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Spatial graduation of fuel taxes; consequences for cross-border and domestic fuelling

P. Rietveld *, F.R. Bruinsma, D.J. van Vuuren

Department of Spatial Economics and Tinbergen Institute, Faculty of Economics, Business Administration and Econometrics, Vrije Universiteit, De Boelelaan 1105, 1081 HV, Amsterdam, The Netherlands

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Abstract

Substantial differences exist among fuel taxes between various countries. These differences represent a form of fiscal competition that has undesirable side effects because it leads to cross-border fuelling and hence to extra kilometres driven. One possible way of dealing with this problem of low fuel taxes in neighbouring countries is to introduce a spatial differentiation of taxes: low near the border and higher farther away. This paper contains an empirical analysis of the consequences of such a spatial graduation of fuel taxes for The Netherlands. Impacts on fuelling behaviour, vehicle kilometres driven, tax receipts, and sales by owners of gas stations are analysed. The appropriate slope of the graduation curve in order to prevent fuel-fetching trips is also discussed. Our conclusion is that in a small country such as The Netherlands, a spatial graduation of fuel taxes will lead to considerable problems, even when the graduation curve is not steep that fuel-fetching trips are prevented. The reason is that – given their activity patterns – car drivers will change the location of their fuelling activity leading to substantial problems for owners of gas stations in areas with high taxes. © 2001 Elsevier Science Ltd. All rights reserved.

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1. Introduction

Fuel taxes are in many countries a major component of the fuel price. These taxes are a simple way for governments to collect money for construction, operation and maintenance of road networks and possibly serve as a source for general public expenditures. In addition, they provide

* Corresponding author. Tel.: +31-20-444-6097x090; fax: +31-20-444-6004.
E-mail address: prietveld@econ.vu.nl (P. Rietveld).

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an incentive for drivers to buy fuel-efficient cars and to reduce mileage in view of environmental effects related to fuel consumption.

One of the limitations of the present fuel tax is that it addresses the local externalities of car use in a very crude way. For example, 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. A spatial graduation of fuel taxes might be a means of overcoming this problem, but it has received little attention in actual policy making or in the research literature. Hau (1992, p. 16) briefly mentions it in his review of alternatives to congestion pricing: "Compared with a uniform fuel tax, a spatially differential fuel tax with non-uniform rates would respond better to congestion. But this too has its problems. Even though a differential fuel tax is administratively simple, it may result in wasteful 'fuel-fetching' journeys, and would work only, for example, if distances between urban and rural areas were sufficiently large". Indeed, the risk of unintended fuel-fetching trips is a problem that has to be taken seriously: it might easily destroy the potentially positive effects of fine-tuning the taxation of external effects of road transport.

There is yet another reason why spatial graduation of fuel taxes may be relevant. The lack of co-ordination in fiscal policies of various countries – or more generally, fiscal competition between countries – may lead to rather large gaps between the fuel taxes of neighbour countries. In such a situation, a spatial graduation may be used to prevent cross-border fuel-fetching trips. A country with high fuel taxes could discourage fuel fetching in neighbouring countries with low fuel taxes by introducing border zones with lower taxes. Or, to give an opposite example, a country may introduce low fuel taxes near its border in order to induce drivers from neighbouring countries to shift their fuelling behaviour; the effect would be an increase of the share of foreigners in its tax base.

Note that in the case of border regions, spatial graduation in the high tax country is designed to *prevent* cross-border fuel-fetching trips, whereas in the case of an urban-rural graduation of fuel taxes mentioned above, the opposite may occur, since in this situation, graduation may be *inducing* fuel-fetching trips. This is an intriguing contrast which will be further elaborated in this paper since the introduction of graduation to prevent cross-border fuel-fetching may lead to a domestic fuel-fetching problem when drivers adjust their fuelling behaviour towards low cost zones.

In the literature, little is found about the fuelling behaviour of car drivers. Since fuel is an almost homogeneous product, one may expect car drivers to be highly sensitive to price differences across gas stations. Given the rather high spatial density of gas stations, most drivers will pass various stations during their trips so that they would in principle be free to select the cheapest one without incurring additional transport costs. There are, however, factors that discourage such a pattern. First, perceived quality differences (for example, between brand and non-brand stations) may lead one to choose a more expensive station. The presence of extra facilities (shop, garage) will also add to a differentiation among suppliers, thus implying lower price sensitivity. In addition, suppliers may develop saving campaigns to discourage their customers from going to competitors. Finally, there is a category of drivers that does not care about price differences as long as they are rather small.

A sine qua non-condition for the successful introduction of a spatial graduation of fuel taxes is that the graduation profile should not be too steep. The slope should be so moderate that drivers would lose in terms of generalised costs by making specific fuel-fetching trips. In Section 4 we discuss how steep a graduation profile can be without creating the risk of fuel-fetching trips. Even when a sufficiently moderate slope of a graduation profile can exclude fuel-fetching trips, this does not imply that fuelling behaviour will remain unaffected. Especially drivers making long-distance trips might well be in the position to buy fuel where it is much cheaper than at their place of residence. This phenomenon of *changes in the location of fuelling with an unaltered pattern of trips* will be investigated in Section 5. Special attention will be given to the effects graduation may have on market shares of gas stations given their location along the graduation profile. Empirical results are presented for The Netherlands.

The aim of this paper is to analyse the consequences of a spatial graduation of fuel taxes in terms of shifts in fuelling patterns, tax receipts and mileage. The paper starts with an introduction on international differences in fuel taxes and fuel prices in certain European countries (Section 2), plus a short discussion of the consequences of fuel price differences on fuelling behaviour (Section 3). Revealed and stated preference behaviour concerning cross-border fuelling in The Netherlands is analysed in Section 4. The potential consequences of spatial graduation are addressed in Section 5, whereby opportunities to save money by fuelling at cheap locations given the current travel patterns of Dutch car drivers are analysed. Section 6 concludes.

2. Fuel prices in European countries

In a project for the Dutch Ministry of Economic Affairs, Coopers Lybrand (1996) compared the structure and level of fuel prices in a number of European countries in 1996 (see Table 1). [1]

Beginning with the bottom row of Table 1, it appears that the gas station price of Euro 95 fuel in France and The Netherlands is relatively high compared with price levels in neighbouring Belgium and Germany. These price differences lead to cross-border fuelling behaviour by Dutch and French car drivers living in the proximity of those borders, as will be shown in the following sections. The United Kingdom has by far the lowest fuel prices, but cross-border fuelling trips towards the UK are not attractive due to the natural barrier formed by the Channel. The advantages of purchasing cheaper fuel are outweighed by the costs of crossing the Channel.

In Table 1 we start with the spot prices, which are based on the market prices as generally accepted by the oil industry and the oil trade after the refinery process has taken place. Table 1 shows that the price differences in spot prices are small. The differences in the shares of the spot price in the gas station price are due to large differences in the other cost components within the five countries considered.

The distribution margin encompasses storage costs, costs of provision for the gas stations, costs of the oil company and the gas station, and the profit margins of the oil company and the gas station. The share of the distribution margin seems to differ most among the five countries. In The Netherlands and Belgium it is relatively high, France and Germany have intermediate values, and the distribution margin in the United Kingdom is relatively low.

[1] This section is mainly based on Coopers Lybrand (1996).

Table 1
Price levels and structure for Euro 95 fuel in five European countries (June 1996, in €-cents per litre)

	Netherlands		Belgium		Germany		France		UK	
Spot price*	11.2	12.5%	11.2	13.3%	11.3	13.9%	11.8	12.9%	11.4	17.5%
Distribution margin	12.9	14.4%	11.7	13.9%	9.6	11.8%	7.8	8.6%	3.1	4.7%
Levies	52.3	73.2%	46.5	72.7%	49.8	74.3%	56.0	78.5%	41.1	77.8%
VAT	13.4		14.6		10.6		15.6		9.7	
Gas station price**	89.8		84.0		81.3		91.2		65.3	
Price index	100		93.5		90.5		101.6		72.7	

* Based on Platt's prices (market price of fuel in the oil industry and trade (profit margin refinery included)).
** National average of the actual gas station price of the largest oil companies. 1 €≈1.10 US$.
Source: based on Coopers Lybrand, 1996.

In all countries, by far the largest percentage, 72.7–78.5%, of the gas station price is the share taken by the government in the form of levies and VAT.

A striking piece of information in Table 1 is the wide range in the distribution margin in the countries examined. To further clarify those differences, we will now discuss the market structure of the countries in greater detail (see also Table 2).

In The Netherlands, where the margin is largest, there is a strongly regulated fuel market. Environmental, safety and employment (wage, safety and working hour restrictions) standards are very stringent and the legal regime is also the most severe of the countries considered. Moreover, Dutch people love saving campaigns, such as free trading stamps. The costs of these saving campaigns, which aim at increasing brand loyalty, have to be paid out of the distribution margin. The Netherlands has the most dominant market leader – Shell – and the market share of the four largest oil companies is also the largest of the countries considered. In particular in France and the United Kingdom, many relatively small oil companies have entered the market. The Netherlands is the only country in which the amount of the fuel sold at supermarkets is insignificant, whereas in all the other countries the entry of supermarkets into the fuel market has led to price wars which have most often been won by the supermarkets. Supermarkets accept low profits or even losses at gas stations in order to attract customers to their shops. Only in Belgium

Table 2
Characteristics of the fuel market in the five European countries (1991–1996)[a]

	Netherlands	Belgium	Germany	France	UK
Share market leader	31%	17.5%	20%	14%	15%
Market share four largest companies	65%	55.5%	53%	38%	44.5%
Change market share 1991–1995	4%	3%	−5%	−4%	−9%
Share sales supermarket	4%	13%	11%	44.5%	22.5%
Share sales non-brand	15%	<13%	21%	3%	3%
Number of gas stations	4200	5225	18,130	18,710	16,610
Decrease of gas stations 1993–1995	9%	6%	2%	6%	10%
Average sales per gas station (m^3)	1750	1150	2650	2075	1990
No. gas stations per 1000 km road	25	38	36	23	42
No. stations per 100,000 inhabitants	29	52	23	33	29
No. gas stations per 100,000 cars	75	121	44	73	79

[a] *Source*: Coopers Lybrand, 1996, and own calculations.

has the entry of supermarkets into the fuel market not led to a price war, because the oil companies bought the gas stations of the supermarkets to keep the price constant. Supermarkets entered into the former East German fuel market that, prior to the opening of this market, had been the monopoly of a state-owned oil company. However, due to the already low fuel prices in this region, no real price war began here (see also the next section). The most severe price wars occurred in France and particularly the United Kingdom. In France the liberalisation of the fuel market aggravated further price competition between oil companies and supermarkets (the latter having already been active on the fuel market since the end of the sixties). However, in France the law forbids the sale of fuel below the cost price (in Belgium the government has done the opposite: a maximum price has been fixed). Nevertheless, the share of the fuel sales by supermarkets (4000 gas stations) in the French fuel market is high at 44.5%. The fuel price differences in France occur particularly in areas where large Hypermarché's (Carrefour, Leclerc, Auchan) are situated. The Hypermarché's sell fuel at 10% to 15% less than the official gas stations Total and Elf. Since Hypermarché's are located outside the built-up area, low fuel prices are a special enticement for urban customers. A major price war also took place in the United Kingdom between supermarkets and regular oil companies. Esso offered the lowest price guarantee for an area within three miles from its gas stations. Trade margins for fuel narrowed and loyalty-enhancing saving campaigns were halted. In the United Kingdom supermarkets seem to be the winners: their market share in fuel sales has increased from about 7% in 1990 to 22.5% in 1995. The average sales of supermarkets (9.300 m^3) are about three times higher compared to the national average. The losers – both in the United Kingdom and France – are the small, often non-brand gas stations. However, one has to remember that the figures presented concern the situation in 1996. When the price war ends, one may expect an increase in the margins of the firms.

Two more remarks concerning fuel price setting in the countries considered are noteworthy in our context. The first concerns the higher fuel prices in peripheral regions such as the Massif Central in France. These areas are remote and have fewer numbers of people; therefore the spatial density of the gas stations is low. This leads to relatively high costs for oil companies to provide these gas stations. The provision costs are differentiated in France. Thus, in remote areas people have to pay higher fuel prices and sometimes must detour for fuel because of the low density of gas stations.

The second remark concerns the price setting of gas stations located along German highways. They are allowed by the government to add 10.6 pfennig (5 €-cent) extra to the price of fuel. However, they are obliged to remain open 24 h a day and keep gas stations manned.

The three bottom lines of Table 2 indicate the density of the gas station network. In The Netherlands, the United Kingdom and France the density of gas stations is of the same order of magnitude, with the exception of the number of gas stations per 1000 km of road in the United Kingdom. Given these common network characteristics, it is no surprise that the average sales per gas station in those three countries are also similar. The shorter average travel distances in a small country like The Netherlands can account for the slightly lower average sales in The Netherlands. The average density of the Belgium gas station network is relatively high; as a consequence average sales are low in Belgium. The opposite occurs in Germany, where the density of gas stations per 100,000 inhabitants and per 100,000 cars is low and average sales are high. Given the low density of gas stations in Germany, it is in accordance with our expectations that the number of gas stations decreased the least in Germany during the period 1993–1995.

3. Spatial differences in fuel prices and their consequences on fuelling behaviour

In this section, we review situations in other countries which have spatial differences in fuel prices. Special attention will be paid to the consequences on fuelling behaviour. In Section 4 we will give a more detailed account of one particular case, namely cross-border fuelling of Dutch car drivers in Belgium and Germany.

Singapore has a fuel tax that is much higher than its neighbour Malaysia, but Singapore has discovered a way to reduce the fuel-fetching strategies of its car drivers. The government has imposed a law whereby cars leaving the city-state should have filled their tanks to at least 75% capacity. A small number of the cars crossing the border are halted to check for compliance. If the law is broken a fine is given. The result of this combination of regulation and fining is that cross-border fuel fetching becomes insignificant.

In Italy, another policy is followed to discourage cross-border fuelling to the much cheaper neighbour of Slovenia. Italian car owners along the border region receive a smart card containing information on the distance to the border and on the numberplate. Gas stations in the border region have a device that can read the smart card. The shorter the distance from a driver's residence to the border the lower the tax charged to the fuel buyer. The device produces reports for the Treasury with information on the volume of fuel sold at the various tax levels. As one moves away from the border, the tax increase per litre per kilometre is about 0.3 €-cent. This seems to sufficiently discourage large-scale cross-border fuel fetching. The system is functioning rather smoothly; the disadvantages of producing and distributing smart cards and the necessity for gas station owners to invest in special devices are minimal, because the border region is sparsely populated. However, there are possibilities for fraud: for example, someone visiting a friend in the region might use the friend's smart card to obtain cheap fuel and the gas station owner has no incentive to check if the car's number plate corresponds to the number on the smart card.

Luxembourg uses fiscal competition strategies to attract drivers of foreign cars, trucks and buses by offering low fuel taxes. The balance between the loss of tax receipts due to the lower tax collected from its own citizens, and the gain in receipts by the attraction of foreign tax payers indeed tends to be positive for small countries. The price difference between Luxembourg and the average price levels in its neighbouring countries is relatively high. For example, in Luxembourg the price of a litre of Euro 95 is 27 Belgian Francs (BFr) – 64 €-cent – compared to 36, 34 and 37 BFr in Belgium, Germany and France, respectively. Fuel-fetching trips are not only undertaken by inhabitants of border regions in France, Belgium and Germany, but also by freight transporters and coach operators located as far away as The Netherlands, who detour in order to refuel in Luxembourg. To avoid the French toll highways, lorries and coaches continue their southbound trips by passing through Luxembourg to reach the German toll-free highways. The environmental cost of this heavy traffic passing through the entire country is the price Luxembourg pays for this international fuel trade. Nevertheless, its financial gain appears to be more highly valued. Approximately 1 to 2% of the Luxembourg Gross National Product is earned from this international sale of fuel directly to foreign consumers. In reaction to situations such as that in the German-Luxembourg border region, fuel prices in Germany are regionally differentiated. The prices are low in regions bordering Eastern Europe and Luxembourg due to low fuel prices in those neighbouring countries. Fuel is even sold with losses at some locations in former East Germany along the border with Poland. Unfortunately, Coopers Lybrand (1996) do not indicate whether these lower fuel prices are due to a reduction in the governmental levies, or if they have to be paid for out of the distribution margin. Nor does it give information about the fuelling behaviour on the German side of those border regions.

An interesting case of spatial graduation within a country can be found in Norway which has implemented a strategy of collecting money for road expansion at the regional level by creating toll-rings around the cities of Bergen, Oslo and Trondheim. For the city of Tromsø another approach has been adopted. In this city and its vicinity, the fuel tax has been increased at a level of about 0.65 Kroner (about 10 €-cent) above the national level. The additional levies are raised to finance the orbital motorway of Tromsø, including some expensive tunnels underneath a deep fjord and beneath the city centre. Given the spatial structure of the Tromsø area where a large part outside the centre is scarcely populated, the number of fuel-fetching trips to inexpensive fuel areas has been small: the distance is simply too far to be worthwhile. The nearest inexpensive gas stations are along the highway running from the upper north to the south of Norway which passes Tromsø at a distance of about 70 km. This is not to say that fuelling behaviour has not changed. Those residents who make long distance trips to other destinations use the opportunity to buy cheap fuel there. It is estimated that as a consequence of the introduction of this local tax, fuel consumption in Tromsø has decreased by about 30%. Nevertheless, research by the Norwegian Institute of Transport Economics (TØI, 1991) showed that no significant negative mobility impacts occurred, since the fuelling is incorporated within the normal mobility pattern. However, it cannot be disregarded that in some cases the advantage of cheaper fuelling might be of decisive importance when comparing the pros and cons of a trip in the direction of cheaper gas stations.

4. Cross-border fuelling of Dutch car drivers

Given the difference in the fuel tax in The Netherlands and its neighbouring countries of Germany and Belgium, a substantial number of Dutch car drivers living in the border areas do their fuelling in the neighbour country. This has several adverse effects for The Netherlands:

(a) substantial losses for owners of gas stations in the Dutch border region;
(b) a loss of taxes (levies and VAT) for the Dutch Ministry of Finance;
(c) reduction of sales in shopping centres in the Dutch border region because the fuel price difference stimulates cross-border shopping;
(d) extra kilometres driven in The Netherlands for fuel trips.

The extent to which these adverse phenomena occur depends on the sensitivity of car owners to fuel price differences and on the spatial density of car owners in border regions. In the Dutch case it appears that this density is rather high (cf. Rietveld and Boonstra, 1995). There are numerous cities of more than 100,000 inhabitants located 20 km or less from the border. In 1992 and 1997 surveys were conducted on the extent to which car owners in border regions are actively involved in cross-border fuelling (NEI, 1997). The 1997 survey also contained stated choice questions where drivers could indicate if they would fuel abroad when price differences reached certain hypothetical levels. In this section we will first discuss in greater detail the empirical outcomes and then we will model the decision on the cross-border fuelling as a discrete choice problem.

The Dutch Ministries of Transport and Finance and the BOVAG (the Dutch organisation of car dealers and repair shops) assigned the survey-study in order to investigate the cross-border

Table 3
Prices and price differences in the Dutch border regions compared to neighbouring countries (Euro 95 in Dutch guilders, 2.2 guilders is 1 €)[a]

	Price in The Netherlands	Price difference compared to The Netherlands	
		Germany	Belgium
Price before 1 July 1997	201.3	−19.1	−4.4
Price after 1 July 1997	215.3	−29.5	−11.8

[a] *Source*: NEI, 1997.

fuelling impact of the increased fuel prices in The Netherlands by the first of July 1997. Table 3 provides information about the price of fuel in the Dutch border regions and the differences with the neighbouring countries before and after the increase of the Dutch levy. The border region is defined as an area up to 30 km on the Dutch side of the border. The fieldwork took place before (April–June 1997, 450 respondents), and after (September–October 1997, 475 respondents) the increase in the fuel tax.

Due to an increase in the Belgium fuel levy, the price difference compared to the Dutch price in the 'after' situation has not increased as much as it has in Germany. An interesting finding of the study was that respondents systematically over-estimated the price differences between the Dutch and the foreign fuel prices. This holds true for Belgium, where respondents could have been unaware of the increased levy in Belgium, but it also holds true for Germany. This over-estimation can partly be explained by the possible unawareness of the respondents that fuel prices in the Dutch border regions are slightly lower than the national average.

In Table 4 the percentages are given of Dutch car owners in the 30 km-wide region towards the German or Belgian border who are fuelling in The Netherlands, abroad, or in both respective countries. The results give a first indication of the cross-border fuelling behaviour. Given a difference of 4.4 cents per litre, 82% of Dutch car owners regard the price difference as too small to make cross-border trips worthwhile. This percentage decreases to 77, 72 and 58% by increasing the price difference to 11.8, 19.1 and 29.5 cents, respectively.

In a stated preference approach we tested how large the cross-border fuel leakage would be, given fixed differences in fuel prices. When price differences are relatively small some remarkable differences are found. The stated cross-border leakage of fuel consumption is similar in both border regions from about 20 cents upwards, as can be seen in Table 5. With small price differences the leakage to Germany is smaller than the leakage to Belgium. Later on in this section we will demonstrate that there is indeed a higher threshold value for cross-border fuelling in Germany.

Table 4
Revealed fuel behaviour of residents of the Dutch border region (0–30 km distance from border) before and after 1 July 1997[a]

	Country of fuelling			Country of fuelling		
	Netherlands %	Germany %	Both %	Netherlands %	Belgium %	Both %
Before	72	9	19	82	9	9
After	58	28	14	77	13	10

[a] *Source*: NEI, 1997.

Table 5
Stated fuel behaviour for various cross-border price differences in cents per litre (as % of the total fuel consumption of the Dutch car owners in border regions bought abroad)[a]

	5 cent	10 cent	15 cent	20 cent	30 cent	40 cent
Germany	4.7%	6.0%	–	35.2%	48.3%	56.3%
Belgium	–	20.8%	29.1%	37.9%	51.0%	56.6%

[a] 100 cents are equal to 1 guilder. *Source*: own calculations based on NEI, 1997.

Table 6
Main reason for Dutch drivers to fuel abroad, before and after fuel tax raise[a]

	Germany		Belgium	
	Before (%)	After (%)	Before (%)	After (%)
Fuelling	29	63	16	27
Shopping	28	13	25	22
Work	5	5	6	4
Family visit	12	5	19	14
Other	26	14	34	33

[a] *Source*: NEI, 1997.

The survey gives interesting information about the reasons behind the fuel behaviour of the Dutch car owners in the German and Belgian border regions. Table 6 shows that in most cases cross-border fuelling occurred in a multi-purpose trip in which another activity, such as shopping or social visits, was decisive in undertaking the trip. The increase in Dutch fuel taxes after the first of July 1997 has significantly increased the cross-border trips towards Germany and Belgium for which fuelling is the main incentive.

In Table 7 the main reasons are given why car owners in the border regions make no cross-border fuelling trips. In those results no distinction is made between the German and the Belgian border region. The percentage of respondents who do not make such cross-border fuelling trips decreases from nearly 30 to just 20% by the rise in the fuel tax. The main reason for not making cross-border fuelling trips is because the gains are unsatisfactory compared to the costs. The costs are here expressed in time and distance. However, after the rise in the Dutch fuel tax the time element in particular becomes less important. The percentage of respondents who only receive reimbursement with Dutch tickets is unexpectedly low. A relatively large number of the respondents are misinformed; they think that fuel prices abroad are higher than Dutch prices. [2]

After having presented a qualitative discussion on the results of the survey, we now proceed with a quantitative analysis of the fuel behaviour based on the data. We formulate the decision on the location of fuelling as a discrete choice problem with two alternatives; fuelling in The Netherlands and fuelling abroad. We assume that fuelling in one's own country does not lead to

[2] Here a misinterpretation might occur. Business drivers often stated that fuel abroad was more expensive because they could not get reimbursement for fuelling abroad. Thus, apart from the fuel prices, fuelling abroad is expensive for business drivers.

Table 7
Main reason for Dutch drivers to *not* fuel abroad[a]

	Before 1 July 1997		After 1 July 1997	
	All respondents (%)	People fuelling only in The Netherlands (%)	All respondents (%)	People fuelling only in The Netherlands (%)
Price difference too small	4.5	15.1	3.6	17.4
Repayment of fuel costs	1.7	5.6	1.2	5.7
Distance to the border	4.4	14.8	2.7	13.0
Too time consuming	9.3	31.4	3.7	17.7
Fuel more expensive abroad	3.1	10.5	1.6	7.7
Other reasons	6.7	22.6	8.0	38.5
Total	29.7	100	20.8	100

[a] *Source*: NEI, 1997.

extra kilometres driven: people merely fuel near their residence or they purchase fuel while en route for travel purposes.

With regard to fuelling abroad we make the opposite assumption that it does lead to extra kilometres driven. The number of cross-border trips made by Dutch residents is small: Dutch residents live 'with their backs to the border' (see Rietveld, 1994). For example, cross-border commuting is a rather unimportant phenomenon. The number of extra kilometres for a fuelling trip is estimated to be the distance from the residence to the border. This is indeed an approximation, but one should realise that on all main roads crossing country boundaries there are gas stations at border sites. This implies that if people decide to go further into the neighbouring country it is likely that they have other motivations than just fuelling. For example when people decide to fuel abroad some of them decide to combine fuelling with shopping abroad.

Let now the utility of fuelling in one's own country N be equal to:

$$U_{\mathrm{N}} = \alpha_{0\mathrm{N}} + \alpha_1 p_{\mathrm{N}} + \varepsilon,$$

where p_{N} is the fuel price that has to be paid in The Netherlands (Dfl's). The α's are parameters that have to be estimated.

The utility of fuelling in Germany is:

$$U_{\mathrm{G}} = \alpha_{0\mathrm{G}} + \alpha_1 p_{\mathrm{G}} + \alpha_2 d_{\mathrm{G}} + \varepsilon.$$

Here, p_{G} is the price paid in Germany and d_{G} is the distance to the German border (km). Under the usual assumptions on the distribution of ε (see Cramer, 1991), the logit model allows us to estimate the coefficients α_1, α_2, and $\alpha_{0\mathrm{N}} - \alpha_{0\mathrm{G}}$ (denoted as $\alpha_{0\mathrm{GN}}$). The latter coefficient represents the expected difference between the non-price and non-distance related aspects of attractiveness of fuelling in one's own country compared with fuelling in a border country. If $\alpha_{0\mathrm{GN}}$ is positive, it implies that the combination of the price and distance difference should exceed a certain threshold before Dutch residents would fuel abroad.

A similar formulation can be carried out for Dutch residents in the Belgian border region (*G* is replaced by *B*). The estimations of the resulting logit model are presented in Table 8.

Table 8
Estimation results for logit model on cross-border fuelling (revealed preference data and stated preference data)

Data	Estimated logit coefficients				Standard errors				Log likelihood	
	α_{0GN}	α_{0BGN}	α_1	α_2	$\sigma(\alpha_{0GN})$	$\sigma(\alpha_2)$	$\sigma(\alpha_2)$	$\sigma(\alpha_2)$	Unrestricted	Restricted
Stated	−1.3955	−1.0508	−0.0805	−0.0731	0.1033	0.0033	0.0033	0.0033	−2174.2826	−2803.2811
Revealed	−2.0263	−1.0685	−0.1071	−0.1236	0.4045	0.0084	0.0084	0.0084	−678.2960	−909.5408
Both	−1.6201	−1.1309	−0.0867	−0.0806	0.0926	0.0030	0.0030	0.0030	−2891.6866	−3785.6037

We report estimations for the stated preference data, the actual fuelling data, and the combination of both. [3] Note that price is measured in Dutch guilders (Dfl.), as is the case in the remainder of this section. We observe that the resulting parameters of the two types of data are of comparable orders of magnitude. In Fig. 1 we present the results of the estimation in the form of a curve indicating the percentage of respondents who will fuel in Germany as a function of the distance from the residence for various levels of price differences. It appears that with a difference in fuel prices by 10 cents per litre, approximately 30% of people living at the border decide to fuel in Germany. On the other hand, approximately 5% of all respondents living at a distance of 30 km from the border will still fuel in Germany. Given this price difference there is clearly a substantial variability among people in their responses to the option of fuelling abroad. [4]

The trade-off between price difference and extra kilometres is equal to the ratio-α_2/α_1. This ratio equals −0.91,−1.15 and −0.93 [dimension: cent per litre of fuel per km] for the three estimates in Table 8, respectively. This means that drivers living at (say) 10 km from the border observing a price difference of (say) 20 cents per litre will have the same utility as drivers at 11 km with a price difference of 21 cents per litre (more accurately: 20.93 cents per km).

How does this trade-off compare with the actual gains and costs of cross-border fuelling? Consider a person living at a distance of 10 km from the border. The fuel price is about Dfl 2.00 at the German side of the border. Assuming an efficiency of some 13 km per litre, the fuel trip vice versa would cost about Dfl 3.00 in fuel. The potential gains would be about 40 litres (the size of the tank) times the price difference. Per kilometre, the break-even price difference in fuel would be about 0.75 cents per litre, which happens to be slightly lower than our estimate.

The difference between the two figures can be explained by the driver's evaluation of travel time. If we would assume an average speed of 60 km/h, the round trip of 10 km would require 20 min. These 20 min would break even with the gap between the monetary gains of the trip (Dfl 4.00) and the monetary costs (Dfl 3.00). This implies that car drivers use a very low value for their travel time saving related to fuelling trips (Dfl 1.00 per 20 min implies only Dfl 3.00 per hour). This may be explained by the fact that fuelling abroad often occurs during weekends when time schedules are more relaxed. [5]

[3] The joint estimation has been based on the assumption of homoscedasticity of errors in revealed preference and stated preference data. For a review of approaches to model heteroscedasticity we refer to Hensher et al. (1999).

[4] The estimation results presented in Table 8 and Fig. 1 are not directly comparable to the outcomes of Table 4 and Table 5; the difference is that Table 4 and Table 5 relate to the total border zone (0 to 30 km from the border), whereas Fig. 1 gives an estimate for each distance separately.

[5] Other possible explanations are that the fuelling trips are often combined with cross-border shopping. In addition the low value of time that is found here may result from an underestimate of the monetary costs of fuelling trips.

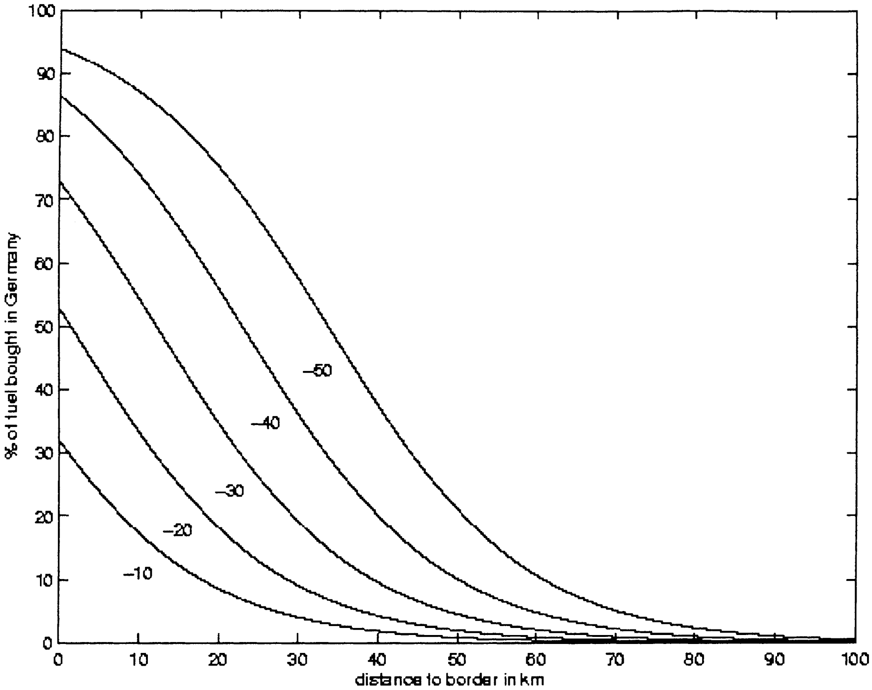


Fig. 1. The expected fraction of Dutch residents that buy their fuel in Germany, given price differences between the two countries (10–-50 cents per litre).

It must be emphasised however, that there is much variability among drivers. The trade-off value of 1 cent per litre per km that was computed earlier is an average figure from which there may be quite some deviation for the individual driver. Fig. 1 confirms this preference heterogeneity.

In a similar way as above we can estimate the trade-off between the price difference in two countries and the dislike for fuelling abroad. By computing the ratio between α_{0GN} and α_1, we find the border threshold expressed in terms of Dfl per litre of fuel. For the German border this ratio equals about 18 cents per litre. Thus, the average driver living at the border is indifferent to fuelling in both countries when the price difference equals about 18 cents per litre. For the Belgian border we find a somewhat smaller amount of 13 cents per litre. This difference may be explained by the language difference (Belgium and The Netherlands have Dutch as a common language, whereas The Netherlands and Germany speak different languages). Another explanation may be that Belgium is a more attractive country for shopping compared to Germany because of more liberal opening times (see Rietveld, 1994, for a more extensive discussion of border-related barriers on spatial interaction).

The implication of this analysis is that the average Dutch driver trade-off distance travelled to a cheaper gas station at about 1 cent per litre per km. If this figure were to be taken as a basis for a graduation profile in The Netherlands, we would obtain substantial spatial differences in fuel prices. However, although such a slope is based on the break-even level, such a steep graduation profile would induce substantial movements of drivers to places with inexpensive fuel. Fig. 1 shows that the variation in fuelling behaviour is large: a substantial number of drivers are keen on fuelling at cheap places and underestimate the costs involved. Therefore, if a government wants to minimise fuel fetching trips within the country it is recommended to set the slope of the graduation profile lower than 1 cent per litre per km. Note that the slopes implied by the Italian and Norwegian case equal 0.67 and 0.30 cent per litre per km, respectively.

5. Graduation profiles and criteria for evaluation

Kanbur and Keen (1993) show that if the maximisation of tax receipts is the most important objective of a government, then the smaller country is mostly better off by setting the tax rate at a lower level than the bigger neighbour country. In that case the lower tax receipts from the own population are more than compensated for by the tax receipts from the inhabitants from the neighbouring country. This theoretical result seems contradictory with the case in hand, where the small country (The Netherlands) imposes a higher tax rate than its neighbours. The fact is however that the Dutch government does not simply act as a revenue maximiser. Instead the government may aim at the following multiplicity of objectives:

1. maximise the opportunities for achieving a decrease in driving mileage (particularly in regions where severe congestion occurs);
2. minimise the undesired side effects of fuel-fetching trips: detours that incur extra mileage;
3. minimise the decrease in fuel sales by gas station owners in areas located near inexpensive fuel regions;
4. maximise the total fuel tax revenues within the country.

One can think of several policies to deal with these objectives. In Section 3 we mentioned (partial) closed border policies and spatial tax differentiation. Given the fact that the EU is a free trade zone, the first policy is not a likely alternative for the Dutch government, so we focus on the policy of a spatial differentiation of the tax profile. We note that this policy is probably not optimal from an international (EU) perspective. If foreign governments became an integrated part of the analysis, then cooperative policies could have been studied, like for example *tax harmonisation*. For now however we take the foreign tax rates as given.

Below we will confront various forms of spatial tax differentiation with the four criteria mentioned above. In this section the evaluation of those forms will be in a qualitative manner, as opposed to Section 6 which will test some policies in a quantitative way. The emphasis in this quantitative analysis is on the average tax level, the average tax level when fuel behaviour changes within present mobility patterns, the impact for fuel sales in various areas of The Netherlands, and the impact on the mileage. The calculations are based on and compared with the present mobility pattern of car owners in The Netherlands. Before sketching alternative spatially differentiated fuel tax profiles, the current situation will be described.

5.1. Current situation

Differences in the fuel prices are now largely due to differences in national taxes as shown in Section 4. Car owners in the Dutch border regions are making fuel-fetching trips to Germany and Belgium. There is an increase in cross-border fuel behaviour as the distance from the residence of the car owner to the border decreases. Given the result of Fig. 1, the foreign fuel leakage can be

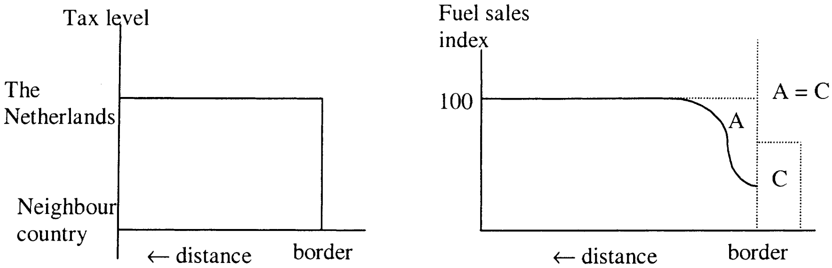


Fig. 2. The current situation of cross-border fuelling in The Netherlands.

represented by an s-shaped curve (see Fig. 2). In Fig. 2, 'A' represents the fuel leakage to foreign countries ('C'), thus in the current situation $A = C$, and fuel sales at level 100 means that the sales level is equal to the fuel demand of local residents. [6]

The present situation does not meet with any of the four above-mentioned criteria. It is noteworthy that in the case of fuel leakage abroad, the Dutch government loses all fuel tax, whereas the consumer only gains the difference between the foreign tax level and the domestic tax level. In other words, the loss of taxes of the national government is larger than the gains to the consumer.

5.2. Alternative 1: low tax border zone

A solution for preventing the leakage of fuel taxes abroad might be a uniform tax raised throughout the country with the exception of a small zone along the border. In this zone, taxes should be set so that the same price level as in the neighbouring country is achieved. Such a system will to a large extent avoid cross-border fuel-fetching trips (see Fig. 3). Car owners will refuel just before the border and then turn around. Tax revenues will be maximal due to the surge of fuel sales in those zones, which before had leaked abroad. The sales of the gas station owners in these zones will increase strongly, but the gas station owners just outside these zones will suffer from a severe drop in sales. This profile does not alter the current situation of fuel-fetching trips, nor does it decrease mileage in congested regions.

There will be a shift in the receiver of the gains of car owners fuelling at cheaper locations (see Fig. 3). Where in the present situation loss in sales (A) leaks abroad, in this profile the majority remains in the country (B), and only a minor percentage will continue to leak abroad (C).

5.3. Alternative 2: linear tax profile

In a linear profile the fuel prices on the border equal the prices of the neighbour country and increase by a fixed amount when the distance to this border increases (see Fig. 4). This is another

[6] The constraint $A = C$, or $A = B + C$ in the next figures is imposed to indicate that total domestic plus cross border fuel consumption is constant. In reality this is a simplification which is not entirely correct. First of all, fuel use for cross border trips is not taken into account. In addition, since fuel in the neighbour country is cheaper, it will induce a somewhat higher level of demand.

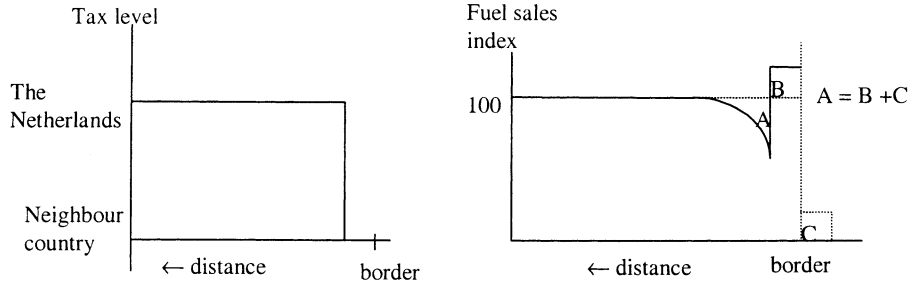


Fig. 3. Low tax border zone.

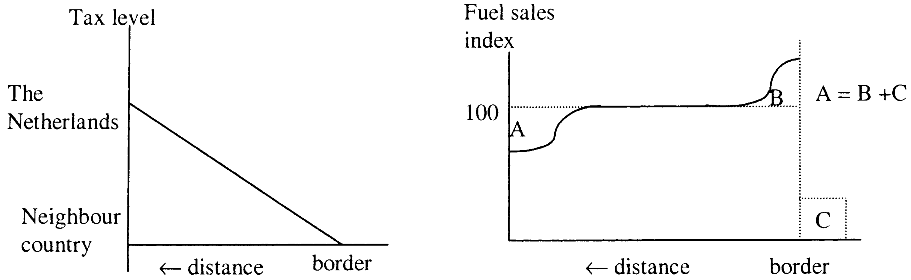


Fig. 4. Linear tax profile.

solution for solving the problem of cross-border fuel-fetching trips. When such a profile is implemented, fuelling behaviour will change accordingly. Car owners will refuel at the time when they are nearest to the border. Thus, the most inland-located gas station owners will confront a serious decrease in their fuel sales; however, gas station owners near the borders will gain fuel sales. Two regimes can be discerned here: a moderate profile, where financial gains of fuel-fetching trips are smaller than their costs and a steep profile, where fuel-fetching trips are profitable.

5.4. Alternative 3: linear tax profile with ceiling

If one wants to avoid the decrease of sales of inland gas station owners, one might apply a gradual profile up to an upper limit and keep the price constant from there onwards (see Fig. 5). Also in this profile, gas station owners located in the area near the point where the ceiling is reached will encounter decreases in their fuel sales, depending on the steepness of the slope.

In Table 9 we present the impacts of the profiles on the criteria mentioned at the beginning of this section. Given the present situation the profiles are compared by their impacts on:

1. maximisation of fuel tax revenues;
2. impacts on the sales of gas station owners in: (i) border region, (ii) middle part of the country, and (iii) most inland part of the country;
3. fuel-fetching trips in the three above-mentioned regions;
4. impacts on the mileage in those three regions.

Table 9 is of a tentative character. The exact size of the impacts is strongly dependent on the steepness of the slopes of the profiles. When considering the mileage, one has to remember that

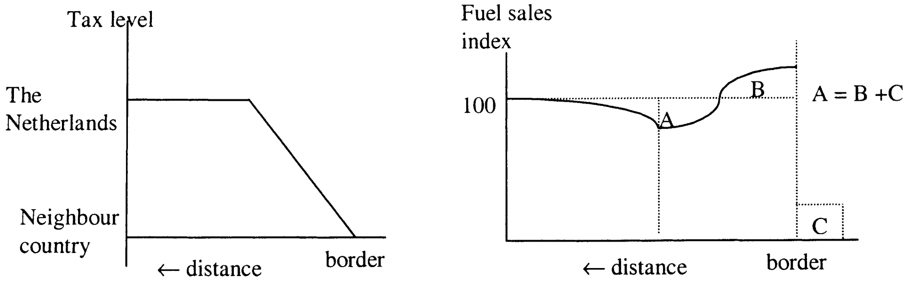


Fig. 5. Linear tax profile with ceiling.

Table 9
Overview of the impacts of the spatially differential fuel tax profiles (reference case: situation in which cross-border taxes are equal)[a]

	Present situation	Low tax border zone	Linear steep	Linear moderate	Linear ceiling
Fuel tax revenues/Sales gas station owners*					
Border region	– –	+++	++	+	++
Middle part of the country	–	–/– –	–/0	–/0	–/– –
Most inland part	0	0	– –	–	0
Fuel-fetching trips					
Border region	– –	– – –	0	0	0
Middle part of the country	–	–/– –	– –	–	–/– –
Most inland part	0	0	– –	–	0
Average fuel price paid by inhabitants					
Border region	+	– – –	+	+/0	+
Middle part of the country	++	0	++	+/++	++
Most inland part	++	0	+++	++	++

[a] Impacts are equal when gas station owners are not compensated by governmental subsidies.
* + = positive impact given the policy criteria, – = negative impact given the policy criteria.

two opposing forces are at work here: (i) a steep profile encourages fuel-fetching trips and (ii) a steep profile means on average high fuel prices, and thus low mileage (price elasticity of fuel). The exact balance between the two opposing forces is difficult to determine a priori.

Another perspective from which to compare the graduation profiles is from the legal standpoint. A possible legal problem with the 'maximum revenues' policy is that it puts gas station owners in an unevenly competitive position. Legislation on fair competition within countries may prevent governments from introducing large differences in fuel taxes. [7] The remaining linear profiles are interesting for further research. We will investigate two variants of the linear profile with and without a ceiling. In the next section the average tax level, the actual paid average tax,

[7] It is ironical that where rules of fair competition may obstruct (substantial) tax differences within countries, the present rules in the EU still allow much larger tax differences between countries.

and the impact on the mileage are calculated given the present mobility pattern of car owners and graduation slopes of 0.5 and 1.0 cent per litre per km distance from the border. The ceiling equals the present Dutch tax level of 157.8 cents (levies and VAT).

A final point that deserves attention is the fairness of spatial tax differentiation for the consumers. Spatial graduation is at variance with the horizontal equity principle of 'equal treatment of equals'. One may argue, however, that this is not an absolute principle since property taxes, parking fees and public transport subsidies also vary from place to place. Also, a uniform fuel tax that is higher than the tax in the neighbouring country leads to inequality, because only citizens near the border can benefit from the low tax in the other country. Finally, a rationale for spatial differentiation of taxes is that external effects of transport vary across space, for example when congestion levels are low in border regions.

6. Changes in the location of fuelling for alternative graduation profiles: simulation methods

In this section, we analyse the individual opportunities of car owners to buy cheaper fuel when a spatially differentiated fuel tax is implemented. The starting point for the analysis is the current mobility pattern of car owners in The Netherlands. This means that we analyse the possibilities for buying cheaper fuel in The Netherlands other than what is paid at the residence location. We assume in our analysis that only fuel behaviour will change. As a database we use OVG, which is the most complete survey of travel behaviour in The Netherlands. There is a problem, however, when one wants to use it for a study of refuelling behaviour: the OVG only contains observed travel behaviour during one day, whereas refuelling behaviour usually occurs in cycles greater than one day (often a weekly cycle is used). To investigate the potential opportunities for drivers to refuel at cheap locations, one needs to know the locations they typically visit each week. Taking information on trips made during only one day would lead to an underestimate of the opportunities for cheap refuelling during a weekly cycle. Therefore, we use a method to simulate weekly travel patterns based on daily data, by creating a large number of strata of drivers in terms of their distance to the border (30 groups in distance classes of 5 km), and in terms of their reported annual mileage in thousands of kilometres (5 groups: 0–10, 10–16, 16–25, 25–40 and >40). By using these two dimensions it is expected that drivers with similar opportunities for cheap refuelling are combined in the strata. The next step is that we simulate for each stratum weekly travel patterns based on daily patterns by combining the dimensions. Since many drivers have a regularity in their behaviour of similar travel patterns during weekdays and other types of travel patterns during the weekend, weekly patterns are simulated by assuming that the weekday pattern is repeated five times and then combined with two independent drawings of daily trip patterns made on Saturdays and Sundays. For each simulated weekly pattern it is assumed that drivers refuel at the cheapest location. When they drive long distances during the week, so that one fuelling is insufficient given the capacity of the tank, they are assumed to do additional refuelling at the cheapest possible location during the days their tank would become empty. For certain categories of drivers it will appear that opportunities for refuelling at cheaper locations other than at the residence location are limited: this pertains to drivers who live near the border, who only make short trips, or who only travel to places where fuel is more expensive (farther away from the border).

Details on the simulation method can be found in Bruinsma et al. (1998). The lack of data on weekly travel patterns is obviously a disadvantage when one wants to analyse refuelling behaviour. Our results depend to some extent on the approach used to simulate weekly travel patterns as well as on the assumption that drivers will always use the opportunity to refuel at the cheapest place. This means that they are assumed to be fully informed, that there is a low-cost gas station at the closest location to the border where they happen to be (as is the case at most border crossings), and that they use every opportunity to refuel at a cheaper place, even if the price difference is very small. The results reported below may be interpreted as maximum estimates of changes in refuelling behaviour.

The tax gains for the average car owner due to refuelling at cheaper locations than in the residence location are given in Table 10. Obviously, the tax gains are higher in profiles without a ceiling due to the larger number of car owners who achieve gains. The financial effects in the case of a steep graduation profile (without a ceiling) are about two times stronger than the effects with a moderate profile. About two out of every three drivers (64%) will benefit from the introduction of a graduation profile. Those who do not benefit are drivers who live very near the border on the one hand and drivers whose travel pattern is oriented away from the border on the other hand. The table also shows that the introduction of a ceiling in the graduation profile apparently leads to smaller effects.

The average percentage reduction in the fuel taxes if car owners fully use opportunities to refuel at the cheapest locations instead of fuelling at the residence location, given the present mobility pattern, are shown in Table 11 (for the absolute figures we refer to Bruinsma et al., 1998). In this table the different mileage classes are identified along with a number of distance zones, which refer to the residence location of the car owners in relation to the border.

Reductions in fuel taxes increase (in absolute and relative terms) as mileage of car owners increases. The reductions also increase (in absolute and relative terms) by increasing the distance of the location of residence from the border when profiles without a ceiling are implemented. The absolute increase in fuel tax is obviously larger than the reduction received, thus by an increasing distance of the location of residence from the border, the fuel tax is increasing.

When a profile with a ceiling is implemented, the reduction is increasing at short distances from the border. Due to the ceiling this reduction decreases again at a rather short distance from the border. In our study the reduction falls below 3% at a distance of about 80 km from the border with a slope of 0.5 cent per litre per km, or by about 40 km when a slope of 1.0 cent per litre per km is implemented. However, the absolute fuel tax paid is lower at greater distances from the border when a profile with a ceiling is implemented. For instance, when a profile with a slope of 1.0 cent per km without a ceiling is implemented, car owners living between 145 and 150 km from

Table 10
Potential weekly gains of car users for refuelling at cheaper locations

	Slope 0.5 cent per kilometre		Slope 1.0 cent per kilometre	
	No ceiling	Ceiling	No ceiling	Ceiling
Paid tax	Dfl 57.41	Dfl 54.84	Dfl 67.09	Dfl 56.33
Tax gains	Dfl 2.90	Dfl 1.54	Dfl 5.74	Dfl 1.34
Percentage drivers who benefit	64%	45%	64%	33%
Average gains of car owners who benefit	Dfl 4.53	Dfl 3.42	Dfl 8.97	Dfl 4.06

Table 11
Difference between the paid fuel tax at the cheapest location and the fuel tax paid at the location of residence (as a percentage of the tax paid at the location of residence)

	Slope 0.5 cent per kilometre		Slope 1.0 cent per kilometre	
	No ceiling	Ceiling	No ceiling	Ceiling
Total	4.8	2.7	7.9	2.3
Mileage				
<10,000 km	3.6	2.0	6.0	1.9
10,000–16,000 km	4.1	2.3	6.7	2.1
16,000–25,000 km	4.6	2.6	7.5	2.3
25,000–40,000 km	5.4	3.0	8.7	2.5
>40,000 km	5.9	3.5	9.6	2.8
Distance to the border				
<5 km	1.0	1.0	1.0	1.0
20–25 km	3.1	3.1	5.3	5.1
45–50 km	4.1	4.0	6.8	2.8
70–75 km	6.0	3.5	9.3	1.6
95–100 km	8.0	2.8	11.8	1.7
120–145 km	7.9	1.3	12.1	0.7
145–150 km	12.4	1.4	17.3	0.5

the border pay Dfl 107.45 fuel tax (including a reduction of Dfl 22.55), whereas in the same profile with a ceiling, these figures drop to Dfl 60.35 and 29 cents, respectively.

After discussing the gains for car owners, we now focus on the spatial impacts of the changed fuel behaviour on fuel sales (see Fig. 6). The changing fuel behaviour of car owners will have impacts on the sales of gas stations according to their distance to the border. Some gas stations will experience an increase in sales, whereas others will encounter severe decreases in their sales. When the profiles without a ceiling are implemented, it is clear that gas station owners near the border have an advantage. All car owners will fuel at the location closest to the border within their weekly mobility pattern. Thus, car owners living at 50 km from the border will refuel at a distance of about 25 km from the border, and car owners living at 75 km will refuel at a distance of about 50 km. The most inland-located gas station owners will be burdened by severe reductions in their fuel sales. The fuel sales balance becomes negative at a distance of about 70 km from the border. The spatial shift in fuel behaviour will be relatively large: gas station owners in the border region will double their sales, but sales drop below 50% for gas station owners at locations beyond 100 km from the border. However, this is the worst case scenario: in which all car owners have optimised their fuel behaviour. In particular when a moderate slope is implemented, some car owners ignore the price differences. It may be expected that car owners will only respond to price incentives once a certain threshold is exceeded.

When a profile including a ceiling is implemented, gas station owners located in the surrounding regions where the ceiling is reached (30 and 60 km from the border, depending on the slope of 1.0 and 0.5 cent per km, respectively), have lower sales. However, the decrease in sales by the more inland-located gas station owners is fairly small.

Finally, we analyse the impacts of the four spatially graduated profiles on the average paid fuel tax and the average mileage driven. We compare the results with the situation before the last tax increase in July 1997. In other words, what would the impact have been if a spatially differentiated

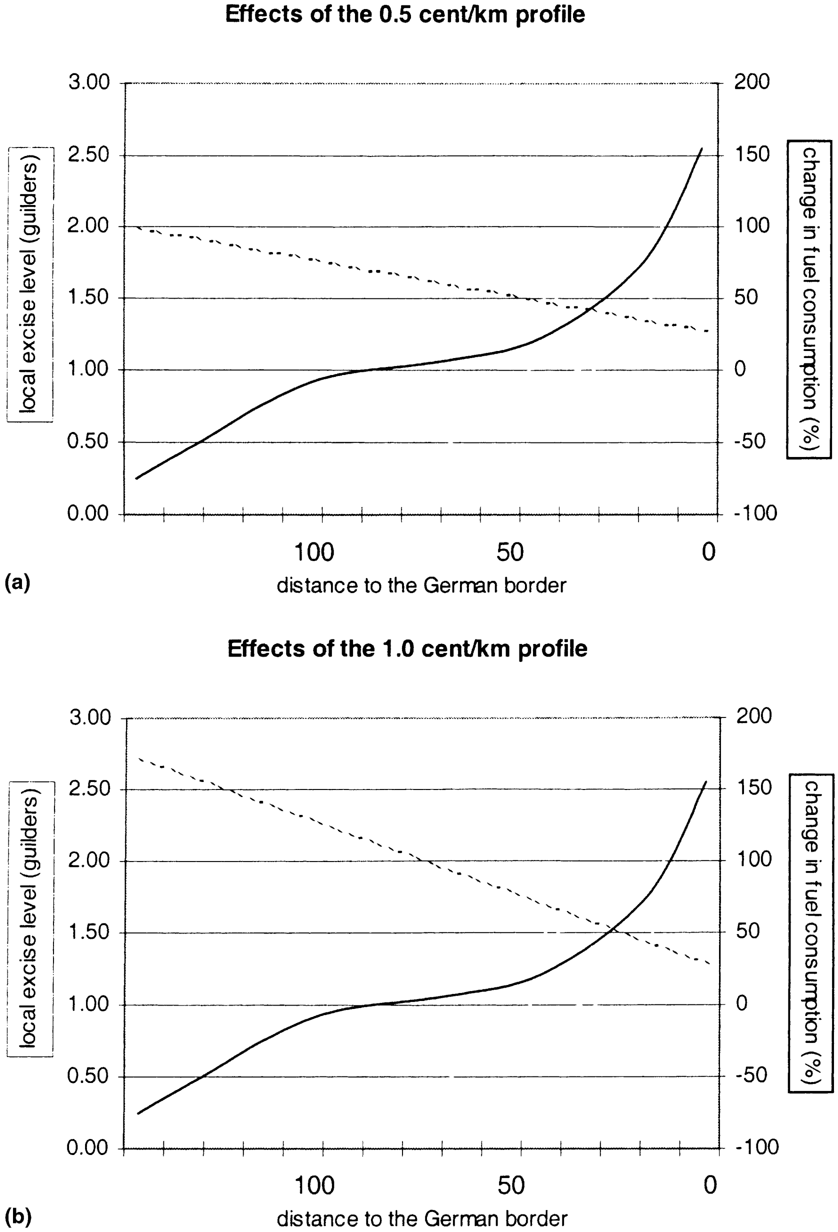
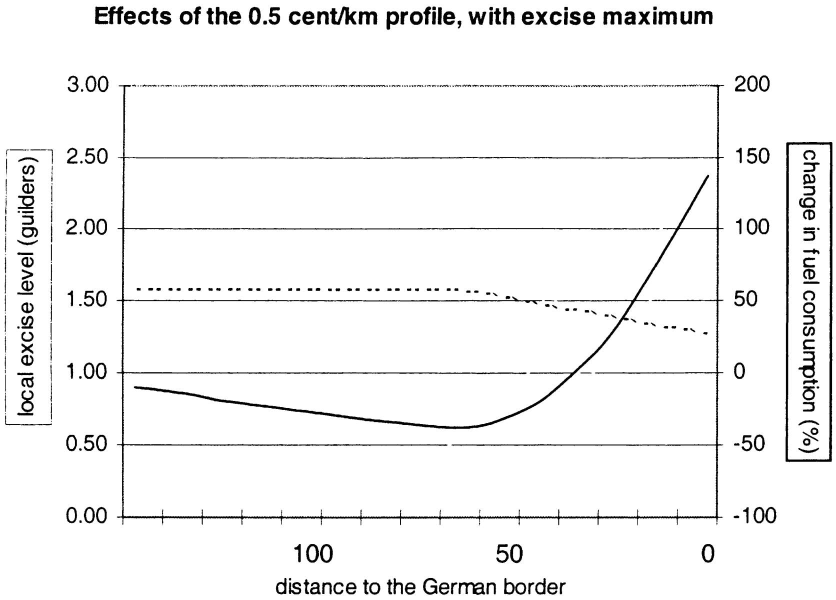


Fig. 6. Effects of various graduation profiles.

tax regime were implemented instead of the uniform increase in the fuel tax of July 1997? Although there were already differences in fuel prices between The Netherlands and Germany and Belgium, we estimate that due to the tax increase of July 1997, cross-border fuel-fetching trips have led to a doubling of the fuel leakage abroad. Annually, 325 million litres of fuel – about 5.6% of total Dutch fuel sales- is leaking abroad, compared with 160 million litres prior to mid-1997 (NEI, 1997).



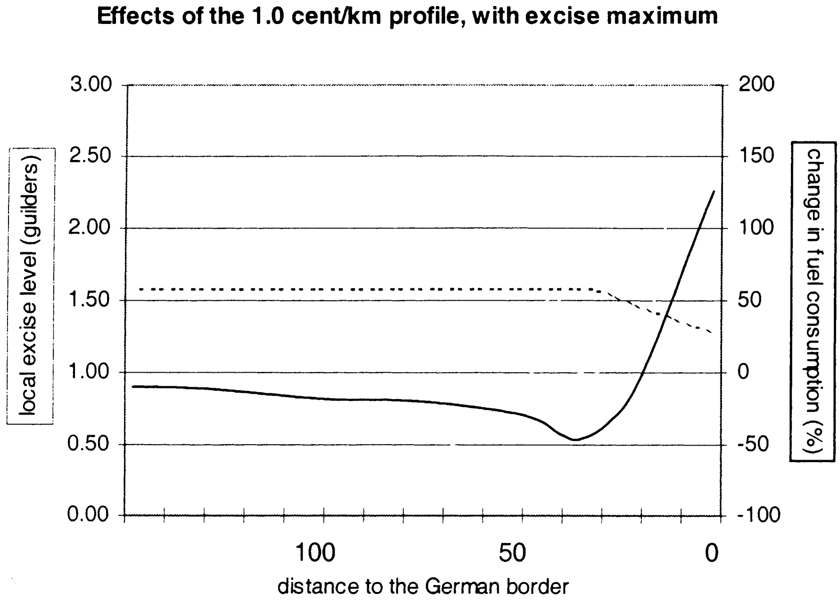


Fig. 6. (Continued).

In the profile with a ceiling at the level of the Dutch fuel tax after June 1997 (158 cents per litre), the minimum price at the German border is 126 cents per litre. The average tax level when the moderate profile (0.5 cent per litre per km (c/l/km)) is implemented, would be 148 cents per litre if all car owners continue to refuel at their location of residence (see Table 12). In the event of the steeper 1.0 c/l/km profile, the average tax level would be 152 cents per litre. However, when car

Table 12
Impacts of tax profiles on the average tax level paid and mileage

	Average fuel tax, changing fuel behaviour excluded (cents per litre)	Average fuel tax, changing fuel behaviour included (cents per litre)		Impact on mileage, compared with policy-off situation (%)	
		Optimal	50% opt.	Optimal	50% opt.
Policy-off Fuel tax June 1997	142	142	142	–	–
0.5 c/l/km profile	155	147	151	−1.4	−0.8
0.5 c/l/km + ceiling	148	144	146	−0.6	−0.3
1.0 c/l/km profile	181	166	174	−5.0	−3.7
1.0 profile + ceiling	152	148	150	−1.2	−0.9

owners optimise their refuelling behaviour without changing their mobility patterns, the average taxes paid decrease to 144 and 148 cents per litre, respectively. As already mentioned above, these figures should be considered as minimum levels.

Due to a neglect of relatively small price incentives and car owners' lack of information on fuel prices, it is more realistic to expect about half of the opportunities to be used. In this situation the average fuel tax will be 146 cents with the moderate profile and 150 cents in the case of the steep profile. These tax levels are slightly higher than the June 1997 tax level. The impacts of these profiles on the average mileage will be accordingly moderate.

Assuming a −0.3 price elasticity of the demand for car kilometres [8] (and a fuel price of 50 cents without levies), mileage is expected to decrease by about 1% in the profile with a steep slope and about half of that percentage in the moderate slope profile.

The increases in the average tax paid in the profiles without a ceiling are considerable: 155 and 181 cents in the profile with slopes of 0.5 and 1.0 cent per km, respectively. Because of changes in fuelling behaviour the fuel taxes paid will be between 147 and 151 cents in the profile with a moderate slope and between 166 and 174 cents in the profile with a steep slope.

Thus, only when the steep profile without a ceiling is implemented, would the average tax paid become higher than the actual situation due to the uniform tax increase to 158 cents by July 1997. This is also the only profile that leads to a substantial negative impact on the mileage driven by car owners. An opportunity to increase this impact on car mobility would be to allow a small price difference with neighbouring countries. [9]

We conclude that the largest effects may be expected from the steep graduation profile. However, this profile has the clear risk that substantial fuel-fetching trips will occur. A more moderate profile is therefore preferred. Another consideration is the position of gas station owners. As shown in Fig. 6, spatial graduation may substantially affect the profitability of gas station owners in particular zones. This holds true especially for the graduation profiles without a ceiling. In the long run it may lead to the closure of many gas stations in these zones.

[8] This is the figure used by the Dutch Ministry of Transport (1990). It is not far from the average figure reported by Oum et al. (1992) and Goodwin (1992) in an international comparative study.

[9] Note that we found in Section 4 that cross-border fuelling remains at low levels as long as the price difference between countries is not higher than about 5 cents per litre.

Compensation to these owners may be expensive. The profiles with a ceiling perform better than the linear profiles in this respect.

Remarks are in order about the assumptions on which our approach is based. We have assumed that fuel price differences are so small that fuel-fetching trips will not be undertaken, however, our assumption that travel behaviour will not change accordingly may not be entirely true. The problem is that spatial price differences in fuel may affect travel behaviour: for example, the location of shopping activities may shift if a shopping alternative becomes more attractive because fuel is cheap at certain places. The same holds true for other leisure trips. The effect of this change in travel patterns is probably that drivers increase their mileage. Another point worthy of attention is that in our simulation we have assumed that travel patterns will remain the same. However, when drivers gain access to cheaper fuel this will (slightly) affect their travel patterns (note the non-zero price-elasticity of demand for car travel mentioned above). Therefore, our simulation method may slightly underestimate the effects of lower prices on demand.

The results found for The Netherlands cannot be transferred simply to other countries. Much depends on the size and spatial structure of a country. It is expected that the problems of shifts in fuelling locations, which are acute in a small country such as The Netherlands with its high population densities near neighbouring countries, are not equally severe in other countries. Another issue we have ignored in our study of The Netherlands and which may be important in other countries is the extent to which gas station owners will adjust their margins as a consequence of an introduction of spatially differentiated fuel taxes. We have assumed that fuel stations in the low tax regions will fully pass the lower tax on to consumers. In the case of collusion or monopolistic price setting, they might also try to absorb part of it into their margins.

7. Conclusions

Substantial differences exist among fuel taxes in various countries in Europe. This is a form of fiscal competition that has undesirable side effects because it leads to cross-border fuelling and hence to extra kilometres driven. Our empirical analysis of cross-border fuelling in The Netherlands reveals that with a price difference of about 5 €-cents per litre, approximately 30% of the Dutch car owners living at the border would fuel in Germany where gas stations would be found at a negligible distance. On the other hand, about 5% of the car owners living at a distance of 30 km from the border would still take the trouble to fuel in Germany even though a purely financial analysis reveals that the costs of such a trip would outweigh the financial benefits. Thus, there is a substantial variability among car drivers in their responses to the option of fuelling abroad. The trade-off of the average driver of the price difference between the two countries and the distance travelled is about 0.5 €-cent/l/km. This implies a low implicit value of time involved in cross-border fuelling trips which makes sense, since these are often combined with shopping trips.

In some countries with high tax levels interesting ways have been developed to overcome the problem of fuel-fetching trips to low cost neighbouring countries. For example, in Singapore the cars leaving the country are required to have almost full tanks. In Italy, car owners near the Slovenian border have the right to buy fuel at a low tax rate through the use of a smart card.

One possible way to solve the problem of low fuel taxes in neighbouring countries is the introduction of a spatial differentiation of fuel taxes: low near the border and higher farther away. It is argued that to avoid substantial volumes of fuel-fetching trips, the slope of the graduation curve should be moderate (lower than 0.5 €-cent/l/km, preferably 0.25 €-cent/l/km). The issue remains that even when trip patterns are left largely unaltered substantial changes in fuelling behaviour may take place, implying that drivers would fuel in cheap locations.

The introduction of the common currency of the Euro may be expected to aggravate the problems of cross-border fuelling between EU-countries for two reasons. First, prices in neighbouring countries are easier to compare, and second the costs involved in changing money will disappear. Both developments make consumers more alert for cross-border opportunities. Thus, it will become more difficult for high tax countries to continue a high tax policy. A spatial graduation of taxes therefore deserves attention.

Our main conclusion based on a simulation study of The Netherlands is that the introduction of a spatial graduation of fuel taxes would lead to substantial changes in the decision of where to refuel. One may expect substantial claims for the compensation of gas station owners in high tax regions that would make the system rather expensive for a government dedicated to the increase of fuel prices as part of a transport policy. The Italian smart card system might be a practical alternative. Since low tax fuel is only sold to people who live in the border zones, there is no risk of a large-scale shift in fuelling behaviour away from high tax zones. However, with this alternative there are possibilities for fraud, which require resolution.

The feasibility of a spatial differentiation of fuel taxes clearly depends on the spatial structure and density of a country. The high population density in the Dutch border zones leads to considerable adverse effects and hence makes it an unappealing policy. In other countries with sparsely populated border regions it may be a more attractive policy alternative, however.

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