Charles University in Prague

Faculty of Social Sciences
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BACHELOR THESIS

Do Small Countries Outcompete Large Countries in Diesel Taxes? Evidence from the EU-16

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Academic Year: **2012/2013**

Declaration of Authorship

The author hereby declares that he compiled this thesis independently, using only the listed resources and literature. This thesis was not used to obtain another academic degree.

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Prague, May 13, 2013

Signature

Acknowledgments

I would like to express my highest gratitude to PhDr. Martin Gregor, Ph.D. for supervising my work on this thesis. All of his insights and suggestions were greatly appreciated.

Abstract

This thesis investigates what drives the diesel fuel taxation policy of European countries and, in particular, assesses the importance of tax competition. Using panel data of diesel prices for both noncommercial and commercial use coming from 16 European countries between 2005 and 2010, we estimate the relation between countries' fuel price and a weighted average of the neighbors' prices and other control variables. Our results reveal that the tax competition among European countries plays a significant role in the setting of diesel excise taxes and that small countries tend to charge lower fuel taxes than large countries.

JEL Classification	H70, H77, H87
Keywords	cross-border shopping, diesel price, European Union, tax competition

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Abstrakt

Tato práce zkoumá, co ovlivňuje daňovou politiku evropských zemí v oblasti motorové nafty. Zejména pak hodnotí význam daňové konkurence. K odhadnutí vztahu mezi cenou paliva dané země a váženým průměrům cen sousedních zemí a dalšími vysvětlujícími proměnnými využíváme soubor panelových dat obsahující ceny nafty jak pro komerční, tak pro nekomerční využití ze 16 evropských zemí za roky 2005 až 2010. Naše výsledky ukazují, že daňová konkurence mezi evropskými zeměmi hraje při stanovování spotřebních daní z motorové nafty významnou roli a že malé země mají tendenci uvalovat nižší spotřební daně než velké země.

Klasifikace JEL	H70, H77, H87
Klíčová slova	přeshraniční nakupování, cena nafty, Evropská unie, daňová konkurence

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Acronyms

2SLS	Two-Stage Least Squares
EC	European Commission
EEC	European Economic Community
EU	European Union
FE	Fixed Effects
GDP	Gross Domestic Product
OECD	Organisation for Economic Co-operation and Development
OLS	Ordinary Least Squares
RE	Random Effects
VAT	Value Added Tax
U.S.	United States
USA	United States of America
USD	United States Dollar

Bachelor Thesis Proposal

Author	Kryštof Krotil
Supervisor	PhDr. Martin Gregor, Ph.D.
Proposed topic	Do Small Countries Outcompete Large Countries in Diesel Taxes? Evidence from the EU-16

Topic characteristics Fuel is an attractive base for taxation in all countries, but the governments impose upon it different excise taxes. The main aim of this thesis is to investigate what drives the diesel fuel taxation policy of European countries. We will do empirical research to explain how the key factors, particularly the different tax rates of neighboring countries, influence the excise rates.

Methodology Econometric analysis of panel data of consumer and net prices of petroleum products, potentially with spatial econometrics techniques.

Outline

1. Introduction
2. Survey of current literature
3. Empirical analysis of data
4. Interpretation of results
5. Conclusion

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Chapter 1

Introduction

The importance of tax competition as a research topic is growing in line with the increasing international mobility of tax bases. This subject is particularly important for the European Union, characterized by a high degree of economic integration, large asymmetry in terms of size between Member States, common currency and free movement of goods, services, persons and capital.

Despite the harmonization efforts undertaken by the European Commission, fuel taxes still vary widely across the member states. In 2010 the average pump price of liter of diesel fuel in the United Kingdom was equivalent of 1.84 USD. Of this, 1.16 USD (63%) were taxes. On the other hand the average total tax on diesel for noncommercial use in Luxembourg was 58 U.S. cent per liter. Such substantial differences have large impact on the fueling behavior of both car drivers and road haulage companies. For example, in Germany where fuel is more expensive than in neighboring countries due to higher excise duties on mineral oils, 10% of all domestically consumed fuel was cross-border shopped in 2004 (Paizs 2010). On the other hand, in Luxembourg where fuel prices are 10 to 20% lower than in the neighboring countries, cross border purchases represented 75% of all sales in 2010 (OECD 2010). Even though there is no general study measuring the importance of fuel tourism in Europe, it is apparent that it has an important impact on tax revenues at least in some Member States.

The goal of this thesis in general is to investigate what drives the diesel fuel taxation policy of the European countries and in particular to assess the importance of tax competition. We use panel data of diesel prices both for noncommercial and commercial use from 16 European countries between 2005 and 2010 to estimate the relation between countries' fuel price and a weighted average of the neighbors' prices and other control variables. We come to the conclusion that tax competition among

European countries plays a significant role in the setting of diesel excise taxes and that small states tend to set lower taxes than large states.

The reminder of this thesis is organized as follows. Chapter 2 presents the finding of prior research done in this field. In Chapter 3 we describe existing legal framework for taxation of diesel fuel. Chapter 4 discusses data and variables we use in our analysis. Chapter 5 covers data analysis and presents empirical results. The conclusions will be given in Chapter 6.

Chapter 2

Literature review

The basic mechanics of tax competition have been initially formalized by Zodrow & Mieszkowski (1986). The model considers two countries competing for internationally mobile tax base. One country's tax revenue is affected by the other country's tax rate. For instance, if the country A lowers its tax rates it will, as a result of cross-border shopping, produce a reduction in the revenue collection of country B and vice versa. The model predicts a 'race to the bottom' in taxation as both countries try to attract mobile tax base. Following the work of Zodrow & Mieszkowski (1986) the literature has branched out in many directions. We are particularly interested in the extension of initial model with respect to the country size.[1] Many economists have shown that the relative sizes of economies involved play significant role in shaping international tax relations (Bucovetsky 1991; Wilson 1991; Keen & Kanbur 1991; Trandel 1994; Wang 1999; Nielsen 2001). If competing countries are of equal size, the Nash equilibrium is symmetric and both countries lose revenue (symmetric tax competition). The situation is different, however, if country sizes differ. The increase in demand that either government expects to induce by cutting its tax rate depends on the size of the other country. The smaller country therefore perceives higher elasticity of demand and consequently undercuts the larger country and suffers less in the non-cooperative equilibrium (asymmetric tax competition). Moreover, if the differential in size is sufficiently great the small country benefits from the tax competition. Losses of revenue as a result of the implicit restriction on the ability to extract surplus from own citizens might be more than offset by revenue gains from cross-shoppers.

The impact on consumption of tax rate differentials among neighboring countries has been analyzed by many empirical studies. The existence of the cross-border

[1] See Genschel & Schwarz (2011) for other extensions of the baseline model.

effect has been confirmed for various goods, geographical areas and time periods. Results reveal that cross-border shopping tends to focus on highly excise goods – fuel, liquor and tobacco.

Concerning cross-border fueling empirical analysis of Rietveld *et al.* (2001) revealed that with a price difference of about 5-cents per liter, approximately 30% of Dutch car owners living at the border would fuel in Germany where gas stations would be found at a negligible distance. They also find that the trade-off of the average driver of the price difference between two countries and the distance travelled is about only 0.5 cent per liter per km, which implies a low implicit value of time involved in fueling trips. Using a panel data set for the three regions of Switzerland bordering Italy, Germany, and France, over the period 1985 – 1997 Banfi *et al.* (2005) showed that there is a significant impact of the gasoline price differential on fuel demand. The estimated price elasticity suggests that a decrease of 10% in the ratio of the Swiss gasoline price to the price in the bordering country will lead to a reduction in demand of between 6.7 to 7.7%. Moreover, they utilize the estimated equation to simulate the effect of fuel tourism; the simulations indicate that from 1985 to 1992 fuel tourism accounted for about 15% of overall gasoline sales in the three regions, falling to about 7% from 1992 to 1997.

Manuszak & Moul (2009) exploit variation in gasoline and cigarettes taxes in adjacent political jurisdictions for northern Illinois and Indiana to examine consumers' trade-off between prices and travel. They develop a model that relates activity in the retail gasoline industry around the tax borders to consumer locations. Results indicate that the willingness of a typical consumer to travel an additional mile to buy gasoline corresponds to about \$0.065 to \$0.084 per gallon. According to their estimates, the observed area of Chicago, the jurisdiction with the highest taxes, is missing approximately 40% of the capacity that would exist were taxes equalized.

Leal *et al.* (2009) showed that the differences among neighboring Autonomous Communities (i.e. Spanish political-administrative regions) in automotive fuel prices resulting from the application of the regional tranche of the Hydrocarbon Retail Sales tax affect the decisions taken by individuals regarding the region in which to purchase fuel. In particular, they have demonstrated that the raising of the average prices of automotive diesel in Catalonia and Madrid in relation to prices in Aragon has a positive and significant long-term effect upon sales of this fuel in Aragon.

Despite the overwhelming evidence for intensity of tax base mobility and arbitrage relatively little attention has been paid to analysis of competitive policy responses in consumption taxation and estimation of so-called fiscal reaction functions, which measure the responsiveness of a countries' tax rate to the rate of neighboring countries.

Using aggregate indicator of commodity taxation for 22 OECD countries over the period 1965–1997, Egger *et al.* (2005) analyzed tax competition in a multilateral and spatial framework and found strong support for hypotheses of upward-sloping tax reaction curves and of a positive impact of domestic country size. Devereux *et al.* (2007) investigated vertical and horizontal tax competition for the cigarette and gasoline unit taxes in the USA. In the case of cigarettes, their central estimate is that a one cent increase in the neighbor-density weighted average of the unit tax in other states would induce a rise in the home tax rate of 0.7 cents in the long run, implying an important effect of cross-border shopping. For gasoline strategic interactions are not always statistically significant.

Jacobs *et al.* (2010) analyzed consumption tax competition between U.S. states, employing a panel of state-level data for 1977-2003 and found overwhelming evidence for strategic interaction among state governments, but only partial support for the effect of spatial characteristics on tax setting.

Using a panel data set of 12 EU countries over a period of 17 years from 1987 to 2004 and a spatial econometrics approach, Lockwood & Migali (2009) found that for all excise duties they considered (still and sparkling wine, beer, ethyl alcohol, and cigarettes), strategic interaction between countries significantly increased after the introduction of the Single Market in 1993.

To the best of our knowledge, only three studies analyzed European diesel tax competition by econometric tools. Evers *et al.* (2004) empirically explore whether size of the country matters for it responsiveness to other countries' tax rates and if the magnitude of initial excise rate matters for the strategic tax response of a country. In estimating their Nash-type fiscal reaction functions for diesel excises, they exploit a panel of 17 European countries between 1978 and 2001. They provide evidence for the presence of tax competition in diesel excises in Europe, but not for asymmetric tax competition. Furthermore they conclude that the magnitude of the tax rate matters for the intensity of the tax competition (high-tax countries compete more aggressively than low-tax countries).

Based on the literature on public finance Rietveld & van Woudenberg (2005) discuss a number of considerations governments may have to determine the level of fuel taxes. Using cross-sectional data – fuel prices for about 100 countries in 1998 – the authors found empirical evidence for asymmetric tax competition in the European subsample.

Paizs (2010) examines tax competition on panel data largely similar to the one used by Evers *et al.* (2004). His analysis reveals that country sizes positively affect not only the level of equilibrium taxes but also the slopes of the tax reaction functions between countries. The estimation shows that in response to a 10% increase in neighboring countries' diesel tax rates, an average large country raises its tax rate by 4.4% while an average small country increases its tax rate only by 1.3%.

Chapter 3

Legal framework

The baseline model conceptualizes tax competition as a single-exit situation leaving governments with only one policy response to international tax arbitrage: tax cuts. But there is a problem with this conceptualization. Governments, unlike business firms, can change the institutional rules under which they compete. Instead of reducing statutory tax rates to competitive levels, they can take action to restrict tax arbitrage. Tax base mobility may trigger tax cooperation as well as tax competition (Genschel & Schwarz 2011).

3.1 VAT harmonization

Multilateral cooperation is most advanced in the EU where it encompasses both tax harmonization and information exchange. Interestingly, harmonization concerns mostly VAT and excises. The basic aim of harmonizing indirect taxes was creating a functioning, borderless single market in an integrating Europe. In 1967 the first directive was adopted, requiring Member States to replace their system of turnover taxes with the common system of value added tax (EC 1967). Ten years later Sixth Council Directive set the Community wide standards for setting the tax base, territorial application, taxable persons and transactions, etc. It has, however, maintained a lot of exemptions, thus keeping the systematic imbalances generally intact (EC 1977). The idea of a complete harmonization of VAT that appeared in the era of the Single European Act was met with a strong opposition from the Member States, unwilling to surrender a part of their tax and fiscal sovereignty to the European Union. But some change to the VAT structure was necessary, since border controls, upon which the contemporary system was constituted, were to be abolished in the Single Market project. To address this issue a destination principle has been adopted for transactions between registered taxpayers from different Member States. This solution, however, left room for VAT optimization by households. Therefore, in order to prevent excessive tax competition, common minimum VAT rate of 15% has been introduced in 1993 (EC 1992). This level is actually non-binding for most countries in the European Union as only Luxembourg sets its standard VAT rate at 15%. The rates in the rest of the Member States range from 18 to 27%. Concerning the two countries from the outside of the European Union included in our panel, Switzerland sets its standard VAT rate at 8% and Norway at 25%. From the facts stated above, we conclude that tax competition in VAT, which is significantly reflected in diesel pump prices of diesel for noncommercial use,[2] is generally unrestricted.

3.2 Excise duty harmonization

As in the case of VAT, the main part of the EU legislation for excise duties was adopted in preparation for the establishment of the Single Market. It consists of 3 major parts. Firstly, the products subject to excise duties are specified and the way of tax calculation is defined. Secondly, the minimum amount of tax rates for taxable products are set. And thirdly, the general arrangements for production, holding, movement and monitoring of such products within EU are imposed. Council Directive 2003/96/EC restructuring the Community framework for the taxation of energy products and electricity adopted the minimum excise duty for gas oil for propellant use of 302 Euro per 1000 liters,[3] among others (EC 2003). It entered into force in 2004, but long transitional periods have been defined for countries with low compliance rates during which they were required to gradually reduce the gap. The fact that excises have the form of a specific tax, rather than of the ad-valorem tax (which is the case with VAT) has important consequences. Since specific taxes are set in nominal terms, they are subject to inflation and tend to fall over time. Furthermore, excise duty rates are denominated in national currencies and are therefore also subject to exchange rate fluctuations. For instance, Ševčík & Rod (2010) showed that in 2010 price of diesel (without VAT) in Czech Republic denominated in Euro increased by 7% due to the appreciation of Czech crown. For these reasons countries regularly change their excise rates and, of course, also the minimum rates of excise duties have to be adjusted over time to keep the desired effect. Therefore the minimum excise duty for diesel fuel has been increased to 330 euro per 1000

[2]VAT is fully reimbursed to commercial users irrespective of country of purchase.

[3]The volumes are measured at a temperature of 15 °C.

liters in 2010. The last thing we need to mention with respect to the rules of taxation is that Directive 2003/96/EC allowed Member States to differentiate between commercial[4] and non-commercial use of gas oil used as propellant, provided that the Community minimum levels are observed and the rate for commercial gas oil used as propellant does not fall below the national level of taxation in force on 1 January 2003. Furthermore, Member States which introduce a system of road user charges for motor vehicles or articulated vehicle combinations intended exclusively for the carriage of goods by road may apply a reduced rate on gas oil used by such vehicles, that goes below the national level of taxation in force on 1 January 2003, as long as the overall tax burden remains broadly equivalent, provided that the Community minimum levels are observed and that the national level of taxation in force on 1 January 2003 for gas oil used as propellant is at least twice as high as the minimum level of taxation applicable on 1 January 2004 (EC 2003).

In Member States, which decide to decouple their excise duty rates on diesel, there is still only one diesel price at tank stations, but entrepreneurs or firms are reimbursed for the difference between commercial and noncommercial rates once they have proven that they are professional users. The fact that some states actually use this option gives us another reason why we need to differentiate between households and commercial carriers in our analysis.

[4]Where commercial gas oil used as propellant shall mean gas oil used as propellant for the purposes of the carriage of goods for hire or reward, or on own account, by motor vehicles or articulated vehicle combinations intended exclusively for the carriage of goods by road and with a maximum permissible gross laden weight of not less than 7,5 tones or the carriage of passengers, whether by regular or occasional service, by a motor vehicle of category M2 or category M3, as defined in Council Directive 70/156/EEC of 6 February 1970 on the approximation of the laws of the Member States relating to the type-approval of motor vehicles and their trailers.

Chapter 4

Data and variables

We construct a balanced panel of data from 16 European countries[5] between 2005 and 2010. As a measure for the diesel tax, we take the pre-VAT price for commercial users and the pump price for households (both in USD per liter) from the International Energy Agency's Energy Prices and Taxes database. Paizs (2010) points out that potential advantage of end-user prices over taxes is that from the consumer perspective it is the price that matters. The disadvantages of this measure are that governments have direct control over tax rather than price and, more importantly, that diesel prices across countries follow the world price of crude oil and are therefore correlated due to common oil price shocks. Ability to convincingly demonstrate asymmetric tax competition of this variable should nevertheless not be curtailed. Another reason why we select price as a dependent variable is that studies using statutory tax rate (Paizs 2010) or ratio of the excise and price (Evers *et al.* 2004) have already been carried out. For the purposes of our analysis, we formulate the following variables in Table 4.1 and discuss them below.

Country size

As was indicated above, small countries may impose lower fuel taxes to attract cross-shoppers from the neighboring countries. Therefore we have to construct a variable that is proxy for the relative importance of the domestic demand for diesel compared with the potential international demand. While Rietveld & van Woudenberg (2005) use purely spatial characteristics to measure country size for this purpose, Keen & Kanbur (1991) suggest that the outcome of tax competition is

[5] These countries are Austria, Belgium, Czech Republic, Denmark, France, Germany, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Switzerland, Sweden and United Kingdom.

Table 4.1: Summary of factors that affect fuel taxes

Variable to be used	Symbol	Source
Government expenditure as a share of GDP	GOV/GDP	Eurostat
Low price elasticity; proxied by GDP per capita	GDP/CAP	World Bank
Price in neighbor country	NP	OECD; Own Data
Size of international market relative to domestic	SIZE	Nations Encyclopedia; Own Data; World Bank
Car density	CARDENS	World Bank
Length of public roads per motor vehicle	ROAD/CAR	OECD; World Bank

also likely to be dependent on the differences in population densities. A large country with a relatively high population density gets even larger relative to its neighbors, and conversely it may become smaller if it is relatively sparsely populated. For this reason, we construct in addition to relative country size used by Rietveld & van Woudenberg (2005) two other variables to measure country size: population and GDP. In order to construct these variables measuring relative size of domestic and foreign demand we first have to compute the land area of foreign market using the following formula.

$$\text{FOREIGN} = \text{share (surface of the ring with radius } r \text{ and } (r + 40))$$

Where r is determined by solving $S = \pi r^2$ (S is the country's surface in square kilometers), the distance for cross-border fueling is arbitrarily set at 40km and the share is the percentage of the country that border land. This is important because geometry of a country plays very significant role. For instance this share is just slightly below three percent for United Kingdom, whereas it is, obviously, equal to one for a landlocked country like Czech Republic. Second, we compute total population and GDP in that area. This is done by calculating average population and GDP densities in the country's neighbors, weighted by the length of their joint borders, and multiplying them by the area. The final step is to compute ratios "FOREIGN/DOMESTIC" for area, population and GDP.

In Table 4.2, we provide three rankings, each corresponding to one measure of size suggested above. One observation is that rankings across all four measures are reasonably similar. To see this, it is useful to consider which countries are ranked "large" and "small" by each ranking. We always find Denmark, Italy, Norway, Spain

Table 4.2: Measures of relative country size

Area		Population		GDP	
Denmark	0.007366	United Kingdom	0.002142	United Kingdom	0.002832
United Kingdom	0.008644	Denmark	0.013329	Denmark	0.009429
Norway	0.027221	Norway	0.033967	Norway	0.019140
Italy	0.054776	Italy	0.038031	Italy	0.055731
Spain	0.056597	Sweden	0.065782	Spain	0.065542
Sweden	0.090052	Spain	0.073461	Sweden	0.098318
France	0.090832	Germany	0.119622	Germany	0.125688
Ireland	0.120741	France	0.162144	France	0.183168
Germany	0.154194	Portugal	0.163268	Portugal	0.236470
Portugal	0.210301	Netherlands	0.405176	Netherlands	0.357383
Austria	0.549598	Ireland	0.487225	Ireland	0.369479
Netherlands	0.567614	Belgium	0.609676	Switzerland	0.453087
Czech Republic	0.568652	Czech Republic	0.690405	Belgium	0.700436
Switzerland	0.819556	Switzerland	0.752646	Austria	0.709802
Belgium	0.931801	Austria	0.938711	Czech Republic	1.247209
Luxembourg	4.732125	Luxembourg	6.474829	Luxembourg	2.662163

and the United Kingdom at the top of the table, while Austria, Belgium, Czech Republic, Luxembourg and Switzerland are at the opposite end. Not surprisingly, international markets are more important for landlocked countries.

Weighting scheme

If a country has more than one neighbor, the value of the neighbors' price in country i in year t is computed using the following formula:

$$NP_{i,t} = \sum_{j \neq i} \omega_{ij,t} P_{j,t}$$

where $P_{j,t}$ is the diesel price in country j in year t and $\omega_{ij,t}$ are exogenously chosen weights, normalized so that $\sum_{j \neq i} \omega_{ij,t} = 1$. This procedure is widely used but there is considerable discussion of the appropriate weights in the literature (Devereux *et al.* 2007).

We construct three weighting schemes that should take into account the relative importance of neighbors, again in terms of area, population and GDP. Thus when some weights are used to calculate the value of neighbors' price in our regression analysis, then the equivalent measure is used to calculate the relative size of international market as well.

For instance, population weights are specified as follows:

$$\omega_{ij,t} = \begin{cases} l_{ij}\delta_{j,t} / \sum_{j \in N_i} l_{ij}\delta_{j,t} & \text{if} \quad j \in N_i \\ 0 & \text{if} \quad j \notin N_i \end{cases}$$

where N_i is the set of states that border state i, l_{ij} is the length of the border between state i and j and $\delta_{j,t}$ is the population density in the state j in year t.[6]

Control variables

Fuel has the attraction of having a moderate price elasticity of demand. Empirical works show that the short-run elasticity of motor fuel is in the range of -0.2 and -0.3, while the same numbers for the long-run elasticity are in between -0.6 and -0.8 (Fulton & Noland 2005). The Ramsey rule of efficient taxation says that goods whose demands are inelastic should be taxed at a relatively high rate in order to minimize the distortionary effect of government taxation as a whole, i.e. the deadweight loss of the tax (Ramsey 1927). Since price elasticity of demand tends to be lower in high-income countries, efficiency principle would suggest that in high-income countries, fuel tax should also be high. Therefore we use GDP per capita[7] as the proxy for price elasticity.

Whereas the Ramsey rule of taxation primarily focuses on the relative tax rates on goods, it is also important to note that the overall tax rate depends on the fiscal policy of a government. While a less elastic demand should lead to a higher tax rate of that particular good, the magnitude of government expenditure is expected to increase the overall tax rate of all goods. Government expenditure as a share of GDP should reflect this.

The Pigouvian tax prescribes that a tax should incorporate all the externalities that are caused by the consumption of a good, in order to reduce the consumption of that good to its socially optimal point. In the case of motor vehicle transport, externalities are influenced by multiple factors, one of which is car density. Rietveld *et al.* (2001) points out, however, that one of the limitations of the present fuel tax is that it addresses the local externalities of car use in a very crude way. It does not differentiate between transport in urban areas with high external costs in terms of noise, accidents and congestion, and rural areas where these costs are much lower. Authorities have more effective policy tools at hand to correct the market

[6] $\delta_{j,t}$ stands for GDP density in case of GDP weights and is dropped out of the formula in case of area weights.

[7] Where GDP is measured in thousands of U.S. dollars.

outcome such as introduction of 'congestion charging zone'. Moreover, Johansson & Schipper (1997) report that the larger part of an elasticity of fuel demand is related to fuel efficiency changes than to changes in kilometers driven, so there is almost no behavioral effect.

Finally, fuel taxes may be charged to recover the cost of providing roads (including construction, maintenance and operations), as the quantity of fuel use is broadly linked to the extent of use made of the road system, both in terms of distance travelled and in terms of size of vehicle. A fuel tax is mildly progressive for car users, in that users of larger cars, which are usually more expensive to purchase, use more fuel and pay higher taxes. In this case, the fuel tax follows from the benefit principle (Musgrave & Musgrave 1989). Fuel tax is limited, however, when it comes to larger vehicles because the damage caused to roads rises exponentially as axle load rises. Again, as in the case of negative externalities, a more direct benefit tax would be the imposition of tolls, which is already widely used across European Union since the costs of toll collection declined substantially in line with technological progress. Despite these arguments, we include road stock per car[8] in our analysis in order to correlate for the benefit principle.

[8] Where road length is measured in kilometers.

Chapter 5

Empirical Investigation

5.1 Noncommercial diesel

Based on the variables included in Table 4.1, we estimate the following equation:

$$P_{i,t} = \beta_0 + \beta_1 NP_{i,t} + \beta_2 SIZE_{i,t} + \beta_3(NP_{i,t} * SIZE_{i,t}) + \beta_4 GOV/GDP_{i,t} + \beta_5 GDP/CAP_{i,t} + \beta_6 CARDENS_{i,t} + \beta_7 ROAD/CAR_{i,t} + \nu_{i,t}$$

where $P_{i,t}$ represents the diesel price in country in country i and year t in U.S. dollars per liter. We also include an interaction term for SIZE and NP. This allows us to test whether if small countries tend to respond less strongly to changes in their neighbors' diesel tax rates than large countries do.
The results of the estimation of the equation above using both fixed and random effect are reported in Table 5.1. There are six columns of results: in the first two, both country size and neighbors price variables are based on surface area, in column 3 and 4 the surface-based weightings are replaced by its population-based equivalent and in the last two columns by its GDP-based equivalent. Each pair of columns includes first an FE model and then an RE model for the purpose of comparison.

The Hausman test does not provide any evidence against RE in any of the three cases. Therefore we will interpret the results for RE as the theory suggests: that they are more efficient (Wooldridge 2006). We find very high level of explanatory power for NP. As for the other key variables of interest - SIZE and the interaction term - they are individually insignificant at 5% level, but jointly significant even at 1% level. GOV/GDP is not significant at all and GDP/CAP is significant only with surface-based weightings. While CARDENS is insignificant even at 50% level, ROAD/CAR is significant even at 5% using GDP weightings. However, it has the

Table 5.1: FE & RE estimates for noncommercial diesel prices (1)

	(1) FE	(2) RE	(3) FE	(4) RE	(5) FE	(6) RE
GDP/CAP	0.00324*	0.00312**	0.00380**	0.00267*	0.00210	0.00176
	(1.80)	(2.20)	(2.01)	(1.90)	(1.19)	(1.35)
SIZE		-0.0879*	0.222	-0.0532	-0.155	-0.128*
		(-1.74)	(1.36)	(-1.52)	(-1.09)	(-1.82)
GOV/GDP	0.00202	0.00192	0.00256	0.00182	0.00222	0.00193
	(1.13)	(1.32)	(1.40)	(1.25)	(1.24)	(1.33)
NP	0.920***	0.915***	0.907***	0.923***	0.945***	0.942***
	(22.81)	(24.39)	(21.87)	(25.00)	(21.14)	(25.27)
NP*SIZE	-0.0207	-0.0185	-0.00321	-0.0163	-0.0335	-0.0214
	(-0.78)	(-0.73)	(-0.15)	(-0.86)	(-0.68)	(-0.50)
ROAD/CAR	-2.563	-3.400*	-2.585	-2.973	0.328	-3.508**
	(-0.26)	(-1.82)	(-0.26)	(-1.63)	(0.03)	(-2.01)
CARDENS	0.000162	0.000166	0.0000637	0.000193	0.000190	-0.0000441
	(0.18)	(0.34)	(0.07)	(0.39)	(0.21)	(-0.10)
_cons	-0.128	-0.0427	-0.282	-0.0767	-0.152	0.0897
	(-0.18)	(-0.17)	(-0.39)	(-0.30)	(-0.21)	(0.37)
N	96	96	96	96	96	96
R^2	0.952		0.953		0.952	

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

opposite sign than expected. It might actually be the case that this variable reflects rather some negative externalities than any benefits received by taxpayers.

There is a problem with the estimation of the original model, because SIZE and NP*SIZE are almost perfectly correlated.[9] To avoid multicollinearity we have to drop one of the predictor variables. The main reason why we chose to exclude SIZE instead of the interaction term is that we want to estimate the marginal effect of a change in neighbors' price for countries of different size. Furthermore, we exclude CARDENS as it has shown no explanatory power at all. This approach results in the estimated parameter values in Table 5.2, which is organized in the same manner as Table 5.1.

If GDP/CAP is 10 000 USD higher, the diesel price is predicted to be about 3 cents higher for both area and population weightings. The probable reason why it is insignificant for GDP weighting is that it is already reflected in NP. GOV/GDP

[9]The actual correlation between SIZE and NP*SIZE is about 99% for all three measures.

Table 5.2: FE & RE estimates for noncommercial diesel prices (2)

	(1) FE	(2) RE	(3) FE	(4) RE	(5) FE	(6) RE
GDP/CAP	0.00329*	0.00315**	0.00292*	0.00287**	0.00281*	0.00195
	(1.86)	(2.37)	(1.68)	(2.20)	(1.71)	(1.64)
GOV/GDP	0.00201	0.00211	0.00197	0.00208	0.00213	0.00194
	(1.13)	(1.49)	(1.11)	(1.48)	(1.20)	(1.39)
NP	0.921***	0.936***	0.922***	0.938***	0.934***	0.965***
	(23.03)	(26.17)	(22.97)	(26.30)	(21.58)	(27.34)
NP*SIZE	-0.0207	-0.0517***	-0.00966	-0.0378***	-0.0308	-0.0799***
	(-0.79)	(-2.91)	(-0.47)	(-2.88)	(-0.63)	(-2.79)
ROAD/CAR	-3.770	-3.237**	-3.784	-3.005*	-2.732	-3.307**
	(-0.52)	(-1.98)	(-0.52)	(-1.88)	(-0.37)	(-2.00)
_cons	-0.00974	-0.0189	-0.00950	-0.0270	-0.0535	-0.00275
	(-0.03)	(-0.18)	(-0.03)	(-0.27)	(-0.18)	(-0.03)
N	96	96	96	96	96	96
R^2	0.952		0.952		0.951	
Upper quartile	0.920	0.935	0.922	0.937	0.963	0.963
Median	0.916	0.924	0.919	0.928	0.946	0.946
Lower quartile	0.885	0.845	0.901	0.854	0.859	0.859

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

remains insignificant for all three measures. This result is somewhat surprising to us. The reason why the magnitude of government expenditure does not have a significant effect on the diesel taxation might be that governments are aware of the fact that a higher tax rate need not necessarily lead to higher revenues, which is probably the governments' main objective, due to the presence of the cross-border effect. The estimated effect of ROAD/CAR is nontrivial and significant for two out of the three measures. Ten more meters of road stock per car decrease diesel price roughly by 3 cents. Both NP and NP*SIZE are statistically significant even at the 1% level. In order to quantify the importance of country size, we computed the marginal effect of neighbors' price at the upper quartile, median and lower quartile of country size and reported them at the bottom of the table. The results indicate a substantial difference between the behavior of the large and the small countries in the tax competition game. While a 10 cents increase in the weighted average of unit price in neighboring countries will induce a large country (represented here by the upper quartile of country size) to raise its own price by 9.35 to 9.63 cents, (depending on the weighting scheme) a small country (represented here by the lower quartile of country size) raises its price 'only' by 8.45 to 8.59 cents. There is, however, a problem with this kind of interpretation, because the effect of the change in neighbors' price crucially depends on what is behind the change of the neighbors' price. While the fluctuations in the crude oil prices should be reflected in pump prices of diesel in all countries very similarly, as differences should stem only from the different rates of VAT, a different situation arises when the change in the neighbors' price is tax induced. In such a case, size and geographic location of a country certainly plays an important role in the decision of the government how to respond. So even though exactly determining marginal effect of neighbors' price on home price is not possible, we can definitely say that countries that are relatively smaller tend to levy lower excise duty on diesel fuel.

There still remain two problems with the RE estimation of the revised model. First, following from the assumption that the prices in different countries are jointly determined, both the neighbor's price and the interaction term should be treated as endogenous. Second, spatial error dependence can arise when the error term includes omitted variables that are themselves spatially correlated (LeSage & Pace 2009). For instance quality of diesel fuel might be similar among neighboring countries if they are supplied by same set of refineries. Since quality of diesel fuel is not a variable included in the set of explanatory variables, the higher than expected diesel price might reflect a premium for higher fuel quality. If this would be the case, interpreting the finding that prices from neighboring countries are useful for prediction as evidence for tax competition would be erroneous as the RE estimation of the model would indicate spatial dependence through the neighbor price even though it would be simply generated by spatially correlated errors.

To address these problems, we now apply an approach with instrumental variable. In the first stage, we estimate the fuel price by using the following empirical relation.

$$\begin{aligned} P_{i,t} = \; & \beta_0 + \beta_1 SIZE_{i,t} + \beta_2 GOV/GDP_{i,t} + \beta_3 GDP/CAP_{i,t} \\ & + \beta_4 CARDENS_{i,t} + \beta_5 ROAD/CAR_{i,t} + u_{i,t} \end{aligned}$$

In the equation above, no explanatory variables are a function of the fuel price. By estimating it with OLS, an estimate for the fuel price is obtained. This estimate, $\widehat{P}_{i,t}$, can be used to calculate an estimate for the average fuel price in country i's adjacent countries in year t, $\widehat{NP}_{i,t}$. In the second stage, we estimate the following empirical relation by using predicted values of NP obtained in the first stage as explanatory variables.

$$P_{i,t} = \beta_0 + \beta_1 \widehat{NP}_{i,t} + \beta_2(\widehat{NP}_{i,t} * SIZE_{i,t}) + \beta_3 GOV/GDP_{i,t} + \beta_4 GDP/CAP_{i,t} + \beta_5 ROAD/CAR_{i,t} + u_{i,t}$$

This procedure yields unbiased and consistent estimates given that the instruments are valid. A valid instrument has to meet two criteria. It has to be both uncorrelated with the error term, and correlated with the endogenous variable. While we can easily test the latter (the actual correlation is about 0.22 for all measures), the former can never be tested. We have to rely on the economic theory to decide about exogeneity. Macroeconomic variables might not work very well as instruments since the possibility of simultaneity from macroeconomic aggregates (like GDP per capita or share of government expenditure on GDP) cannot be ruled out as economic cycles across countries in Europe are correlated (Paizs 2010). The results of this 2SLS approach are reported in Table 5.3.

Table 5.3: OLS & 2SLS estimates for noncommercial prices

	(1) OLS	(2) 2SLS	(3) OLS	(4) 2SLS	(5) OLS	(6) 2SLS
GDP/CAP	0.00341***	0.00560***	0.00328***	0.00453***	0.00128	0.00205**
	(3.38)	(4.79)	(3.40)	(3.90)	(1.60)	(2.11)
GOV/GDP	0.00247	0.000244	0.00270	-0.00161	0.00222	-0.00204
	(1.01)	(0.08)	(1.17)	(-0.56)	(0.97)	(-0.72)
NP	0.773***	1.342***	0.804***	1.665***	0.875***	2.406***
	(10.65)	(6.37)	(11.59)	(7.17)	(12.87)	(8.24)
NP*SIZE	-0.0715***	-0.0906***	-0.0527***	-0.0617***	-0.0975***	-0.0824***
	(-6.13)	(-6.44)	(-6.51)	(-6.32)	(-6.25)	(-4.15)
ROAD/CAR	-3.080***	-5.813***	-2.932***	-6.397***	-3.136***	-7.958***
	(-3.60)	(-4.68)	(-3.68)	(-5.27)	(-3.98)	(-6.05)
_cons	0.213	-0.578*	0.144	-0.961***	0.162	-1.951***
	(1.38)	(-1.84)	(0.99)	(-2.93)	(1.11)	(-4.62)
N	96	96	96	96	96	96
R^2	0.670	0.519	0.709	0.565	0.717	0.571
Upper quartile	0.771	1.334	0.803	1.664	0.873	2.404
Median	0.757	1.321	0.790	1.649	0.852	2.387
Lower quartile	0.645	1.182	0.687	1.528	0.745	2.296

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

In comparison to the OLS coefficient estimates, both the 2SLS coefficients on NP and ROAD/CAR are substantially larger for all three weightings. Specifically, 2SLS results reveal coefficients on NP of 1.342, 1.665 and 2.406 for area, population and GDP weightings respectively. These coefficient estimates are 73%, 107% and 175% larger than the respective coefficients estimated under OLS. In the case of ROAD/CAR, the 2SLS coefficient estimates are 89%, 118% and 153% larger than their OLS counterparts.

This could be interpreted so that OLS underestimates the impact of these variables on the domestic pump price of diesel fuel, but common sense tells us that such explanation is not plausible since the 2SLS estimates are simply too large. More likely it is the case when the cure is worse than the disease. The empirical finding that the 2SLS estimate increases compared to the OLS estimate may indicate that the instrument is not orthogonal to the stochastic disturbance, i.e. not valid. The resulting bias can be substantial and it actually can exceed the OLS bias, leading to an increase in the estimated 2SLS coefficient over the estimated OLS coefficient (Hahn & Hausman 2005). 2SLS estimators can also perform poorly in finite samples when there are weak instruments. One aspect of this poor accuracy is finite sample bias. When instruments are weak, i.e. only weakly correlated with the endogenous regressors, the 2SLS estimator is biased in the direction of the OLS estimator (Bun & Windmeijer 2010). Therefore, we have to interpret these results with caution.

5.2 Commercial diesel

Our model is not very well suited for analysis of tax competition in case of diesel for commercial use. The problem lies with the definition of our variable reflecting the relative importance of international market for each country. As big trucks can cover between 1500 and 3000 kilometers on a single tank and fuel costs make up between 20 and 30 percent of the running cost of a road haulage business, one could say that the distance for cross-border fueling of 40 kilometers is too low in the case of diesel for commercial use (Paizs 2010). But increasing the distance, for instance, to 100 kilometers would generally affect only the magnitude of coefficient of the interaction term since the ratios between different countries would remain almost the same. Therefore haulers located near the borders do not pose a problem. The situation is different with haulers involved in international activities. Evers *et al.* (2004) point out that road haulage companies can substantially save on production costs by active fiscal planning of international transport routes. So it actually might be the case that Luxembourg is competing more intensively with Poland or Spain rather than with Germany or France. To have a better idea about how large the potential international demand relative to the domestic one is, we would need to know details about traffic flows in Europe. Unfortunately, such data are not available to us and therefore we will use the same variables for the measuring of relative country size as in the previous case. Following the similar econometric procedure, in Table 5.4 we first present the results of estimation by both fixed and random effects for the purpose of comparison.

Table 5.4: FE & RE estimates for commercial diesel prices

	(1) FE	(2) RE	(3) FE	(4) RE	(5) FE	(6) RE
GDP/CAP	0.00218	0.00218*	0.00212	0.00221*	0.00218	0.00166
	(1.36)	(1.70)	(1.37)	(1.77)	(1.48)	(1.47)
GOV/GDP	0.00147	0.00158	0.00152	0.00164	0.00164	0.00150
	(0.90)	(1.18)	(0.94)	(1.24)	(1.02)	(1.14)
NP	0.919***	0.935***	0.915***	0.930***	0.929***	0.956***
	(20.62)	(22.53)	(20.76)	(22.76)	(19.61)	(23.60)
NP*SIZE	-0.00271	-0.0356*	-0.00130	-0.0300*	-0.0286	-0.0772**
	(-0.09)	(-1.66)	(-0.06)	(-1.89)	(-0.53)	(-2.30)
ROAD/CAR	-5.059	-3.473**	-5.112	-3.292*	-4.296	-3.576**
	(-0.76)	(-1.97)	(-0.78)	(-1.94)	(-0.65)	(-2.18)
_cons	0.0611	0.0188	0.0565	0.00625	0.0187	0.0250
	(0.23)	(0.18)	(0.21)	(0.06)	(0.07)	(0.25)
N	96	96	96	96	96	96
R^2	0.940		0.940		0.940	
Upper quartile	0.919	0.918	0.915	0.929	0.928	0.954
Median	0.918	0.910	0.914	0.922	0.922	0.937
Lower quartile	0.914	0.856	0.912	0.864	0.890	0.853

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Since the Hausman tests indicate that RE are consistent for all three weightings, we will again interpret just these results for reasons mentioned earlier in the text. While NP is significant even at 1% level across all three measures, the interaction term is significant only for the GDP weighting. This may be caused by the fact that the size of the road haulage industry in a country is better represented by GDP than by area or population. Neither GDP/CAP nor GOV/GDP are significant for any of the three measures and ROAD/CAR is significant for two out of the three measures.

Depending on the weighting scheme, a 10 cents increase in neighbors' prices is predicted to induce a large country (represented here by the upper quartile of country size) to raise its own price by 9.18 to 9.54 cents, a small country (represented here by the lower quartile of country size) to raise its price by 8.53 to 8.56 cents. In comparison with marginal effects of neighbors' price in the case of diesel for noncommercial use, we can see that differences between larger and smaller countries are slightly narrowing. This might be caused by two factors. Firstly, some large states tax diesel used for commercial purposes at a lower rate than diesel used by private cars. Secondly, prices for commercial carriers do not reflect VAT rates, which on average tend to be lower in relatively smaller states. But overall, these differences are negligible and coefficient magnitudes are remarkably similar to the estimated parameter values in case of VAT–inclusive prices.

Also in this case, both the neighbor's price and the interaction term should be treated as endogenous, so we apply the 2SLS approach. Results are depicted in Table 5.5 together with OLS for purpose of comparison.

Table 5.5: OLS & 2SLS estimates for commercial diesel prices

	(1) OLS	(2) 2SLS	(3) OLS	(4) 2SLS	(5) OLS	(6) 2SLS
GDP/CAP	0.00216*	0.00362***	0.00238**	0.00335***	0.000989	0.00213**
	(1.95)	(3.44)	(2.23)	(3.12)	(1.11)	(2.33)
GOV/GDP	-0.000890	-0.00334	-0.000567	-0.00450	-0.00135	-0.00510*
	(-0.33)	(-1.23)	(-0.22)	(-1.64)	(-0.52)	(-1.81)
NP	0.658***	1.274***	0.688***	1.374***	0.746***	1.740***
	(6.97)	(6.73)	(7.47)	(6.46)	(8.21)	(6.30)
NP*SIZE	-0.0617***	-0.0810***	-0.0490***	-0.0592***	-0.0986***	-0.102***
	(-3.99)	(-5.29)	(-4.48)	(-5.35)	(-4.67)	(-4.50)
ROAD/CAR	-2.814***	-5.788***	-2.722***	-5.675***	-2.785***	-5.963***
	(-2.99)	(-5.25)	(-3.04)	(-5.12)	(-3.19)	(-5.00)
_cons	0.487***	-0.173	0.412**	-0.265	0.450***	-0.648*
	(2.86)	(-0.71)	(2.47)	(-1.02)	(2.72)	(-1.91)
N	96	96	96	96	96	96
R^2	0.449	0.457	0.493	0.460	0.514	0.437
Upper quartile	0.656	1.272	0.687	1.373	0.744	1.738
Median	0.644	1.255	0.675	1.356	0.723	1.716
Lower quartile	0.549	1.131	0.580	1.243	0.615	1.604

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

It is immediately apparent that 2SLS estimates suffer from the same problems as in the case of noncommercial diesel, since the coefficients on NP and ROAD/CAR are again substantially larger than their OLS counterparts for all three weightings Therefore, also these results need to be interpreted with caution.

Chapter 6

Conclusion

In this thesis we analyze tax competition in diesel excises in Europe over the period from January 1, 2005 to December 31, 2010. We focus primarily on asymmetric tax competition between countries of different size. Modified empirical model of Rietveld & van Woudenberg (2005) is employed to test the theoretical predictions of Keen & Kanbur (1991) on a balanced panel of 16 European countries, containing diesel prices both inclusive and exclusive of VAT. Our empirical approach differs particularly in the measurement of country size and the weighting scheme used to aggregate neighbor' prices. While Rietveld & van Woudenberg (2005) use purely spatial characteristics for this purpose, we consider the differences in population and GDP as well in construction of our variables.

Estimates obtained from random effects model for noncommercial diesel indicate that a 10 cents higher price in neighboring countries induces a large country to raise its own price by around 9.2 to 9.6 cents, whereas a small country just by around 8.4 to 8.6 cents. Rietveld & van Woudenberg (2005) estimate the difference between large and small countries to be about twice as large in 1998. We therefore come to the same conclusion as Evers *et al.* (2004) and Paizs (2010) that harmonization efforts of the EU reduced the intensity of tax competition in diesel excises and led to convergence of rates.

Two caveats are important to consider when interpreting our study's findings. First, interpretation of marginal effect of change in neighbors' prices is problematic, because it is not possible to separate reactions to tax-induced changes in neighbors' prices from common oil price shocks. Second, since we were not successful in identifying appropriate instrumental variable for neighbors' prices, we acknowledge the always-present possibility that our estimates may suffer from simultaneity bias as well as spatial error dependence.

Addressing these issues remains a major challenge for further research, but there is certainly room for improvement also in other areas. It would be very beneficial to gather data for OECD-nonmembers bordering the European Union so that more countries from the eastern enlargement could be included in the analysis, potentially demonstrating the universality of these study findings. Lastly, new weighting schemes for neighbors' prices and measures of country size should be considered in order to better reflect the international form of road haulage business.

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