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What does improved fuel economy cost consumers and taxpayers?
Some illustrations

by

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1. Introduction

"Green growth" is a useful emerging paradigm that re-packages several existing concepts, including durable economic activity, reduced environmental impact and sustained growth in high-quality jobs, under one banner and in such a way as to frame coherent, cross-sectoral policies. Focusing on "green growth" as such does not obviate the need for governments to assess policies carefully according to their long-term economic, environmental and social impacts. There are tradeoffs between the various dimensions of green growth and government policies determine who gains and who loses. As we hope to show in this paper, an examination of "green growth" policies in the transport sector provides an interesting case in point. Reducing emissions comes at a cost to road users and to taxpayers and it may be necessary to review the way the transport sector is taxed and contributes to aggregate tax revenue. In Section 2 of this paper, we first discuss the impact of fuel-efficiency enhancing policies in the transport sector on government fuel tax revenue. In Section 3, we then use a simple stylized model to illustrate how fuel economy improvements are valued by drivers and how they affect fuel tax revenues. We also look into the potential of kilometre taxes to compensate for the erosion of the fuel tax base. Section 4 discusses our results in a policy context and offers concluding remarks.

2. The impact of green-growth in transport on fuel-tax revenue

Central to the idea of "green growth" in the transport sector is that transport technologies should shift from more to less polluting options. Improved fuel economy is a central component in this shift as it is generally understood to deliver a number of important benefits. Improvements in fuel economy decrease the cost of driving and reduce environmental impacts from GHG emissions to the extent that these benefits are not eroded by more driving. On the other hand, some negative impacts may result as well – such as increased congestion and local pollution generated by any increase in driving. Society, on balance, is generally thought to benefit from these policies and improving light-duty vehicle fuel economy has been a central focus of transport policy in many countries in recent years. But how costs compare to benefits depends on how ambitious fuel economy improvement goals are and on how they are designed. One element in the appraisal that we highlight is that governments may experience a significant erosion of fuel tax revenue as fleet-wide fuel economy improves.

The recent change in CAFE fuel economy standards in the United States is expected to result in 61.6 billion gallons less fuel consumed from 2012 to 2016[1] (NHTSA, 2009) after accounting for a slight increase in driving due to lower travel costs. At a constant, combined Federal and State tax rate of 43 cents per gallon, this results in a drop of 26.4 billion dollars from what otherwise could have been expected under the old CAFE regime. This is a major "loss" of revenue. 26.4 billion dollars is equal to 72% of 2008 US Highway Trust Fund revenues (National Surface Transportation Infrastructure Financing Commission, 2009).

In order to illustrate the upper bounds of what extreme improvements in transport energy efficiency may mean for tax revenues from transport fuels (holding all else equal), we took two scenarios developed by the IEA with its MOMO mobility model to assess future liquid fossil fuel demand for light-duty vehicles (LDVs - cars and light trucks) in France, Japan, and the USA. In both scenarios, fuel taxes are held constant at their current level and fuel costs increase in line with the IEA World Energy Outlook projection. Light-duty vehicle travel decreases in France and Japan (by 23% and 33%, respectively in 2050 compared to 2005). In the US, light-duty vehicle travel essentially stabilises at current levels.

[1] From the "business-as-usual" projection

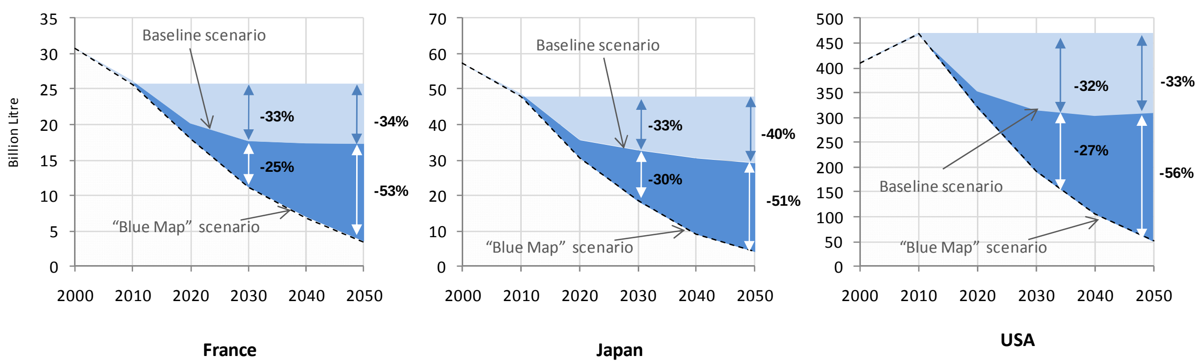
The baseline scenario assumes that current and expected policies are implemented and that the fleet is still dominated by internal combustion engines (gasoline and diesel). These two technologies represent 80% of total LDV stocks in France and 70% of LDV stocks in Japan in 2050. The remainder of the LDV fleet is essentially comprised of gasoline and diesel hybrids (including plug-in hybrids). Electric vehicles make little penetration in the fleet by 2050 in this scenario. Fuel consumption of new LDVs improves along current trends (See Table 1) resulting in a 34%, 40% and 33% drop in LDV demand for gasoline and diesel fuel by 2050 in France, Japan and the United States, respectively.

Table 1. Percent change in average fuel consumption (l/100km) for new light-duty vehicles in 2050 compared to 2010; MOMO baseline and "Blue Map" scenarios

	Baseline Scenario				**Blue-Map Scenario**			
	Gasoline	Gasoline Hybrid	Diesel	Diesel Hybrid	Gasoline	Gasoline Hybrid	Diesel	Diesel Hybrid
France	-28%	-14%	-12%	-9%	-46%	-29%	-32%	-17%
Japan	-28%	-16%	-16%	-9%	-43%	-38%	-44%	-15%
USA	-32%	-13%	-25%	-6%	-29%	-55%	-42%	-17%

In the MOMO "Blue-Map" scenario, the transport sector significantly decarbonises by 2050, consistent with a global energy use scenario that stabilises atmospheric concentrations of CO_2 at 450 ppm.[2] This scenario is characterised by strong shifts away from "traditional" internal combustion engine technologies and the projected LDV fleets in all three countries are dominated by hybrid, fuel cell and electric vehicles in 2050. At the same time, the fuel consumption of new fossil-fuel consuming vehicles drops significantly as outlined in Table 1. The resulting drop in gasoline and diesel fuel demand is large by 2050 in all three countries – 87%, 91% and 89% respectively in France, Japan and the United States. The corresponding drop in fuel tax revenue is roughly in line with these decreases even accounting for the difference in gasoline and diesel tax rates.

Figure 1. Change in light-duty vehicle gasoline and diesel fuel demand from 2000-2050 under MOMO baseline and "Blue-Map"scenarios: France, Japan and the United States



These are extreme and imperfect scenarios as they assume that governments do not adapt fiscal policies in response to a predictable erosion of revenue. However, they do have the merit of highlighting the order of magnitude of the potential loss in revenue. Further revenue loss could be

2 Under current scientific understanding, a stabilisation of atmospheric concentrations of CO_2 at 450 ppm would have a 50% chance of resulting in no more than a 2 degree rise in average global temperature by 2100.

expected if there were to be no change in current policies towards the taxation of cars. Car purchase and/or registration taxes are differentiated in many countries to promote uptake of low emission, fuel efficient vehicles. A shift to lower emission vehicles reduces revenues from these taxes. The cumulative drop in revenue presents a strong challenge for public finance in the baseline scenario. The situation is untenable in the "Blue-Map" scenario, unless alternative ways to raise taxes at low economic cost are found.

Where fuel tax proceeds are hypothecated to dedicated transport funds (as is the case for the US and was the case until recently for the national portion of the Japanese fuel tax), a drop in revenue will have immediate impacts on the transport sector itself. In the more common case where fuel tax proceeds go to general government revenue, the impact of lower fuel sales will be felt more diffusely. In both cases, the shortfall must be accommodated by increased borrowing, by decreasing expenditures or by introducing new taxes. There are also options for introducing infrastructure use charges in the transport sector and in section 3 we illustrate how some combinations of new charging instruments would affect government revenues and consumer willingness to pay for fuel economy. We first briefly review three principal transport revenue options and discuss the potential impact of rising fuel efficiency on each.[3]

Fuel consumption based taxes

These form the principal revenue stream from the transport sector in most countries. Differences exist in that some countries hypothecate these funds for transport use while others do not. Some countries allow for indexing of taxes to oil prices and inflation while others set fixed rates that are occasionally adjusted. Revenue collection from fuel taxes are a generally attractive option -- collection is relatively easy and low-cost, revenues are generally stable and predictable, it roughly allows for emission-related externalities to be factored in and fuel taxes have served reasonably well as a proxy for taxing infrastructure use given the historic dependence of road transport on fossil energy (although fuel taxes could induce overinvestment in fuel economy rather than align use with capacity). Fuel taxes have contradictory equity effects – on one hand, they fall disproportionally on wealthier households since these consume more fuel, on the other hand, low income households spend a disproportionate share of their income on transport fuels. Fuel taxes cannot address time- and location-specific impacts such as congestion, noise externalities and short-lived localised air pollution. Adjusting these taxes has also proven to be a political liability in many cases. Crucially, however, as fuel efficiency increases or travel activity decreases, these taxes generate relatively less revenue and the link between road usage and fuel taxation weakens. Thus there is an inherent contradiction between the need for governments to preserve as large and steady a revenue base from transport (to pay for infrastructure investment and maintenance or other general government expenditures) and the equally critical goals of reducing fossil fuel dependence and CO_2 emissions.

Travel-based road user charges (kilometre taxes)

Charging for road use on the basis of distance travelled and axle weight allows for a close approximation of user responsibility for infrastructure capital and maintenance costs. Immune as it is to fuel efficiency improvements, it also has the potential to become as durable and predictable a source of revenue as the fuel tax has proven to be though only if travel activity remains relatively steady (e.g. a strong modal shift away from road usage would erode this tax base). Distance-based charges share the same contradictory equity effects as fuel-based taxes. However, contrary to fuel taxes, revenue collection is both more complicated and can be very much more expensive though there are indications that these costs are diminishing as technology develops. A simple user tax based on travel would not directly capture fuel-combustion related costs but could reflect safety costs as these are correlated well with travel distances. Distance-based charging could be differentiated on the basis of

[3] Based on the discussion in (Huang, Lee, Lovellette, & Gomez-Ibanez, 2010)

vehicle technology and time and location of travel and thus better capture the environmental and congestion costs imposed by drivers (though this may exacerbate concerns about privacy which remains one of the political liabilities of such a revenue collection mechanism).

Congestion-based charges

As noted above, road usage charges can be adjusted according to time and location of travel. Insofar as charges are set higher on congested networks and at busy travel times, this may reduce travel demand and increase travel speeds. By directly addressing the largest source of travel-related externalities, this form of charging could considerably improve welfare and by directly accounting for traveller's willingness to pay, could generate significant revenue streams. Relatively high transaction costs related to collection and control would somewhat erode these benefits. Allocating these (local) revenues to general tax revenue may prove difficult as well. Furthermore, the charges may fall more disproportionally on low income users and, while the environmental impacts from travel in congested areas could relatively well be captured, further impacts may arise should travellers lengthen trips to avoid charged areas. As with distance-based charging, revenues from congestion charging would be relatively robust to changes in fuel economy.

In the next section, we illustrate how limited improvements in fuel economy have considerable effects on revenue, and may need to be accompanied by kilometre charges or higher fuel taxes. We abstract from the congestion issue.

3. The value to consumers and to taxpayers of improved fuel economy – an illustration

3.1 Goal of the exercise

This section illustrates some of the main effects that an improvement in fuel economy has on the value of the vehicle for drivers and for the Treasury. Better fuel economy means that driving becomes cheaper. Consequently, drivers should be willing to invest in better fuel economy up to the point where the reduced cost of driving becomes just as large as the marginal cost of investment in fuel economy. In addition, a lower cost of driving could lead to an increased demand for driving, on the general principle that demand increases when prices drop. At the same time, to the extent that better fuel economy leads to lower fuel consumption, it leads to lower fuel tax revenues if the fuel tax does not change. Changes in the fuel tax or the introduction of a kilometre-tax could counteract this effect.

The conceptual foundation for these effects is strong, but there is uncertainty about their size. The purpose of this section is to sketch orders of magnitude, at the level of an average vehicle (not the fleet), of the main impacts of a fuel economy improvement as envisaged in the European Union regulation on CO2 emissions from new cars (EC/443/2009). We draw from literature to establish lower and upper bounds for the main impacts. The result is an indication of whether mandated fuel economy improvements are appealing from consumers' and society's point of view.

Section 3.2 presents the characteristics of the illustration, Section 3.3 provides an overview of results, and Section 3.4 discusses and concludes.

3.2 Model and parameterisation

Policy experiment and vehicle type

The proposed regulation in the European Union aims to reduce average emissions of CO2 from 160g/km (in 2006) to 130g/km (in 2012)[4]. Fergusson et al. (2007) suggest that an average new vehicle emitting 160g/km would cost about 20 000€, and the technology cost of reducing emissions to 130g/km is between 1 000€ and 2 500€. We use these figures as guidance for retail prices, assuming that prices are close to marginal costs in the sector, a plausible assumption given strong competition in the automobile industry. Regarding the technology costs of improving fuel economy, we note that the 1 000 to 2 500€ range is an ex ante estimate. Given a widespread view that ex post costs could be much lower (see e.g. ITF-JTRC, 2008), we use an informal lower bound of zero costs in our discussion of results as well.

We complement the vehicle price data with additional information that roughly represents the the French situation, where the modal new car is a diesel car – as will be assumed throughout our example. Data for 2009 indicate that diesel cars are driven on average 15 762km/year, compared to 9 120 for petrol cars (SOeS, 2010). Since the average diesel car of our example (it could, for example, be a Peugeot 308) is not in the class of heavily used vehicles (large families, professional use,...) we reduce reference situation usage to 12 500km/year. Other data are inspired by Prud'homme (2010).[5] The price of a barrel of crude oil is 75€ throughout[6], the tax per litre of diesel is 0.512€, and other fuel costs equal 0.193€/litre. The results is a fuel cost per kilometre of 7cents. The lifetime of the vehicle is taken to be 15 years, after which its residual value is zero or – more generally – the residual value is the same when different scenarios are compared. Future flows are discounted at 4%, which can be seen as a social discount rate but plausibly also as a current private household discount rate. In any case, choosing a low rate is conservative in the sense that it tends to increase the value households put on future savings on fuel expenditures.

Payback periods for investment in fuel economy

Our analysis mostly abstracts from external costs, focussing mainly on household and tax revenue effects (i.e. adopting a strict cost-effectiveness approach). When external costs are ignored, and as long as households discount flows over the full lifetime of the vehicle and their discount rate equals the social rate, private decisions on fuel economy coincide with the socially optimal ones. There is considerable evidence, however, that households use "payback periods" for investments in fuel economy that are far shorter than the expected lifetime of the vehicle. Survey evidence and industry rules of thumb suggest that households want to see the extra outlays for better fuel economy recovered within 2 or 3 years instead of 15 years (see ITF-JTRC, 2010a); the econometric evidence is more mixed but many studies find implicit discount rates that exceed the market-conform ones by a sginificant amount (see Greene, 2010a, and a recent and very detailed study by Alcott and Wozny, 2010). Given the mixed evidence we define a lower bound on payback periods of 3 years and an upper bound of 15 years.

A key question for the interpretation of the numerical results is what causes payback periods to be short, if in fact they are. One view is that short horizons are caused by "myopia", where a range of market failures lead consumers to demand quick payback. A different view is that consumer behaviour is better described by prospect theory (where loss aversion features large) than by expected utility theory, and this explains short payback periods (Greene, 2010c). Yet a different potential explanation

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4 With a phase in that requires the most fuel efficient 65% of the fleet to meet the standard in 2012 and the full fleet to meet the standard by 2015.

5 Furthermore, the structure of the simplest model version replicates Prud'homme's results.

6 In contrast to Prud'homme where the price rises by 6% per year.

is that short paybacks are the result of fully rational decisions that account for "hidden amenities", i.e. features of the decision process that are hidden to analysts but matter to households (see, e.g. Small, 2010). For example, consumers might prefer that technological potential be used for improved comfort or performance instead of better fuel economy, and this leads to an observation of "too short paybacks" in a model that ignores amenities. Depending on what explanation matters most, the interpretation of results changes. If decisions just reflect hidden amenity values, then the short payback is the socially relevant one and there is no market failure. But when there is myopia and loss aversion, a plausible case can be made that a correction to the short payback period is welfare increasing, as the consumer would be better off for it (in an ex post sense). It is, of course, possible that observed payback periods partially reflect market failures and partially reflect amenity values.

The rebound effect

Our example is set up to find what the consumer would be willing to pay to reduce CO2-emissions of the modal diesel car from 160g/km to 130g/km. Such a reduction is equivalent to an reduction of fuel intensity from 6.0l/100km to 4.9l/100km, or an improvement of fuel economy from 16.6km/l to 20.4km/l. Improving fuel economy makes driving cheaper and so more of it should be demanded. This response is called the rebound effect. While conceptually straightforward, finding out exactly how large the rebound effect might be is difficult. Small and Van Dender (2007a) find that the long run rebound effect in the USA between 1966 and 2001 is on average 20%, in line with the average of earlier evidence. This means that a fuel economy improvement of 10% would reduce fuel consumption by only 8% because of the fuel consumption associated with the increased amount of driving. The authors emphasize, however, that the rebound effect is not a constant but depends on incomes and fuel prices, amongst other things. Considering the period between 1966 and 2001 instead of the sample average, the rebound effect is only 10%, mainly because of income growth.

There is an additional problem with using the empirical evidence on rebound effects in the context of fuel economy improvements. Nearly all econometric estimates of the rebound effect measure a response to the fuel cost of driving, which depends on the price of fuel and on fuel economy. The variation in the fuel cost of driving comes mainly from variation in the fuel price and less from changes in (slow-moving) fuel economy. The assumption that the fuel cost of driving is what matters is in line with textbook economics, but is not necessarily supported by the data. Indeed, Small and Van Dender (2007) find that when fuel prices and fuel economy are accounted for separately, their effects are not the same, and the effect of improved fuel economy on the demand for driving in fact is indistinguishable from zero. Greene (2010b) finds the same result for aggregate USA data. If true, this means there is no rebound effect associated with improved fuel economy. It is quite possible that this finding is more related to data problems than to behaviour, but behaviour could be an explanation as well. Therefore, in summary, it seems reasonable to put lower and upper bounds on the rebound effect (in a European context) of 0% and 20%.

The marginal cost of public funds

Fuel consumption is taxed and fuel tax revenues are a valuable source of government revenues. This, again, is straightforward. But exactly how valuable is 1€ of fuel tax revenue or, more generally, transport tax revenue, to the economy? Answering this question requires recognizing that taxes (except for lump sum taxes) cause distortions in markets (i.e. deviations from the efficient allocation), and these distortions involve a cost (often called deadweight loss). Raising a Euro of public revenue hence costs the economy more than a Euro. Assuming then that total tax revenue is to stay constant ('equal yield'), the question becomes what the cost is to the economy of raising a unit of revenue through a different tax than the fuel tax. Is the distortionary cost of fuel taxes smaller or larger than that of alternative sources of taxes? While it is difficult to give a precise answer, some reasonable bounds can be determined. The most distortionary tax in advanced economies is probably the labour tax. It is also the main source of tax revenues. The marginal cost of a Euro of tax revenue raised by labour taxes is around 1.2 – 1.5 Euro. France, since 2006, uses a value for the marginal cost of public funds of 1.3 in cost-benefit analysis of transport projects (Quinet, 2010). How does the fuel tax or a kilometre tax compare to the labour tax as far as distortionary costs are concerned? If all fuel and all driving were used for commuting or business trips, then fuel taxes and kilometre taxes are effectively labour taxes, and equally costly. An appropriate weight for transport tax revenues in our simple analysis then would be 1. But if, as is the case, transport is used for other purposes than commuting and business trips, taxing transport allows shifting the tax burden away from already heavily taxed labour. This is appealing as it reduces the efficiency cost associated with raising a given amount of total tax revenue. In the extreme, the weight put on transport tax revenues then should be 1.3, i.e. the cost associated with the alternative source of tax revenue (here labour taxes). Hence, in our illustration we use a lower bound on the weight of fuel and kilometre tax revenue of 1 and an upper bound of 1.3.

3.3 Scenarios and Results

Table 2 summarises the assumptions on parameters, discussed in the previous section, in the reference situation and the situation with improved fuel economy. Table 3 repeats assumptions on lower and upper bounds on behavioural reactions and tax revenue weights. Table 4 shows key results for three policy scenarios.

Table 2. Main model parameters and variables

	Reference	Counterfactual Scenarios
Lifetime of the car	15	15
Discount rate	4%	4%
Annual km driven	12,500	12,500; endogenous
Purchase price vehicle	20,000	20,000
Fuel economy (km/l)	16.56	20.38
Price of a barrel of oil (€)	75	75
Specific tax on diesel (€/l)	0.512	0.512
Other fuel cost (€/l)	0.193	0.193
Kilometre tax	-	0.008; 0.05

Table 3. Lower and upper bounds for model inputs

	Lower bound	Upper bound
Rebound effect	No rebound	20% rebound
Payback period fuel economy investment	3 years	15 years
Economic value of **reduced** transport tax revenue	1.3	1
Economic value of **increased** transport tax revenue	1	1.3

In the first scenario, labelled "**Reference fuel tax, no kilometre tax**" CO2-emissions decline from 160g/km to 130g/km. There is no other policy change. The model calculates what consumers are willing to pay for the improvement in fuel economy that drives the emission reduction. When there is no rebound effect, this willingness to pay is the net present value of reduced expenditures on fuel for the reference amount of driving (rectangle ABCD in Figure 2). When there is a rebound effect the increase in consumer surplus associated with the extra driving needs to be accounted for as well. We do this with a linear approximation (triangle CDE in Figure 2). The calculation of willingness to pay assumes the vehicle price does not change, so ignores technology costs. To arrive at a consumer valuation of the policy change, technology costs need to be compared with the willingness to pay. For a social valuation (that abstracts from externalities), the effect on tax revenues needs to be included. Note that the fuel tax, in this and all other scenarios, is maintained at the level of the reference situation.

The second scenario, "**Reference fuel tax, revenue neutral kilometre tax**", repeats the fuel economy improvement and adds a tax per kilometre of slighty less than 0.5c/km. This kilometre tax generates just enough revenue to offset the decline in diesel tax revenues triggered by the improvement in fuel economy (for the situation with a zero rebound effect). In the third scenario, "**Reference fuel tax, kilometre tax 5c/km**", the fuel economy improvement is accompanied by a kilometre tax of 5c/km. This level is intended to capture the order of magnitude that a kilometre tax might reach when it is intended to reflect average marginal external costs related to driving (not to fuel consumption) except for congestion (which we think inadvisable to include in an average tax). The value is in line with Small and Van Dender (2007b, table 5).

Figure 2. Effects of the three scenarios on consumer surplus

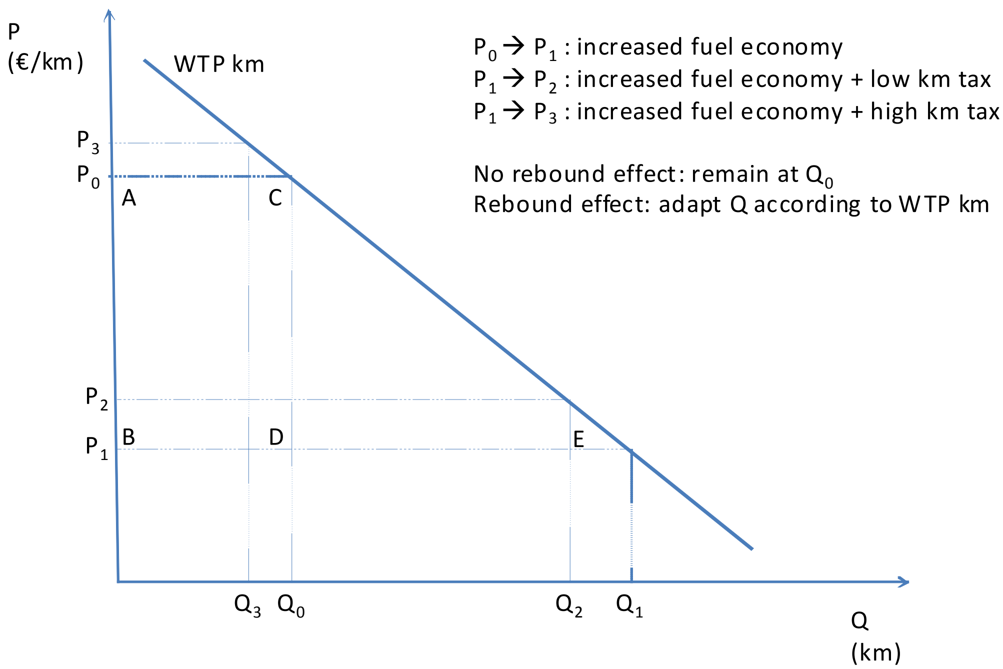

Table 4. Impact of reducing CO2 emissions of a 20 000€ diesel car from 160g/km to 130g/km on consumers'willingness to pay (WTP) and on fuel and kilometre tax revenues

			lower bound[a]	upper bound[b]
1. Reference fuel tax, no kilometre tax				
	No rebound effect	Change in WTP for better fuel economy	453€	1,814€
		Change in economic value of tax revenue	-1,409€	-1,084€
		Sum	**-956€**	**730€**
	Rebound effect = 20%[1]	Change in WTP for better fuel economy	462€	1,852€
		Change in economic value of tax revenue	-1,150€	-885€
		Sum	**-688€**	**967€**
2. Reference fuel tax, revenue neutral kilometre tax (0.8c/km)				
	No rebound effect	Change in WTP for better fuel economy	182€	730€
		Change in economic value of tax revenue	0€	0€
		Sum	**182€**	**730€**
	Rebound effect = 20%[2]	Change in WTP for better fuel economy	184€	736€
		Change in economic value of tax revenue	91€	119€
		Sum	**275€**	**855€**
3. Reference fuel tax, kilometre tax 5c/km				
	No rebound effect	Change in WTP for better fuel economy	-5,135€	-1,282€
		Change in economic value of tax revenue	5,865€	7,625€
		Sum	**730€**	**6,343€**
	Rebound effect = 20%[3]	Change in WTP for better fuel economy	-4,926€	-1,229€
		Change in economic value of tax revenue	4,914€	6,389€
		Sum	**-12€**	**5,160€**
Technology cost for better fuel economy			1,000€	2,500€

Notes

a: lower bound change WTP is for 3 year payback, higher bound for 15 years

a: lower bound change tax revenue (R) is for MCPF=1 when dR>0, for MCFP=1.3 when dR<0

b: upper bound change tax revenue (R is for MCPF=1.3 when dR>0, for MCFP=1 when dR<0

a: lower bound technology cost is for 0% autonomous mass increase, upper bound for 2.5%

1: increase in driving = 530km (+4.2%)

2: increase in driving = 198km (+ 1.6%)

3: reduction in driving = 520km (-4.2%)

Sources

Own calculations except technology cost taken from

Fergusson et. al., 2007, Possible regulatory approaches to reducing CO2-emissions from cars, final report, IEEP, Brussels-London

Table 4 summarises the main results from the three scenarios, distinguishing between lower and upper bounds for payback periods (see the rows on "change in WTP for better fuel economy") and for the marginal cost of public funds (rows labelled "change in economic value of tax revenue"). The lower bound on willingness to pay for better fuel economy refers to the 3 year payback period, the upper bound to 15 years of payback. What is the lower bound for the economic value of tax revenue changes depends on whether tax revenues increase or decline. When they increase, the upper bound is associated with the weight of 1.3, as this is the best case from the Treasury point of view. When tax revenues decline, the weight of 1.3 refers to the lower bound, to indicate the loss of particularly valuable tax revenues (that will need to be replaced by more costly labour taxes).

Table 4 also distinguishes the case where there is no and a 20% rebound effect. When there is an increase in the amount of driving with 20% rebound effect, this will drive up the willingness to pay for better fuel economy because it applies to more distance driven. When driving declines the opposite holds. Kilometre tax revenues increase as long as there is more driving, but what happens to fuel tax revenues depends on opposing forces (lower fuel consumption vs. more driving).

We discuss the results summarized in Table 4 by selecting worst and best case combinations of lower and upper bounds, where "best" is defined from the social point of view. We do this for every scenario.

Main results per scenario

For the "**Reference fuel tax, no kilometre tax**" scenario, the worst outcome occurs when the payback horizon is 3 years, the marginal cost of public funds is 1.3, and the rebound effect is zero. The social value, abstracting from technology costs and external costs, of the switch to the more efficient car is 453€-1 409€ = -956€. This occurs because of the loss in highly valued tax revenues, as from the household point of view the switch is attractive in itself. With a positive rebound effect, the fuel tax base is restored to some extent (driving increases by 4.2%), so tax revenue losses decline. The tax revenue loss is further diminished when the marginal cost of public funds is 1 instead of 1.3. And the project becomes even more attractive from the household point of view when the horizon for paybacks is 15 years instead of 3. In the best case outcome, the social value of the project (before technology and external costs) is 1 852€-885€ = 967€. Taking the technology cost estimates of Fergusson et al., 2007, as guidance, this would be just about enough to justify the extra resource cost of producing the more efficient vehicle. Including external costs of climate change would further add to the attractiveness of the project. Including external costs of local pollution and congestion would reduce the appeal of the project, however, as the amount of driving has gone up. The latter effect is potentially important.

What happens when the fuel economy improvement is accompanied by the introduction of a kilometre tax which is set at the level that it generates just enough revenues to compensate for lower fuel tax revenues? We have chosen tax neutrality to occur when there is no rebound effect. Consequently, the best outcome in the "**Reference fuel tax, revenue neutral kilometre tax**" scenario is when the rebound effect is positive, the payback horizon is 15 years, and the marginal cost of public funds is 1.3. Tax revenues now increase when driving increases (as it does by 1.6% under a positive rebound effect), and these extra revenues are worth more when the marginal cost of public funds equals 1.3. Finally, the investment is worth more to the household when it discounts over a longer horizon.

It is worth noting that in this scenario the project is appealing for all combinations of thresholds, at least before technology and external costs are accounted for. In comparison with the previous scenario, this shows that the introduction of a mileage tax can undo the negative effects of fuel tax revenue losses associated with better fuel economy. Furthermore, the project is appealing to households as well as to the Treasury. This indicates that the revenue neutral mileage tax manages to maintain part of the consumer gain from getting better fuel economy while at the same time turning the revenue loss into a gain. It can, in that sense, be seen as an instrument to obtain both a bigger and a differently distributed total surplus. As before, accounting for technology and external costs will tend to reduce the appeal of the policy change.

The revenue neutral kilometre tax, in our example, is below the level of marginal external costs associated with driving a kilometre. Scenario three, **Reference fuel tax, kilometre tax 5c/km**", introduces a tax more in line with those costs. Driving now declines (by 4.2%), which is good news from an external cost point of view. It is bad news from a taxation point of view, but with the high tax revenues increase spectaculary nevertheless (especially since fuel taxes remain the same as before, an assumption that becomes tenuous here as a second-best justification for current fuel tax levels should involve indirect accounting for driving-related external costs). This increase is weighted more strongly when the marginal cost of public funds is 1.3. The tax base now is largest with a zero rebound. So the best case scenario is with a marginal cost of public funds of 1.3, a zero rebound effect, and a long horizon for paybacks.

Comparing scenarios

As can be seen from comparing sums of impacts, the scenario with the high tax on kilometres outranks the other two as long as the marginal cost of public funds is high and payback horizons are long. The first effect amplifies the interest of raising more tax revenues from transport. The second effect amplifies the interest of investing in better fuel economy from the household perspective, and undoes some of the loss in household surplus caused by the high tax on driving. Things are different with short payback periods, as in that case the revenue-neutral kilometre tax strikes the best balance between maintaining tax revenues and household benefits from improved fuel economy. In general, and obviously, short payback periods strongly reduce the appeal of pushing for better fuel economy. This is in the assumption, however, that the short payback period reflects hidden amenity values (so is optimal from the household point of view). It is not clear if this assumption is tenable in reality, as is discussed in the next section.

A simpler way to compare the scenarios is to define a “middle case”, in which the values for the rebound effect, the marginal cost of public funds, and the payback horizon are set halfway between the lower and upper bounds. The rebound effect then equals 10%, the marginal cost of funds is 1.15, and the payback period is 9 years. This “middle case” should not be seen as representing a more probable case, as we are more inclined to view all values between the upper and lower bound as equally likely than to put a greater probability on the halfway value (and certainly do not see it as an average). Instead, the middle case is defined for ease of interpretation only, with the risk that simplification leads to a loss of information. For the middle case, the high kilometre tax scenario produces the highest net benefits: the value of tax revenue increase by 6 187€ and household surplus declines by 3,363€, leading to a net benefit of 2 824€. Since driving declines by 521 km (-4.2%), external costs decline as well, so that this scenario remains attractive if technology and external costs are accounted for.

In the middle case, the scenario with the revenue neutral kilometre tax remains attractive. Recalling that revenue neutrality is defined at constant mileage, the 10% rebound effect implies a slight increase in driving (+98km or +0.8%) and a slight increase in revenue, of which the value amounts to 52€. Households’ willingness to pay increases by 490€, so the total benefit before technology costs and external costs is 542€. With the technology costs mentioned in Table 4 and with driving-related external costs outweighing fuel-related external costs, it is unlikely that this return remains positive in a broader analysis. This holds a fortiori for the scenario with the zero kilometre tax, where the willingness to pay increases by 1 226€ and the value of tax revenue drops by 1 133€, so that the net benefit – before technology and external costs – amounts to just 93€ (a number that, given the uncertainty on parameters, should be treated as indistinguishable from zero).

4. Discussion and conclusion

Whatever the merit of reducing CO2-emissions from 160g/km to 130g/km, the policy by and large seems justifiable from a combined household and tax revenue perspective. If fuel economy improves without an increase in kilometre taxes (fuel taxes might work too, but were not studied here), the case for better fuel economy is contingent on exactly how expensive the technology to improve fuel economy is. When kilometre taxes are introduced, the case for better fuel economy becomes stronger, especially when the kilometre tax approaches levels that reflect external costs of driving. The downside of such high taxes on driving is distributional: they reduce consumer surplus and increase tax revenues. Raising more tax revenues is particulary attractive when the marginal cost of public funds is high.

The illustration suggests that a mandated fuel economy improvement ideally would be accompanied by a tax on driving. There is an important caveat here, in that we have assumed that kilometre taxes can be raised costlessly (more precisely, that they are not more expensive to raise than fuel taxes). This is far from straightforward, as concerns are mounting that distance-based taxes on transport are expensive to raise (see e.g. Oehry, 2010 and ITF-JTRC, 2010b). Accounting for high collection costs obviously reduces the appeal of the policy package. Furthermore, introducing comprehensive distance-based taxes is not only expensive, it is also politically difficult (as the recent Dutch experience suggests). Assuming that the political difficulty of increasing fuel taxes can be sidestepped by introducing a substantial tax per kilometre, may border on the naive. Taking account of political constraints and collection costs, the more realistic vision seems to be that car use taxes likely will consist of fuel taxes and distance- or congestion-taxes in a limited number of densely travelled areas. While we leave the analysis of the interaction between fuel taxes, kilometre taxes, and fuel economy regulation for future work, it is worth mentioning that the very long term outlook in some countries points to a decline of aggregate distances travelled. This reinforces the problems with raising revenues from transport, as it suggests that the tax base shrinks (although the ability to pay could still increase). Should we expect that the role of the transport sector as a contributor to overall tax revenues will decline in the long run?

Lastly, the illustration highlights the dependence of results on the payback periods that households use when deciding on how much to invest in fuel economy. Short paybacks drastically reduce the benefits of these policies. As indicated in Section 2, the key question here is whether these short payback periods reflect hidden amenities or instead some type of market failure. In the former case, the short payback is the one that matters from the social point of view, meaning that boosting fuel economy truly is less attractive. When there are market failures, making sure that decisions reflect longer paybacks is appropriate, as this now is the socially relevant case. Correcting the market failure as cheaply as possible, where costs of funds need to be accounted for, then becomes key. As we have argued elsewhere (Van Dender, 2009), fuel economy standards can very well have a role to play in that case. But the preliminary question, “hidden amenities or market failures?”, needs to be settled.

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