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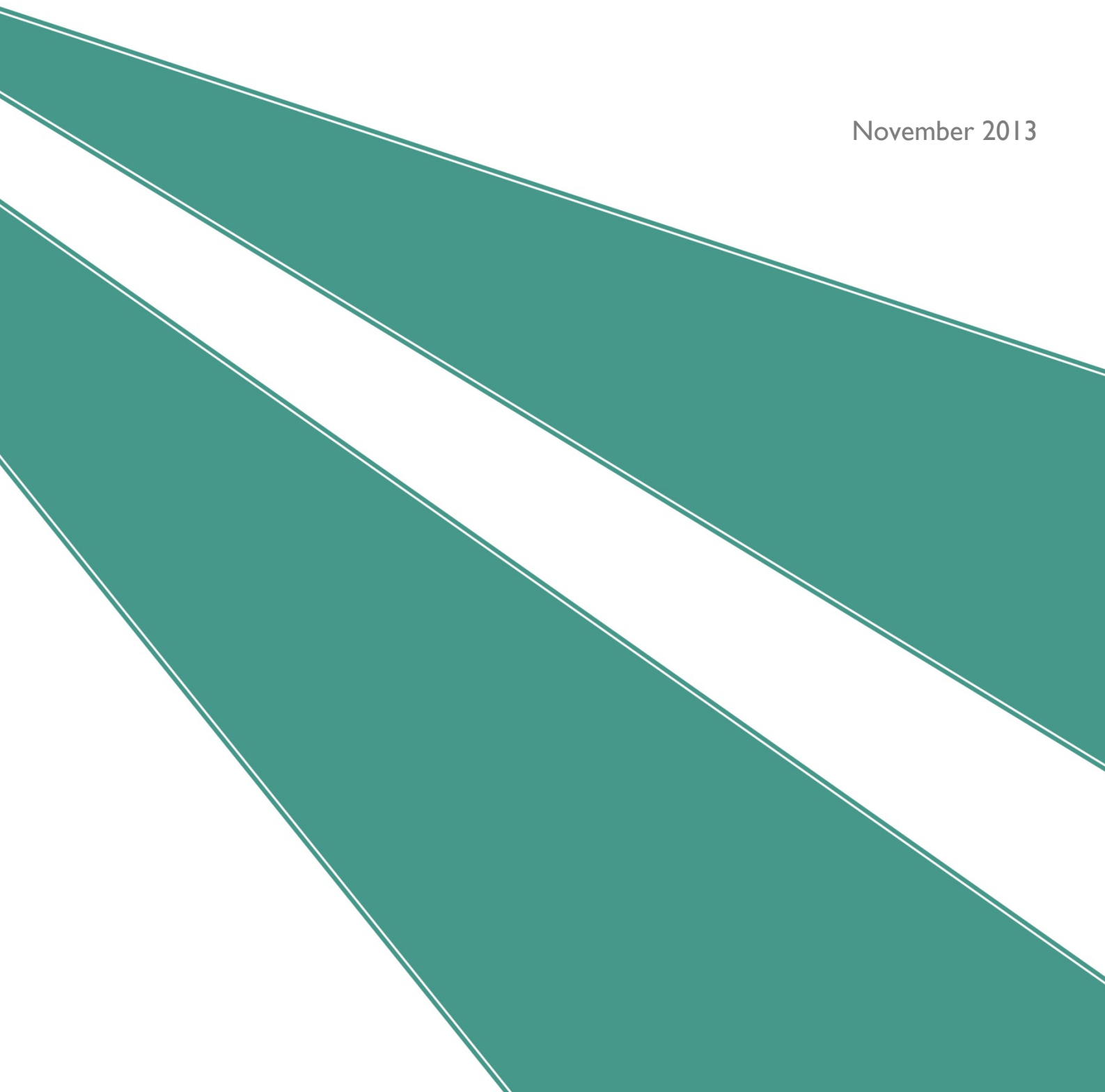
An tÚdarás um Bóithre Náisiúnta
National Roads Authority

Transport Research & Information Note

The Impact of Fuel Prices on Fuel Consumption and Traffic in Ireland

November 2013



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Executive Summary

Back ground to the Study

The National Roads Authority commissioned the AECOM consortium to develop a National Traffic Model capable of predicting traffic volumes on the National Route network for the period up to 2025. One of the determinants of future traffic is the cost of travel, of which the largest variable component is the cost of transport fuels. This study is aimed at providing an insight into the sensitivity of the National Traffic Model outputs to such prices.

Existing traffic data are not available for a long enough period for statistical modelling of price effects. Accordingly, to determine the sensitivity of traffic volumes to fuel prices in an Irish context, this paper relies on estimates of the sensitivity of fuel demand to such prices. Estimates of fuel demand are subject to errors arising from "fuel tourism". Modelling of fuel demand needs to take account of this factor.

Revised estimates of total fuel consumption were calculated for the period from 1988 to 2011 based on the assumption that there is little scope for the average rate of fuel consumption per vehicle to vary between the Republic of Ireland (ROI) and Northern Ireland (NI).

From these, estimates of fuel tourism were derived. It was established that:

- Some 119,000 tonnes of petrol originating in the ROI in 2011 were used by NI consumers. The equivalent figure for diesel is 494,000 tonnes.
- Official data for 2011 overestimate petrol consumption in the ROI by 9.4 per cent and diesel consumption by 29.5 per cent;
- Only 90.6 per cent of reported petrol consumption in 2011 and only 70.5 per cent of reported diesel consumption in the ROI were actually consumed locally in 2011. The balance is represented by fuel tourism.
- Relative price differentials between the ROI and NI are the main determinants of both the direction and scale of cross border fuel movements. For example, in 2002, petrol prices in the UK were on average 44 per cent higher than in the ROI, coinciding with the peak in fuel tourism.

The revised estimates of fuel consumption were used to derive values for the price elasticity of demand for petrol in Ireland. Short term price elasticities of demand for petrol in Ireland were estimated in the range of -0.33 to -0.53, with long term elasticities of -0.40 to -0.88. International experience suggests a short run price elasticity between -0.2 and -0.3 and a long run price elasticity between -0.6 and -0.8. The Irish estimates are at the higher end of the range.

Modelling suggests that diesel demand adjusts in the short term and that there is no long term adjustment process. As a result, only the short run price elasticity is calculated and this is estimated at -0.19. The international literature on elasticities of freight demand with respect to diesel prices is relatively patchy and the modelling specifications vary hugely. There is thus little guidance from this source as to the elasticity of demand for diesel fuel with respect to diesel prices.

Fuel price elasticities of demand indicate the sensitivity to fuel prices of fuel consumption and not travel demand. As fuel demand is a derived demand and fuel is not consumed for its own utility, it follows that transport users will try to retain mobility

in the face of fuel price increases. It follows that the price elasticity of demand for fuel will be above that for travel demand.

International experience indicates that the bulk of adjustment to a fuel price change is in terms of the car kilometres travelled, but in the longer term fuel efficiency changes dominate. When the effects of fuel efficiency are allowed for, the impact of fuel prices on traffic demand can be isolated.

The results of the analysis in this paper suggest that in testing for the impact of petrol prices on car traffic demand in the context of the National Traffic Model, it is suggested that values of -0.2 (low), -0.3(medium); and -0.4 (high) be used. The medium value would accord well with international experience.

Turning to the demand for diesel, one of the problems in assessing the results is the growing proportion of diesel cars in the overall diesel fleet. This means that there are two very diverse sets of users of diesel vehicles and their influence is changing over time.

However, freight vehicles dominate diesel use and their opportunities for fuel efficiency gains are much less. A practical way forward is to assume that the elasticity with respect to diesel traffic kilometres and fuel efficiency are equal, so that an elasticity of diesel traffic demand with respect to diesel prices of -0.1 is proposed.

Based on the proportion of vehicle kilometres of travel by diesel and petrol vehicles respectively and using the central estimates of elasticity mentioned above, a 10% increase in both diesel and petrol prices would reduce traffic volumes in the range 1.5% to 2.5% with a central value of 2%

1. Background to the Study

Introduction

1.1. The National Roads Authority commissioned the AECOM consortium to develop a National Traffic Model capable of predicting traffic volumes on the National Route network for the period up to 2025. This model builds a projection of future traffic volumes on the road system based on projections of population and car ownership levels. As car ownership levels are, in turn, based on future economic growth patterns, the traffic forecasts implicitly take account of the growth in personal incomes. However, future traffic volumes will also be affected by trends in the cost of travel, of which the largest variable component is the cost of transport fuels. This study is aimed at providing an insight into the sensitivity of the National Traffic Model outputs to such prices.

1.2. One of the aspects of the Irish situation is that there are insufficient high quality data on vehicle kilometres of travel in Ireland to enable measurement of elasticities. Estimates of vehicle kilometres of travel were compiled by the National Roads Authority and its predecessor on an almost continuous basis in the period 1976-1996. [1] These estimates were based on both visual and automatic road side traffic counts, which were undertaken on a sample basis. The estimate for any one year relies on growth factors for the sample of locations chosen, and is thus subject to statistical sampling errors.

1.3. More recently, the CSO has compiled estimates of vehicle kilometres for the period 2000-2011. [2] These are based on data provided by the National Car Testing system, supplemented by data from commercial data bases in respect of newer vehicles. There is a concern that reliance on commercial databases, which are partial in the coverage, could have resulted in an underestimate of vehicle kilometres. This view is supported by perusal of the data from the two sources. The NRA estimate of vehicle kilometres for 1996 is 34,532m, while the CSO estimate for the year 2000 is only 30,882m. Traffic count data would suggest that a decline in vehicle kilometres between these two dates is implausible.

1.4. Because of the sampling errors in the NRA data set, the break in the data and the incompatibility of the two sources, it is considered that they do not have the precision required for statistical modelling of price effects. Accordingly, to determine the sensitivity of traffic volumes to fuel prices in an Irish context, this paper relies on estimates of the sensitivity of fuel demand to such prices. Estimates of fuel demand are subject to errors arising from “fuel tourism”. Modelling of fuel demand needs to take account of this factor.

Layout of the Report

1.5. The Report begins by considering, in Section 2, trends in fuel consumption and fuel prices for both Republic of Ireland (ROI) and Northern Ireland (NI) and the extent of fuel tourism in Ireland. Section 3 makes estimates of cross-border fuel movements and derives an adjusted series for fuel consumption in ROI. Section 4 develops

[1] T.J.Holland and M. Kennedy. Traffic Station Counts and Road Travel for 1996. RT.548.1997.

[2] CSO Databases.

models of the demand for fuel in ROI. Section 5 summarises the conclusions and outlines some policy implications.

2. Fuel Consumption Data for Ireland

Introduction

2.1. Data on fuel consumption in the Republic of Ireland (ROI) are compiled by the Revenue Commissioners and are based on the quantities of fuel for which excise duty has been paid. This, however, does not necessarily imply that all duty-paid fuel is consumed within the boundaries of the state. To get a more accurate measure of the quantity of fuel that is physically consumed within the ROI, the official consumption data need to be adjusted for the cross-border movement of fuel.

2.2. This Section begins by outlining the various forms which cross-border fuel movement can take before presenting, in graphical format, the 'prima facie' evidence that it constitutes a significant proportion of total actual consumption. Using official data, it then compares the underlying trends in fuel consumption and vehicle ownership on both parts of the island, concluding that the resultant specific fuel consumption rates are implausible. Finally, it takes an in-depth look at historical fuel prices, describing how significant fuel price differentials have existed for protracted periods of time between the ROI and NI, thereby establishing the incentive for the cross border movement of fuel.

Classification of Cross-Border Fuel Movements

2.3. Cross-border fuel movements can be classified into three components:

- Fuel tourism: The lawful cross border purchases of duty paid fuel to fill up the running tank of a vehicle;
- Smuggling: The unlawful importation of bulk loads across a border for re-sale in the higher priced jurisdiction; and
- Laundering: The unlawful use as road fuel of products, such as gas oil, which carry a much lower rate of duty, and which are then moved across the border.

2.4. This study aims to estimate the portion of cross-border fuel movement that is represented by fuel tourism and smuggling. [3] Their net effect is that more fuel is sourced in the lower-priced jurisdiction, exaggerating its reported consumption and deflating it, to a corresponding extent, in the higher-priced country. As fuel prices in NI are currently higher than those in the ROI, present-day fuel tourism refers to the purchase of fuel in the ROI by Northern Ireland (NI) residents. It should be noted, however, that the terms 'cross-border movement of fuel' and 'fuel tourism' can sometimes be used interchangeably.

[3] The approach adopted essentially aggregates reported fuel sales and/or deliveries upon which the appropriate taxes have already been paid in the ROI and NI and reallocates the total in proportion to the number of vehicles in each part of the island. Fuel laundering is therefore excluded in the sense that its primary motive lies in the avoidance of excise duties.

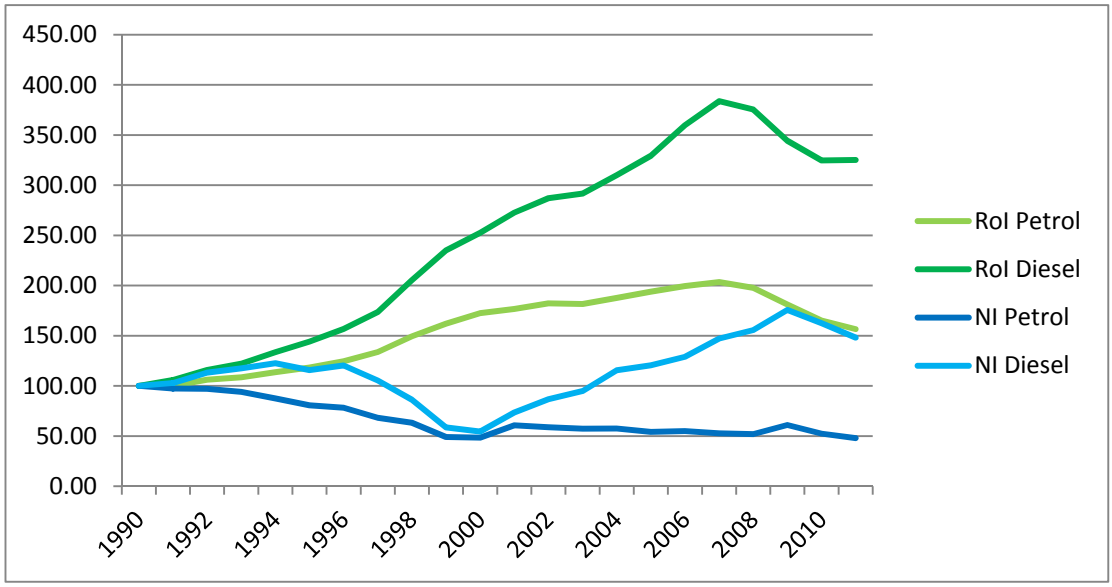
The 'Prima Facie' Evidence of Fuel Tourism

2.5. Figure 2.1 shows the trend in official petrol and diesel consumption figures for both the ROI and NI between 1990 and 2011[4]. The data are expressed in index format, with 1990 being set equal to 100, in order to highlight the divergent trends that have emerged north and south of the border.

2.6. It can be seen that by 2008, petrol consumption had almost doubled in the ROI while it had practically halved in NI. Equally, diesel consumption had nearly quadrupled in the Republic, while it had risen just over 50 per cent in the North. Since 2008 fuel consumption has dropped in both countries, with the economic effects of the recession being the most probable cause.

2.7. The glaring disparity in fuel trends over the last twenty years suggests that substantial amounts of petrol and diesel may be purchased in one jurisdiction but consumed in the other. In order to gauge the extent of such fuel tourism, more detailed information is required on petrol and diesel consumption, vehicle ownership and fuel prices.

Figure 2.1: Trend in Petrol and Diesel Consumption in the ROI and NI between 1990 and 2011



Source: ROI: Revenue Commissioners - Statistical Report
NI: DETI; DRDNI: Northern Ireland Transport Statistics; DECC
AECOM

[4] Data for the ROI are sourced from the relevant editions of the "Statistical Report" of the Revenue Commissioners. Data for NI from 1990 to 1994 are sourced from the Department of Enterprise, Trade and Investment (DETI) and relate to "Direct Deliveries of Petroleum Products for Consumption in Northern Ireland". Data since 1995 for NI are obtained from the "Northern Ireland Transport Statistics" as published by the Department for Regional Development (DRDNI) who, in turn, attribute the source of the data to the Department of Energy and Climate Change (DECC). The data, once again, relate to "Deliveries of petroleum and diesel for use in NI".

Fuel Consumption and Vehicle Ownership

2.8. Table 2.1 outlines the changes that have taken place in petrol and diesel consumption, vehicle ownership and specific fuel consumption in the ROI between 1990 and 2011. While the 56.5 per cent increase in petrol consumption in the Republic poorly matches the 76.7 per cent increase in petrol vehicles, advances in engine fuel efficiency since 1990 can partly explain the difference. Similarly, the 225.1 per cent increase in diesel consumption is at variance with the 285.2 per cent rise in the number of diesel vehicles, though improvements in diesel engine efficiency more than likely explain some of the difference in this case as well.

Table 2.1: Fuel Consumption in the ROI - Official Data

	1990	2011	Per Cent Change
Fuel Consumption in Tonnes			
Petrol Consumption	883,297	1,382,589	56.5
Diesel Consumption	666,926	2,168,725	225.1
Total Fuel Consumption	1,550,223	3,551,134	129.1
Vehicle Ownership			
No. of Petrol Vehicles	785,372	1,387,646	76.7
No. of Diesel Vehicles	265,536	1,022,729	285.2
Total No. of Vehicles	1,050,908	2,410,375	229.4
Proportion of Diesel Vehicles	25.3%	42.4%	
Fuel Consumption per Vehicle			
Specific Petrol Consumption	1.12	0.99	-11.6
Specific Diesel Consumption	2.51	2.12	-8.7

Source: Revenue Commissioners - Statistical Report
Irish Bulletin of Vehicle and Driver Statistics
AECOM

2.9. However, greater inconsistencies are evident within the NI data as can be seen from Table 2.2. Petrol consumption is reported to have fallen by 47.9 per cent in the intervening 19 years even though the number of petrol vehicles rose, albeit by a modest 4.4 per cent. In contrast, the number of diesel vehicles increased by 536.9 per cent but the rise in diesel consumption came nowhere near this figure, amounting to only 48.1 per cent.

Table 2.2: Fuel Consumption in NI - Official Data

	1990	2011	Per Cent Change
Fuel Deliveries in Tonnes			
Petrol Deliveries	648,172	311,000	-47.9%
Diesel Deliveries	307,847	456,000	48.1%
Total Fuel Deliveries	956,019	767,000	-19.8%
Vehicle Ownership			
No. of Petrol Vehicles	451,839	471,604	4.4%
No. of Diesel Vehicles	91,045	579,933	536.9%
Total No. of Vehicles	542,884	1,051,537	93.6%
Proportion of Diesel Vehicles	16.8%	55.2%	
Fuel Consumption per Vehicle			
Specific Petrol Consumption	1.43	0.66	-53.8%
Specific Diesel Consumption	3.38	0.79	-76.6%

Source: 1990 – DVA Licensing Statistics; DETI
2011 – DVA & DECC as quoted in "Northern Ireland Transport Statistics 2010-11"

2.10. The inherent inconsistency in the data is perhaps best illustrated by examining trends in specific fuel consumption (fuel consumption per vehicle) in the two countries. Specific petrol consumption fell by 11.6 per cent in the ROI between 1990 and 2011, whereas it is reported to have fallen by 53.8 per cent in NI. The difference in specific consumption figures for diesel are even more pronounced with a fall of 8.7 per cent in the ROI compared to a 76.6 per cent decline in the North.

2.11. The inevitable conclusion is that a very significant proportion of NI petrol and diesel consumption originates in the ROI, deflating the reported figures for Northern Ireland and correspondingly exaggerating those for the Republic. This conclusion is supported by an examination of trends in fuel prices.

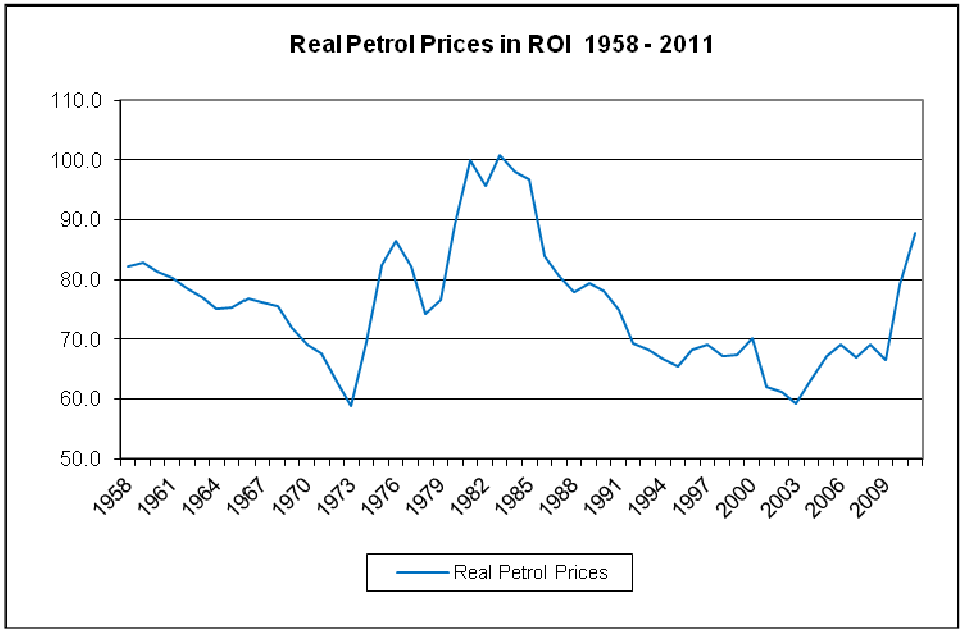
Trends in Fuel Prices

2.12. An incentive for the cross-border movement of fuel is created when fuel prices between the ROI and NI differ. More often than not, these price differences are associated with changes in the levels of excise duties and with fluctuating exchange rates. As these and other underlying cost factors are constantly changing over time, fuel price trends are an important predictor of total cross-border fuel movements.

Trends in Real Petrol Prices in ROI

2.13. Figure 2.2 shows the trend in real petrol prices (i.e. nominal prices adjusted for general inflation) in the ROI from 1958 to 2011, with 1981 being set equal to a base of 100[5]. Interestingly, real petrol prices peaked in 1983 and until recently were lower than in 1958. They hit their lowest point in 1973, coinciding with the start of the first oil crisis, but practically equalled this low again as recently as 2003.

Figure 2.2: Trend in Real Petrol Prices in the ROI between 1958 and 2011



Source: 1958 - 1981: Various Irish Government Departments;
1982 – 1983: Individual oil companies;
1983 – 2011: Central Statistics Office
AECOM

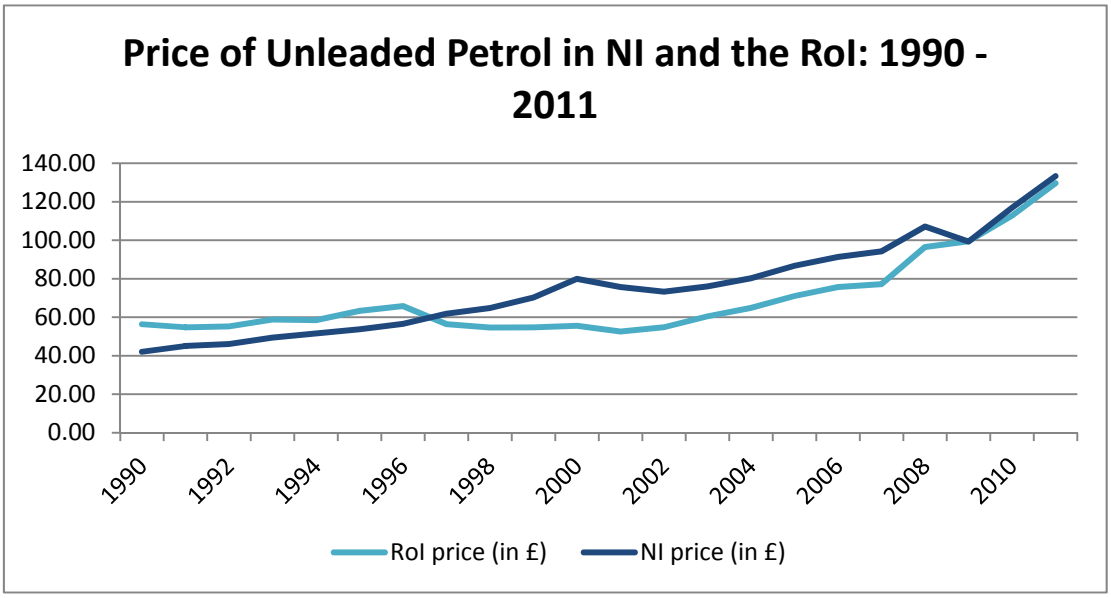
Trends in Relative Petrol Prices between NI and the ROI

2.14. Figure 2.3 shows the trend in the nominal price of unleaded petrol in NI and the ROI in £ cents per litre between 1990 and 2011. Up to 1996, ROI prices were above those in NI. Since then, NI prices have been higher although the differential has closed in recent years

2.15. The size of the price differential between c.1999 and 2007 highlights the extent of the incentive for fuel tourism.

[5] A fuller description of how this data series was constructed is given in Section 4.5

Figure 2.3: Trend in Nominal Petrol Prices in NI and ROI in € cents per litre, 1958 – 2011

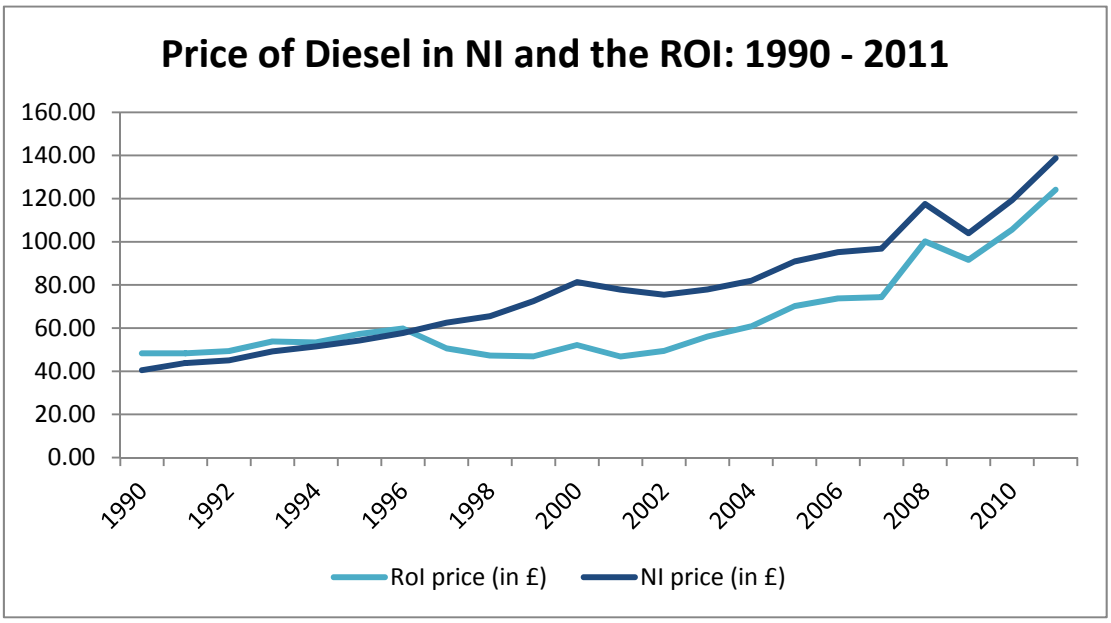


Source: Irish Prices: CSO and AECOM,
UK Prices: United Kingdom Petroleum Industry Association Limited (UKPIA), Department of Energy and Climate Change (DECC)
FX Rates: Datastream

Trends in Relative Diesel Prices between the UK and the ROI

2.16. Figure 2.4 shows the trend in the nominal price of diesel in NI and the ROI in GBP £ per litre between 1990 and 2011. In a repeat of the pattern that was evident with petrol prices, it can be seen that, in 1997, diesel prices in NI rose above those in the ROI, having previously been substantially lower. However, the premium paid by NI motorists expressed as a percentage of prices in the ROI is considerably higher for diesel than it is for petrol. For example, in 2001, diesel prices in the NI were 70 per cent higher than in the ROI. However, the trend change in the absolute size of the differential may be of even greater interest. While there are signs that it may have narrowed in the case of petrol, even approaching zero, it appears to be still relatively stable and positive in the case of diesel.

Figure 2.4: Trend in Nominal Diesel Prices in NI and ROI in Cents per Litre between 1990 and 2011



Source: ROI: Revenue Commissioners UK: HMRC, DECC

Changes in Relative Petrol Tax Rates between NI and the ROI

2.17. Section 2.5.2 highlighted the extent to which the pump price paid for unleaded petrol either side of the border has varied. Table 2.3 examines the average annual difference in excise duties, in GBP £ terms, between the ROI and NI and finds that the bulk of the differential in pump prices can be explained by the difference in tax rates. In 2007, for instance, excise duties in NI were £0.184 per litre higher than in the ROI, more than accounting for the £0.157 differential in pump prices.

2.18. Figure 2.5 summarises these trends. It can be seen that the sharp rise in excise duties in NI between 1995 and 1998 was not replicated in the ROI. The “crossover” in 1995 marks NI’s re-emergence as the high tax jurisdiction with the tax differential peaking in 2000/2001.

Table 2.3: Proportion of Petrol Price Differential Explained by Tax

	Excise Duties in £ pence			Total Price in £ pence		
	Tax RoI	Tax NI	Diff.	RoI	NI	Diff.
1990	35.1	24.5	10.5	56.4	42.0	14.3
1991	34.0	28.2	5.8	54.7	45.1	9.7
1992	33.9	30.1	3.8	55.2	46.1	9.1
1993	36.2	32.8	3.5	58.8	49.4	9.4
1994	37.2	36.2	1.0	58.4	51.6	6.9
1995	40.0	39.6	0.5	63.3	53.8	9.5
1996	40.9	42.9	-2.1	65.8	56.5	9.2
1997	35.1	47.8	-12.6	56.4	61.8	-5.4
1998	33.7	52.7	-19.0	54.7	64.8	-10.1
1999	33.9	57.1	-23.2	54.7	70.2	-15.5
2000	32.9	60.3	-27.4	55.5	79.9	-24.4
2001	29.8	57.7	-27.9	52.6	75.7	-23.1
2002	35.0	56.7	-21.8	54.8	73.2	-18.4
2003	38.1	57.5	-19.4	60.5	76.0	-15.5
2004	41.9	59.0	-17.1	64.9	80.2	-15.4
2005	43.3	60.0	-16.8	71.0	86.7	-15.7
2006	42.4	60.8	-18.4	75.7	91.3	-15.7
2007	44.5	62.9	-18.4	77.2	94.2	-17.1
2008	55.9	66.3	-10.4	96.5	107.1	-10.6
2009	64.1	67.3	-3.3	99.5	99.3	0.2
2010	66.1	74.6	-8.5	112.7	116.9	-4.2
2011	72.5	80.4	-8.0	129.6	133.3	-3.6

Source: Revenue Commissioners; HMRC; DECC; AECOM

Conclusions

2.19. Official data show the starkly divergent trends in petrol and diesel consumption in the ROI and NI between 1990 and 2011:

- Petrol consumption is reported to have increased by 56% in the ROI while it practically halved in NI; while
- Diesel consumption more than tripled in the Republic while it rose just under 50 per cent in the North.

2.20. The most plausible conclusion is that official data are severely distorted by fuel tourism. This finding is supported by an examination of specific fuel consumption rates in the two jurisdictions. For example, using official data, the specific diesel consumption rate in the ROI for 2011 (at 2.12 tonnes per vehicle) is reported to be nearly three times that in NI (at 0.79 tonnes per vehicle). In reality, the rate is more likely to be broadly similar on the two parts of the island, pointing to the existence of extensive cross-border movement of fuel.

2.21. Irrespective of whether fuel tourism takes its classic form of legitimate purchases of duty paid fuel or smuggling, its primary motive can be directly related to the existence of significant price differentials between the two jurisdictions. An examination of historical trends in fuel prices reveals the following:

- Until recently real petrol prices in the ROI were lower than they were 50 years ago with the extent of volatility declining in the last 20 years, however the real price has risen sharply since 2009;
- In contrast, there have been quite dramatic shifts in relative price differentials between the ROI and the NI;
    - Between 1958 and 1975, NI prices were on average 21 per cent higher than in the ROI;
    - Between 1976 and 1996, Irish prices were on average 24 per cent higher than in NI; and
    - Since 1997, NI prices have on average been 26 per cent higher than in the ROI.

2.22. These changes in price differentials are more directly attributable to changes in excise rates and exchange rates rather than to changes in other cost elements.

3. Estimates of Cross-Border Fuel Movements

Introduction

3.1. This section estimates the extent of cross-border movement of fuels. It does this by examining the specific fuel consumption data for Ireland as a whole and redistributing it in proportion to the number of vehicles, by type, in the two parts of the island. To the extent that it is possible to do so, the redistribution process takes explicit account of the different fuel consumption rates of passenger cars, LGVs and HGVs and their relative prevalence in each country.

3.2. The section begins by summarising the findings of previous studies on cross-border fuel movements between the ROI and NI. The methodology for re-distributing the total fuel consumed in the island is then outlined in more detail. This enables estimates of fuel tourism for the period 1988 to 2011 to be derived as well as revised petrol and diesel consumption figures for each country. Finally, the revised data are critically analysed and compared to estimates of fuel tourism that flow implicitly from changes in recent data collection methods in the UK.

Previous Studies of Cross-Border Fuel Movements

3.3. The existence of fuel tourism in an Irish context has been acknowledged in a number of studies over the last ten years with various methods deployed to arrive at estimates of its scale. Three such studies are discussed here. While the studies all refer to different years, and use different methods of estimation, there is a reasonable degree of consistency amongst the results.

Goodbody Economic Consultants

3.4. In September 2001, Goodbody Economic Consultants used two different approaches to estimate the extent of cross-border fuel movements. The first was based on the view that the specific fuel consumption of vehicles in NI and ROI should be identical and adjusted the levels of fuel consumption in the two jurisdictions to achieve this. It estimated the cross-border movement of petrol and diesel in 1998 to be 107,000 and 307,000 tonnes respectively.

3.5. The second method examined differences that emerged in fuel consumption trends and vehicle fuel efficiency rates between NI and the rest of the UK in the period from 1995 and 1998 and then attributed these changes to cross-border fuel movements between the ROI and NI. On this basis, it calculated the cross border fuel movement of petrol and diesel in 1998 to be 239,000 and 233,000 tonnes respectively.

Economic and Social Research Institute

3.6. In its 2008-2015 Medium-Term Review, the ESRI estimated the scale of cross-border fuel shopping using the HERMES model. This measures the sensitivity of the sales of fuel to relative fuel prices in the ROI and UK. It found that, in 2005, between 5 and 9 per cent of total petrol sales in Ireland were consumed abroad with the corresponding figure for diesel being 15 to 20 per cent. .

Environment Protection Agency

3.7. The EPA has estimated that approximately 12 per cent of petrol consumption and up to 25 per cent of diesel sales in Ireland in the years 2000-2004 may have been due to cross-border trade[6].

The Existing Studies on Fuel Tourism Compared

3.8. Table 3.1 facilitates a comparison of the existing studies by expressing fuel tourism in each case as a percentage of total fuel sales that are consumed abroad. It can be seen that, when the outliers are excluded, petrol fuel tourism is estimated to run at 5 to 9 per cent of total petrol sales with diesel fuel tourism estimated to be between 15 and 23 per cent.

Table 3.1: Proportion of Petrol and Diesel Consumed Abroad

	Year	Official Cons.	Fuel Tourism	% Exported	Official Cons.	Fuel Tourism	% Exported
GEC - Method A	1998	1,319	107	8.1%	1,369	307	22.4%
GEC - Method B	1998	1,319	239	18.1%	1,369	233	17.0%
EPA	2002	1,610		5.0%	1,915		25.0%
ESRI	2005	1,713		5 - 9%	2,196		15 - 20%

Source: EPA, ESRI and Goodbody Economic Consultants
Official Consumption and Fuel Tourism are in thousands of tonnes

Methodology for Calculating Fuel Consumption

3.9. Estimates of fuel tourism were made using two variants of the approach used by Goodbody. The first approach (AECOM Method 1) simply assumed that the specific fuel consumption of the average petrol and diesel vehicles in ROI and NI were the same. Actual fuel consumption was then calculated based on the number of petrol and diesel vehicles in each jurisdiction.

3.10. The second approach (AECOM Method 2) took account of the fact that the proportion of diesels accounted for by cars, LGVs and HGVs differs in the two jurisdictions. These different vehicle type have varying specific fuel consumption rates and this was recognised by converting all vehicle numbers into diesel car equivalents. This was based on fuel consumption parameters for the different vehicle types contained in COBA[7]. Actual diesel consumption was based on a standard specific fuel consumption per diesel car equivalent and the number of diesel car equivalents in each jurisdiction. Due to problem of identifying the mix of diesel vehicles in NI, this method could not be applied before 1999.

[6] Source: Environment Protection Agency: "Environment in Focus 2006"
[7] COBA Fuel Consumption Parameters in litres/km (2002) (taken from Table C.8 in the 2004 'Cost Benefit Parameters and Application Rules for Transport Project Appraisal')

3.11. The methodology for estimating fuel tourism is outlined in more detail in Appendix 1 together with a worked example for 2011.

Revised Data Series for Fuel Consumption and Fuel Tourism

3.12. Employing the methodology (AECOM Method 1) described above, revised petrol and diesel consumption data were extracted for 1988 to 2011. These are presented in Table 3.2 together with the estimates for fuel tourism. All figures are in thousands of tonnes. As the fuel tourism data are calculated by subtracting the revised consumption estimates from the officially reported ones, a negative sign denotes use of NI originating fuel by ROI consumers. For example, in Table 3.2, in 2011 the reported fuel consumption by ROI petrol vehicles was in excess of the estimated actual fuel consumption by 119,000 tonnes, indicating the use of ROI originating fuel by NI consumers. Using AECOM Method 2, the value for the same year was estimated at a slightly higher 130,000 tonnes.

3.13. With regard to diesel consumption, Method 1 indicated that 494,000 tonnes of ROI originating fuel were used in NI, rising to 573,000 under Method 2.

3.14. Despite the difference in absolute numbers, the direction and year to year variation in estimated fuel movements were very similar under the two Methods.

Table 3.2: Revised Fuel Consumption and Fuel Tourism Figures for ROI in 000 tonnes (AECOM Method 1)

	Revised Consumption				Fuel Tourism		
Year	Petrol	Diesel	Total		Petrol	Diesel	Total
1988	950	603	1,553		-90.5	-63.2	-153.7
1989	973	667	1,639		-94.3	-63.2	-157.5
1990	972	726	1,698		-88.9	-59.0	-147.8
1991	966	767	1,732		-81.0	-60.5	-141.5
1992	994	828	1,823		-57.2	-55.4	-112.6
1993	1,005	850	1,855		-47.0	-35.1	-82.1
1994	1,027	896	1,923		-23.6	-5.7	-29.2
1995	1,044	916	1,961		0.7	45.2	45.9
1996	1,086	971	2,057		13.4	74.7	88.0
1997	1,109	1,000	2,109		72.6	158.3	230.9
1998	1,204	1,106	2,309		115.8	263.6	379.4
1999	1,235	1,187	2,423		195.9	379.9	575.8
2000	1,322	1,258	2,580		201.6	426.8	628.5
2001	1,422	1,367	2,789		138.8	452.4	591.1
2002	1,466	1,450	2,915		144.6	464.9	609.6
2003	1,456	1,465	2,921		147.6	480.1	627.6
2004	1,514	1,586	3,100		143.7	482.0	625.7
2005	1,552	1,685	3,238		160.8	510.6	671.4
2006	1,609	1,847	3,456		152.9	552.1	705.0
2007	1,631	2,019	3,650		166.3	540.0	706.3
2008	1,594	2,005	3,599		153.0	498.9	651.9
2009	1,526	1,903	3,429		74.7	393.1	467.8
2010	1,345	1,771	3,117		113.5	394.1	507.6
2011	1,264	1,675	2,939		119.0	494.0	613

Source: AECOM Economic Consultants
All figures are in thousands of tonnes

Implications of Revised Petrol and Diesel Consumption Figures

3.15. These revisions in petrol and diesel consumption have three different sets of impacts:

- The absolute and percentage growth rates in petrol and diesel consumption in the ROI over the full period are altered significantly - as the earlier figures are adjusted upwards while the most recent figures are adjusted downwards;
- Official consumption figures which are aggregated on a point of sale basis can now be segregated into what is actually consumed locally and what is lost in cross border flows; and
- Specific fuel consumption patterns between the two countries converge.

3.16. These statistical effects are now examined in more detail:

Level and Growth of Fuel Consumption

3.17. Looking at the point-in-time estimates for 2011, official data overestimates petrol consumption in the ROI by 9.4 per cent (119.0 / 1,264) and diesel consumption by 29.5 per cent (494 / 1,675).

3.18. Petrol consumption in Ireland was reported by the Revenue Commissioners to be 883 thousand tonnes in 1990 and 1,383 thousand tonnes in 2011, representing an increase of 56.6 per cent. The revised levels shown in Table 3.2 (950 and 1,264 respectively) represent a more modest 33.0 per cent growth rate. Equally, official data measures diesel growth at 225.1 per cent whereas the revised figures put it at a considerably lower 177 per cent. These revisions in the trend rates of growth are very significant in the context of calculating elasticities of demand.

Pattern of Fuel Consumption

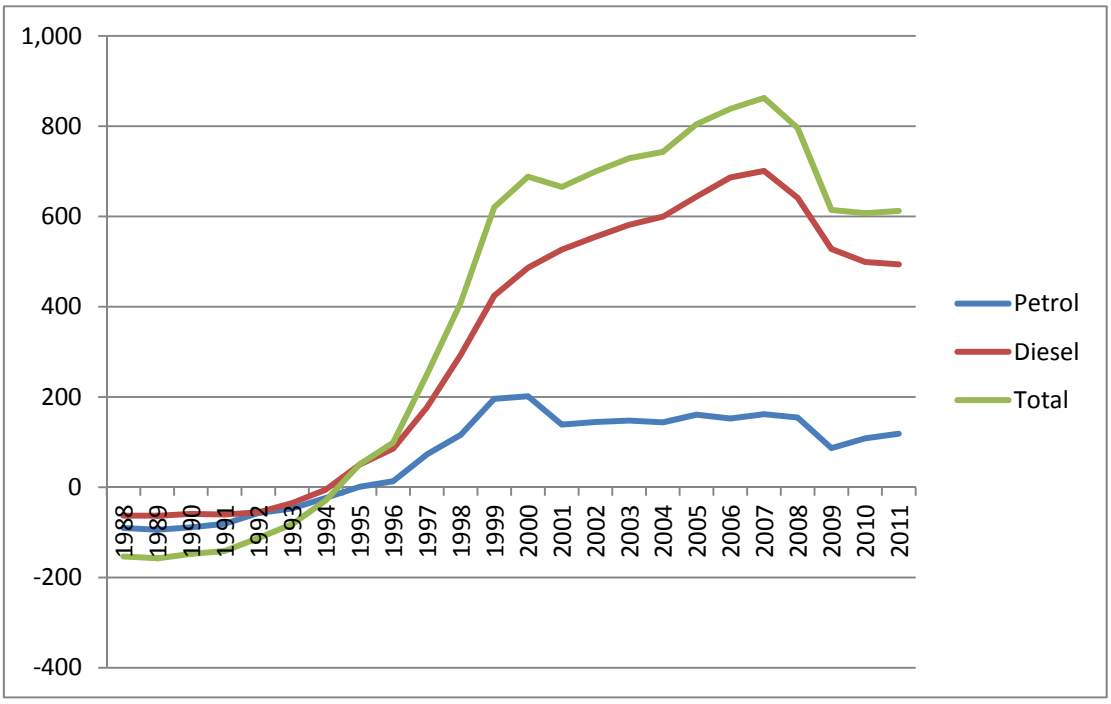
3.19. When the officially reported levels of petrol and diesel consumption in the ROI and NI are adjusted to reflect fuel tourism as calculated above, the overall pattern of consumption within the island as a whole is altered quite radically. Petrol consumption in the ROI, for example, was reported by the Revenue Commissioners to be 1,383 thousand tonnes in 2011. The revised estimate as calculated above puts it at 1,264 thousand tonnes. In other words, only 91.4 per cent of reported consumption is actually consumed locally with the balance of 8.6 per cent represented by leakage into NI. On a similar basis, only 77.2 per cent of reported diesel consumption in the ROI in 2011 is consumed locally with 22.8 per cent leaking across the border.

3.20. Because of its smaller size, the implications are even more striking for Northern Ireland. On the basis of the above estimates, it is calculated that petrol fuel tourism amounted to 38.3 per cent of reported petrol consumption in 2011 while diesel fuel tourism, at 394 thousand tonnes, amounted to 108.3 per cent of reported diesel consumption.

Analysis of Fuel Tourism Figures

3.21. The estimates of fuel tourism, which are listed in Table 3.2, are shown graphically in Figure 3.1. Attention can be drawn to a number of points:

Figure 3.1: Fuel Tourism between the ROI and NI between 1990 and 2011



Source: Goodbody Economic Consultants. All units are in thousands of tonnes.

- In the early 1990s, ROI consumers tended to purchase fuel in NI. The direction reversed in the early to mid 1990s when the relative price differentials changed.
- Fuel tourism in diesel is considerably greater than that in petrol, running at a multiple of approximately 3.3 times since 2001.
- Looking at the graph of fuel tourism in petrol only, it can be seen that cross border flows turned positive in 1995 (i.e. use of ROI originating fuel in NI). An examination of the changes in average price differentials around this time shows the strong link between relative prices and fuel tourism:
  - Average petrol prices in NI were 16.7 per cent higher than in the ROI in 1994;
  - Average prices in the ROI and NI were practically equal in 1995; and
  - Average petrol prices in the ROI were 20.6 per cent higher than in NI in 1996.
- Petrol fuel tourism peaked in 2000, coinciding with the point of maximum price differential between the two countries. In that year, average petrol prices in NI were an average of 44.4 per cent higher than in the ROI.

Conclusions

3.22. Revised estimates of total petrol and diesel consumption from 1988 to 2011 were derived, making allowance for fuel tourism. The revised data for 2011 indicate that:

- Official data in the ROI overestimate petrol consumption in 2011 by 9.4 per cent and diesel consumption by 29.5 per cent;
- Only 91.4 per cent of reported consumption in the ROI in 2011 was actually consumed locally with the balance of 8.6 per cent represented by leakage into NI. Similarly, only 77.2 per cent of reported diesel consumption in the ROI is consumed locally with 22.8 per cent leaking across the border; and
- Because of its smaller size, the implications are even more striking for Northern Ireland with petrol fuel tourism amounting to 38.1 per cent of reported consumption in 2011 while diesel fuel tourism actually surpasses reported consumption.
- Fuel tourism in diesel has been approximately 3.3 times that in petrol since 2001; and
- The direction and scale of fuel tourism matches the trend in relative price differentials very closely.

4. Econometric Models of Consumer Demand for Fuel

Introduction

4.1. This section reviews international estimates of the sensitivity of traffic volumes to fuel prices. This sets the context against which new measures of elasticity in Ireland can be viewed. These price elasticity measures are devised using both the officially reported levels and the revised estimates of fuel consumed in the ROI.

4.2. The section begins by briefly describing the concept of price elasticity of demand. The international evidence on the sensitivity of traffic volumes to fuel prices is then reviewed. The regression model used to arrive at new estimates of elasticities in the ROI is outlined. The various data series and associated regression results are then discussed in detail. Finally, the resultant price elasticities are presented and compared with international estimates.

Price and Income Elasticity of Demand

4.3. The Price (P) elasticity of demand (Q) for petrol is defined as the ratio of the proportionate change in the quantity of petrol demanded to the proportionate change in price. Mathematically, it can be expressed as:

$$eP = |\Delta Q / Q \div \Delta P / P|$$

$$= |\Delta Q / \Delta P \times P / Q|$$

4.4. Thus, the price elasticity, eP, measures the response of consumers of petrol to changes in its price, all other factors being constant. If eP is small (e.g. less than unity), then demand is said to be inelastic and the impact of changes in petrol prices on demand is small. Equally, if the price elasticity of demand is greater than unity, the impact of changes in petrol prices on the quantity demanded is correspondingly greater and demand is said to be elastic. Of course, other factors such as real incomes also influence the demand for petrol.

Specifying the Regression Model

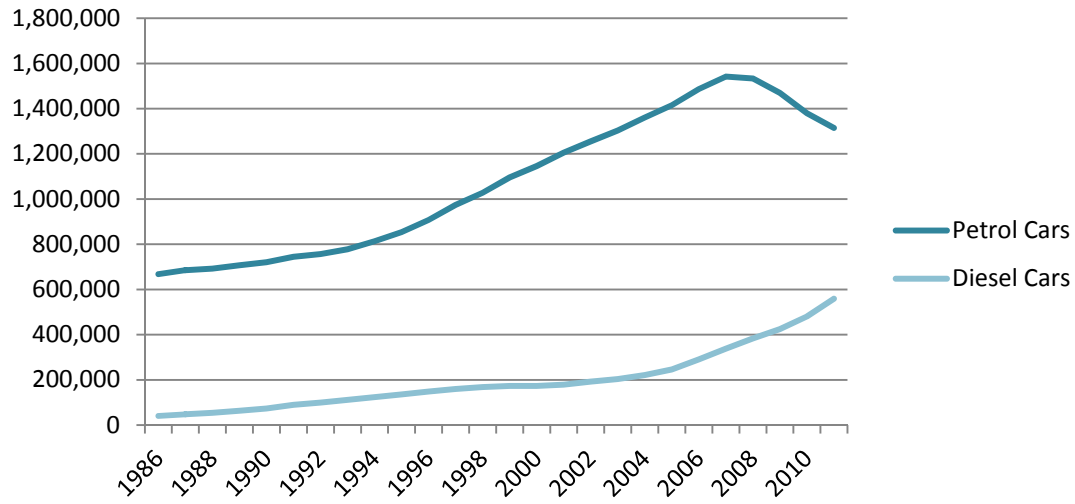
4.5. To obtain price elasticities of demand for fuel, the relationship between fuel consumption and main variables that influence it must first be expressed so that a multiple regression analysis can be undertaken of the available time series data. Two types of model maybe specified: a static demand and a dynamic demand model.

4.6. Static Demand Model: It is assumed that a linear relationship exists between the quantity of fuel demanded and a number of explanatory variables. The static approach implies that all of the impacts of a fuel price change occur within one year of the change. With regard to the explanatory variables, it is usually assumed that demand is related to the fuel price and a measure of economic activity. Real personal consumption expenditure is taken as a proxy for personal income. Separate models for petrol and diesel demand were specified.

4.7. There has been a substantial change in the composition of the car fleet by fuel type in recent years, with a shift away from the petrol car to the diesel alternative as indicated by Figure 4.1. Diesel vehicles have increased at a faster rate and unlike petrol

vehicles have not declined in the post 2008 recession. The demand for fuel is influenced by changes in the mix of vehicles and this needs to be recognised in the model.

Figure 4.1 Numbers in ROI Car Fleet by Fuel Type, 1986-2011



Thus, the demand for petrol was expressed in the following equation:

$$Qt = a\,0 + a\,1P\,t + a\,2\,E\,t + a\,3Vt + u\,t$$

where

Qt = the quantity of petrol demanded in time period t;
Pt = real petrol price in time period t;
Et = real personal consumer expenditure in time period t;
Vt = the number of petrol vehicles; and
ut = random disturbance term.

4.8. The same formulation was applied to diesel demand as follows:

$$Qt = a\,0 + a\,1P\,t + a\,2\,E\,t + a\,3Vt + u\,t$$

where

Qt = the quantity of diesel demanded in time period t;
Pt = real diesel price in time period t;
Et = real GDP in time period t;
Vt = the number of diesel vehicles; and
ut = random disturbance term.

4.9. The economic activity variable for the diesel model was GDP, in recognition of the fact that diesel demand emanates largely from goods vehicles, whose activity levels are driven by the gross output of the economy.

4.10. The formulation can be described as a static demand model as the explanatory variables all refer to changes that occur in the current time period t. Such models can be used to calculate short run elasticities for both price and income utilising the values derived for the parameters a1 and a2.

4.11. Dynamic Demand Model: When any of the factors that affect the demand for fuel change, the range of viable consumer responses is very much dependent on the time period under consideration. If petrol prices rise, for example, typical short term consumer reactions could involve some reduction in kilometres travelled, trip rates or modal choice, or an improvement in fuel efficiency through more economical driving and better vehicle maintenance. Over time, however, the consumer has more scope to make structural changes in travel patterns. These can include changes in the type of vehicle owned and home or work location. As a result, short run and long run elasticities of demand may diverge. In order to calculate long run elasticities, the model specification must be amended to show how changes in the dependent variable (the quantity of petrol demanded) are a function of not just changes in the explanatory variables (real petrol price and real PCE) but also previous changes in the dependent variable itself. As these models automatically incorporate known historical information from previous time periods, they are referred to as dynamic models. A dynamic version of the basic model can be expressed as follows:

$$Q_t = b_0 + b_1 P_t + b_2 E_t + b_3 V_t + b_4 Q_{t-1} + v_t$$

where Q_{t-1} is simply the quantity of fuel demanded in the prior time period.

4.12. Under such models, the short run price effect is described by the b1 co-efficient, while the long run is calculated as b1/ (1-b4). Both petrol and diesel dynamic demand models were tested. [8]

Description and Sources of Data Used

4.13. As explained above, the principal variables used in specifying the equation were the quantity of fuel demanded, real petrol prices, real personal consumer expenditure and the number of vehicles. The factors considered in variable selection are described more fully below together with an outline of the actual sources used.

4.14. **Quantity of Fuel Demanded:** Data series containing the officially reported level of petrol and diesel consumption was compiled. The data was derived from various reports of the Revenue Commissioners which contain the net quantities of petrol retained for home use. These series were adjusted for fuel tourism as shown in Section 3.4. As these data series was dependent on data sourced from Northern Ireland, the data were restricted to the period 1989 to 2011.

[8] This is a distributed lag model. The co-efficient b_4 represent the speed of adjustment to the price variable.

4.15. **Real Petrol Prices:** A data series on nominal petrol prices for the period 1989 -2011 was sourced from the CSO. The real price of petrol was derived by deflating the nominal petrol price by the Consumer Price Index.

4.16. **Real Diesel Prices:** complied for the same period and from the same sources as for diesel prices.

4.17. **Real Personal Consumption Expenditure:** The data on Real PCE was devised using the Index of Personal Consumption of Goods and Services at constant market prices as published by the CSO in "National Income and Expenditure 2008" for the 1989 to 2011 period.

4.18. **Real GDP:** CSO National Income and Expenditure tables for the 1989 to 2011 period.

4.19. **Vehicle Numbers:** The number of petrol and diesel vehicles was obtained from the Irish Bulletin of Vehicle and Driver Statistics, now published by the Department of Transport, Tourism and Sport.

Results

4.20. The static and dynamic regression models described in Section 4.4 were estimated with the results as set out in Table 4.6.

4.21. With regard to the demand for petrol, the simple static model has a high level of explanatory power (R-square of 0.974). The real petrol price has the right sign indicating that an increase in price reduces demand. However, personal consumer expenditure PCE) has the wrong sign, indicating that an increase in spending power reduces fuel consumption. One of the problems with the static model is that PCE and the number of petrol vehicles is highly correlated so that multicollinearity is present.

4.22. Turning to dynamic models, the same multicollinearity arises, so that the formulation (Dynamic 1) that includes both of the PCE and vehicle numbers variables has the problem that the PCE variable has the wrong sign. Dynamic 2 is the preferred model as all independent variables have the right sign and a level of statistical significance as measured by their t-values. [9]

4.23. The petrol price elasticities arising from four model formulations are set out in Table 4.8. [10] As indicated Dynamic 2 is the most successful equation and this suggests a short run price elasticity of -0.53 and a long run effect of -0.88. It may be noted in this regard, that as the stock of petrol vehicles is not explicitly modelled in this formulation, the price elasticity includes the effect of petrol prices on the decision to purchase a petrol or diesel driven vehicle. When the stock of petrol cars is explicitly modelled, the elasticities are much reduced: short term price elasticities are in the range of -0.33 to -0.47, with long term elasticities of -0.40 to -0.57.

Table 4.6: Models of Petrol Demand

[9] Petrol demand may be influenced by diesel prices, which may cause consumers to opt for a vehicle of different fuel type. Attempts to measure this cross price elasticity effect were not successful because of multi-collinearity between petrol and diesel process.

[10] The price elasticity formula is $| \Delta Q / \Delta P \times P / Q |$. The estimated co-efficient b1 is used to derive $\Delta Q / \Delta P$.

Dependant Variable	Model		Real Petrol Price	Real PCE	Qty. of Fuel Lagged	Number of Petrol Vehicles	Adj. R^2	F
	Static (1)	Coeff.	-3.932	-1.028		1.421	0.974	283.6
Petrol Demand		t Value	-2.45	-1.403		2.89		
	Dynamic (1)	Coeff.	-4.368	-0.803	0.096	1.197	0.971	183.7
		t Value	-2.51	-0.98	0.35	1.85		
	Dynamic (2)	Coeff.	-6.441	0.622	0.397		0.967	216.3
		t Value	-4.60	2.17	1.69			
	Dynamic (3)	Coeff.	-5.634		0.176	0.597	0.971	245.1
		t Value	-4.82		0.67	2.785		

4.24. Turning to the demand for diesel, it is a feature of the results that only the static model indicates that diesel prices have a negative effect on diesel demand. In the dynamic formulation the impact of diesel prices is positive and statistically insignificant. Thus, the modelling suggests that diesel demand adjusts in the short term and that there is no long term adjustment process. This is plausible as diesel demand is dominated by freight vehicles. With the exception of very low weight freight vehicles, there are no petrol driven vehicles available on the market and few in use, so the option of converting to diesel operation does not really exist. Moreover, the decision as to the size of the goods vehicle to purchase is driven by market and logistics factors rather than the fuel economy of vehicles of different sizes. For example, the haulage of construction materials requires vehicles capable of carrying large axle loadings which dictates large vehicle sizes. Thus the scope for long run adjustment through changing to a petrol driven vehicle or a vehicle of a different size is much restricted. As a result only the short run price elasticity is calculated and this is estimated at -0.19.

Table 4.7: Models of Diesel Demand

Dependant Variable	Model		Real Diesel Price	Real GDP	Qty. of Fuel Lagged	Number of Diesel Vehicles	Adj. R^2	F
	Static (1)	`Coeff.	-2.835	9.305		0.668	0.982	428.7
Diesel Demand		t Value	-1.57	6.58		3.860		
	Dynamic (1)	Coeff.	1.316	6.538	0.654	-0.206	0.988	460.4
		t Value	0.72	4.71	3.59	-0.75		
	Dynamic (2)	Coffs.	0.229	6.642	0.537		0.988	628.1
		t Value	0.207	4.869	5.780			
	Dynamic (3)	Coeff.	0.457		1.153	-0.335	0.975	286.9
		t Value	0.173		5.35	-0.84		

Table 4.8: Fuel Price Elasticity Estimates

Model Type and Fuel	Short Run Price Elasticity	Long Run Price Elasticity
Petrol		
Static 1	-0.33	
Dynamic 1	-0.36	-0.40
Dynamic 2	-0.53	-0.88
Dynamic 3	-0.47	-0.57
Diesel		
Static 1	-0.19	

Comparison with International Models

4.25. As indicated above, Graham and Glaister undertook a major survey of international fuel demand literature collecting a total of 1,083 elasticity estimates relating to the 1966 to 2000 period. [11] There was a significant degree of variation in the estimates with, for example, approximately 2 per cent of the short and long run price estimates showing positive elasticities. That said, as Table 4.5 shows, the median estimate was very close to the mean in all cases.

4.26. Having reviewed the distribution of estimates, Graham and Glaister concluded that the weight of evidence suggests that:

- the short run price elasticity lies between -0.2 and -0.3;
- the long run price elasticity falls between -0.6 and -0.8;

Table 4.5: International Fuel Demand Price Elasticity Estimates

	No.	Max.	Min.	Mean	Median	SD
Short Run Price	387	0.59	-2.13	-0.25	-0.21	0.24
Long Run Price	213	0.85	-22.0	-0.77	-0.55	1.65

Source: Graham and Glaister (op.cit.)

4.27. Graham and Glaister do not indicate whether their analysis extends to petrol only, diesel only or petrol and diesel demand in total. Perusal of the studies that they surveyed indicates that most of them refer to petrol demand modelling. The preferred Irish estimates for petrol price elasticity derived in this report, at -0.53 in the short run and -0.88 in the long run, therefore appear high by comparison with average international estimates of fuel elasticities. This is particularly true of the short run effects. The estimate for diesel price elasticity at -0.19 is typical of the international values.

[11] D.Graham and S.Glaister. Road Traffic Demand Elasticity Estimates : A Review. Transport Reviews. Vol.24, May 2004.

Implications for Transport Demand Modelling

4.28. Transport demand modelling is concerned with predicting future trips on transport networks. The sensitivity of such predictions to future fuel prices is an important element of overall demand prediction. Transportation planning models, such as the National Transport Model do not normally include the effect of fuel prices at the trip generation stage. Thus, there may be a need to assess the impact of fuel prices separately from the modelling process and use it to employ tests of the sensitivity of demand, as measured by the model, to future fuel price scenarios.

4.29. Fuel price elasticities of demand indicate the sensitivity of fuel consumption not travel demand to fuel prices. As fuel demand is a derived demand and fuel is not consumed for its own utility, it follows that transport users will try to retain mobility in the face of fuel price increases. There are many ways in which fuel consumption can be conserved, without altering travel demand. In the case of the demand for car travel, this includes:

- Changing driving behaviour to economise on fuel;
- Better vehicle maintenance;
- Switching to a diesel vehicle; and
- Switching to a more economical petrol vehicle.

4.30. It follows that the price elasticity of demand for fuel will be above that for travel demand. If we take the petrol price elasticity as referring to car traffic, the price elasticity of demand for petrol may be decomposed as follows:

$$e(d,p) = e(t,p) - e(fe,p)$$

4.31. That is, the elasticity of the demand for petrol (d) with respect its price (p) is equal to the demand for car kilometres (t) with respect to petrol price less the elasticity of fuel efficiency (fe) with respect to petrol price.

4.32. Graham and Glaister estimated fuel price elasticities with respect to both fuel demand and car kilometres. This enabled them to estimate the elasticity of fuel efficiency with respect to fuel prices. Table 4.6 below indicates their overview of the elasticity estimates

Table 4.6: Elasticities for Fuel Demand, Car Kilometres and Fuel Efficiency

Fuel Price Elasticity with respect to	Short Run	Long Run
Fuel demand	-0.25	-0.77
Car kilometres	-0.15	-0.31
Fuel efficiency	0.10	0.46

4.33. The table shows that in the short run, the bulk of adjustment to a fuel price change is in terms of the car kilometres travelled, but in the longer term fuel efficiency changes dominate.

4.34. If we accept the long run fuel efficiency elasticity estimated above (0.46), then the long run elasticity of car kilometres with respect to fuel prices may be estimated in the Irish case at -0.88 +0.46 or -0.42. That is, in the long run a, say, 10% increase in real petrol prices would reduce traffic demand by 4%.

4.35. An alternative estimate of the long run price elasticity of demand for fuel is -0.57, based on Dynamic Equation 3. This would imply an elasticity of car travel with respect to petrol prices of -0.57 +0.46 or -0.17. [12]

4.36. In testing for the impact of petrol prices on car traffic demand in the context of the National Transport Model, it is therefore suggested that values of -0.2 (low), -0.3(medium); and -0.4 (high) be used. The medium value would accord well with international experience.

4.37. Turning to the demand for diesel, one of the problems in assessing the results is the growing proportion of diesel cars in the overall diesel fleet. This means that there are two very diverse sets of users of diesel vehicles and their influence is changing over time.

4.38. However, freight vehicles dominate diesel use and their opportunities for fuel efficiency gains are much less. Improved driving behaviour may yield some benefits, although hauliers will weigh the increased journey times against slower speeds. Similarly, hauliers have an incentive to maintain their vehicles adequately to ensure continuity of operation. Switching to other fuels is not an option and switching to smaller vehicles is often constrained by the need to keep other haulage costs low by exploiting vehicle economies of scale. The international literature on elasticities of freight demand with respect to diesel prices is relatively patchy and the modelling specifications vary hugely. There is thus little guidance from this source. A practical way forward is to assume that the elasticity with respect to diesel traffic kilometres and fuel efficiency are equal, so that an elasticity of diesel traffic demand with respect to diesel prices of -0.1 is proposed.

4.39. Thus, it is suggested that central estimates of elasticities of traffic demand with respect to fuel prices of -0.3 for petrol vehicles and -0.1 for diesel vehicles would be appropriate.

4.40. The CSO makes estimates of the total vehicle kilometres of travel by vehicles of different fuel types. Table 4.7 summarises the 2011 data. Diesel vehicles account for 51.2% of all vehicle kilometres with petrol accounting for 48.2%. Based on these proportions and using the central estimates of elasticity mentioned above, a 10% increase in both diesel and petrol prices would reduce traffic volumes by 2%. The equivalent low estimate is 1.5% and the high is 2.5%

[12] The other long run petrol price elasticity of demand for fuel of -0.40 would not produce a plausible estimate of elasticity with respect to car kilometres.

Table 4.7: Distribution of Vehicles and Vehicle Kilometres of Travel by Fuel Type, 2011

	Number of Vehicles in 000s and (%)		Vehicle Kilometres in millions and (%)	
Petrol	1,415.6	58.5	20,091	48.2
Diesel	989.8	40.9	21,341	51.2
Other	14,1	0.6	248	0.6
Total	2,419.5	100.0	41,680	100.0

Conclusions

4.41. Short term price elasticities of demand for petrol in Ireland are in the range of -0.33 to -0.53, with long term elasticities of -0.40 to -0.88. International experience suggests a short run price elasticity between -0.2 and -0.3 and a long run price elasticity between -0.6 and -0.8. The Irish estimates are at the higher end of the range.

4.42. Modelling suggests that diesel demand in Ireland adjusts in the short term and that there is no long term adjustment process. As a result, only the short run price elasticity is calculated and this is estimated at -0.19. The international literature on elasticities of freight demand with respect to diesel prices is relatively patchy and the modelling specifications vary hugely. There is thus little guidance from this source as to the elasticity of demand for diesel fuel with respect to diesel prices.

4.43. Fuel price elasticities of demand indicate the sensitivity to fuel prices of fuel consumption and not travel demand. As fuel demand is a derived demand and fuel is not consumed for its own utility, it follows that transport users will try to retain mobility in the face of fuel price increases. It follows that the price elasticity of demand for fuel will be above that for travel demand.

4.44. International experience indicates that the bulk of adjustment to a fuel price change in the short run is in terms of the car kilometres travelled, but in the longer term fuel efficiency changes dominate. In testing for the impact of petrol prices on car traffic demand in the context of the National Transport Model, it is suggested that values of -0.2 (low), -0.3(medium); and -0.4 (high) be used. The medium value would accord well with international experience.

4.45. Turning to the demand for diesel, one of the problems in assessing the results is the growing proportion of diesel cars in the overall diesel fleet. This means that there are two very diverse sets of users of diesel vehicles and their influence is changing over time.

4.46. However, freight vehicles dominate diesel use and their opportunities for fuel efficiency gains are much less. A practical way forward is to assume that the elasticity with respect to diesel traffic kilometres and fuel efficiency are equal, so that an elasticity of diesel traffic demand with respect to diesel prices of -0.1 is proposed.

4.47. Based on the proportion of vehicle kilometres of travel by diesel and petrol vehicles respectively and using the central estimates of elasticity mentioned above, a 10% increase in both diesel and petrol prices would reduce traffic volumes in the range 1.5% to 2.5% with a central value of 2%

5. Summary of Conclusions and Policy Implications

Fuel Consumption

5.1. Official data show starkly divergent trends in petrol and diesel consumption in the ROI and NI between 1990 and 2011:

- Petrol consumption is reported to have increased by 56% in the ROI while it practically halved in NI; while
- Diesel consumption more than tripled in the Republic while it rose just under 50 per cent in the North.

5.2. The most plausible conclusion is that official data are severely distorted by fuel tourism. This is supported by an examination of specific fuel consumption rates. Official data estimate them to be more than three times higher in the ROI than in NI whereas, in reality, there is little rationale for them to be different.

Fuel Prices

5.3. The primary motive for fuel tourism can be directly related to the existence of significant price differentials between the two jurisdictions. Historical trends reveal that:

- Until recently real petrol prices in the ROI were lower than they were 50 years ago with the extent of volatility declining in the last 20 years, however the real price has risen sharply since 2009;
- In contrast, there have been quite dramatic shifts in relative price differentials between the ROI and the NI;
    - Between 1958 and 1975, NI prices were on average 21 per cent higher than in the ROI;
    - Between 1976 and 1996, ROI prices were on average 24 per cent higher than in NI; and,
    - Since 1997, NI prices have on average been 26 per cent higher than in the ROI;

Cross-Border Fuel Movements

5.4. The total quantity of fuel actually consumed within the ROI and NI can be calculated by assuming that the specific fuel consumption rates of the various vehicle types are equal in the two jurisdictions. On this basis, revised estimates of total petrol and diesel consumption from 1988 to 2011 were derived together with estimates of fuel tourism.

5.5. The revised data for 2011 indicate that:

- ROI originating fuel used in NI amounted to 119,000 tonnes in the case of petrol and 494,000 tonnes in the case of diesel;
- Official data overestimate ROI petrol consumption by 9.4 per cent and diesel consumption by 29.5 per cent;
- Only 91.4 per cent of reported consumption in the ROI is actually consumed locally with the balance of 8.6 per cent represented by leakage into NI. Similarly, only 77.2 per cent of reported diesel consumption in the ROI is consumed locally with 22.7 per cent leaking across the border; and,

- Because of its smaller size, the implications are even more striking for Northern Ireland with petrol fuel tourism amounting to 38.2 per cent of reported consumption while diesel fuel tourism actually surpasses reported consumption.
- Fuel tourism in diesel has been approximately 3.3 times that in petrol since 2001; and
- The direction and scale of fuel tourism matches the trend in relative price differentials very closely.

Responsiveness of Fuel and Traffic Demand to Fuel Prices

5.6. Short term price elasticities of demand for petrol in Ireland are in the range of -0.33 to -0.53, with long term elasticities of -0.40 to -0.88. International experience suggests a short run price elasticity between -0.2 and -0.3 and a long run price elasticity between -0.6 and -0.8. The Irish estimates are at the higher end of the range.

5.7. Modelling suggests that diesel demand in Ireland adjusts in the short term and that there is no long term adjustment process. As a result, only the short run price elasticity is calculated and this is estimated at -0.19. The international literature on elasticities of freight demand with respect to diesel prices is relatively patchy and the modelling specifications vary hugely. There is thus little guidance from this source as to the elasticity of demand for diesel fuel with respect to diesel prices.

5.8. Fuel price elasticities of demand indicate the sensitivity to fuel prices of fuel consumption and not travel demand. As fuel demand is a derived demand and fuel is not consumed for its own utility, it follows that transport users will try to retain mobility in the face of fuel price increases. It follows that the price elasticity of demand for fuel will be above that for travel demand.

5.9. International experience indicates that the bulk of adjustment to a fuel price change is in terms of the car kilometres travelled, but in the longer term fuel efficiency changes dominate. In testing for the impact of petrol prices on car traffic demand in the context of the National Traffic Model, it is suggested that values of -0.2 (low), -0.3(medium); and -0.4 (high) be used. The medium value would accord well with international experience.

5.10. Turning to the demand for diesel, one of the problems in assessing the results is the growing proportion of diesel cars in the overall diesel fleet. This means that there are two very diverse sets of users of diesel vehicles and their influence is changing over time.

5.11. However, freight vehicles dominate diesel use and their opportunities for fuel efficiency gains are much less. A practical way forward is to assume that the elasticity with respect to diesel traffic kilometres and fuel efficiency are equal, so that an elasticity of diesel traffic demand with respect to diesel prices of -0.1 is proposed.

5.12. Based on the proportion of vehicle kilometres of travel by diesel and petrol vehicles respectively and using the central estimates of elasticity mentioned above, a 10% increase in both diesel and petrol prices would reduce traffic volumes in the range 1.5% to 2.5% with a central value of 2%

Appendix 1 - Methodology for Estimating the Scale of Fuel Tourism

A.1 Detailed Description of the Methodology

An estimate of the scale of fuel tourism can be found using the central premise that the specific fuel consumption of the various vehicle types is the same on both sides of the border. A sample calculation for 2011 is described in the attached table. The various steps involved can be described as follows:

Step 1: Establish the total number of vehicles by type on the island:
The official number of petrol and diesel vehicles is obtained from the Irish Bulletin of Vehicle and Driver Statistics for the Republic of Ireland and from the NI Transport Statistics for Northern Ireland.

Step 2: Obtain official petrol and diesel consumption data for the island as whole:
Reported fuel consumption figures for petrol and diesel for the ROI and NI are aggregated.

Step 3: Calculate specific fuel consumption rates for the island as a whole.
The specific petrol consumption rate is calculated by dividing the total petrol consumption figure by the total number of petrol passenger cars on the island as a whole. The specific diesel consumption rate is calculated by dividing the total diesel consumption figure by the total number of diesel vehicles on the island as a whole.

Step 4: Calculate revised fuel consumption for both countries.
The revised figure for petrol consumption in the ROI is obtained by multiplying the number of petrol cars in the ROI by the island's common specific petrol consumption rate of 0.9117 tonnes per car. The revised level of total petrol consumption in 2011 for the ROI thereby works out at 1,264,002 tonnes. The revised figure for diesel consumption in the ROI is obtained by multiplying the number of diesel vehicles in the ROI by the island's common specific diesel consumption rate of 1.6385 tonnes per vehicle. The revised level of total diesel consumption in 2011 for the ROI thereby works out at 1,675,939 tonnes. Revised levels of petrol and diesel consumption for NI are calculated in a similar fashion.

Methodology for Calculating Fuel Tourism in 2011

		Petrol			Diesel
Number of Vehicles in the ROI		1,387			1,023
Number of Vehicles in NI					
	As per DVA Classification	471			579
Total Number of Vehicles on the Island		1,858			1,602
Reported Fuel Consumption					
	ROI	1,383			2,169
	NI	311			456
	Total on Island	1,694			2,625
Specific Fuel Consumption		0.9117			1.6385
Revised Fuel Consumption					
	ROI	1,264			1,675
	NI	430			950
	Total				2,625
Fuel Tourism					
	ROI	119.0			494.0
	NI	-119.0			-494.0

Source: AECOM
Note: All fuel data are Thousands of Tonnes

Step 5: Calculate Fuel Tourism

The extent of fuel tourism is obtained by subtracting the revised consumption figures derived in Step 4 from the reported consumption figures. From the table it can be seen that 119,000 tonnes of petrol and 494,000 tonnes of diesel travelled across the border from the ROI into NI in 2011.

The above process is repeated for each of the years from 1988 to 2011 thereby deriving revised data series for both petrol and diesel consumption and creating new independent estimates for fuel tourism.