% of Dutch respondents will travel up to 30km to cross the border and purchase fuel in Germany, even though the financial costs of these trips do not outweigh the financial benefits. The authors explain this by the differences in the value of time among drivers.

3.2.3. Fiscal Competition and Its Outcomes: Forces Leading to Slowing of Tax Harmonization and Coordination

The first argument in favor of slow tax coordination is that EU members are limited in their repertoire of policy tools. Once they become EU members, countries

[24] See Wlazlowski, Giulietti, Binner and Milas (2009) for one of the most recent reviews of fuel tourism literature.

agree to align their policies with European treaties. In addition, sixteen[25] members out of twenty seven share a common monetary policy, forming the Eurozone. These countries have agreed to follow a strict common monetary policy, leaving themselves with even fewer available policy tools than before. With Brussels pressuring for further tax harmonization, these countries have to give up even more in terms of policy-setting and budgetary freedom (e.g. Angelier & Sterner, 1990). Until the recent financial crisis of the late 2000s, taxation was always thought of as a sovereign decision of an individual country, and member states were relatively protective of this type of 'sovereignty' (e.g. Ring, 2008).[26] If countries resist giving up this sovereignty in the area of motor fuel taxation, taxes on fuel will not converge, and may even diverge in the long run.

The second factor that is important to recognize when discussing tax setting and its outcomes is that individuals might perceive fuel taxes differently from other taxes. For example, numerous trucker strikes such as the ones in Spain, France and the U.K. in the 2000s suggest that the general public is much more politically sensitive to levels and changes in motor fuel prices in part due to fuel tax policies. In addition, some studies show that since fuel prices and policies are consistently discussed by the media, individuals seem to change their attitudes towards gasoline taxes because of these discussions (Löfgren & Nordblom, 2010). If individual consumers see fuel taxation as a tool for decreasing GHG emissions and improving the environment, then they might be more tolerant of increases in taxes in a given place and time. In this case, the convergence in fuel tax rates may slowly occur. If individuals and their politicians perceive fuel

[25] Seventeen Eurozone members as of January 2011.

[26] The EU members (except for the U.K. and the Czech Republic) recently signed a Fiscal Compact Treaty (2012) and collectively agreed upon tightening fiscal measures in the Union (European Council, 2012).

taxation as a symbol of sovereignty, convergence in fuel rates across all EU members may not occur. In either case, governments and politicians use fuel taxes as a strong signaling device. It is also possible that the governments may use fuel taxes to 'signal' low tax environments to consumers and producers, when other forms of taxes may be 'hidden.' Changes in tax policies are also politically challenging and costly for individual politicians, which will slow down harmonization of motor fuel taxes among EU members.

Geography is the next factor that may lead to motor fuel tax divergence or to slower tax convergence. Some European countries are located further from others and may be geographically secluded by water or mountains from most neighbors. Cross-border shopping is difficult under these circumstances, consumer price of fuel may not converge or converge very slowly, and the pressure to harmonize motor fuel taxes will be weak. Thus, for some tax convergence to occur, countries have to have sufficient infrastructure between neighbors.

Finally, this paper suggests that mixed signals from Brussels may serve as forces that slow tax convergence in general. Since the formation of the Single Internal Market in 1993, the EU body seems to increasingly aim to 'coordinate' from above or 'harmonize' tax structures across the EU members (e.g. European Community Treaty, Article 93; EC, 1998). In 2001, however, the EU published an official communication 'Tax Policy In The European Union – Priorities For The Years Ahead' in which it diverged from promoting harmonization of tax structures across Europe: "It is clear that there is no need for an across the board harmonization of Member States' tax systems. Provided that they respect Community rules, Member States are free to choose the tax systems that they consider most appropriate and according to their preferences" (EC, 2001, p.8). In 2006, tax convergence, as opposed to tax harmonization, was unofficially described as a corridor of common policies, with a minimum fuel tax level for protecting European social structure and a maximum tax level for retaining fair tax competition.[27] On the one hand, according to the EU Community rules, nations are free to design their own tax systems.[28] On the other hand, during the last fifteen years there has been an increase in bureaucratic 'coordination' to achieve harmonization of tax systems of individual countries to safeguard the European Common Market. Thus, during this time, a degree of tax coordination and harmonization was not always well communicated by Brussels.

3.2.4. Environmental Aspects of Motor Fuel Taxes in the U.S. and in the EU

Since Pigou (1932), economists recognize that the objective of taxing vehicle fuels is somewhat different from taxing other goods. Traditionally, the Pigouvian tax is praised by environmental economists as a tool to discourage polluters' activity to a degree when, in theory, marginal cost of pollution will be equal to marginal benefits of abatement and the level of pollution is reduced to a socially-optimal level.[29] Pigou (1932) used the motor fuel example when he famously argued that per-unit tax (or subsidy)

[27] For example, interview with Guy Verhofstadt, Prime Minister of Belgium at the time of the interview in January 2006 (the member of European Parliament), that is available at: http://www.youtube.com/watch?v=HsOlhQNA82Q

[28] The situation has changed in 2012 when the EU members, except for the U.K. and the Czech Republic, signed a Fiscal Compact Treaty to collectively tighten fiscal measures in the Union (European Council, 2012).

[29] Environmental economists, however, acknowledge issues associated with the Pigouvian tax. The biggest issue concerning most environmental policies, including the Pigouvian tax, is imperfect information about social costs as well as uncertainty about the estimates of social benefits from removing externalities (e.g. Baumol & Oates, 1971; Kolstad et al., 1990). In addition, critiques of the Pigouvian tax note that collected revenues are typically paid to the government, that is, victims of pollution may not be necessarily compensated because revenues are not earmarked for projects that improve the environment.

solves the problem of divergence between the values of marginal social consumption and marginal private net product, and that tax compensates for the externality:

> *It is, however, possible for the State, if it so chooses, to remove the divergence in any field by "extraordinary encouragements" or "extraordinary restraints" upon investments in that field. The most obvious forms which these encouragements and restrains may assume are, of cause, those of bounties and taxes... The principle... is employed... in the British levy of a petrol duty and a motor-car license tax upon the users of motor cars ...* (Pigou, 1932, §13, p.192-193).

The motor fuel consumer is also the producer of exhaust emissions and has no economic incentives to supply socially-optimal levels of exhaust emissions. Motor fuel tax, in this case, presents the second-best solution, yet one that is administratively simpler when compared to a technically challenging task of taxing vehicle emissions directly (e.g. Fullerton & West, 2002; Harrington et al., 1998). A Pigouvian tax raises the price of gasoline and should, in theory, encourage drivers either to drive fewer miles or, in the long run, to replace their vehicle with the one that is more efficient. Thus, theoretical environmental literature portrays vehicle emission tax as a tool to discourage tailpipe pollution and to compensate a portion of the social costs associated with vehicle emissions.[30]

Compared to other types of consumption goods, motor fuels are different because of the environmental externalities and other social costs associated with their consumption (e.g. Parry & Small, 2005; Newbery, 1988). In addition to its original purpose of generating tax revenue for governments, fuel taxes also partially reduce social

[30] Climate change is considered to be one of the negative externalities arguably caused by increasing stock of emissions in the atmosphere. See McKibbin and Wilcoxen (2002) for earlier general discussion of a link between economic policy, emissions, and climate change. This debate on uncertainty, urgency, severity of economic policies and estimated social costs of climate change continues after a publication of the Stern Review on Economics of Climate Change (2007) and its critiques by Nordhaus (2007) and Weitzman (2007), among others.

costs associated with both fuel consumption and production, including harm to the environment (e.g. Baumol & Oates, 1971; Barthhold, 1994; England, 2007).

Because marginal social costs associated with fuel consumption differ across individual nations, there is no logical reason for fuel taxes to converge in absolute levels among EU members, unless politicians have their own hidden objectives. The empirical literature provides some quantitative estimates of both per-mile cost estimates as well as per-gallon cost estimates of external and social costs associated with transport. For example, estimations of the external component of the motor fuel tax in the U.K. are €0.6 per liter for petrol and €0.67 per liter of diesel (in €2000) (Newbery, 1988). Parry and Small (2005) account for such marginal external costs of gasoline consumption as pollution, accidents, and congestion; they calculate an optimal gasoline tax rate of $1.01 for the U.S. and $1.34 for the U.K. Newbery (2005b, p.221) provides a comprehensive review and discussion of the environmental component of motor fuel tax; his estimates of the costs associated with motor fuel consumption in the U.K., are £0.36 per liter of gasoline and £0.40 per liter of diesel. These estimates include costs of air pollution, global warming impact, water pollution, noise, and road costs.

A comparison of social costs across studies, however, remains challenging because different studies take into consideration different types of social costs (e.g. Newbery & Santos, 1999); there is no uniform approach across studies. Viscusi et al. (1994), for example, estimate that in the U.S. in 1986 gasoline taxes were roughly equal to externality costs, or 17% of the final gasoline price. At the same time, taxes on diesel fuel accounted for about 13% of the final price, which was far below estimated external costs of 50%.

From the perspective of theoretical environmental economics, the motor fuel tax is, first of all, a tax on emissions in a second best policy setting. According to the theoretical environmental literature, emission charges and fees, including motor fuel taxes, are aimed at either increasing the price of emission-associated good or improving the quality of emissions by encouraging development of cleaner technologies (e.g. Hanley, Shogren & White, 1997).

In reality, revenues from fuel taxation are spent on compensating social cost reduction (e.g. Tingsong, 2001; Fullerton, 2001). In the U.S., the original purpose of taxing fuels was to generate revenues for road projects to local and federal governments, and it remains to be the major purpose today (e.g. Barthold, 1994; Newbery & Santos, 1999).[31] According to Fullerton (2001, p.230), in the U.S. certain taxes on motor fuels are called environmental not because they are Pigouvian in nature, but because revenues from these taxes are earmarked for specific expenditure programs or used in social insurance premiums to fund contaminated site cleanups. Barthold (1994, p.136) states that the U.S. federal gas excise taxes on motor fuel "much resemble the textbook model of a Pigouvian tax." He suggests that among other factors, both political considerations as well as regional impacts are typically excluded from economic neoclassical models of tax-setting. Compared to the U.S. where gasoline taxes are earmarked for highway-related projects (e.g. Sterner, 2007), motor fuel tax revenues in the EU are not

[31] According to the report by the Transportation Research Board of the National Academies (2006), fuel taxes generate about 64 percent (in 2004) of all highway user fee revenues. Out of $136.4 billion the U.S. government has spent on highway-related expenditures, $104.8 came from highway users, including 31 percent from federal, 32 percent from state and 1 percent from local fuel tax revenues. The concern is that fuel taxes may become a lesser reliable source of revenues by 2025 due to expected higher oil prices, more technologically efficient vehicles, and changes in perception of transportation infrastructure quality by the drivers. The Report also shows that while in Western Europe fuel tax revenue structure is similar to one in the U.S., road user revenues exceed highway-related expenditures roughly 2:1, and occasionally 3:1 (p. 39).

specifically earmarked for the purpose of highway projects (National Academies, 2006, p.86-89). For example, Newbery and Santos (1999) state that earmarking of road user charges, including fuel excise taxes, as an 'unsuccessful' and 'inadequate' practice in the U.K.

The European Commission officially states that transport-related taxes are tools of reducing social costs and controlling mobility (e.g. EC, 2008, p.2). Environmental emphasis of the motor fuel tax in the EU results in higher levels of taxes, but not necessarily tax harmonization because externalities are different among EU members. Newbery (2005a, p.7) suggests that the negative externality argument is directly "relevant to the EU agenda of energy tax harmonization," because fuel pollutants cross national borders (Newbery, 2005a, p.7). In addition, Sterner (2012) empirically shows that regressivity of motor fuel taxation in the EU is minimal, and that the impact of fuel tax is mostly proportional. Thus, if nations are concerned with stock pollutants and cross-border environmental impacts caused by tax differences, taxes on motor fuel may eventually harmonize across European nations.

3.3. MODELING MOTOR FUEL TAX INTERDEPENDENCE

3.3.1. Hypothesis

The hypothesis of this paper is built upon the literature on horizontal tax competition, which suggests that in hierarchical government systems, there exists tax competition among governments of the same level (e.g. Wildasin, 1988; Brülhart & Jametti, 2006; Devereux, et al., 2007; Goodspead, 2002). This literature generally concludes that such tax competition depends on two factors, the degree of tax base mobility (Oates, 1968) and the discrepancy of tax bases for a specific tax (e.g. Kanbur & Keen, 1993; Wilson, 1991). The question in hand, therefore, is to determine how mobility of national motor fuel tax bases impacts motor fuel fiscal competition among the EU countries.

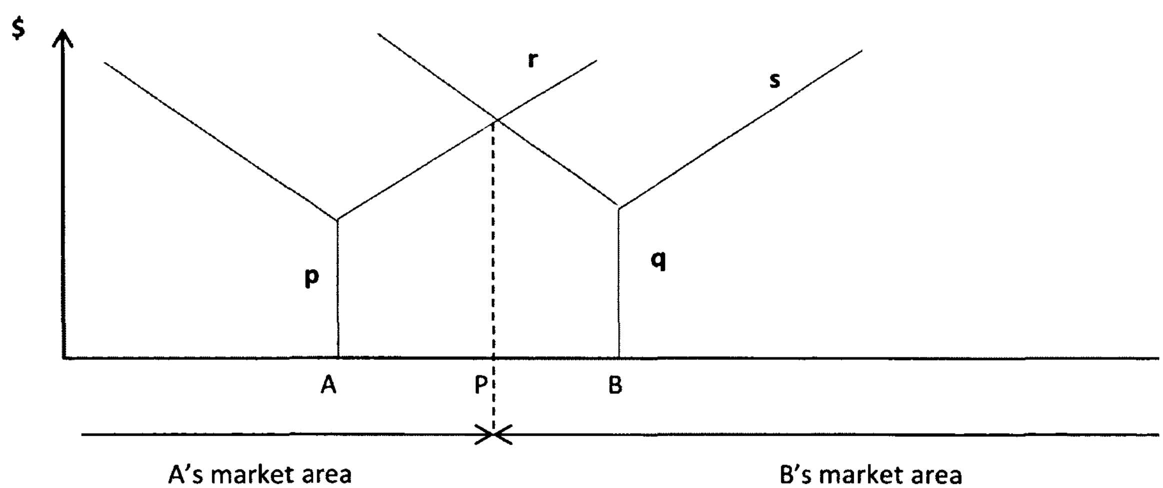
Prior empirical studies of motor fuel tax competition provide some evidence for the U.S., but not for the EU. Rork (2003), for example, finds that for taxes with a relatively *mobile tax base*, such as gasoline excise taxes, home governments respond positively to changes in a neighboring state's tax rate (↑↑). At the same time, he finds that for taxes with a relatively *immobile tax base*, such as VAT or sales taxes, home governments respond in an opposite direction to a neighbor's tax change. Nevertheless, the latter outcome suggests two possible scenarios for taxes with an *immobile* tax base: (1) a decrease abroad matched by a tax increase at home (↓↑), or (2) an increase abroad matched by a tax decrease at home (↑↓). If a state government is aware of inelastic response by its residents, it is plausible that the government may increase a home tax in response to a neighbor's tax drop. Yet, it seems counterintuitive that home state would decrease its motor fuel tax rates in response to a neighbor's tax increase (↑↓). In this case, if the home politicians are aware of inelastic response to home tax changes, they would be willfully decreasing home tax revenues by lowering their taxes. One possible explanation for such behavior could be home politicians' personal motives for reelection and an opportunity to make a political statement by decreasing home taxes with an inelastic tax base. As a general tax setting approach, Rork (2003) suggests that, to ensure stable tax revenues, states in the U.S. should gradually shift their reliance from taxes with a mobile tax base to taxes with an immobile tax base, such as income and sales taxes. Thus, they should shift away from taxes with mobile base, including excise taxes on motor fuels.

My analysis, however, concentrates *only* on motor fuels and looks at the fuel tax base mobility for the case of the EU, where both levels of taxes on motor fuels and the variation among the EU members are much higher than among states in the U.S. I argue that if mobility of the tax base matters in constructing national motor fuel tax policy, it should definitely matter in Europe, because of its Common Internal Market and common environmental objectives. Thus, it becomes important to determine whether the motor fuel tax matching pattern is different in the EU than in the U.S.

Since VAT rates are higher in the EU compared to sales taxes in the U.S., motor fuel tax base of a European country depends on both excise taxes as well as the VAT. Moreover, in the economic literature VAT is typically considered a tax with a relatively immobile tax base, while the excise tax is typically referred to as a tax with a relatively mobile tax base. Hence, the interacting aspect between the two types of taxes impacts the mobility of national motor fuel tax bases of the EU countries. This impact of the VAT on the mobility of the motor fuel tax base may occasionally either lessen or outweigh the impact of the excise tax. What I expect to find is that motor fuel tax base is less mobile in Europe than it is in the U.S. As a result, in the EU motor fuels are taxed at higher and more differentiated rates because individual EU countries are less afraid of tax competition from their neighbors. In this setting, the hypothesis is that the EU members are more willing to match a motor fuel excise tax increase and less willing to match a decrease.

My modeling approach is inspired by the Economic Law of Market Areas formulated by Fetter (1924) and Hyson and Hyson (1950). The initial idea behind the Law can be traced back to the late 1800s, to work by two European scientists Launhardt (e.g. 1885) and Cheysson (1887) (see Shieh, 1985 for discussion). The Law deals with the relationship between any two geographical markets as a function of relative prices and freight costs.

Figure 35. The Law of Market Areas



Keeping the original notation, Figure 35 demonstrates a simple logic behind the Law of Market Areas for two identical geographical markers, A and B. If commodity prices p and q as well as transportation costs s and r are equal in both markets, then the geographical distance between AP and PB is the same. The geographical position of the point P is determined by the intersection of the two Y-shaped figures. The length of the stem of each Y-shaped figure is the price of a good (p or q) in that market; the slope is the transportation cost (r and s) for that market. For example, even if prices in both markets A and B are equal ($p = q$), point P will be closer to the center of the market A if the transportation cost for that market is higher ($r > s$).

Subsequent developments of the theory behind the Law of Market Areas include the discussions of special cases when either prices or transportation costs may not be equal either between the two markets (e.g. Hebert, 1972; Parr, 1995a; Shieh, 1985) or among multiple markets (Parr, 1995b). My theoretical model is built for a general case when prices between two markets are not equal because of differences in taxes. The model presented here, therefore, explicitly includes both transportation cost as well as differences in prices between two countries that are caused by differences in taxation rates. I, however, look at the transportation cost not as a cost to the producer, but as a cost to the consumer who lives in one area and can travel to other areas. In addition, I explicitly allow for a representative individual to choose between purchasing gasoline at home or abroad, or both. The resulting theoretical model is flexible enough to implicitly show the impact of changes in either motor fuel excise tax, VAT, or both, which allows capturing an additional impact of double taxation of motor fuels in the EU.

3.3.2. Theoretical Model

In order to examine home government's reaction to changes in neighbor's tax rate, I develop a two-stage sequential model with two EU countries. The first stage solves the utility maximization problem of the representative individual in "home" country. By assumption, all individuals are identical in all aspects. The representative individual observes prices and taxes in two countries and makes a decision about the share of gasoline she/he will buy at home. The remaining income, by construction, is spent on either gasoline purchases abroad or on transportation costs. The second stage of the model is the home government's problem of choosing the optimal home tax rate on motor fuels, based on the knowledge of the individual's reaction function to tax rates. All tax revenues are spent by the home government on the provision of a public good to home residents. Both the home and foreign governments levy gasoline taxes. When reacting to changes in a neighbor's tax, the home government takes into account the potential change in its national tax base. The government's optimization problem becomes to maximize utility of a representative individual, a consumer of both gasoline and public good, subject to budget constraints.

A representative individual's preferences are captured by an additively separable utility function, which is defined over private good X, gasoline, and per-capita level of G, a domestically provided public good (Equation 17):

$$U(X,G) = u(X) + v(G) \tag{17}$$

To ensure well-behaved consumer preferences, the utility function is defined as continues, strictly monotonic, and strictly concave, such that $u'(.) > 0$ and $u''(.) < 0$ and $v'(.) > 0$ and $v''(.) < 0$. The separability assumption assures that an individual chooses the relative level of expenditure on domestic and foreign gasoline independently from the amount of public good received. That is, gasoline demand depends only on motor fuel prices (taxes) both at home and abroad, and not on consumption of public goods.

For simplicity, the exogenous income of the representative individual is entirely spent on fuel purchases and cost of traveling abroad. An individual is free to move across a border to choose where to purchase fuel. By assumption, all individuals are identical in all aspects; they all have identical preferences. Obtaining fuel abroad has an associated cost $C = C(\theta) \geq 0$. The term $\theta \ni [0,1]$ denotes the proportion of fuel bought abroad. By definition, the proportion of fuel bought domestically becomes $(1 - \theta)$. If an individual spends the entire income at home, then $\theta = 0$ and $C(\theta) = 0$. By construction, $C'(\theta) > 0$ and $C''(\theta) > 0$, implying that the marginal cost of acquiring fuel abroad is positive and increasing. Other models with mobile tax bases, for example, income tax models, typically require that individuals permanently relocate first, and by doing so, permanently choose where to pay all taxes – at home or abroad. My model is fundamentally different; it is a generalized case with continuous $\theta \ni [0,1]$, meaning that individuals do not have to commit to paying taxes only in their country of residents. Individuals in my model can freely move across national borders to fuel shop both abroad and home.

Equation 18 shows the individual's budget constraint; the representative individual spends all of her/his income on fuel both at home and abroad, and on the associated cost of traveling abroad in order to purchase foreign fuel:

$$y = (1 - \theta)XpT_1 + \theta XT_2 + XC[\theta] \quad (18)$$

where y is the exogenous income, p is exogenous pre-tax domestic price of gasoline relative to the foreign price (foreign price is set equal to 1), and $T_i = (1 + \tau_i)$, where τ_i for $i = 1,2$ is the tax rate paid on motor fuel. By assumption,$pT_1 > T_2$, so that the consumer has an incentive to accept the cost of shopping abroad. It is worth noting that τ_1 and τ_2 can represent the combination of two types of taxes that are typically levied on motor fuels in the EU, a specific lump-sum motor fuel excise tax and a general ad valorem VAT. Comparative static results showing the effect of a change in tax τ_i can represent changes in either motor fuel excise taxes or VAT rates as a reaction to a change in either type of these taxes abroad. Under this flexible construction, even changes in the VAT of a neighboring country may trigger changes either in the excise tax, the VAT, or both in the home country (see Essay 1 for discussion).

The representative individual maximizes utility (Equation 17) subject to a budget constraint (Equation 18). Re-writing the budget constraint gives Equation 19:

$$X = \frac{y}{(1-\theta)pT_1 + \theta T_2 + C[\theta]} = \frac{y}{\theta(T_2 - pT_1) + pT_1 + C[\theta]} \tag{19}$$

For notational simplicity, let the denominator of the Equation 19 be denoted as function $A(\theta) = \theta(T_2 - pT_1) + pT_1 + C[\theta]$; $A[\theta] > 0$. Substituting Equation 19 into the utility function (Equation 17) and differentiating it with respect to θ gives the first order condition (Equation 20):

$$-u_X \cdot X_\theta = 0 \tag{20}$$

where $X_\theta = \frac{-((T_2 - pT_1) + C_\theta)y}{\{A[\theta]\}^2}$. Given that the marginal utility is always positive, it follows from Equation 20 that $X_\theta = 0$. The numerator of X_θ implicitly describes $\theta^* = \theta(p, T_1, T_2)$:

$$(T_2 - pT_1) + C_\theta = 0 \tag{21}$$

Equation 21 shows that the consumer is willing to engage in cross-border shopping up to the point when the marginal benefit of money saved equals marginal cost. To see this, note that the cost premium that consumers pay at home compared to abroad, $M[\theta]$, is captured by multiplying the quantity of domestically bought gasoline by the post-tax price difference between domestic and foreign fuel (Equation 22):

$$M[\theta] = (1 - \theta)X(pT_1 - T_2) \tag{22}$$

The marginal benefit (negative cost premium) of cross-border shopping can be derived as the first derivative of Equation 22: $\frac{dM}{d\theta} = -X(pT_1 - T_2)$. As the share of gasoline bought abroad (θ) increases, cost premium changes by the amount $X(pT_1 - T_2)$.

Equation 21 gives an implicit solution for the optimal share of motor fuel to be bought abroad $\theta^* = \theta(p, T_1, T_2)$ as long as $A[\theta] \neq 0$. By implicit function theorem, the solution can be obtained by plugging the optimal value $\theta^* = \theta(p, T_1, T_2)$ back into the first order condition (Equation 21) and differentiating it with respect to T_1.

$$C_\theta\big(\theta(p, T_1, T_2)\big) + T_2 - pT_1 = 0 \tag{23}$$

Differentiating Equation 23 with respect to T_1 and T_2 and solving for $\frac{d\theta}{dT_1}$ and $\frac{d\theta}{dT_2}$ gives:

$$\frac{d\theta}{dT_1} = \frac{p}{C_{\theta\theta}} \tag{24}$$

$$\frac{d\theta}{dT_2} = -\frac{1}{C_{\theta\theta}} \tag{25}$$

Since the marginal cost of cross-border shopping is always positive and increasing ($C_{\theta\theta} > 0$), Equations 24 and 25 suggest that as either domestic taxes on motor fuels increase or foreign taxes decrease, the share of foreign fuel consumption also increases. For simplicity, I also assume $\frac{d^2\theta}{dT_1 dT_2} = 0$, which is equivalent to assuming that third and higher-order derivatives of the cost function equal zero.

Just like in a Stackelberg problem, a home government sets its taxes on motor fuel knowing the reaction function of home residents. Given this reaction function $\frac{d\theta}{dT_1}$, the second stage of the model is home government's decision. The home government finances its expenditures on the public goods using revenues from taxes levied on motor fuels. For the government, choosing T_1 is the same as choosing τ_i. Since, by assumption, all individuals are identical, the home governments' motor fuel tax revenues are entirely spent on provision of public goods to home individuals (Equation 26):

$$G = \tau_i NX(1-\theta)p = (T_1 - 1)NX(1-\theta)p \qquad (26)$$

where N is the number of home country's residents. In this setting, the home country government pays attention to the mobility of the motor fuel tax base because the government's spending on public goods depends on individuals' purchases of motor fuel at home.

The problem of the home government, hence, is to choose the local level of gasoline tax so that it maximizes the representative individual's utility (Equation 17), subject to an individual's and home government's budget constraints (Equations 18 and 26), evaluated at the representative individual's optimal choice θ^*. Substituting the budget constraints into the objective utility function, and noting that $\theta^* = \theta^*(y, p, T_1, T_2)$ is now endogenous, government's maximization problem becomes (Equation 17a):

$$\max_{T_1} \quad U(X,G) = u\big(X(\theta(y,p,T_1,T_2),T_1,T_2)\big) + v\big(X(\theta(y,p,T_1,T_2),T_1,T_2)\big) \qquad (17a)$$

The first order condition of the home government's maximization problem takes the following general form:

$$u_X\big(X_\theta \theta_{T_1} + X_{T_1}\big) + v_G\big(G_\theta \theta_{T_1} + G_{T_1}\big) = 0 \qquad (27)$$

Given that, from Equation 20, $X_\theta = 0$, the first term in the brackets in the Equation 27 is zero:

$$u_X X_{T_1} + v_G G_\theta \theta_{T_1} + v_G G_{T_1} = 0 \qquad (28)$$

From Equation 19 $X_{T_1} = \frac{-p(1-\theta)y}{\{A[\theta]\}^2} < 0$, suggesting that the first term of the Equation 28 depicts lost utility of reduced motor fuel consumption caused by an increase in home tax. The second and the third terms of Equation 28 depict utility from consumption of extra pubic goods. This additional public goods is associated with additional tax revenues collected by the home government. An increase in home tax, however, also induces the representative consumer to cross the border and increase her/his share of foreign gasoline purchases, indirectly decreasing the provision of home public goods.

Next, I'll plug in the specific constraints (Equations 19 and 26) into the home government's objective function (Equation 17a) and solve it for the optimal tax rate T_1^*. Differentiating the objective function with respect to home tax T_1 gives the first order condition (Equation 27):

$$u_X\big(X_\theta \theta_{T_1} + X_{T_1}\big) + v_G\big(NX(1-\theta)p + (T_1 - 1)\big[N\big(X_\theta \theta_{T_1} + X_{T_1}\big)(1-\theta)p - NX\theta_{T_1}p\big]\big) = 0 \qquad (27a)$$

Since $X_\theta = 0$ from Equation 20, Equation 27a becomes Equation 28a:

$$u_X X_{T_1} + v_G Np\big(X(1-\theta) + (T_1 - 1)\big[X_{T_1}(1-\theta) - X\theta_{T_1}\big]\big) = 0 \quad \text{(28a)}$$

Equation 28a can be re-written as Equation 29:

$$u_X X_{T_1} + v_G Np\left(X\big(1 - \theta - T_1\theta_{T_1} + \theta_{T_1}\big) + (T_1 - 1)X_{T_1}(1-\theta)\right) = 0 \quad \text{(29)}$$

Equation 29 implicitly gives the solution to the home government's optimal motor fuel tax. The optimal tax rate $T_1^* = T_1^*(y, p, N, T_2)$ is a function of income, population size, prices, and the neighboring country's fuel tax.

The goal, however, is to examine the impact of changes in motor fuel tax in a neighboring country (T_2) on a home country's optimal tax $T_1^* = T_1^*(y, p, N, T_2)$. This means that as foreign prices get more expensive, a representative consumer is affected because it (1) reduces overall spending power, (2) causes a shift in domestic taxes (further affecting spending power) and (3) causes a shift in the optimal mix between the amount of foreign and domestic fuel purchased. Since the consumer has already optimized, the impact of that third path is zero – differential changes in the tax don't cause changes in the mix; the representative agent already chose $X_\theta = 0$. By the implicit function theorem the solution to $\frac{dT_1}{dT_2}$ can be derived using Equation 29 by differentiating it with respect to T_2 (Equation 30):

$$u_{XX}\left(X_\theta\left(\theta_{T_1}\frac{dT_1}{dT_2}+\ \theta_{T_2}\right)+X_{T_1}\frac{dT_1}{dT_2}+X_{T_2}\right)X_{T_1}+u_XB$$

$$+\,v_{GG}Np\left(X\left(1-\theta-T_1\theta_{T_1}+\theta_{T_1}\right)+(T_1-1)X_{T_1}(1-\theta)\right)$$

$$+\,v_GNp\left(\left(X_\theta\left(\theta_{T_1}\frac{dT_1}{dT_2}+\ \theta_{T_2}\right)+X_{T_1}\frac{dT_1}{dT_2}+X_{T_2}\right)\left(1-\theta-T_1\theta_{T_1}+\theta_{T_1}\right)\right.$$

$$-X\left(\left(\theta_{T_1}\frac{dT_1}{dT_2}+\ \theta_{T_2}\right)+\frac{dT_1}{dT_2}\theta_{T_1}+T_1\left(\theta_{T_1T_1}\frac{dT_1}{dT_2}+\theta_{T_1T_2}\right)-\left(\theta_{T_1T_1}\frac{dT_1}{dT_2}+\theta_{T_1T_2}\right)\right)$$

$$\left.+\frac{dT_1}{dT_2}X_{T_1}(1-\theta)+(T_1-1)\left(B(1-\theta)-X_{T_1}\left(\theta_{T_1}\frac{dT_1}{dT_2}+\ \theta_{T_2}\right)\right)\right)$$

$$=0 \qquad (30)$$

where $B=X_{T_1T_1}\frac{dT_1}{dT_2}+X_{T_1T_2}+X_{T_1\theta}\left(\theta_{T_1}\frac{dT_1}{dT_2}+\ \theta_{T_2}\right)$.

Recall that $\tau_i=T_i-1, X_\theta=0$ (Equation 20), and, by assumption, $\theta_{T_1T_2}=0$. Then, Equation 30 simplifies to Equation 31:

$$u_{XX}\left(X_{T_1}\frac{dT_1}{dT_2}+X_{T_2}\right)X_{T_1}+u_XB+v_{GG}Np\left(X\left(1-\theta-\tau_1\theta_{T_1}\right)+\tau_1X_{T_1}(1-\theta)\right)$$

$$+\,v_GNp\left(\left(X_{T_1}\frac{dT_1}{dT_2}+X_{T_2}\right)\left(1-\theta-\tau_1\theta_{T_1}\right)\right.$$

$$-X\left(\theta_{T_2}+2\frac{dT_1}{dT_2}\theta_{T_1}+\tau_1\theta_{T_1T_1}\frac{dT_1}{dT_2}\right)+\frac{dT_1}{dT_2}X_{T_1}(1-\theta)$$

$$\left.+\,\tau_1\left(B(1-\theta)-X_{T_1}\left(\theta_{T_1}\frac{dT_1}{dT_2}+\ \theta_{T_2}\right)\right)\right)=0 \qquad (31)$$

where $X=\frac{y}{\theta^*(T_2-pT_1)+pT_1+C[\theta^*]}$ and τ_1 is a home country's optimal tax τ_1^*.

Re-writing Equation 31 as $\frac{dT_1}{dT_2} = \frac{D(.)}{E(.)}$ suggest that the sign of the numerator D determines the sign of $\frac{dT_1}{dT_2}$ because the sign of the denominator, $E(.)$, is negative by the second order condition and:

$$D = u_{XX}X_{T_2}X_{T_1} + u_X\left(X_{T_1T_2} + X_{T_1\theta}\theta_{T_2}\right) + v_{GG}Np\left(X\left(1-\theta-\tau_1\theta_{T_1}\right) + \tau_1 X_{T_1}(1-\theta)\right)$$
$$+ v_G Np\Big(X_{T_2}\left(1-\theta-\tau_1\theta_{T_1}\right) - X\theta_{T_2}$$
$$+ \tau_1\left(\left(X_{T_1T_2} + X_{T_1\theta}\theta_{T_2}\right)(1-\theta) - X_{T_1}\theta_{T_2}\right)\Big) \qquad (32)$$

If $D(.) < 0$, the home government at least partially matches a foreign tax increase. If $|D(.)| > |E(.)|$, the home government increases taxes more than proportionally. Although some terms in Equation 32 can be clearly signed for example – $u_{XX}X_{T_2}X_{T_1}$ and $\tau_1 X_{T_1}(1-\theta)$ are both negative – the overall sign of Equation 32 is not easily determined. The slope of the reaction function of the home government appears ambiguous. Thus, the next chapter will empirically examine the direction of the slope of the home governments' motor fuel tax reaction function.

There are two possible extensions of this simplified model that may be worth pursuing in future research: (1) setting up the model as an interactive tax matching game with a non-cooperative outcome; and (2) introducing heterogeneity of individuals into the model. The first extension will allow both governments to set their motor fuel taxes strategically. The second extension will introduce the median voter into the government's decision. It will also allow exploring how differences in individual's fueling costs associated with cross-border shopping (driving distances) influence the optimal motor fuel tax rate.

3.3.3. Empirical Model

3.3.3.1. Spatial Lag and Spatial Error Models. There are three categories of variables that may impact motor fuel tax rates in the EU: geographical, political, and socio-economical. By drawing from the economic spatial theory literature (see Brueckner, 2003, for discussion) and the spatial econometrics literature[32], this sub-chapter examines geography and the importance of space in understanding motor fuel tax competition in such a large region as the EU.

Space can enter the model in two ways, resulting in two types of models: spatial lag and spatial error models (Anselin, 1988). Spatial lag models are built upon the theoretical idea of interaction between economic agents and the existence of a spatial reaction function among them, that is, spatial dependence (Cliff & Ord, 1973). These models of spatial dependence fit the idea that national governments react to changes in motor fuel taxes in neighboring EU countries. In a general form, such interaction among national governments is captured in the model by a spatially-weighted lag of the dependent variable (Equation 33). Spatial lag models, hence, facilitate separation of a spatial trend in data and allow for more accurate inference of β-coefficients than non-spatial models (e.g. Anselin & Lozano-Gracia, 2009, p.15).

$$T = \rho WT + X\beta + \epsilon \qquad (33)$$

Under the second specification, space enters these models in the form of spatially autocorrelated error terms. Equation 34 shows the basic spatial error model:

$$T = X\beta + (I - \phi W)^{-1}\zeta \qquad (34)$$

[32] See e.g. Anselin, Florax, Rey, 2004; LeSage & Pace, 2009; Anselin & Rey, 2010 for discussion of recent developments in the spatial econometrics literature.

where ζ are well-behaved errors with zero mean and symmetrical diagonal variance-covariance matrix $(\delta^2 I)$. Spatial error correlation in such models is the result of unobserved national variables that have a spatial structure but are omitted from the model. For example, in the EU, such unobserved spatial factors could be unmeasured cultural driving habits or behavioral aspects of the population across Europe. Environmental externalities from transport that cross national borders could also play a role in explaining variations in European motor fuel tax rates. These spatial error models are fundamentally different from the spatial lag models because the expected value of the dependent variable is the same as in non-spatial models (e.g. LeSage & Pace, 2009, p.21):

$$E(T) = X\beta \tag{35}$$

Although Equation 35 suggests that unobservable omitted factors are important in explaining motor fuel tax levels in the EU, it is more crucial to identify the impact of spatially distributed observable factors, such as in a spatial lag model. In addition, spatial lag models are more consistent with the public economics literature on inter-jurisdictional competition and the formal theoretical framework for strategic interactions by Brueckner (2003).

3.3.3.2. Spatial Autocorrelation and Spatial Weights. Spatial distributions of motor fuel excise taxes and total tax levels in the EU in 1995, 2004 and 2010 are portrayed in Figures 35-40. These figures show that the neighboring EU members often belong to the same distribution interval, informally suggesting spatial correlation of motor fuel taxes among European neighbors. The concept of spatial autocorrelation (e.g.

Cliff & Ord 1973; 1981, p.7-10) implies that spatially located data like motor fuel tax rates are likely to be related across different locations in space, in our case across the European continent. Unlike one-directional temporal correlation when taxes may depend only on past taxes and not on future values, spatial autocorrelation is multi-directional (Whittle, 1954). While the assumption of non-spatial independence is embedded in non-spatial panel models, ignoring spatial patterns may produce inaccurate empirical results. In order to determine what kind of spatial patterns among neighbors fit the actual distribution of motor fuel taxes, it is important to discuss several criteria for guiding this choice.

The structure of spatial connectivity among neighbors is typically incorporated into empirical models with the help of a spatial weight matrix W. This spatial weights matrix that was originally introduced by Cliff and Ord (1973, 1981) is designed upon the concept of potential interaction between any two neighbors in space. The economic literature provides few formal sets of rules for choosing the "correct" weights, the elements of the spatial weight matrix w_{ij} (e.g. Florax & Rey, 1995; Anselin, 2006, pp.909-910 for discussion). Prior studies of tax competition typically used contiguity and population weight structures (e.g. Rork, 2003, 2009; Rork & Wagner, 2008). The contiguity matrix is one of the simplest and most popular tools for formally establishing connections among neighbors. Elements of contiguity matrix w_{ij} are equal to one if two countries i and j in the dataset are geographical neighbors, that is, if they share a common border; w_{ij} equal zero otherwise. In addition, weight matrixes are typically row-standardized, so that $\sum_j w_{ij} = 1$.

Since the contiguity matrix may be a rather simplified way of treating spatial weights, this paper tests a variety of more complex spatial weights to assess the sensitivity of results. These matrices are the row-standardized contiguity matrix ($W1$), the inverse distance weights matrix ($W2$), the population-contiguity matrix ($W3$), the in-land neighbor's border length matrix ($W4$), the population-border contiguity matrix ($W5$), and the inverse distance matrix with a limited radius ($W6$). Figures 41-46 depict graphical representation of these spatial weight matrices.

The simple row-standardized contiguity matrix ($W1$) embeds the assumption that every neighbor has an equal weight in impacting the home country's motor fuel tax rate. It also suggests that the more neighbors a country has, the weaker the influence of any particular neighbor is. For example, Ireland will be influenced by only the U.K., but Luxembourg is equally influenced by France, Germany and Belgium (Figure 41).

The contiguity type matrices ($W1, W3, W4, W5$), however, only take into consideration immediate, or so-called, first-order neighbors, that is, countries that share a *common border*. By contrast, in the inverse-distance setting, the closest neighbors have the most influential impact on the home country's motor fuel taxes, and this impact decays with the distance. The inverse distance matrix ($W2$) allows capturing the impact of not only immediate neighbors, but also all other EU members. For example, Austrian motor fuel taxes will have the biggest impact on taxes in Slovenia, and Spain will have one of the weakest influences (Figure 42). Matrix ($W6$) also captures the impact from all countries within the radius of about 1,000 km, an average distance between two European capitals. In order to capture the spherical surface of the earth, I use the haversine formula to calculate the distances between the EU countries.

The in-land neighbor's border length matrix $(W4)$ assumes that the neighbor with the longest border has the most influence on motor fuel taxes in a home country. The elements of this matrix are constructed as shares of relative border length with a given neighbor in relation to the total border perimeter of the home country. Such an assumption seems plausible under the fuel tourism hypothesis: if presented with incentives, consumers that live near national borders may easily cross them to purchase fuel abroad. Then, matrix $(W4)$ ensures that neighbors with the longest common border present more opportunities for crossing the borders and have the biggest influence on a home country. For example, according to matrix $(W4)$, Slovakia will have the largest influence on Hungary because it has a longer common border with Hungary than other Hungarian neighbors (Figure 44). Countries with longer in-land borders and closer effective distances are also more likely to engage in tax matching. These countries will be potentially more willing to match both a fuel tax increase and a fuel tax decrease. European countries with smaller territories and shorter neighboring borders, for example, Luxembourg, may be less likely to match the fuel tax increase because they strategically wish to attract additional fuel consumers from neighboring countries.

Finally, the population weight matrices $(W3, W5)$ ensure that more populated neighbors have a higher weight in determining the average level of motor fuel taxes in neighboring countries. For example, the construction of a population-contiguity matrix $(W3)$ suggests that Germany will have the biggest influence on motor fuel taxes in the Czech Republic out of its four neighbors (Figure 43). However, in this case, Romania and not Slovakia has the biggest impact on Hungary (Figures 43 and 44). In order to take into consideration the impact of both population size and border length, I construct the population-border contiguity matrix ($W5$). Before row-standardizing, each element of this matrix is constructed as border length with a given neighbor, weighted by its population size, and equals zero otherwise (Figure 45). In this setting, in the example with Hungary, Romania remains the neighbor with the strongest influence on Hungarian motor fuel taxes (Figure 44).

To formally test for spatial autocorrelation in the entire EU sample, I use two common tests: the Moran's I test (Moran, 1950) and the Geary's C test (Geary, 1954) (Table 14). Although both tests produce an index of global spatial autocorrelation, the Moran's I statistic is not bounded by the $[-1, 1]$ interval. Typically, a zero value of the Moran's I index indicates no spatial similarity and a value of one indicates either positive or negative association, depending on the corresponding sign. By contrast, Geary's C index takes on values between zero and two and smaller values suggest stronger spatial correlation. Zero values of the Gary's C test imply perfect positive spatial correlation, value of one implies no spatial correlation, and value of two implies perfect negative spatial autocorrelation.

Both tests deserve a few important words of caution when analyzing motor fuel tax patterns in the EU. Firstly, both tests rely on the assumption that fuel taxes are normality distributed; otherwise they produce poor estimations of true variances $var(I)$ and $var(C)$ that are later used in construction of tests' global indices. Anselin and Florax (1995) compare finite sample properties of the Moran's I test and seven other large sample asymptotic tests and confirm good properties of the Moran's I against other tests. Secondly, the Moran's I test is sensitive to the choice of spatial weights and trend to over-reject the hull hypothesis of no spatial dependence for some matrix specifications, for example, for the rook case (Anselin & Rey, 1991; Anselin & Florax, 1995). This is why I use both the binary type weights matrices and the inverse distance type matrices. Lastly, the Moran's test may also produce spurious results in the presence of other trends in the data such as time trends (e.g. Bivand, et al., 2008, p.260-261 for discussion); hence, I perform both tests by year.

Test results suggest that motor fuel excise tax rates across the European continent are spatially correlated (Table 14). The null hypothesis of spatial independency is rejected in almost all cases for the excise tax rates and for the overall real tax level levied on motor fuels, but not for the VAT taxes. In both Moran's *I* and Geary's *C* tests, the inverse distance weights produce stronger test results for both unleaded gasoline and diesel. Test results for unleaded gasoline also tend to be slightly more significant than for diesel.

3.3.3.3. The Empirical Model of Motor Fuel Tax Competition in the EU. This paper models spatial nature of motor fuel fiscal competition in the EU in the spirit of Rork (2003).

Equation 36 shows a reduced form model of the motor fuel tax competition in the space-time lagged autoregressive model specification.

$$T_{it} = \rho W T_{it} + X_t \beta + \pi_i + \mu_t + u_{it} \quad (36)$$

where T_{it} represents home tax at time *t* in country *i*; *W* is the spatial weights matrix; ρ is the scalar of spatial dependence of motor fuel taxes in the EU, hence, $\rho W T_{it}$ is the spatial lag variable; X_t denotes socio-economic factors that influence home taxes for motor fuels; π_i are country fixed effects; μ_t are time fixed effects; u_{it} is the error term.

Coefficient ρ in Equation 36 implies that tax policies in the neighboring countries have a contemporaneous effect on tax levied on motor fuels in the home country.

In the theoretical framework, I modeled only the overall level of taxes on motor fuels and expressed it in an *ad valorem* form. However, in my empirical analysis I'll examine both types of taxes separately, in order to comment on the role of each tax in the total tax burden. The general form of the above model specification (Equation 36) allows this by selecting a different explanatory variable each time I run the model. Thus, I will run the model three times and separately analyze the hypothesis of fiscal competition in excise tax, VAT taxes, and total taxes paid per unit of motor fuels in the EU.

This model may produce inconsistent estimates if estimated by OLS because of the potential endogeneity problem (e.g. Ord, 1975; Anselin, 1988, p.58-59). Endogeneity may arise if the spatial lag WT_{it} (or any explanatory variable) is correlated with the error term u_{it}. Moreover, in the case of spatial motor fuel tax dependency, for example, lagging variables on the right hand side (e.g. Rork, 2009) may not solve the problem, because if there is a serial correlation among the error terms u_{it}, then WT_{it-1} will be still correlated with u_{it}. In my spatial lag model with a simultaneous senders-receivers type set-up, 'senders' can also serve as 'receivers', meaning *interdependence* of taxes on motor fuels in the EU. Such simultaneity serves as a source of the endogeneity issue in Equation 36 (Franzese & Hays, 2007; Brueckner & Saavedra, 2001). That is, in my model, not only neighboring countries influence home country's tax motor fuel rates in the EU, but also home country's taxes influence taxes in the neighboring states.

Equation 36 can be estimated using either the maximum likelihood method (ML) or the instrumental variables (IV) approach to address potential endogeneity. Compared to the ML estimation that assumes a normal distribution of the error terms, the IV approach has a lesser restrictive parametric framework and still produces consistent results (Anselin, 1988, ch.7, p.81-86). The efficiency of the IV estimator strongly depends on the proper choice of the instruments; hence, I use the popular spatial IV procedure developed by Kelejian and Prucha (1998, 2004, 2007, 2010). Following Kelejian and Prucha (1998), in the first stage, this two-stage estimation procedure uses weighted values of the exogenous variables (*WX*) as instruments for the spatial lag (*WT*). In the second stage, the predicted values of the spatial lag are included as explanatory variables in Equation 36.

Lastly, it is worth mentioning one important factor: neither my theoretical nor empirical model addressed the potential substitutability between the two types of taxes – VAT and excise tax. This is because from the revenue generation perspective, governments may perceive two taxes as substitutes for one another. There exists a large economic literature on optimal taxation (see Selim, 2007 for a comprehensive literature review) and the double dividend of environmental taxes (e.g. Parry, 2003; Glouder, 2005) that examines the interacting effect between taxes in every detail. Although a thorough examination of this issue is beyond the scope of this dissertation, one can examine such tax substitutability and interdependence by using, for example, a computational general equilibrium model. In the case of European motor fuels, national governments are likely to take into consideration VAT in deciding on changes to motor fuel excise taxes. Motor fuel excise taxes, however, are not likely to significantly influence the government's decision about newer VAT rates because the uniform VAT is levied on most goods and services. In addition, the data suggest that in the 2000s, the EU countries were slowly switching away from excise taxes towards higher VATs (see Chapter 1 for discussion).

3.3.4. Determinants of Motor Fuel Tax Rates in the EU

While the previous sections of this essay discussed geography as the factor of motor fuel tax setting behavior in the EU, this section discusses both political and socio-economic factors. Both types of these factors are important to control for in explaining motor fuel tax changes in the EU. Table 13 provides a description of these explanatory variables.

According to the 'political economy' view of the fiscal federalism literature described earlier, the political atmosphere remains a crucial factor of tax setting behavior. I include two variables to control for national political climates, the parliamentary election year dummy and the dummy indicating whether the head of the government is from the same political party as the major party in a country's parliament. Fiscal stress is another major factor of tax setting behavior (e.g. Alm, et al., 1993; Man, 1999). At a time of financial trouble, states in the U.S., for example, tend to turn to gasoline and sales taxes for additional revenues (Rork, 2003). In the EU, Greece is one country that recently dramatically increased its motor fuel excise and VAT taxes as a response to a widespread national economic crisis. Thus, the EU countries that experience greater fiscal pressure may be more likely to match their neighbor's fuel tax increase and less likely to match a neighbor's fuel tax decrease. Using the data from the Eurostat on-line statistical database, fiscal stress is measured as a national government debt (or surplus) as a percent of GDP.

Given the common nature of environmental responsibility in the EU, some EU members may face pressure from the European Commission and from other members directed towards meeting a country's individual emission reduction goals. By contrast, in the U.S., states do not face similar peer pressures because managing the emissions from gasoline consumption is delegated to the Federal government. Then, the EU members that face lower Kyoto targets or milder peer pressure to comply with their emission reduction goals may have lower fuel tax rates, for example, some newer member countries. They may be more willing to match both a fuel tax increase as well as a fuel tax decrease. The EU countries that are not successful at reaching their individual targets, however, may be willing to respond in a more similar way to a fuel tax rate increase of their neighbors, but not to a fuel tax decrease. I measure the environmental pressure as the level of greenhouse gas emissions relative to its level in 1990, because Kyoto emission targets for each country are also constructed relative to emissions in 1990. The EU emissions data comes from the European Environment Agency.

Among socio-economic factors, I include per capita income to measure the overall wellbeing of a country's citizens. This variable is included because the mobility of the fuel tax base depends, among other factors, on the value of time that individuals place on traveling across borders to purchase gasoline. Thus, it is expected that in Europe income is positively correlated with tax levels because tax base mobility reduces with an increase in income.

I also include the country's unemployment rates because the unemployed tend to drive shorter distances, make fewer trips, or even to sell their vehicles all together. On the one hand, the unemployed may support higher taxes on motor fuel because they would advocate for higher unemployment benefits. On the other hand, the EU governments with a large unemployed population may also raise taxes to partially compensate for large budgetary needs to support the unemployed. Rork (2003), for example, finds a positive correlation between state sales taxes and unemployment rates in the U.S. Thus, the EU members with a large unemployed population may be more willing to match a motor fuel VAT tax increase and less likely to match a tax decrease.

Differences in national inflation rates among the EU members matter for setting motor fuel excise taxes because these taxes are imposed in the form of a lump-sum. Higher inflation rates may require frequent excise tax rate changes to make up for lost revenues (England, 2007). The data on per capita income, a share of elderly population, unemployment and inflation rates come from the Eurostat on-line statistical database.

Lastly, country fixed effects are also included to capture all time-invariant national characteristics that may impact motor fuel taxes in the EU. Natural geographical barriers such as mountain ranges, for example, may prevent some fuel tourism between two neighboring EU countries and reduce incentives for motor fuel tax competition. Such natural geographical characteristics are invariant in time and are captured by country fixed effects. In addition, the Eurozone membership and whether a country is an older or a newer member state are important factors that are also captured by country fixed effects. This is because motor fuel prices in the Eurozone countries are denoted in common currency and consumers can easily compare gasoline taxes and prices. The Eurozone members, hence, may be more willing to match both a tax increase and a tax decrease. Year fixed effects control for factors that influence all the EU members in every particular year, such as business cycles and the price of oil. Due to relatively short time series in the panel, I do not automatically include year fixed effects in all model specifications, and use the Wald test to determine when to include them.

The data for the dependent variable, motor fuel taxes, comes from the EU Oil Bulletin published by the European Commission on its web-site. The weekly tax data is for two types of motor vehicle fuels, the unleaded gasoline (Euro-super-95) and the automotive gas oil (diesel), and has been aggregated to yearly averages. The balanced panel is for twenty seven EU countries for the period from 2004 to 2010.

3.4. THE RESULTS

Tables 15-20 report spatial IV estimation results for Equation 36. This equation is estimated six times, each time with a different spatial weights matrix. The analysis is repeated for the following dependent variables: excise taxes, VAT, and the total level of taxes both on unleaded gasoline and diesel fuel. The first column of each table displays results using the contiguity matrix ($W1$), the next column reports the results for the inverse distance matrix ($W2$), the third and the fourth column – for the population weights matrix ($W3$), the fourth column – for the common border matrix ($W4$), the fifth column – for the border-population matrix ($W5$), and the sixth – for the inverse distance weights matrix with an area limit ($W6$).

3.4.1. The Results for Excise Taxes on Unleaded Gasoline and Diesel Fuel in the EU

The results for excise taxes on unleaded gasoline and diesel fuel are presented in Tables 15 and 16 respectively. All signs for the estimated coefficients are as expected. The results illustrate that the spatial lag coefficient is positive and statistically significant in every case of spatial weights, meaning a positive relationship between the neighbors' excise taxes on motor fuels in the EU. For unleaded gasoline, a 10% increase in a weighted neighbors' excise tax leads up to a 5.99% increase in home excise tax rate. For diesel fuel, a 10% increase in a neighbors' excise tax rate results in an up to 4.18% increase in home tax rate. It is worth noting that the coefficients for a spatial lag variable for $W2$ and $W6$ in Tables 15 and 16 should be interpreted with caution. The magnitude of these coefficients is different from the rest of spatial weighting schemes, because the inverse distance matrices are not row-standardized. These coefficients, hence, suggest only the direction of the spatial relationship, but not the elasticity of this relationship to the dependent excise tax variable.

The coefficients for national debt in Tables 15 and 16 are negative and statistically significant, indicating that, as national debt increases, governments decrease their excise taxes for motor fuels in lieu of other taxes, including VAT. Environmental pressure, however, seems to play a less important role in excise tax setting behavior in the EU than originally anticipated, as the coefficient for this variable is positive but statistically insignificant in most cases. The positive relationship suggest that in the EU countries, an increase in the national level of greenhouse gas emissions relative to a country's 1990 level results in an increase of the excise taxes for unleaded Euro-super-95 gasoline. For diesel fuel, the sign of the environmental variable is also insignificant.

There is also some evidence that unemployment rates are positively correlated with excise taxes on motor fuels. The unemployed may drive fewer distances, buy less fuel and may even eventually sell their cars during long periods of unemployment. Thus, as a country's unemployment rate increases, national governments in the EU face lower motor fuel tax revenues and, at the same time, have to provide unemployment benefits to a larger share of population. Hence, it makes sense for national governments in the EU to seek quick and easy ways to collect additional tax revenues by increasing indirect taxes on goods with low price elasticity, such as excise taxes on motor fuels. In addition, inflation rates seem to be positively correlated with excise taxes on unleaded gasoline, but not for diesel. This is consistent with the notion that as inflation rates increase national governments have to impose new, higher excise tax rates for this lump-sum tax.

3.4.2. The Results for VAT Taxes in the EU

The results for VAT also show a positive relationship between a home country's VAT and changes in neighbors' VAT rates among the EU members (Tables 17 and 18). Under all weighting schemes, the measure of fiscal competition in VAT is positive, relatively small, but statistically significant. My results suggest that when neighbors' weighted VAT rate increases, for example, 1.10 times, or from 20% to 22%, a home country reacts by increasing its rate up to 1.0187 times, or from 20% to up to 20.374%.

The direction of this reaction by the EU home governments is different from the direction of reaction among the U.S. states to their sales tax changes. Rork (2003), for example, finds that a 10% sales tax decrease by neighboring states in the U.S. leads up to a 2.37% increase in home state sales taxes. Unlike Rork's (2003) findings that suggest that state governments in the U.S. perceive their state tax bases as relatively immobile, my results suggest that national governments in the EU recognize some mobility of their VAT bases. Alternatively, my findings suggest that the EU countries engage in the yardstick competition among themselves more often than the U.S. states. At the same time, the magnitude of fiscal interdependence in VAT in the EU is small relative to, for example, excise taxes on motor fuels.

The results also strongly suggest that in the EU, both unemployment rates and a country's debt are positively correlated with VAT rates. As expected, higher unemployment prompts the EU national governments to rely more heavily on indirect sales taxes, such as VAT, to provide sufficient benefits to the unemployed. In contrast to excise taxes, a country's national debt is also positively correlated with VAT rates, meaning that at times of financial hardship governments rely on VAT to raise additional revenues.

Finally, there is some weak evidence of inflation being negatively related to VAT rates, which may be due to national governments' efforts to reduce the magnifying impact of this percent tax on prices. VAT is an ad valorem (percent) tax; in the presence of inflation, VAT magnifies nominal price growth initially caused by inflation. In addition, the OLS results suggest that, unlike the U.S., the EU per capita income has a positive relationship with VAT rates. It appears that tax bases in wealthier EU countries are less mobile than tax bases in the EU countries with relatively low per capita income. Since high income consumers have higher value of time, they seem to engage less in fuel tourism, reducing the mobility of tax base in their EU home country.

3.4.3. The Results for Total Real Taxes Levied on Motor Fuels in the EU and the Influence of VAT and Excise Taxes on These Levels

In spite of relatively strong Moran's *I* and Geary's *C* test results in favor of spatial correlation in real overall motor fuel tax levels among the EU neighbors, regression results find weaker support of such interdependence (Tables 14, 19, and 20). For unleaded Euro-super-95 gasoline, results for two model specifications with inverse distance spatial weight matrices show that the fiscal competition variable is positive and statistically significant. In the remaining four model specifications with spatial weights based on contiguity, this variable, although statistically insignificant, also has a consistent positive sign. These findings suggest that as neighboring countries increase their overall tax level on unleaded gasoline by an average of 10%, a home country increases its real overall tax level by 2.2% (Table 19). As in the case with VAT and excise taxes, model specifications based on inverse distance spatial weights matrices $W2$ and $W6$ can only suggest the direction of the relationship and not the magnitude because these matrices are not row-standardized.

For diesel fuel, the results of spatial dependence in real overall tax levels are somewhat weaker than for unleaded gasoline, which is also consistent with the Geary's C spatial correlation test results. The sign for the fiscal competition variable is positive in most cases, except for model specifications based on borders-related weight matrices. The magnitude of response is statistically insignificant and small compared to fiscal competition in unleaded gasoline; an average 10% change in real overall tax levels on diesel by neighboring EU member-countries results in less than a 1% change by the home country (Table 20).

Overall, my findings suggest that inflation strongly influences real total tax levels levied on motor fuels in EU: as inflation rises, real tax levels drop. At times of financial hardship in the EU, national governments may be especially concerned with the magnifying impact of ad valorem VAT taxes on already inflated prices on domestic commodities, including motor fuels. In addition, Tables 19 and 20 show that national debt is statistically significant and negatively correlated with overall tax levels for unleaded gasoline; the sign for the debt variable is also negative for diesel fuel. At time of financial hardship and increasing debt, therefore, national motor fuel excise tax policies overshadow the effect of increasing VAT policies on real overall motor fuel tax levels. Thus, compared to findings for nominal excise and VAT taxes, it appears that decreasing excise taxes have a stronger influence on the real overall level of taxes levied on motor fuels in the EU, forcing them to drop as well.

Given that the EU nations fiscally compete with their neighbors in both excise and VAT taxes, as the economic crisis progresses and national debts across Europe rise, the EU countries are more likely to engage in growing fiscal competition. As a result, they would more actively switch from excise taxes to VAT. Such substitutability between taxes may eventually result in the situation when excise taxes will bottom out and real overall taxes on motor fuels will start rising. This outcome would also have negative consequences for the environment because of the decreasing Pigouvian role of the excise tax. Subsequently, as national debts rise and fiscal competition flourishes, national exhaust pollution levels would also rise along with VAT rates. Moreover, the tax burden will be slowly switching from motor fuel consumers, who are polluters, to the general public.

3.5. CONCLUDING DISCUSSION

The EU traditionally has higher taxes on motor fuels than the U.S., in part due to a more predominant Pigouvian role of taxes and common environmental goals among the Union members and commitment pressures to lower greenhouse gas emissions. Because of this complex nature of political interactions among these twenty-seven united member countries, the goal of this paper was to explore whether the EU national governments engage in fiscal competition. This paper was set to empirically examine taxes on motor fuels in the EU and the impact of neighbors' tax changes on a member's tax policy.

My key finding is that in the EU, national governments positively react to tax changes by their neighbors in setting both VAT and motor fuel excise taxes. Moreover, my results indicate that for motor fuel excise taxes, the magnitude and the direction of the discovered relationship in the EU is similar to the one among the U.S. states found by previous studies (Rork, 2003). In setting their VAT taxes, however, the EU national governments seem to behave differently than the U.S. states in terms of sales taxes. The EU countries respond positively to VAT changes of their neighbors.

One of the key takeaway messages is that unlike excise taxes that are levied only on specific goods like motor fuels, VAT taxes are levied on almost all goods in the EU. Fiscal competition in VAT taxes, therefore, has a much broader impact on the functioning of the Common European Market. Race-to-the-bottom in VAT taxes would, for example, have a strong economic impact by increasing per capita consumption. At the same time, race-to-the-top would result in slowing down of economic activity because higher sales taxes discourage consumption.

These results are consistent with the political economy view of the fiscal federalism, suggesting that this tax competition among the EU members could be driven by a variety of incentives: from politicians' own objectives, for example, re-elections, to passive mimicking of neighbors' taxation policies by the national governments. In addition, national governments may be purely driven by comparing the size of their national budgets or national-level externalities associated with gasoline consumption, to those of their neighbors. My findings also support the traditional fiscal federalism view that member governments in the EU may recognize a relative mobility of their tax base and compete for it with their neighbors.

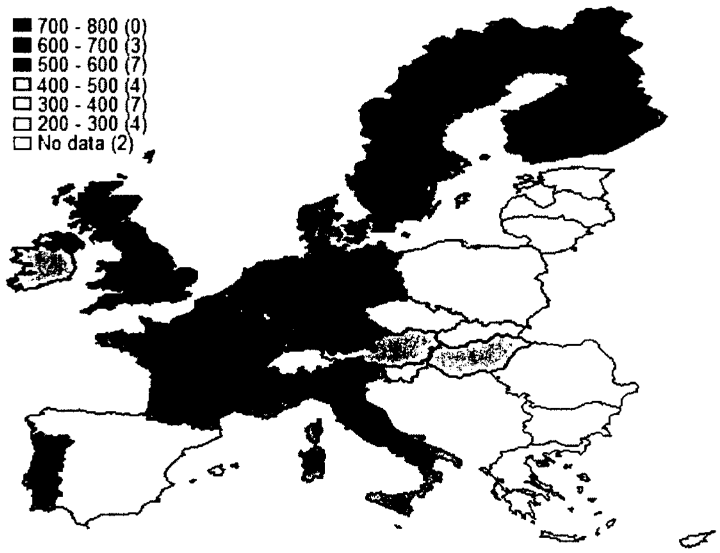
Under certain assumptions, including free, competitive markets, fiscal competition may eventually lead to the establishment of a single tax level across the EU, at least in theory. In the long run, the outcome of tax matching behaviors of individual governments would cause harmonization of tax rates across the entire EU, that is, either to race-to-the-bottom or race-to-the-top. Race-to-the-bottom in motor fuel excise taxes would result is a substantial increase in greenhouse gas emissions from transport in Europe. The extent of this race in the EU depends on mobility of tax base and on the stringency of the political will of national governments.

On the contrary, race-to-the-top in motor fuel excise taxes would likely result in a substantial reduction of emissions, but at the expense of efficiency loss. Given that individual EU member countries differ in their characteristics, tax harmonization could lead to reduction of efficiency in addressing national-level externalities associated with motor fuel consumption. Fullerton (2001), for example, suggests that a geographically differentiated fuel tax may be more efficient that a uniform tax, yet not politically feasible to administer. Nevertheless, the race-to-the-top outcome is only possible when there is either sufficient peer pressure among the EU members or strong bottom-down political pressure from the higher levers of the EU government. In 2008-2012, for example, this role was played by the Kyoto targets. Without specific safeguarding constraints such as tax floors, race-to-the-bottom becomes inevitable, unless certain member countries take strong positions of environmental leaders in the EU and lead the race-to-the-top. In either case of tax harmonization, race-to-the-top or race-to-the-bottom, continuing fiscal competition in motor fuel excise taxes is likely to result in harmonized tax rates across the EU and fewer fuel tourists.

To conclude, it is likely that during the current financial crisis, as national debts rise, VAT tax rates are also likely to race-to-the-top across the EU, slowing down the economic recovery of the Union. This is because higher taxes discourage consumption. One way to address this issue could be a temporary reduction of VAT tax floors in the EU, which may prompt member countries to fiscally compete downwards, and, at the same time, a temporary increase in motor fuel excise taxes. This policy scenario is consistent both with the EU long-term environmental objectives, economic recovery goals, and the fiscally competitive nature of the members' tax setting behavior.

Figure 36 (a, b). Excise Taxes on Unleaded Euro-super-95 Gasoline in the EU in 2004 (a) and 2010 (b)

(a)



(b)

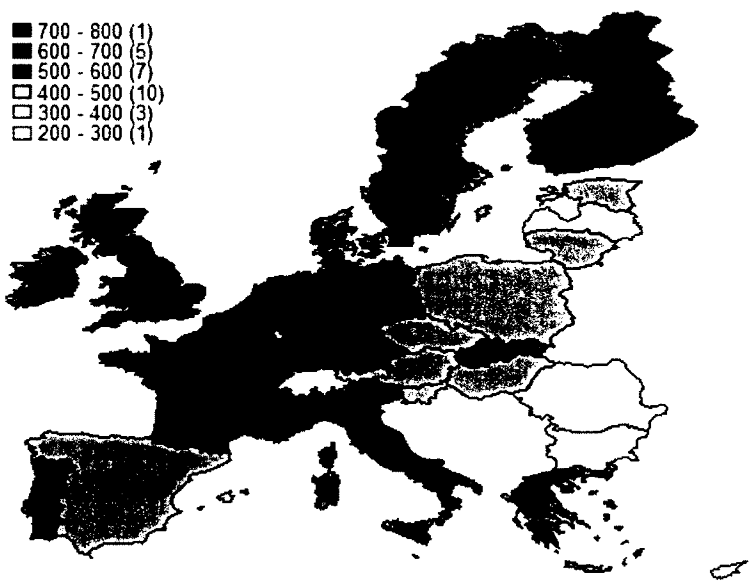
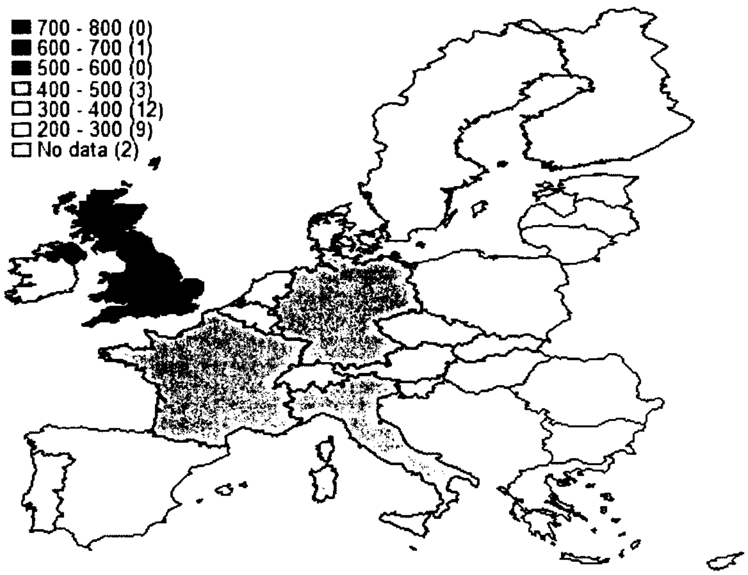


Figure 37 (a, b). Excise Taxes on Diesel Fuel in the EU in 2004 (a) and 2010 (b)

(a)



(b)

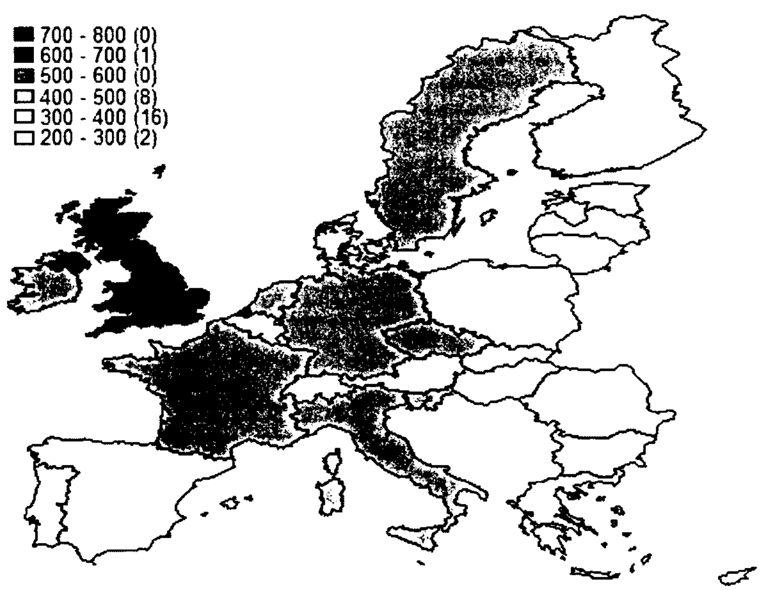
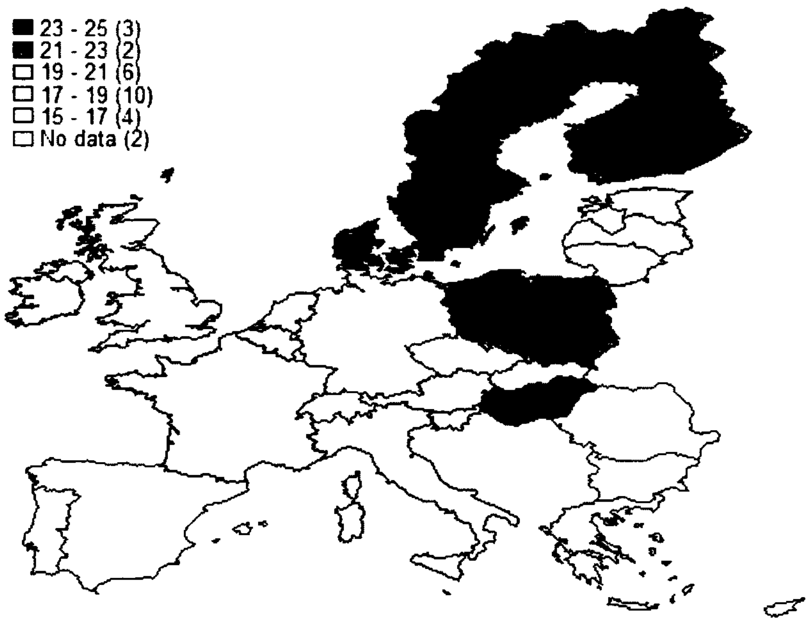


Figure 38 (a, b). VAT Levied on Motor Fuels in the EU in 2004 (a) and 2010 (b)

(a)



(b)

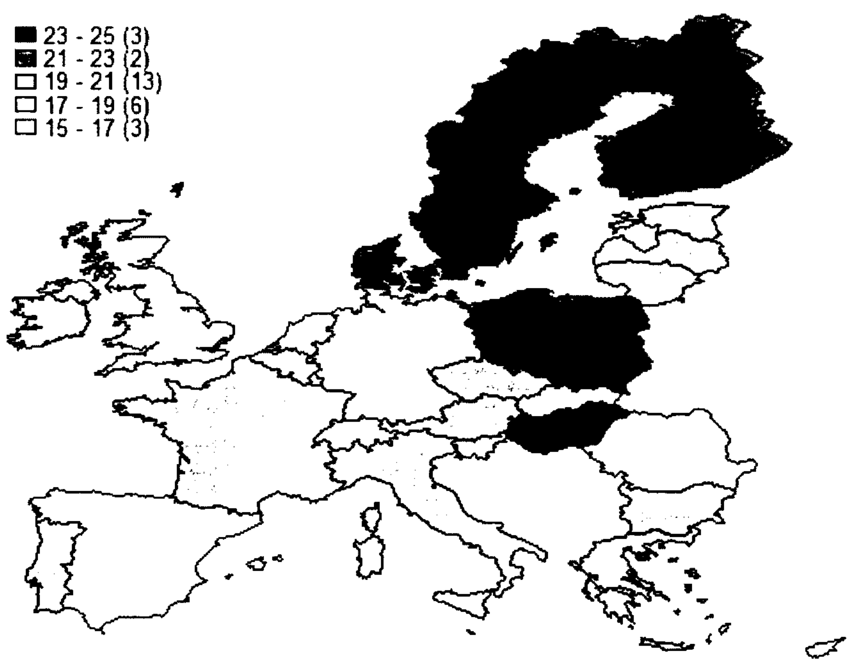
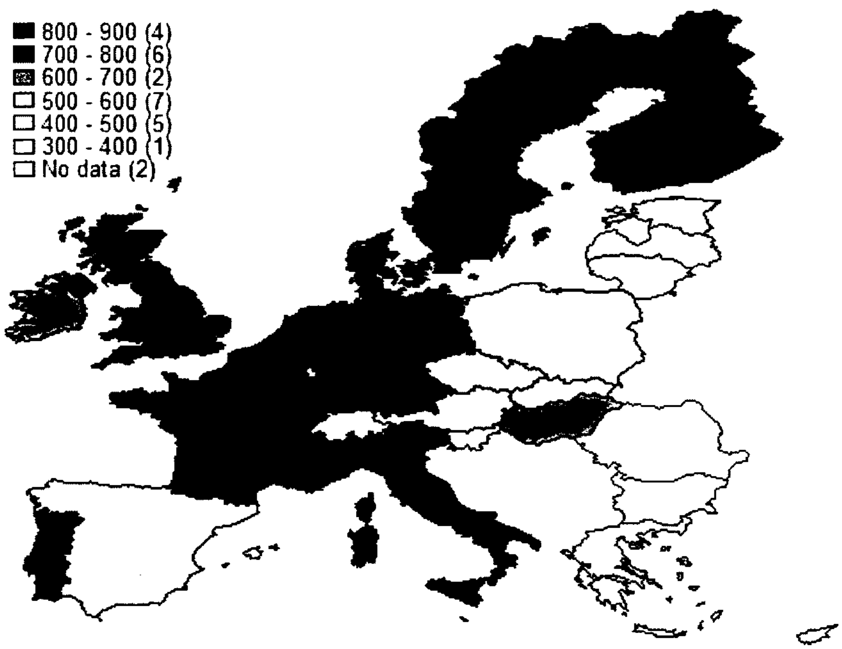


Figure 39 (a, b). Average Real Total Taxes Levied on Unleaded Euro-super-95 Gasoline in 2004 (a) and 2010 (b) in the EU

(a)



(b)

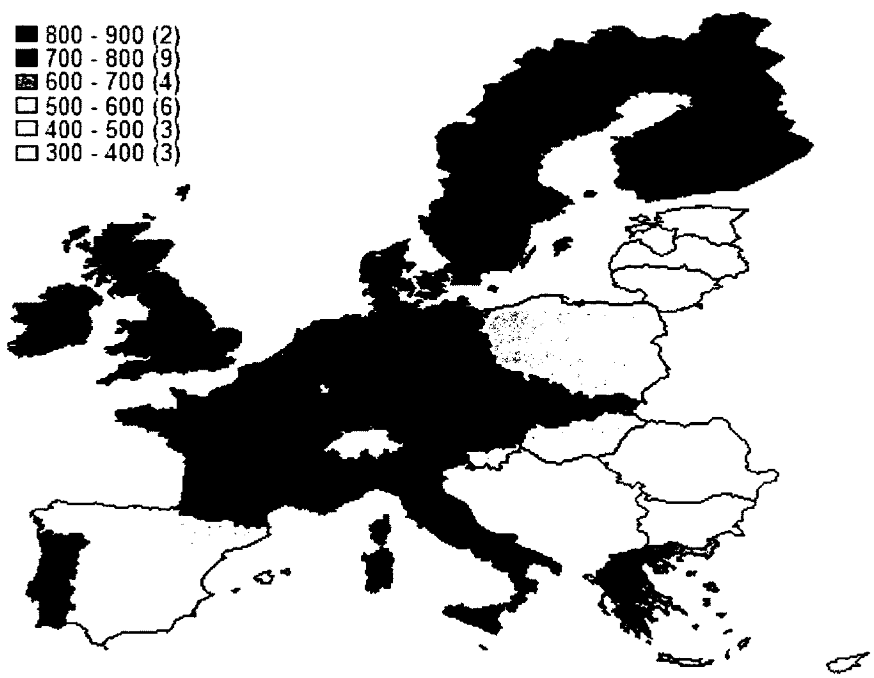
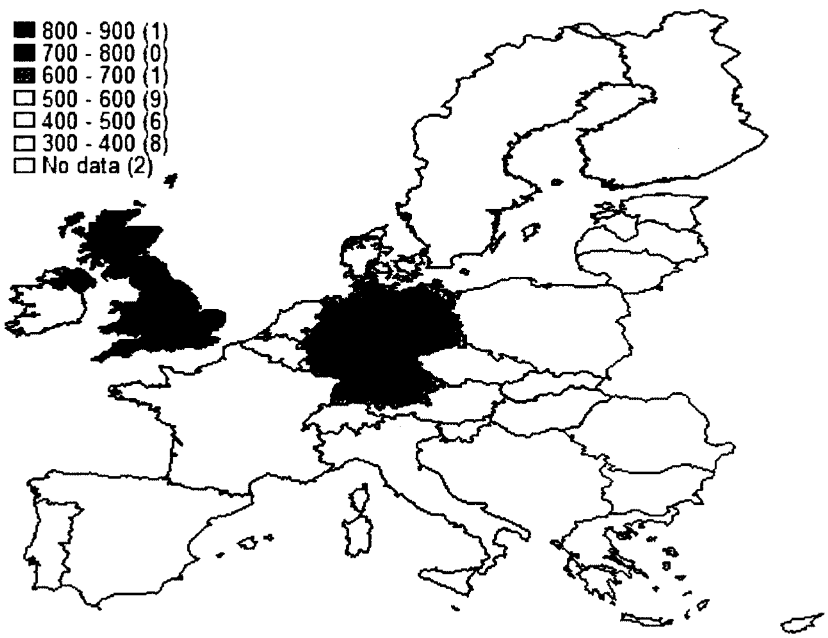


Figure 40 (a, b). Average Real Total Taxes Levied on Diesel Fuel in 2004 (a) and 2010 (b) in the EU

(a)



(b)

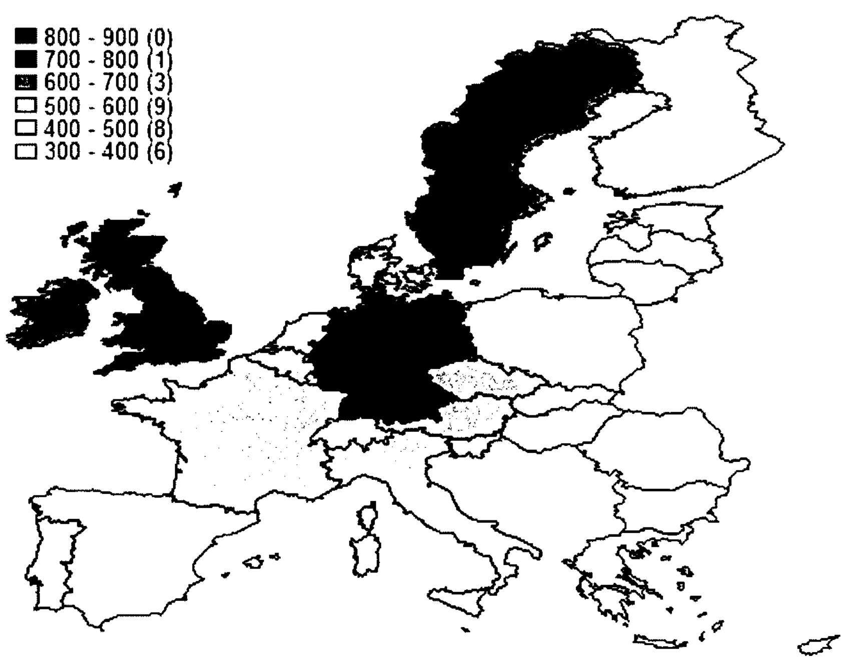


Figure 41. Spatial Weights Matrices W1

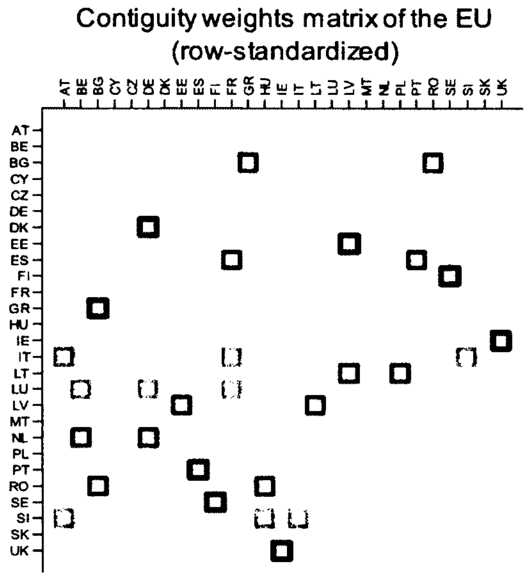


Figure 42. Spatial Weights Matrices W2

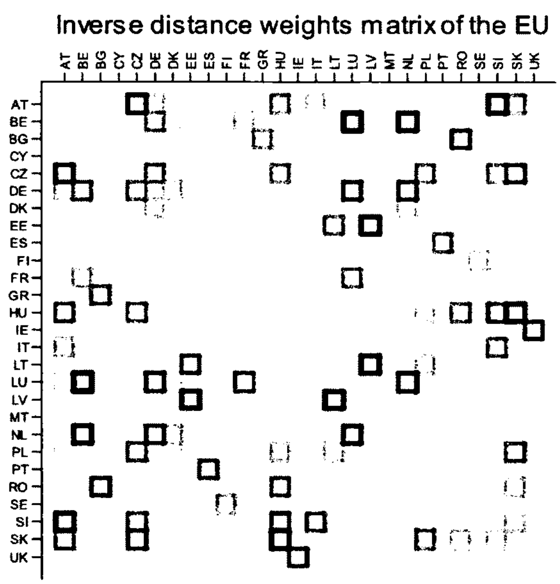


Figure 43. Spatial Weights Matrices W3

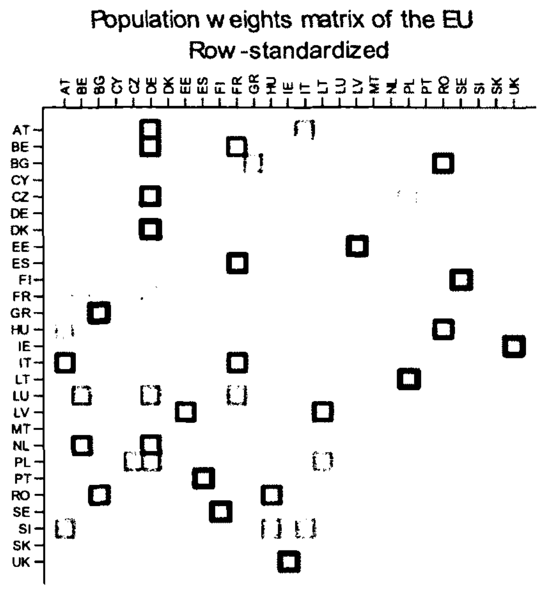


Figure 44. Spatial Weights Matrices W4

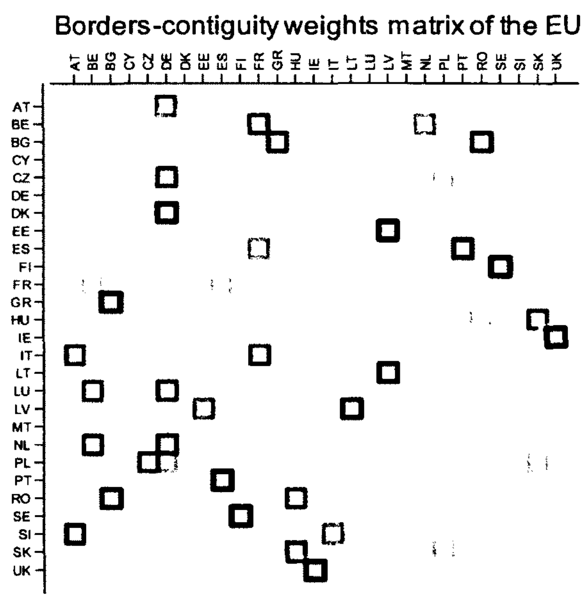


Figure 45. Spatial Weights Matrices W5

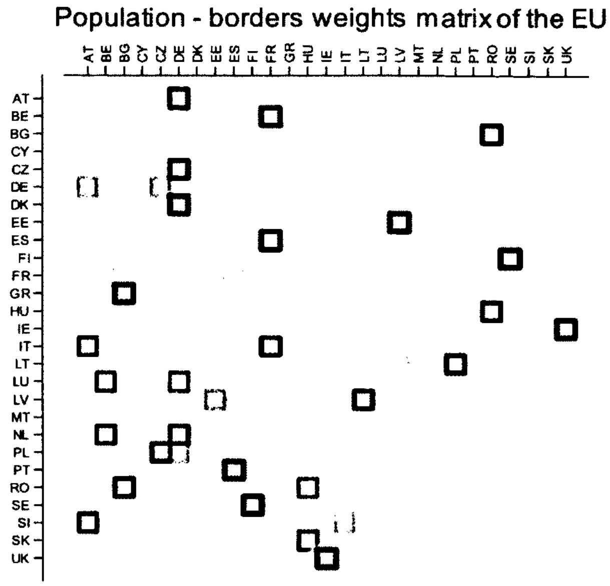


Figure 46. Spatial Weights Matrices W6

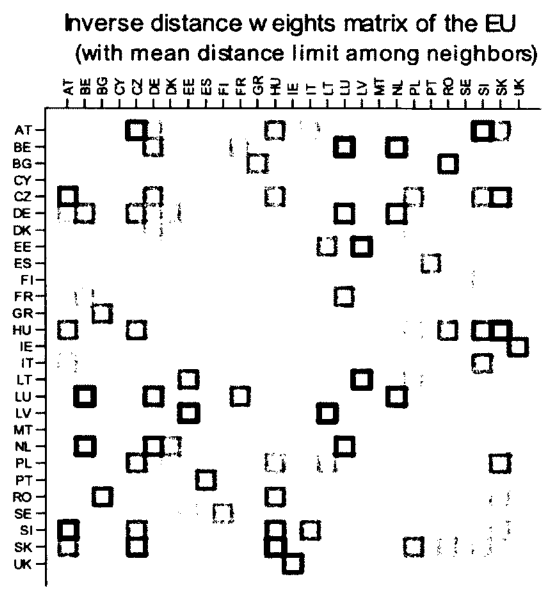


Table 13. Description of Variables

Variable	Description	Mean	Standard Deviation	Min	Max
(1)	(2)	(3)	(4)	(5)	(6)
next	Motor fuel excise tax on unleaded gasoline Euro-super-95, in euro currency per 1000 liters (nominal)	471.12	121.86	260.98	719.90
nexd	Motor fuel excise tax on diesel, in euro currency per 1000 liters (nominal)	353.59	90.34	221.98	714.71
vf	Value added tax levied on 1 unit of unleaded Euro-super-95 gasoline, %	19.54	2.58	12.00	25.00
vd	Value added tax levied on 1 unit of diesel, %	19.56	2.54	15.00	25.00
avlf	Total annual average level of taxes paid per 1000 liters of unleaded gasoline, in euro (real)	616.12	155.53	335.11	895.34
avld	Total annual average level of taxes paid per 1000 liters of diesel fuel, in euro (real)	488.81	110.07	300.80	898.85
elec	Parliamentary elections dummy: 1=election year, 0=otherwise	0.26	0.44	0.00	1.00
ycpi	Annual average consumer price index (CPI)	107.13	8.92	92.08	139.93
sameprty	Same party dummy: 1=president(or prime minister) is from the same party as the major party in parliament; 0=otherwise	0.57	0.50	0.00	1.00
debt	Fiscal stress measured as a country's debt/surplus as a percent of GDP	-2.81	4.30	-31.20	5.30
env	Environmental pressure, calculated a country's greenhouse gas emissions relative to emissions in 1990	96.09	32.45	40.31	192.11
inc	State per capita income is defined as the value of all goods and services produced minus the value of any goods or services used in their creation. The volume index of GDP per capita in Purchasing Power Standards (PPS) is expressed in relation to the EU average (EU-27 = 100)	97.94	44.08	34.00	279.00

Table 13. (continued)

Variable	Description	Mean	Standard Deviation	Min	Max
(1)	(2)	(3)	(4)	(5)	(6)
unemp	A country's unemployment rate as a percent of total labor force	7.95	3.35	3.10	20.10
infl	Inflation rates are denoted by annual average rate of change of Harmonized Indices of Consumer Prices (HICPs, designed for easy international comparisons of consumer price inflation), %	3.03	2.45	-1.70	15.30
pcnt65	Percent of population 65 years or older as a share of a country's total population	15.78	2.14	10.86	20.66

Table 14. Global Spatial Correlation Test: Moran's *I* and Geary's *C*

Variable	Moran's *I*		Geary's *C*	
	binary weights[33]	inverse distance weights	binary weights	inverse distance weights
(1)	(2)	(3)	(4)	(5)
Unleaded Gasoline Euro-super-95				
Total tax				
avlf04	0.225**	0.129***	0.735**	0.786***
avlf05	0.220**	0.140***	0.722**	0.774***
avlf06	0.234**	0.153***	0.771**	0.768***
avlf07	0.191**	0.151***	0.745**	0.767***
avlf08	0.234**	0.157***	0.692***	0.786***
avlf09	0.306***	0.167***	0.616***	0.779***
avlf10	0.214**	0.137***	0.658***	0.781***
Nominal excise tax				
next04	0.278***	0.158***	0.715**	0.768***
next05	0.268***	0.159***	0.713**	0.766***
next06	0.278***	0.164***	0.704**	0.761***
next07	0.231**	0.151***	0.730**	0.744***
next08	0.257***	0.159***	0.675***	0.779***
next09	0.312***	0.151***	0.607***	0.780***
next10	0.193**	0.120***	0.665***	0.785***
VAT tax				
vf04	-0.024	-0.049	0.994	1.021
vf05	-0.036	-0.047	0.950	0.938
vf06	-0.057	-0.054	0.932	0.896
vf07	-0.030	-0.045	0.877	0.864
vf08	-0.014	-0.042	0.865	0.863*
vf09	0.051	-0.032	0.856	0.857*
vf10	0.095	-0.021	0.806*	0.909
Diesel Fuel				
Total tax				
avld04	0.148**	0.038**	0.954	0.774*
avld05	0.146*	0.045**	0.923	0.761*
avlf06	0.134*	0.055**	0.927	0.752**
avld07	0.106	0.060**	0.947	0.766**
avld08	0.114*	0.070**	0.879	0.820**
avld09	0.260***	0.081***	0.733**	0.831**
avld10	0.326***	0.096***	0.606***	0.746***

[33] Binary weights for the weights matrix in both tests are constructed slightly differently. The neighbors are defined based on the distance limit from the center of the country. Cyprus, hence, has no neighbors. The matrix is row-standardized.

Table 14. (continued)

Variable	Moran's *I*		Geary's *C*	
	binary weights[34]	inverse distance weights	binary weights	inverse distance weights
(1)	(2)	(3)	(4)	(5)
Excise tax				
nexd04	0.165**	0.040**	0.975	0.771
nexd05	0.167**	0.043**	0.958	0.757*
nexd06	0.152**	0.044**	0.970	0.753*
nexd07	0.112*	0.036**	1.002	0.755*
nexd08	0.066	0.022*	1.003	0.827*
nexd09	0.155**	0.011	0.903	0.862
nexd10	0.241***	0.041**	0.772*	0.749**
VAT tax				
vd04	-0.018	-0.042	0.949	0.953
vd05	-0.036	-0.047	0.950	0.938
vd06	-0.057	-0.054	0.932	0.896
vd07	-0.030	-0.045	0.877	0.864
vd08	-0.014	-0.042	0.865	0.863*
vd09	0.051	-0.032	0.856	0.857*
vd10	0.095	-0.021	0.806*	0.909

[34] Binary weights for the weights matrix in both tests are constructed slightly differently. The neighbors are defined based on the distance limit from the center of the country. Cyprus, hence, has no neighbors. The matrix is row-standardized.

Table 15. Regression Results for Unleaded Euro-super-95 Gasoline, Excise Taxes

Dependent variable – ext			
Matrix	**W1**	**W2**	**W3**
Weights	**Contiguity**	**Inverse Distance**	**Population-contiguity**
Estimation	**IV, ID FE**	**IV with ID FE**	**IV, ID FE**
	(1)	(2)	(3)
Spatial lag	0.599*** (0.152)	24.109*** (4.445)	0.575*** (0.158)
elec	-5.117 (6.840)	-3.685 (5.909)	-7.117 (9.455)
sameparty	-14.087 (10.041)	-1.470 (8.370)	-0.816 (12.360)
debt	-2.346** (1.139)	-1.013 (1.030)	-3.723*** (1.393)
inc	0.493 (1.176)	0.710 (0.961)	1.809 (1.348)
env	0.846 (0.877)	0.959 (0.744)	0.563 (1.110)
unemp	3.114 (1.865)	4.092** (1.565)	1.860 (2.423)
infl	0.719* (1.991)	0.171 (1.733)	-0.633 (2.627)
constant	0.849 (171.277)	-158.466 (155.688)	-183.798 (224.953)
R^2	0.928	0.946	0.934
Adjusted R^2	0.908	0.931	0.902
F-test	46.66	62.37	29.17
F-test p-value	0.000	0.000	0.000
*SarganN*Rsq p-value*	0.001	0.001	0.011
Basmann p-value	0.004	0.023	0.061

Table 15. (continued)

Dependent Variable – ext			
Matrix	**W4**	**W5**	**W6**
Weights	**Borders-contiguity**	**Population-borders**	**Limited Inverse Distance**
Estimation	**IV with ID FE**	**IV, ID FE**	**IV with ID FE**
	(4)	(5)	(6)
Spatial lag	0.528*** (0.141)	0.470*** (0.146)	36.202*** (6.597)
elec	-4.543 (6.545)	-6.167 (6.769)	-3.674 (5.992)
sameparty	-13.362 (9.638)	-12.962 (9.950)	-7.743 (8.522)
debt	-2.510** (1.090)	-2.911** (1.119)	-1.873* (1.009)
inc	0.864 (1.105)	1.131 (1.128)	0.554 (0.982)
env	0.549 (0.822)	0.640 (0.877)	0.898 (0.746)
unemp	2.837 (1.825)	3.141* (1.867)	4.569*** (1.578)
infl	0.809 (1.907)	0.488 (1.964)	1.151 (1.747)
constant	4.254 (164.753)	-49.866 (175.740)	-375.756* (200.110)
R^2	0.934	0.931	0.944
Adjusted R^2	0.915	0.911	0.929
F-test	50.76	48.26	60.70
F-test p-value	0.000	0.000	0.000
*Sagan N*Rsq p-value*	0.000	0.000	0.083
Basmann p-value	0.002	0.000	0.182

Table 16. Regression Results for Diesel Fuel, Excise Taxes

Dependent Variable – exd			
Matrix	**W1**	**W2**	**W3**
Weights	**Contiguity**	**Inverse Distance**	**Population-contiguity**
Estimation	**IV, ID FE**	**IV with ID FE**	**IV, ID FE**
	(1)	(2)	(3)
Spatial lag	0.418*** (0.139)	23.020*** (4.667)	0.362*** (0.133)
elec	-4.504 (5.472)	-3.654 (4.959)	-3.149 (7.159)
sameparty	-12.151 (8.141)	-3.583 (7.019)	-8.353 (9.405)
debt	-2.022** (0.909)	-0.718 (0.871)	-2.837*** (1.057)
inc	0.888 (0.913)	0.601 (0.800)	1.654 (0.999)
env	0.472 (0.718)	0.772 (0.630)	0.127 (0.834)
unemp	1.879 (1.475)	2.443* (1.307)	1.463 (1.823)
infl	-0.638 (1.601)	-0.988 (1.458)	-0.172 (2.006)
constant	32.289 (138.182)	-103.230 (131.106)	-27.728 (168.727)
R^2	0.916	0.930	0.930
Adjusted R^2	0.892	0.910	0.895
F-test	38.99	47.46	26.84
F-test p-value	0.000	0.000	0.000
*SarganN*Rsq p-value*	0.005	0.300	0.037
Basmann p-value	0.018	0.471	0.156

Table 16. (continued)

Dependent Variable – exd			
Matrix	**W4**	**W5**	**W6**
Weights	**Borders-contiguity**	**Population-borders**	**Limited Inverse Distance**
Estimation	**IV with ID FE**	**IV, ID FE**	**IV with ID FE**
	(4)	(5)	(6)
Spatial lag	0.387*** (0.131)	0.337** (0.130)	31.730*** (6.949)
elec	-3.995 (5.417)	-4.881 (5.453)	-3.828 (5.070)
sameparty	-11.620 (8.042)	-10.975 (8.067)	-8.150 (7.223)
debt	-1.992** (0.902)	-2.277** (0.904)	-1.358 (0.859)
inc	1.025 (0.889)	1.199 (0.884)	0.664 (0.820)
env	0.286 (0.685)	0.313 (0.710)	0.621 (0.637)
unemp	1.717 (1.480)	1.961 (1.469)	2.982** (1.332)
infl	-0.703 (1.592)	-0.667 (1.593)	-0.265 (1.478)
constant	43.663 (136.363)	24.250 (139.793)	-121.451 (136.794)
R^2	0.917	0.917	0.927
Adjusted R^2	0.893	0.894	0.906
F-test	50.76	39.61	45.36
F-test p-value	0.000	0.000	0.000
*Sagan N*Rsq p-value*	0.012	0.006	0.245
Basmann p-value	0.037	0.019	0.408

Table 17. Regression Results for VAT Tax on Unleaded Euro-super-95 Gasoline

Dependent Variable - vf			
Matrix	**W1**	**W2**	**W3**
Weights	**Contiguity**	**Inverse Distance**	**Population-contiguity**
Estimation	**IV, ID FE**	**IV with ID FE**	**IV, ID FE**
	(1)	(2)	(3)
Spatial lag	0.187*** (0.064)	14.081*** (3.200)	0.146** (0.064)
elec	0.017 (0.134)	0.027 (0.118)	-0.007 (0.193)
sameparty	-0.293 (0.210)	-0.023 (0.168)	-0.121 (0.257)
debt	0.057*** (0.022)	0.079*** (0.020)	0.030 (0.027)
inc	0.010 (0.022)	-0.005 (0.020)	0.019 (0.027)
unemp	0.111*** (0.035)	0.099*** (0.031)	0.088* (0.048)
infl	-0.060 (0.039)	-0.072** (0.035)	-0.074 (0.054)
constant	15.049*** (2.571)	10.685*** (2.480)	14.820*** (3.349)
R^2	0.934	0.938	0.935
Adjusted R^2	0.916	0.924	0.904
F-test	53.06	67.16	30.69
F-test p-value	0.000	0.000	0.000
*Sagan's N*R-sq p-value*	0.606	0.189	0.543
Basmann's p-value	0.734	0.319	0.757

Table 17. (continued)

Dependent Variable - vf			
Matrix	**W4**	**W5**	**W6**
Weights	**Borders-contiguity**	**Population-borders**	**Limited Inverse Distance**
Estimation	**IV with ID FE**	**IV, ID FE**	**IV with ID FE**
	(4)	(5)	(6)
Spatial lag	0.128** (0.054)	0.126** (0.051)	21.494*** (5.141)
elec	0.009 (0.125)	0.007 (0.126)	0.020 (0.127)
sameparty	-0.221 (0.195)	-0.222 (0.194)	-0.204 (0.185)
debt	0.050** (0.020)	0.047** (0.020)	0.063*** (0.020)
inc	0.017 (0.020)	0.016 (0.020)	-0.007 (0.021)
unemp	0.112*** (0.033)	0.110*** (0.034)	0.113*** (0.033)
infl	-0.061* (0.037)	-0.062* (0.037)	-0.042 (0.038)
constant	15.311*** (2.398)	15.583*** (2.420)	9.017*** (2.841)
R^2	0.943	0.942	0.941
Adjusted R^2	0.927	0.926	0.925
F-test	60.88	60.08	59.61
F-test p-value	0.000	0.000	0.000
*Sagan's N*R-sq p-value*	0.326	0.321	0.173
Basmann's p-value	0.478	0.472	0.299

Table 18. Regression Results for VAT Tax on Diesel Fuel in the EU

Dependent Variable - vd			
Matrix	**W1**	**W2**	**W3**
Weights	**Contiguity**	**Inverse Distance**	**Population-contiguity**
Estimation	**IV, ID FE**	**IV with ID FE**	**IV, ID FE**
	(1)	(2)	(3)
Spatial lag	0.187*** (0.064)	14.081*** (3.200)	0.146** (0.064)
elec	0.017 (0.134)	0.027 (0.118)	-0.007 (0.193)
sameparty	-0.293 (0.210)	-0.023 (0.168)	-0.121 (0.257)
debt	0.057*** (0.022)	0.079*** (0.020)	0.030 (0.027)
inc	0.010 (0.022)	-0.005 (0.020)	0.019 (0.027)
unemp	0.111*** (0.035)	0.099*** (0.031)	0.088* (0.048)
infl	-0.060 (0.039)	-0.072** (0.035)	-0.074 (0.054)
constant	15.049*** (2.571)	10.685*** (2.480)	14.820*** (3.349)
R^2	0.934	0.949	0.935
Adjusted R^2	0.916	0.935	0.904
F-test	53.06	68.80	30.69
F-test p-value	0.000	0.000	0.000
*Sagan's N*R-sq. p-value*	0.606	0.189	0.543
Basmann's p-value	0.734	0.319	0.757

Table 18. (continued)

Dependent Variable - vd			
Matrix	**W4**	**W5**	**W6**
Weights	**Borders-contiguity**	**Population-borders**	**Limited Inverse Distance**
Estimation	**IV with ID FE**	**IV, ID FE**	**IV with ID FE**
	(4)	(5)	(6)
Spatial lag	0.129** (0.054)	0.126** (0.051)	21.494*** (5.141)
elec	0.009 (0.125)	0.007 (0.126)	0.020 (0.127)
sameparty	-0.221 (0.195)	-0.222 (0.194)	-0.204 (0.185)
debt	0.050** (0.020)	0.047** (0.020)	0.063*** (0.020)
inc	0.017 (0.020)	0.016 (0.020)	-0.007 (0.021)
unemp	0.112*** (0.033)	0.110*** (0.034)	0.113*** (0.033)
infl	-0.061* (0.037)	-0.062* (0.037)	-0.042 (0.038)
constant	15.311*** (2.398)	15.583*** (2.420)	9.017*** (2.841)
R^2	0.943	0.942	0.941
Adjusted R^2	0.927	0.926	0.925
F-test	60.88	60.08	59.61
F-test p-value	0.000	0.000	0.000
*Sagan's N*R-sq p-value*	0.326	0.321	0.173
Basmann's p-value	0.478	0.472	0.299

Table 19. Regression Results for Unleaded Euro-super-95 Gasoline,

Total Tax Level

Dependent Variable – avlf			
Matrix	**W1**	**W2**	**W3**
Weights	**Contiguity**	**Inverse Distance**	**Population-contiguity**
Estimation	**IV, ID YR FE***	**IV, ID YR FE**	**IV, ID YR FE**
	(1)	(2)	(3)
Spatial lag	0.224 (0.153)	49.501* (28.981)	0.223 (0.135)
elec	-8.333 (6.456)	-8.531 (6.800)	-10.668 (8.228)
sameparty	-2.331 (9.805)	-2.989 (10.078)	6.432 (11.142)
debt	-2.938** (1.348)	-3.883** (1. 649)	-3.690** (1.603)
inc	0.706 (0.956)	0.476 (1.032)	1.236 (1.118)
env	0.728 (0.893)	0.512 (0.909)	0.585 (1.037)
unemp	-0.107 (1.721)	-0.599 (1.827)	-1.291 (2.095)
infl	-5.286** (2.208)	-4.620* (2.389)	-4.452* (2.587)
constant	304.882* (168.606)	-10.500 (232.526)	223.028 (209.324)
R^2	0.957	0.952	0.958
Adjusted R^2	0.944	0.938	0.941
F-test (40, 140)	77.18	69.66	54.54
F-test p-value	0.000	0.000	0.000
*SarganN*Rsq p-value*	38.584	14.409	26.383
Basmann p-value	46.303	11.590	21.597

Table 19. (continued)

Dependent Variable – avlf			
Matrix	**W4**	**W5**	**W6**
Weights	**Borders-contiguity**	**Population-borders**	**Limited Inverse Distance**
Estimation	**IV, ID YR FE****	**IV, ID YR FE****	**IV, ID YR FE**
	(4)	(5)	(6)
Spatial lag	0.120 (0.138)	0.085 (0.125)	45.286** (20.496)
elec	-7.913 (6.311)	-8.242 (6.366)	-8.471 (6.813)
sameparty	0.436 (9.592)	1.429 (9.533)	-5.977 (10.290)
debt	-2.646** (1.334)	-2.589* (1.371)	-3.750** (1.492)
inc	0.938 (0.916)	0.975 (0.920)	0.468 (1.009)
env	0.535 (0.861)	0.531 (0.875)	0.875 (0.935)
unemp	-0.267 (1.686)	-0.265 (1.696)	-0.185 (1.816)
infl	-5.403** (2.168)	-5.592** (2.159)	-4.113* (2.420)
constant	356.940** (165.818)	367.779** (171.102)	-308.322 (368.507)
R^2	0.958	0.958	0.952
Adjusted R^2	0.946	0.946	0.938
F-test (38, 90)	80.54	79.77	69.32
F-test p-value	0.000	0.000	0.000
*Sagan N*Rsq p-value*	41.126	38.699	12.632
Basmann p-value	39.399	36.442	10.054

Table 20. Regression Results for Diesel Fuel, Total Tax Level

Dependent Variable – avld			
Matrix	**W1**	**W2**	**W3**
Weights	**Contiguity**	**Inverse Distance**	**Population-contiguity**
Estimation	**IV, ID YR FE*****	**IV, ID YR FE***	**IV, ID YR FE***
	(1)	(2)	(3)
Spatial lag	0.024 (0.143)	15.890 (21.180)	0.010 (0.128)
elec	-7.271 (5.490)	-7.507 (5.650)	-7.215 (6.998)
sameparty	1.642 (8.527)	-0.279 (8.373)	2.026 (9.635)
debt	-1.259 (1.176)	-1.593 (1.220)	-1.510 (1.391)
inc	0.819 (0.806)	0.701 (0.827)	0.815 (0.950)
env	0.098 (0.788)	0.126 (0.759)	0.026 (0.901)
unemp	-1.114 (1.469)	-1.046 (1.509)	-1.501 (1.781)
infl	-6.322*** (1.866)	-6.125*** (1.937)	-4.396** (2.205)
constant	377.815** (146.211)	134.103 (365.208)	383.767** (177.076)
R^2	0.937	0.934	0.941
Adjusted R^2	0.919	0.915	0.916
F-test	52.25	49.43	37.52
F-test p-value	0.000	0.000	0.000
*SarganN*Rsq p-value*	37.948	7.644	31.247
Basmann p-value	35.547	5.908	26.851

Table 20. (continued)

Dependent Variable – avld			
Matrix	**W4**	**W5**	**W6**
Weights	**Borders-contiguity**	**Population-borders**	**Limited Inverse Distance**
Estimation	**IV, ID YR FE*** **	**IV, ID YR FE*** **	**IV, ID YR FE***
	(4)	(5)	(6)
Spatial lag	-0.040 (0.133)	-0.042 (0.118)	16.099 (15.711)
elec	-7.210 (5.490)	-7.078 (5.492)	-7.572 (5.639)
sameparty	3.650 (8.549)	3.775 (8.385)	-1.588 (8.509)
debt	-1.011 (1.178)	-0.960 (1.206)	-1.603 (1.160)
inc	0.897 (0.793)	0.903 (0.790)	0.679 (0.818)
env	-0.022 (0.768)	-0.044 (0.776)	0.251 (0.776)
unemp	-1.152 (1.465)	-1.156 (1.462)	-0.854 (1.527)
infl	-6.365*** (1.668)	-6.341*** (1.862)	-5.921*** (1.956)
constant	414.919*** (145.438)	419.671*** (145.915)	173.857 (246.602)
R^2	0.937	0.937	0.934
Adjusted R^2	0.919	0.919	0.915
F-test	52.12	52.36	49.60
F-test p-value	0.000	0.000	0.000
*Sagan N*Rsq p-value*	36.886	39.258	8.038
Basmann p-value	34.297	37.114	6.227

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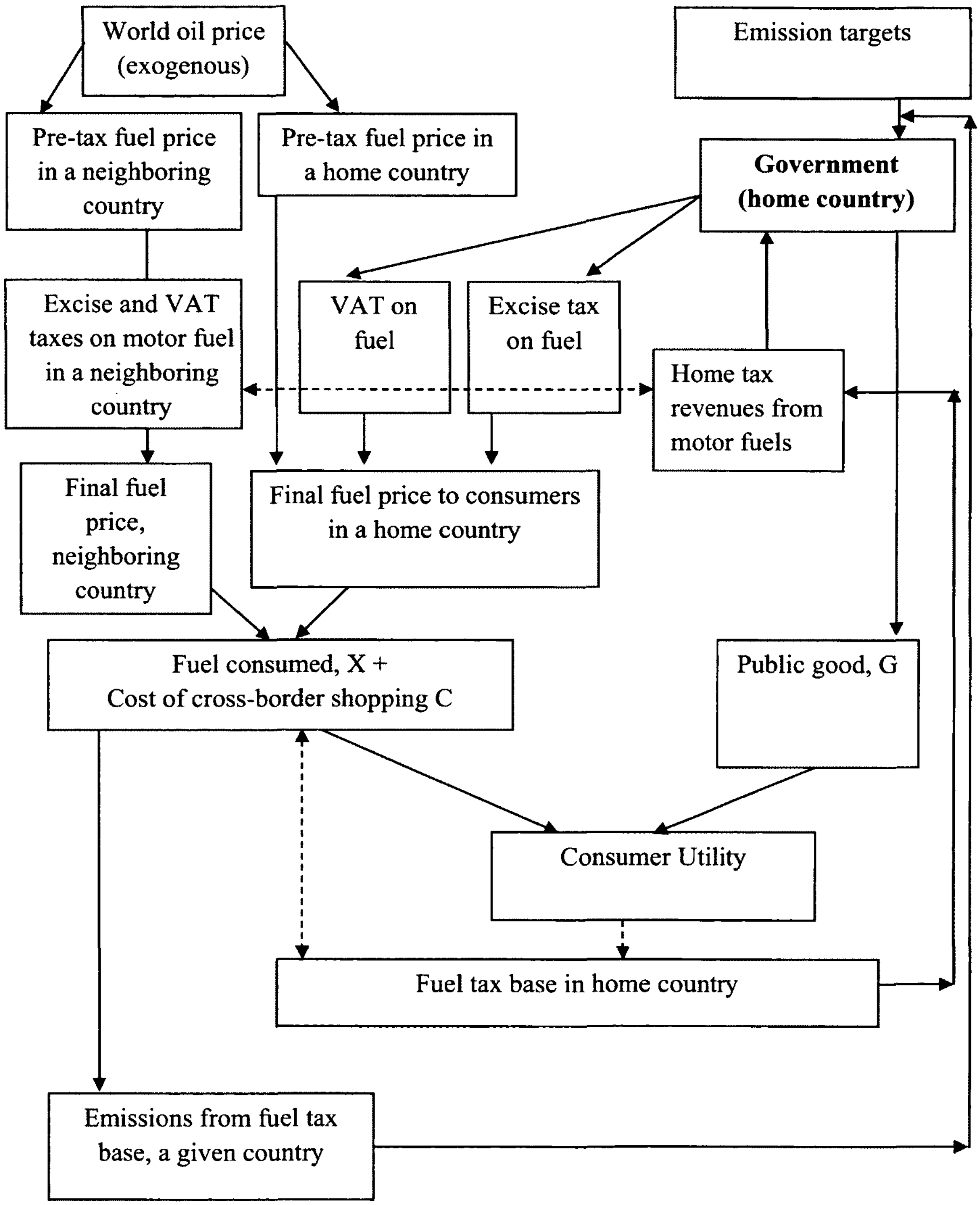
APPENDICES

APPENDIX 3.A

Figure 47. The Model



CONCLUSION

Taxation of motor fuels is an important factor of both economic development and addressing greenhouse gas emissions, especially in a setting like the EU, where multiple economic agents are acting both as independent nations and as members of a single Union. Since the creation of the EU and its Common Internal Market, both political and market forces influenced the motor fuel tax-setting behavior of its member states, including the occurrence of fiscal competition among them. This dissertation contributes to the explanation of these phenomena by examining several specific aspects of European motor fuel price and tax behaviors.

The first essay of this dissertation discussed the important historical factor that reshaped the Union, the policy-setting behavior of its members, and its market for motor fuels: the multi-stage enlargement of the EU. The results show that in 1994-2010, real motor fuel prices in the EU have, on average, increased only slightly for unleaded gasoline and LPG fuel, but have increased by about 25% for diesel, with the price gap remaining between the older and newer member states. These changes were primarily driven by the production side, as the EU member states were slowly switching away from motor fuel excise taxes towards higher VAT rates.

The next essay improved upon traditional modeling of motor fuel tax and price dynamics by addressing non-linear aspects of the price/tax analysis. By using a flexible newer club convergence methodology, the second essay addressed non-linear features of prices and eliminated pre-specification of club memberships traditionally used by other methods. The results of the second essay showed that the EU members converge in their total motor fuel tax levels, but this convergence is fragile. In addition, the results suggested an occurrence of motor fuel market segmentation.

The third essay of this dissertation included spatial considerations of fiscal competition among the EU members. In other words, it examined how taxes on motor fuels in one EU country depend on taxes in neighboring countries. The results of the last essay showed that motor fuel excise tax-setting behavior of the EU members is similar to the excise tax setting behavior of the U.S. states, found by previous studies. VAT tax-setting behavior, however, is found to be different in the EU than in U.S. This signals that either the EU national governments recognize the mobility of their tax base, or that they have political motives of their own when engaging in tax competition.

The key contributions of this dissertation are as follows. Firstly, my dissertation research has a theoretical contribution. By building upon existing theoretical models of the income tax competition, I develop a new, generalized, two-country-single-good model of the horizontal fiscal competition and a tax-induced tourism. My model is fundamentally different from these models, because an individual consumer in my model does not have to permanently relocate to another country in order to make his purchasing decision, and, subsequently, a decision on where to pay sales and excise taxes. Instead, based on the tax rates that he observes in both countries, he can choose to purchase fuel both at home and abroad.

Secondly, my dissertation also contributes to a limited, yet a growing empirical literature on fiscal competition and tax harmonization, as well as to the empirical literature on the LOP. To the best of my knowledge, I am also the first to use a newly-available motor fuel tax and price data for the ten newer EU member-countries and to compare these findings with findings for OMS.

Finally, in a broader sense my dissertation research is closely relevant to a current economic situation and fiscal coordination policy dialogs in Europe. By using the newly available data for motor fuels as an example, I provide some insights on how twenty seven diverse countries, both older and newer members of the European Union, make their tax-setting decisions, and whether they coordinate fiscal behavior among themselves. My findings also contribute to some current policy discussions related to GHG emissions from transport. These policies include a revision of the National Emission Ceiling Directive and a proposed Directive that recommends setting tax floors based on the CO_2 content of each motor fuel.