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The impact of tax reform on new car purchases in Ireland

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ABSTRACT

We examine the impact of recent tax reforms in Ireland on private car transport and its greenhouse gas emissions. A carbon tax was introduced on fuels, and purchase (vehicle registration) and ownership (motor) taxes were switched from engine size to potential emissions. We use a demographic model of the car stock (by age, size, and fuel) and a car purchase model that reflects the heterogeneous distribution of mileage and usage costs across various engine sizes. The model shows a dramatic shift from petrol to diesel cars, particularly for large engines. The same pattern is observed in the latest data on car sales. This has a substantial impact on tax revenue as car owners shift to the lower tax rates. The tax burden has shifted from car ownership to car use, and that the overall tax burden on private car transport falls. As diesel engines are more fuel efficient than petrol engines, carbon dioxide emissions fall modestly or, if we consider the rebound effect of travel costs on mileage, minimally. From the perspective of the revenue, the costs per tonne of carbon dioxide avoided are (very) high.

1. Introduction

Private car transport accounted for approximately 12% of total CO_2 emissions in Ireland in 2006 (O'Gallachoir et al., 2009). This represented a significant increase over time, both in absolute terms and in terms of its share of total emissions. Transport,[1] as a whole, accounted for around 36% of total CO_2 emissions in this period. The transport sector was identified as a serious cause for concern to policymakers due to its unsustainable dependence on oil and its negative environmental impacts. The National Climate Change Strategy Ireland (NCCSI, 2007) forecasted that this sector would account for the largest increase in emissions by 2010 if no policy measures were taken. This, along with concerns over the long-term supply of oil, provided some of the background for policy intervention in 2007. One such policy objective is improving the efficiency of the car fleet by incentivizing purchase of more fuel efficient cars. This can be done by incentivising the purchase of diesel cars, which are more energy efficient and have lower running costs than comparable petrol cars.

The number of private cars in Ireland has risen significantly in the last two decades. This has led to a noticeable convergence in the number of cars per thousand between Ireland and its European counterparts. This is a crude measure for comparing levels of car ownership across countries. Although a deep recession has delayed many of the negative trends in private car transport, this does not mean that private car transport has become more sustainable. The recent depression led to a collapse in new car sales, but new car sales have now started to recover. Government policy can significantly influence this purchase decision though taxation (Mayeres and Proost, 2001; Verboven, 2002; Ryan et al., 2009).

Private car transport produces many negative externalities, particularly in relation to the environment (Mayeres and Proost, 2001). This provides a further rationale for government intervention. Taxation can achieve a reduction in this negative externality (Baumol, 1976). This can be done in terms of a tax, which taxes emissions directly or indirectly through a differential taxation regime on purchase. The EU have set emission targets for new cars that enter the car fleet. They have adopted a target of 130 g/km CO_2 for weighted new car sales by 2015 and 110 g/km CO_2 by 2020 (EC, 2002, 2005). As noted in Kunert and Kuhfeld (2007), Ryan et al. (2009), and Mandell (2009), there is a European consensus to move away from purchase taxes and move towards use taxes, which are differentiated by emissions. The European Commission also proposes abolishment of registration taxes. Ireland has no indigenous car manufacturing industry and is thus a technology taker. Because it is such a small market, tax changes in Ireland will have a negligible effect on the design of cars.

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[1] This refers to the two digit NACE code 36, which covers all aspects of transport including freight.

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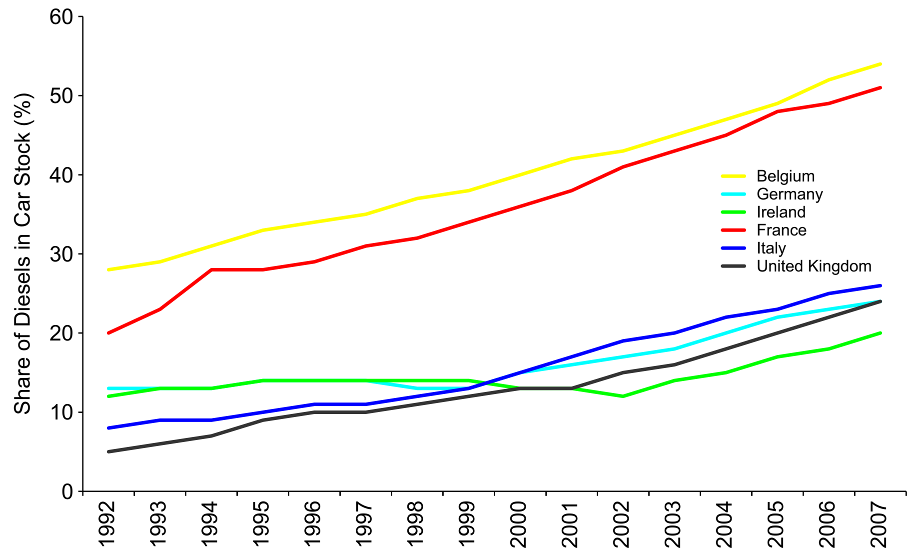

Fig. 1. The share of diesel across Europe.

However, car manufacturers will respond to a coordinated policy change across the entire European Union.

In July 2008, the car tax structure was changed in Ireland. Taxation on new private cars is now based on (potential) emissions per kilometre rather than engine size. This change affects both the purchase price and the ownership costs of new private cars but has no effect on the usage costs. The impact on carbon dioxide emissions is therefore indirect. A more carbon efficient fleet will result in lower emissions, although there may be a change in mileage that partly offsets these gains.

Similar schemes exist in many other European countries. In 2002, the UK introduced a carbon-differentiated vehicle taxation policy. This policy was also accompanied by a modified benefit-in-kind tax policy on company cars to encourage purchase of more efficient vehicles. However, this policy only impacted on the ownership cost per year and had no effect on initial purchase cost. The difference between the tax bands was substantially smaller compared to the Irish system. This taxation system changed again in April 2010. Although there still remains only one type of vehicle tax, the revamped tax further encouraged the purchase of low emitting vehicles. 'First-year taxes' are such that low emitting cars are exempt from vehicle tax in the first year in contrast to high emitting vehicles that are penalised heavily in the first year. Sweden has previously utilised a car taxation policy similar to that of Ireland. Although they have no direct purchase taxes, Sweden has offered a subsidy (~€1000/car) to encourage the purchase of environmentally friendly cars. This policy was used in conjunction with carbon-differentiated ownership taxes, which had the effect of encouraging the purchase of cars with emissions of under 120 g/km. This system was intended to remain in operation until 2010 but was amended in 2009 due to the unexpectedly large sales that it caused (Mandell, 2009). The subsidy was replaced by a five year exemption from motor tax.

There are various reasons for adopting a new tax regime that switches tax incidence onto emissions rather than engine size. As we show in the paper, there is not perfect correlation between engine size and emissions and thus this tax change has significant effects for the market share of each fuel type. This also means that the tax change will create a structural break when projecting emissions from private car transport.

In this paper, we present a methodology to explain the significant effect the recent tax change has had on the fuel share of new car sales in Ireland. Section 2 surveys the relevant literature. Section 3 discussed the data used in the analysis. Section 4 presents the methodology. Section 5 discusses the results. Finally, Section 6 offers conclusions.

2. Previous research

Since the late 1980s, the share of diesel cars has increased steadily across Europe (Pock, 2010). However, the environmental benefit of diesel cars over petrol cars is contentious (Verboven, 2002; Mayeres and Proost, 2001). In terms of CO_2 emissions, diesel cars are superior due to their higher fuel efficiency. However, diesel engines produce higher NO_x emissions and also produce particulates (North et al., 2006). Improvements in the diesel engine, like the introduction of turbo and direct injection, have helped to reduce the gap considerably between petrol and diesel cars in important physical attributes like acceleration and speed (Verboven, 2002; Mayeres and Proost, 2001). This has had the effect of making the two fuel types closer substitutes in terms of consumer preferences. However, these two fuels are treated very differently across the European countries in terms of taxation policy. These heterogeneous taxation policies largely explain the different penetration rates of diesel in the European Union (Ryan et al., 2009).

The share of diesel sales varies considerably across the European countries (see Fig. 1). There are three types of taxation that affect the car purchase decision—purchase, ownership, and usage. The rates applied to these vary significantly. Kunert and Kuhfeld (2007) examine these various rates across the EU.[2] They find that Ireland has the 3rd highest tax burden on petrol and diesel car ownership within the EU 25. They conclude that the structure of vehicle taxes should be rebalanced with CO_2 not being the sole focus. Verboven (2002) examines the diesel tax policies in Belgium, France, and Italy. He concludes that these differential tax rates have led to a certain degree of price discrimination in the diesel car market. He also finds that when controlling for engine size, annual mileage is the main determinant factor in the fuel choice decision. Verboven (2002) focuses

[2] See also Mayeres and Proost (2001) for an account of the various taxation policies towards diesel fuel in the European Union. The European Commission reports (COWI, 2002 and TIS, 2002) also give a full account of the various fiscal treatments in 2002.

on the tax differential in relation to two of its components, namely purchase and ownership.[3] The other component is in relation to the amount of excise applied to each litre of the fuel. This can have both a direct and indirect effect on emissions. It directly affects usage and it indirectly affects the efficiency level of purchased new cars. Many studies have looked at both the short-run and long-run price elasticity of fuel demand using both micro and macro data (see Goodwin et al., 2004 for a recent review of this literature). Sterner (2007) highlights the importance of these fuel taxes in relation to controlling emissions from private car transport. These fuel prices also have an impact on the efficiency of the car stock as noted in Li et al. (2009). They conclude that a 10% increase in fuel prices leads to a 0.22% increase in car fleet economy in the short-run and a 2.04% increase in the long-run.

Ryan et al. (2009) explicitly examine the impact of the different fiscal regimes on passenger car sales and the associated CO_2 emissions intensity of these sales. They conclude that carbon-differentiated circulation taxes are preferable to registration taxes when attempting to encourage a more efficient fleet. Verboven (2002) uses these tax differentials to analyse the extent of price discrimination that they have created in three European car markets. He finds that countries with a low tax burden on diesel cars (France and Belgium) have a higher level of price discrimination compared with normal tax burden (Italy). Mayeres and Proost (2001) examine the rationale for the different taxation treatment of diesel cars. Using a general equilibrium framework, they conclude that the negative environmental costs of diesel cars have a higher social cost than its petrol equivalent. Thus, increasing the taxation on diesel can achieve significant welfare improvements. This paper essentially puts a higher social cost on the negative effects of diesel cars (NO_x) over the negative effects of petrol cars (CO_2).

These studies focus on the effects of the differential tax regimes that are in place for diesel engines. However, another important effect is the fuel choice decision which affects the penetration rates of diesel cars. Rouwendal and de Vries (1999) design a model that looks explicitly at the fuel choice decision. They conclude that the tradeoffs between petrol and diesel are dependent on the number of kilometres driven. This is in agreement with Verboven (2002), who argues that all vehicle attributes are homogenous to a first approximation.

There is a relatively small literature that directly looks at the impact of taxes differentiated by (potential) carbon dioxide emissions. Mandell (2009) examines the system in Sweden and finds that when the tax change affects the purchase and ownership, these types of policies can have a much larger impact on the market share of diesels. In the UK, assessing the exact impact of the 2002 tax change has proved complex (Ward-Jones, 2010). It has been shown that motor tax is not significant in the car choice decision (Lehman et al., 2003), but more recent analysis would suggest that consumers are indeed switching to lower emission vehicles (SMMT, 2007). However, the UK system penalises high emissions far less than the current Irish system. The recent change to incorporate 'first-year taxes' somewhat addresses this imbalance.

Many studies have looked at modelling vehicle choice (Bresnahan and Schmalensee, 1987; Berry et al., 1995; Brownstone and Train, 1998) and the effect of the various car attributes on this choice. These papers attempt to model the various levels of product heterogeneity, which are apparent in car choice decisions. Berry et al. (1995) provide the seminal work in this area using a random coefficient logit model to investigate vehicle choice. This type of model provides more realistic substitution patterns than the traditional logit model. This methodology produces higher cross-price elasticities for cars with more similar attributes. This model uses knowledge of income distribution to infer willingness to pay estimates for the various products attributes. However, this model has not been applied explicitly to the fuel choice decision.

Pock (2010) uses a similar model to the model used in this paper to explain (but not predict) the different diesel to petrol ratios across Europe, which is important when constructing estimates of gasoline demand. Verboven (2002) uses a utility maximising model where mileage is the only heterogeneity among consumers. Heijnen and Kooreman (2006) extend this model, relaxing the assumption that the price elasticity for mileage is zero, and look at Nash equilibria to examine the interactions between taxation and car use. Rouwendal and de Vries (1999) construct a structural model, which consists of a logit model for fuel choice, with a sample selection for mileage. These models suffer from limited knowledge of the exact form of the mileage distribution and the assumption that the mileage distribution is homogenous across engine sizes. Verboven (2002) specifies the cumulative distribution function parametrically as a simple function of mean annual mileage and standard deviation.

In Ireland, recent research has focused on the efficiency of the new car fleet (O'Gallachoir et al., 2009; Howley et al., 2007). Hennessy and Tol (2010) focus on modelling the car stock and point out that changing patterns of new car sales have little effect on stock efficiency in the short run. They also emphasise the important of an engine size disaggregated model when making future projections about the car stock. Other research on car purchase decisions in Ireland includes Mariuzzo et al. (2009), who investigate new car sales using a nested logit approach. This research examines the existence of price co-ordination among sellers in the new car market.

Giblin and McNabola (2009) have modelled the recent tax change using the COWI cross-country car choice model[4] to simulate the impact of both the VRT change and the motor tax change, collectively and separately. They find that the change in ownership taxes has a larger effect on car choice than the change in purchase tax. They predict an increase (6%) in the market share of diesel cars. This is very much against recent observed data which suggests that the share of diesel cars has actually increased from 25% to 57% (Central Statistics Office, 2000).

3. Data

We use car and mileage data. The car data is collected from a variety of sources. The mileage data is constructed by the Central Statistics Office (CSO) of Ireland and has been disaggregated by engine size, fuel type and age.

The car prices, disaggregated by 9 engine categories, are taken from Society of Irish Motoring Industry (SIMI). Before the tax change, the average difference between petrol and diesel was approximately €2000. This is in line with previous estimates (Verboven, 2002; Ryan et al., 2009). Fuel prices are taken from the AA database of fuel prices. These are annual prices which are normalised across the year and the country. Diesel prices have been historically lower then petrol prices in Ireland (see Fig. A1). However, this trend was reversed in 2007 but has since returned. In terms of the model, the relative difference in purchase prices

[3] The net savings in relation to fuel usage are indeed calculated. However, the difference across the three countries is small in comparison with the differences apparent in annual car tax.

[4] The COWI model was developed in Denmark as part of the European Commission project. It is a discrete choice car model, which has previously been used to study the potential effects of fiscal measures on the efficiency of new passenger vehicles in the EU (COWI, 2002).

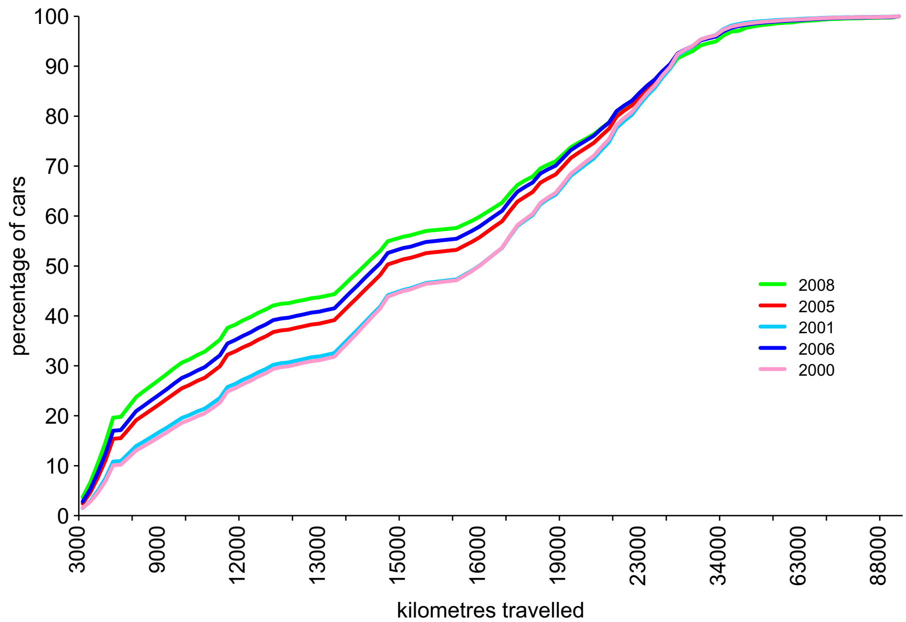

Fig. 2. Cumulative distribution of annual mileage for selected years.

and fuel prices between the two fuel types is the desired input value. We assume homogenous maintenance costs and that the resale value of the car is a function of the initial purchase price including taxes. Other car attributes like horsepower, speed and size are assumed to be homogenous to a first approximation as in Verboven (2002).

The use of mileage distribution data when evaluating car purchase decisions is limited in the literature.[5] The random coefficient model of Berry et al. (1995) allows for the use of distributional data to examine heterogeneity in consumer preferences. In their paper, they use income and demographic distributional data. However, no mention of mileage distribution is included in this paper or any subsequent paper using this type of methodology. Our mileage distribution data is provided by the CSO. This dataset uses two types of administrative data to construct estimates of annual mileage disaggregated by engine size, fuel type and age. First, it uses data collected from the National Car Test (NCT), which constructs estimates of mileage based on odometer readings. This procedure is described and analysed in Kelly et al. (2009). However, the NCT is only conducted on cars that are 4 years or older. This leads to the need for supplementary data source for newer cars. Information on cars less than 4 years old is appended to the dataset from various private sources.[6]

Fig. 2 shows the aggregate distribution of mileage from the year 1999 to 2008. The proportion of cars that can be described as high mileage cars ($>25,000$ km) remains constant over the time period. The biggest change is in the low to medium mileage cars. There are now more cars that drive fewer kilometres than in 1999. This can be partially explained by the increase in the number of multi-car households.

The main advantage of using the complete distributional data is that it allows us to identify the relevant market for a more efficient engine type. Fig. 3 shows that the shapes of the mileage distribution (for 2008) are different between engines sizes. High (low) mileage and large (small) engines go together. Consumers who drive the least will care little about the savings of driving a more efficient car and thus be heavily influenced by initial purchase price. Fig. 3 also shows the break-even distance pre- and post-tax reform, discussed below.

4. Model

We quantify the effect of the recent tax change in Ireland, which has switched the incidence of taxation from engine size to carbon dioxide emissions. We are interested in the fuel share given an exogenous car stock disaggregated by engine size.[7] We construct a total life-cycle cost model, which is used to estimate the mileage break-even point. A rational car-owner who drives more than this break-even point will opt for the more efficient car and choose a diesel.

The costs of a car consist of the purchase price, the operational cost, the maintenance cost and resell value (1). These can be compared across both fuel types. We assume that the various attributes within comparative engine size of petrol and diesel cars are homogeneous to a first approximation (Rouwendal and de Vries, 1999; Verboven, 2002).[8] The total life-cycle cost of car ownership is given by

$$C_i = P_i(1+\alpha_i)+\beta_i+\sum_{t=0}^{T_i}\frac{M_{i,t}+\gamma_{i,t}+(\pi_{i,t}+\delta_{i,t})\varepsilon_{i,t}D_t}{(1+\rho)^t}-\frac{S_i}{(1+\rho)^t} \quad (1)$$

where

- C_i is the net present cost of a car of type I;
- P is the purchase price;
- α is the value added tax and stamp duty;
- β is the vehicle registration tax;
- M is the annual maintenance;
- γ is the annual motor tax;

[5] The notable exception to this is Verboven (2002), who uses mileage distribution data taken from industry associations ACEA, FEBIAC, ANDTRI, and from survey data by De Borger (1987).

[6] Motorcheck.ie provides a database of private cars in Ireland. This provides information on annual mileage of cars that are less than 4 year old.

[7] This exogenous car stock, disaggregated by age and engine size is taken from the ISus Car Model which is described in Hennessy and Tol (2010).

[8] The rationale for this assumption has improved in the last decade with the advent of turbo and direct injection. This considerably reduces the noticeable drag that characterised previous diesel fuelled cars.

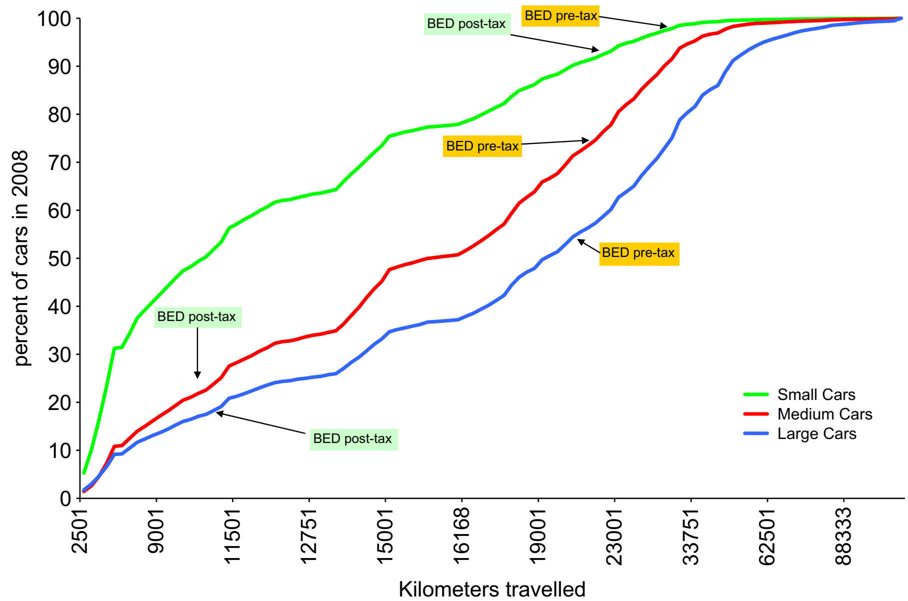

Fig. 3. The effect of tax reform on break-even distance.

- π is the price of fuel;
- δ is the excise duty on fuel;
- ε is the fuel efficiency of the car;
- D is the annual distance drive;
- ρ is the discount rate;
- T is the life-time of the car; and
- S is the sell value of the car.

If we hold all parameters constant over time and at their current value (as a car buyer might), then (1) simplifies to

$$C_i = P_i(1+\alpha_i)+\beta_i+\frac{(1+\rho)^{T_i}-1}{(1+\rho)^{T_i}}\frac{1+\rho}{\rho}\left[M_i+\gamma_i+(\pi_i+\delta_i)\varepsilon_i D\right]-\frac{S_i}{(1+\rho)^{T_i}} \tag{2}$$

Diesels are more expensive to buy but cheaper to drive. For the same life-time, the break-even distance is given by

$$D^* = \frac{\frac{(1+\rho)^T}{(1+\rho)^T-1}\frac{\rho}{1+\rho}\left[\Delta(P(1+\alpha))+\Delta\beta-\frac{\Delta S}{(1+\rho)^T}\right]+\Delta M+\Delta\gamma}{\Delta((\pi+\delta)\varepsilon)} \tag{3}$$

where ΔS denotes the difference between a petrol car and the equivalent diesel car.

Eq. (3) gives the break-even distances for each engine size. We evaluate this pre- and post-tax reform, changing the excise duty on fuel, the annual motor tax and the vehicle registration tax, but keeping all other variables constant. We do so for each engine size. This is important as the computed efficiency advantage of diesel over petrol varies by engine size. Following Verboven (2002), we assume that anyone with a mileage above the break-even distance buys a diesel car. We use the discount rate to calibrate the break-even distance before tax reform (see Fig. 3) to the observed market shares in 2007. Eq. (3) is thus used to estimate *the change in* the market shares of diesel and petrol.

Note that we assume that the resale value of cars is not unaffected by the tax reforms. This assumption is incorrect, but probably not particularly influential. In the medium-term, the tax reforms induce an increase in both the demand and the supply of diesel cars, so the price response on the second-hand car market is muted. Trade in second-hand cars with the United Kingdom further dampens the response of the market to tax reform.

We integrated this break-even distance model into the ISus Car Model. This model is described in Hennessy and Tol (2010) and it forecasts the private car stock in Ireland out to 2025. It provides forecasts of the number of cars disaggregated by engine size, age, and fuel type. It also provides forecast of mileage by engine size and fuel type. This allows us to examine the effect of the tax change in relation to emissions. There is also a tax component of this model, which allows us to project the amount of tax revenue generated by private car taxation.

We show the results of two different versions of the model. In the first version (without rebound), we assume that some people switch to a diesel car but drive the same distance as they would have had they bought a petrol car. In the second version (with rebound), we assume that people take advantage of the lower costs and drive more than they otherwise would have. Lacking information on the price elasticity of mileage demand, we note that diesel cars have large engines than the petrol cars with similar performance. We further note that larges engines are associated with higher mileage. In the second version of the model, we assume that people switch to a diesel car and increase their mileage to match the larger engine. While the first version of the model provides an upper bound to the estimate of the reduction of carbon dioxide emissions, the second version gives a lower bound.

5. Results

In this section, we discuss the results of the model with specific details of the changes in relative break-even distance and how this along with the distribution of mileage by engine size affects the market share of diesels. We use the cumulative mileage distribution in 2008 as it best represents the current population. We conduct a number of different simulations to examine the different effects on the share of diesel cars per engine size.

5.1. Baseline scenario

Our baseline specification includes all aspects of current government car taxation policy. As discussed previously, this includes a purchase tax (VRT) and an ownership tax (Motor tax) based on CO_2 emissions rather than engine size as before 2008.

Table 1 shows the taxes before and after the 2008 reform. We find a substantial effect overall, varying by engine size. The break-even distance figures are shown in Table 2 and Fig. 3. The effect of the tax reform is greatest in the medium size car market. It has little effect on the small size car market where the tax change has benefited both diesel and petrol. Furthermore, smaller cars tend to be driven less far. This effect is also evident for large cars (over 2 l engine) where petrol cars have lost substantial market share. However, the tax reform has also meant that this segment of the car market has decreased. Table 2 shows the impact on the market share of diesel cars.

Our impact estimates are greater than the impact found of similar schemes in the literature (Lehman et al., 2003; Mandell, 2009). However, as discussed previously, this particular tax reform is far larger than the scheme's that have been analysed in the previous studies. When it is compared against the VED scheme in the UK, the Irish band based system has a much wider range than the UK system (see Table A1). This, along with the system of no car purchase taxes in the UK, explains why of the Irish carbon-differential tax scheme has such a large effect.

5.2. Decomposition

We apply the model to a scenario where only the purchase price changed as a result of the tax change. This reduces the purchase price of lower emission cars. It has no direct effect on annual ownership taxes or annual usage costs. We find a substantial effect in the predicted market share of diesels by engine size (Table 3) when compared with the observed shares of diesels before the tax change.

We also apply the model to a scenario where only the ownership cost changes as a result of the tax change. This imposes solely an annual cost on car ownership regardless of usage. The simulation results are reported in Table 3. Again, we see a substantial increase in the 'dieselisation' rate across the medium to large engine classes.

Previous literature (Ryan et al., 2009; Giblin and McNabola, 2009; Mandell, 2009) has that the effect of ownership tax reform is more important than that of the purchase tax reform. We confirm this for cars with engine sizes over two litres. However, for smaller cars, motor tax reform is more effective.

5.3. Effect of tax reform on government revenue

We examine the impact of the tax change on government revenue. The motor tax reform only affects cars registered after June 2008. Thus, it takes time for this tax change to have a significant effect on motor tax revenue (see Fig. 4). By 2025, the tax shortfall will be as much as €400 million compared to the situation of unreformed taxes. This assumes that motor tax rates remain constant.

In contrast, the effect on Vehicle Registration Tax revenue is immediate. As new car sales have fallen sharply due to the severe recession, there has been a collapse in VRT revenue. However, with the advent of the tax reform, a return to "normal" car sales will not mean a return to pre-reform VRT revenues. Fig. 4 shows that a significant shortfall will emerge in VRT revenue. This effect depends on the rate of recovery in the economy which affects both the amount and cost of cars being purchased (see Table 4). Giblin and McNabola (2009) estimate that based on annual sales of approximately 130,000 new cars, the shortfall in tax revenue will be €181 million. This is broadly similar with the estimates derived in this analysis (Table 4).

A carbon tax was introduced in late 2009 in Ireland. This has placed an extra unit cost on each litre of fuel consumed. The carbon tax raises the price of a litre of petrol by 4.2 cents and the price of diesel by 4.9 cent. This reflects the higher carbon content in diesel fuel. Table 5 shows the projected tax revenue, which exceeds the revenue foregone by the motor and vehicle registration tax reform in the first year (2010) only. After that, the overall tax burden on private transport is lower than it would have been without tax reform—by up to half a billion euro in 2025. The tax reforms of 2008 and 2009 shifted the burden of taxation from car ownership to car use – as many economists would recommend

Table 1
Tax rates before and after the July 2008 reform.

Diesel						Petrol					
Tax[a]	ISus	VRT[b]		MT[c]		Tax[a]	ISus	VRT[b]		MT[c]	
		bef (%)	aft (%)	bef	aft			bef (%)	aft (%)	bef	aft
A	A	22.5	14.0	165	104	A	A	22.5	14.0	165	104
B	B	22.5	16.0	165	156	B	B	22.5	16.0	165	156
B	D	22.5	16.0	275	156	B	D	22.5	16.0	275	156
B	E	25.0	16.0	320	156	C	E	25.0	20.0	320	302
B	F	25.0	16.0	343	156	D	F	25.0	24.0	343	447
B	G	25.0	16.0	428	156	D	G	25.0	24.0	428	447
C	H	25.0	20.0	550	302	E	H	25.0	28.0	550	630
E	I	30.0	28.0	800	550	F	I	30.0	32.0	800	1050
G	J	30.0	36.0	1150	2100	G	J	30.0	36.0	1150	2100

This table shows how the engine size classes in the ISus car model (A–J) are transformed into new emissions bands (A–G). Note this is an illustrative example. The concordance table used to create emissions bands is based on actual sales in 2008–2009. This shows that petrol with the same engine size does not necessarily end up in the same emission bands.

[a] Classification in the tax code.
[b] Vehicle Registration Tax, ad valorem.
[c] Motor Tax, specific duty, €/year.

Table 2
The effect of tax reform on the break-even distance and the market share of diesel.

Engine size (CC)	Break-even distance (1000 km)		Diesel market share (fraction)	
	Before	After	Before	After
< 900	50.7	51.6	0.00	0.00
901–1000	50.7	51.3	0.00	0.00
1001–1300	27.2	23.5	0.03	0.06
1301–1400	26.4	18.3	0.08	0.30
1401–1500	21.2	9.7	0.26	0.90
1501–1600	27.5	14.4	0.09	0.57
1601–2000	14.0	8.6	0.68	0.89
2001–2400	18.1	5.6	0.52	0.94
> 2401	17.8	10.3	0.50	0.81

Table 3
The break-even distance and the market share of diesel after tax reform if only the Vehicle Registration Tax or only the Motor Tax had been changed.

Engine size (CC)	Break-even distance (1000 km)			Market share of diesel (fraction)		
	Before	VRT	MT	Before	VRT	MT
< 900	50.7	51.6	50.1	0.00	0.01	0.01
901–1000	50.7	51.3	50.1	0.00	0.00	0.00
1001–1300	27.2	28.7	21.7	0.03	0.03	0.10
1301–1400	26.4	26.8	17.6	0.08	0.06	0.31
1401–1500	21.2	14.6	13.1	0.26	0.56	0.63
1501–1600	27.5	22.1	19.5	0.09	0.23	0.33
1601–2000	14.0	15.1	9.8	0.68	0.65	0.85
2001–2400	18.1	13.4	17.8	0.52	0.71	0.53
> 2401	17.8	11.2	17.6	0.50	0.77	0.50

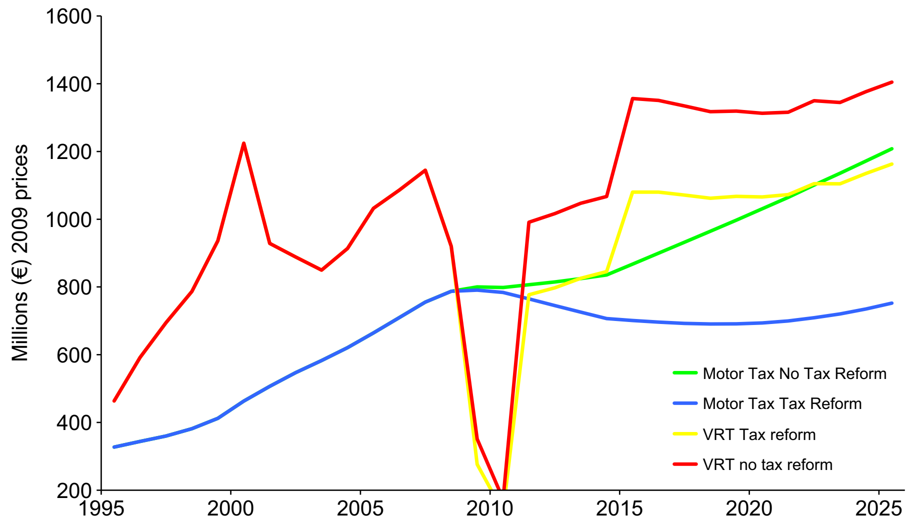

Fig. 4. The effect of tax reform on tax revenue.

Table 4
The effect of tax reform on car tax revenue (million euro).

	Motor Tax			Vehicle Registration Tax		
	No tax reform	Tax reform	Difference	No tax reform	Tax reform	Difference
2010	800	782	18	242	190	52
2015	857	693	164	1041	819	222
2020	968	652	316	973	768	205
2025	1066	657	409	1006	796	210

Table 5
Emissions and tax revenue lost.

	Tax revenue			Carbon dioxide avoided		Revenue forgone per emission avoided	
	Million euro			Thousand tonnes of CO_2		€/tCO_2	
	MT+VRT[a]	CT[b]	Total	With rebound	Without rebound	Minimum[c]	Maximum[d]
2010	−70	120	50	6	14	5150	−4381
2015	−386	116	−270	133	210	1840	93,071
2020	−521	116	−405	139	346	1506	107,713
2025	−619	114	−505	148	382	1621	120,987

[a] Change in tax revenue due to motor tax and vehicle registration tax reform.
[b] Change in tax revenue due to introduction of carbon tax on transport fuel.
[c] Without rebound, without carbon tax.
[d] With rebound, with carbon tax.

(Verhoef et al., 1995; Proost et al., 2002; Ubbels et al., 2002) – but also reduced the total tax burden—a topic on which opinions diverge (Parry and Small, 2005).

5.4. *Emissions and tax revenue lost per tonne of carbon dioxide*

Tax reform impacts carbon dioxide emissions. There are two effects. First, the fuel efficiency of cars improves as drivers switch from petrol to diesel. Table 5 shows that the effect is relatively modest—about 0.2 million tonnes of carbon dioxide in 2015 rising to 0.4 million tonnes in 2025, compared to some 6.0 mln tCO_2 for total private transport emissions (in 2008). However, higher fuel efficiency implies lower driving costs. If we include this rebound effect, carbon dioxide emissions still fall, but only by a little bit. See Table 5.

Table 5 also shows the cost to the exchequer per tonne of carbon dioxide avoided. In 2011, it varies between €3,800/tCO_2 without the rebound effect and the carbon tax and €17,000/tCO_2 with rebound and carbon tax. The range gets wider over time, increasing to 1600–121,000 €/tCO_2 in 2025.

For comparison, the 2010 price of carbon dioxide in the EU ETS is about €15/tCO_2; this may rise to 30–70 €/tCO_2 in 2020 (Boehringer et al., 2009). One cannot, of course, compare the marginal welfare cost to the marginal tax revenue. The tax revenue foregone is a transfer from the government to owner and drivers of cars. Nevertheless, the government is responsible for meeting the targets for greenhouse gas emission reduction—and it can meet such targets through the purchase of certified emission credits, which tend to trade at a price slightly below ETS permits.

6. Conclusions

This paper studies the impact of shifting vehicle registration and motor taxes from engine size to potential emissions, as introduced in Ireland in July 2008. This has led to a substantial shift to diesel cars, particularly for larger engines. We estimate that the overall market share of diesels will increase from 25% to 58% as a direct result of the tax reform. As a result, the revenues from the vehicle registration tax dropped instantaneously and permanently; while the revenues from the motor tax drop gradually over time as the car stock adjusts to the new pattern of car sales. The government introduced a carbon tax on transport fuels in November 2009. In the long run, the extra revenue from the carbon tax is about 1/6 of the revenue foregone from the vehicle registration and motor taxes. Although the tax burden has shifted from car ownership to carbon use, the overall tax burden has fallen. Because diesel cars are more fuel efficient, carbon dioxide emissions fall but only modestly. As travel costs fall, people may well drive more; correcting for this rebound effect, the drop in emissions is minimal. As a consequence, the cost to the revenue per tonne of carbon dioxide avoided is high if not very high.

These results come with a number of caveats. First, the model predicts a large shift from petrol to diesel. This has been consistently observed over the last 18 months. While this is a

Fig. A1. Time series of monthly fuel prices.

Table A1
Comparison of ownership taxes in Ireland and the UK.

Emissions	UK rates (£)	Irish rates (€)
Up to 100	0	104
101 to 110	35	104
111–120	35	104
121–130	120	156
131–140	120	156
141–150	125	302
151–165	150	447
166–175	175	447
176–185	175	630
186–200	215	630
201–225	215	1050
226–255	405	2100
Over 255	405	2100

welcome validation of the model, car sales were at an exceptionally low level because of the depression of the Irish economy. Our predictions should be checked with data once the economy has returned to normal. Second, we foresee a reduction in tax revenue of half a billion euro per year. This is probably not acceptable given the fiscal situation. It is therefore likely that tax rates will be adjusted upwards. Tax bands may also be changed. The lowest band at present is 120 g/km and this gives no incentive to purchase a 90 g/km car over a 119 g/km car. This problem will be highlighted as larger numbers of low emissions hybrid cars come onto the market. Thirdly, we use a simple car purchase model, calibrated with aggregate data. The robustness of our results should be checked against more detailed models estimated with micro-data. The same is true for our assumptions about distance driven. All this is deferred to future research.

Appendix A1

See Fig. A1 and Table A1.

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