The Taxation of Motor Fuel: International Comparison

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Abstract. We apply the Parry-Small (2005) framework to asses whether the level taxation of motor fuel is broadly appropriate in a group of countries (OECD, BRICs and South Africa) accounting for more than 80 percent of world greenhouse gas (GHG) emissions. This paper deals with emissions from oil combustion in transport, which accounts for about 40 percent of CO_2 emissions. In the benchmark specification, we find that six countries (accounting, in turn, for more than 40 percent of motor-fuel GHG world emissions) would be undertaxing motor fuel. We evaluate the sensitivity of the results to the values of the elasticities and externalities that we use. We find that varying the values of these parameters (within the level of uncertainty reasonably associated with them) significantly affects the results. This implies that, while informative, the results must be taken as indicative. Further analysis for a particular country must rely in a well-informed choice for the values of their country-specific parameters.

Keywords. Fuel taxation, climate change, greenhouse gas emissions

JEL Classification System. H23, Q48, H87

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1. Introduction

The taxation of motor fuel displays a great variability across different countries (Fig. 1). While these products are generally subject to broadly similar consumption taxes (*i.e.*, VAT and excises), the rates applied by individual countries, especially on the excise component, vary substantially. As a consequence, the final share of taxes in the final price paid by consumers ranges from a high 70 percent (*e.g.*, The Netherlands, U.K., or Turkey) to virtually zero or negative (*e.g.*, subsidies in oil-producing countries).

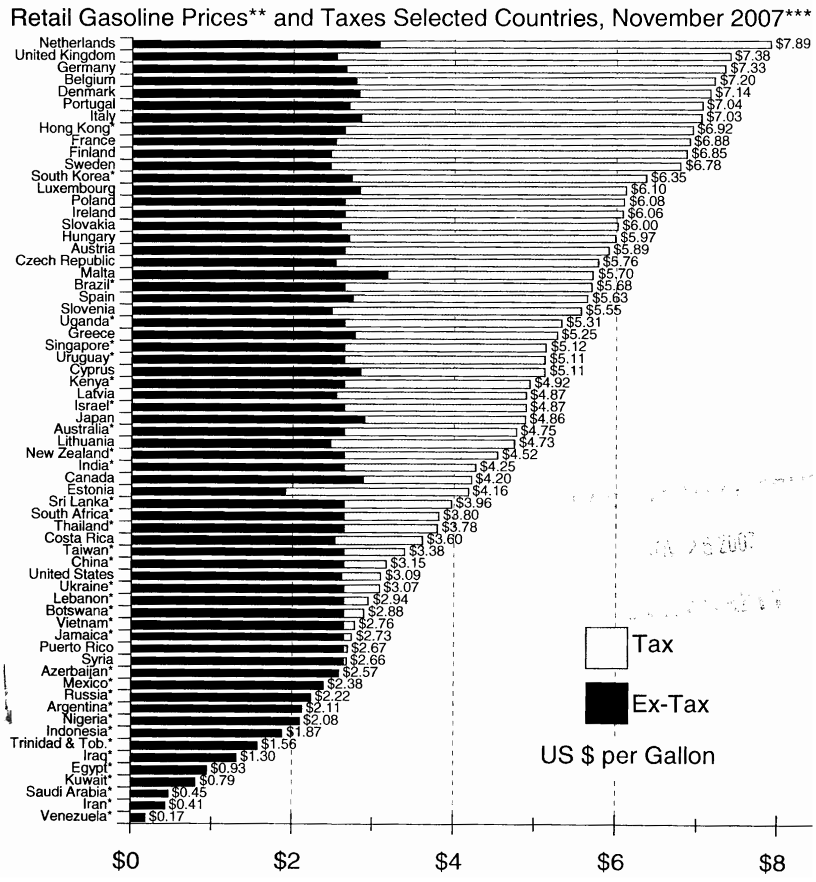

Fig. 1. Gasoline Taxation around the World (2007).
(Source: Energy Détente November 2007 issue.)

From a national perspective; should motor fuel be taxed differently than other goods? While the public finance literature provides guidance on the optimal structure for indirect taxation (*e.g.*, Atkinson and Stiglitz, 1980) which implies different rates for different goods, from a practical point of view, administrative costs generally discourage differential taxation. However, excisable goods are an exception, since these are easy to tax at the source (typically imports or reduced number of domestic producers). Moreover, in the case of motor fuel, its consumption generates substantial external effects, which justifies its differential taxation. In addition, the taxation of oil rents could warrant specific taxation

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for motor fuel. Bergstrom (1982) argued that an excise tax is an appropriate instrument for oil-importing countries to capture some of the oil rents that would otherwise accrue to the oil-exporting countries.[1]

There is a large amount of work providing the theoretical basis for environmental taxes (Baumol, 1972; Baumol and Oates, 1971, 1988). Moreover, in theory, petroleum taxes have the potential of not only improving environmental quality but also raising revenue and reducing welfare costs offering a so-called "double dividend" (Pearce, 1991). However, in practice, the answer to how large motor fuel taxes should be is less than straightforward (Metcalf and Weisbach, 2009).

To address this issue, of the appropriate level of motor fuel taxation, Parry and Small (2005) develop a model balancing the level motor fuel taxes against all other taxes. They show that the second-best optimal tax on motor fuel can be broken into several components: an adjusted Pigovian tax to account for the external effects of motor fuel; a general Ramsey-type consumption tax component; and a reduced-congestion feedback.

The Pigovian tax component has received renewed attention when considering the workings of a global carbon tax for climate-change mitigation (Aldy *et al.*, 2008). More recently, the French government has announced the introduction of an 'ecotax' with an initial rate of €15.42 per ton of CO_2 (€17 per metric ton), gradually increasing over time. Table 1 displays the implications of this tax; the entries for the \$10 tax are multiplied by 2.31 (= 1.542 × 1.5€/\$). An issue that arises in the context of international carbon pricing through taxation is that if 'carbon' is already taxed to a certain extent; how could compliance with an internationally-agreed carbon tax be determined? As seen in Fig. 1, many countries already apply taxes well in excess of the ¢20.33/gal of gasoline implied by the new proposed French ecotax. But, of course, these taxes already in place may be justified on other grounds, distinct from climate-change considerations.

This paper poses the question of whether the Parry-Small (P-S) framework offers suitable guidance for the level of taxation of motor fuel across countries. We apply the P-S framework to the group of countries that currently account for the larger consumption of motor fuel (*i.e.*, including the OECD and BRICs), allowing for country-specific characteristics (*i.e.*, elasticities, costs, etc). We compare the P-S estimated second-best optimal taxes with the actual taxes in these countries, and we assess the sensitivity of the results

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[1] Given the significant market power in the extraction and refining of oil products Kay and King (1980) argue that "the imposition of a tariff on oil may be a rational response by OECD countries to the OPEC cartel" (Kay and King, 1980). An excise on oil products could play the same role for non oil-producer countries. However, a more recent literature on th effects of adding motor fuel tariffs arrives to different conclusions. Maskin and Newbery (1991) and Karp and Newbery (1991, 1992) point to the problem of the dynamic inconsistency that may arise in 'open loop' models. For instance, tariff time trajectories announced by large importers of the resource may not be credible as long term commitments since it will pay the importer to deviate from the announced plan as time evolves. Karp and Newbery (1991) show, however, that 'open loop' Nash equilibria with competitive or oligopolistic suppliers and competitive or oligopsonistic consumers all are dynamically consistent in a tariff setting game. Finally, Farzin (1996) shows how rent acquisition will still be a feature with an environmental tax, a finding confirmed by Amundsen and Schöb (1999), who show that the total resource rent may be appropriated through co-ordination and combination of environmental taxes without jeopardizing Pareto optimality. We do not deal with any of these issues in this paper.

Table 1. Equivalency of Units

Tax per ton of CO_2		equals:
\$10.00	€15.42	
\$36.67	\$84.71	per ton of Carbon
\$4.77	\$11.02	per barrel of oil
¢8.80	¢20.33	per gal of gasoline
¢2.29	¢5.29	per liter of gasoline
¢0.78	¢1.80	per kilowatt-hour of electricity

Source: Own calculations and Aldy *et al.* (2008).

with respect to key parameters.

We find that, in the benchmark specification, a set of broadly large-emission countries are undertaxing motor fuel. We evaluate the sensitivity of the results to the values of the elasticities and externalities we use in the application of P-S framework. We find significant effects on the optimal taxes within the level of uncertainty reasonably associated with the values of these parameters. Increasing the shadow value on GHG emissions to \$100 per ton of carbon (from the \$25 benchmark value) and the size of the labor-leisure substitution response to wages result in more than half the countries undertaxing motor fuel.

Section 2 reviews the issues on optimal indirect taxation. Section 3 applies the P-S framework to a set of countries and discusses the results. Section 4 concludes.

2. Optimal Taxation of Petroleum Products

There are several well-established principles guiding the design of an efficient system of commodity taxes in the absence of market imperfections (see, *e.g.*, Atkinson and Stiglitz, 1980; Myles, 1995). The first principle is that, in the absence of market imperfections, taxation should be restricted to final goods, thus leaving untaxed all intermediate inputs in the production process (Diamond and Mirlees, 1971). By preventing tax-induced distortions in the allocation of resources, this approach maximizes total output, and hence the potential tax base.

A second principle (Ramsey, 1927) dictates that commodity taxes should result in similar reductions in demand for all commodities—where 'similar' refers to 'equally-costly' from the perspective of the consumers' welfare. This principle implies higher taxation falling on commodities displaying smaller (substitution) responses to price changes—*i.e.*, on the more price-inelastic goods. The objective is to equalize, across commodities, the proportional reduction in demand relative to the no-tax situation. This proportional reduction in demand is termed the *index of discouragement* by Mirlees (1976). Moreover, to ameliorate the disincentive effects distorting leisure-work choices (since commodity taxes lower the reward to work), heavier taxes should fall on goods which are more complements to leisure (*i.e.*, substitutes to work), and lighter taxes should fall on goods that are more complementary to work.

Finally, some degree of differential taxation can also be justified on distributional concerns and, as we shall discuss below, on the correction of externalities (Pigou, 1920).

In practice, most countries combine VAT (or sales taxes) and excise taxes on selected commodities to create a tax structure broadly conforming to the principles discussed above. In effect, the VAT, through the credit-invoice method, discharges intermediate inputs from taxation. Furthermore, the excises on selected products (typically tobacco, alcoholic drinks, motor fuel products and luxury goods) allow for some degree of discriminatory taxation along the lines discussed above.

Against this background, several characteristics differentiate motor fuel from other commodities justifying their heavier taxation. First, the consumption of motor fuel generates substantial external effects. These include congestion, noise, local pollution, and emissions of greenhouse gases. The presence of these externalities requires that prices incorporate the external costs that the consumption of motor fuel imposes on society. Thus, when motor fuel are used as inputs in production, their intermediate quality in the production process is lost since the externalities generated are effectively final consumer products. Consequently, marginal-cost pricing on intermediate transactions must now include the external costs. Second, from a revenue perspective, the consumption of motor fuel displays a low own-price elasticity (at least in the short-term) and a high income elasticity. These characteristics make their heavier taxation attractive from both efficiency and distributional perspectives.[2]

2.1. Parry-Small Framework

Parry and Small (2005) consider a revenue-neutral tax reform, and they examine the tradeoff of taxes on gasoline versus the rest of the taxes, aggregated as a tax on labor. In this context, they estimate the second-best optimal gasoline tax taking into account the corresponding externalities (adjusted Pigovian tax), the balance between commodity taxation and labor taxation (Ramsey tax), and congestion feedback. The second-best optimal gasoline tax, t_F, can be implicitly expressed as:

$$t_F = \underbrace{\frac{MEC_F}{1+MEB_L}}_{\text{Adjusted Pigovian tax}} \tag{1}$$

$$+ \underbrace{\frac{(1-\eta_{MI})\epsilon^c_{LL}}{\eta_{FF}}(q_F+t_F)\frac{t_L}{1-t_L}}_{\text{Ramsey tax}} \tag{2}$$

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[2] Nonetheless, the regressive incidence of motor fuel taxes—especially in places with poor public transportation—is widely regarded as one of its main defects. Zhang and Baranzani (2000) present findings from other studies in the US and UK showing that the relative burden of the additional tax is heavier for the poorer deciles. However, for the U.K., Johnson, McKay and Smith (1990) show that adjusting for household composition results in a more equal distribution of absolute motor fuel expenditures. A recent study by Parry *et al.* (2006) shows that measures of tax incidence over the life-cycle, instead of annual, income, find that CO2 taxes are less regressive than static analyses suggest.

$$+ \underbrace{\frac{\beta}{(M/F)} E^c[\epsilon_{LL} - (1 - \eta_{MI})\epsilon^c_{LL}] \frac{t_L}{1 - t_L}}_{\text{Congestion Feedback}} \tag{3}$$

Note that the optimal tax, t_F, enters into the three terms (1)–(3); through the expressions for MEC_F, MEB_L, and t_L (Table 2). Consequently, the expression above is an implicit function for t_F, and must be solved using numerical methods.[3]

[1] The first component stands for the adjusted Pigovian tax. This term is proportional to the sum of all marginal externalities, MEC_F, and inversely proportional to (one plus) the marginal excess burden associated with the labor tax, MEB_L. In a first-best world, pollution taxes should be set equal to marginal damage—the level that fully internalizes an externality. However, the presence of pre-existing distortionary taxes changes this conclusion. Environmental taxes typically exacerbate pre-existing tax distortions and, therefore, the optimal pollution tax should lie below the Pigovian level. This is driven by the tax-interaction effect, which arises when the pollution tax affects the equilibrium quantity of another taxed good, such as labor. Thus, the excess-burden term accounts for the tax-interaction effect arising from pre-existing distortions due to taxation. Another perspective on this issue is that, relative to a lump-sum taxation world, society is poorer when it has to use distortionary taxation to raise public funds and, consequently, it must live with a larger level of externalities.

[2] The second component stands for the Ramsey component that involves the usual price and income elasticities of motor fuel use, and of vehicle-miles traveled, which underlie the main idea that motor fuel should be more heavily taxed if it is a relatively weak substitute for leisure. The smaller the price and income elasticities of motor fuel, (η_{FF}, and η_{MI}) the larger this Ramsey component will be. Also, this component is proportional to the compensated labor elasticity, and it grows to allow for decreases in the labor tax, t_L when labor is more elastic.

[3] The third component stands for the positive congestion feedback effect of reduced congestion on labor supply. Since labor is taxed, reducing congestion is welfare-improving. The reduced congestion increases time available for both labor and leisure. As it turns out, this component is not very large in practice. Note that the congestion externality is already part of the Pigovian component (1).

MEC_F is the marginal external cost of motor fuel use, which includes carbon emissions (E^{P_F}; ¢6/gal or \$25 per ton of carbon), and costs associated with congestion (E^C), accidents (E^A) and pollution (E^{P_M}; ¢2/mile):

$$MEC_F = E^{P_F} + \frac{\beta}{(M/F)}(E^C + E^A + E^{P_M})$$

MEB_L is the marginal excess burden of labor taxation, which increases with both the wage tax, t_L and the wage elasticity of labor, ϵ_{LL}:

$$MEB_L = \frac{t_L \epsilon_{LL}}{1 - t_L(1 + \epsilon_{LL})}$$

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[3] A *Mathematica* notebook that will solve for the optimal t_F is available from the authors.

Table 2. Notation and Parameter Values

(Parameter values common for all countries are in parentheses.)

η_{MI} : (0.60) Elasticity of demand of vehicle-miles traveled with respect to disposable income.
η_{MF} : (0.22) Elasticity of demand of vehicle-miles traveled with respect to gasoline price.
η_{FF} : (0.55) Own-price elasticity of demand for gasoline.
ϵ_{LL} : (0.20) Elasticity of labor supply.
ϵ^c_{LL} : (0.35) Compensated elasticity of labor supply.
β : (0.40) Fraction of motor fuel demand elasticity due to reduced vehicle-miles traveled; $\beta = \eta_{MF}/\eta_{MM}$.

Fuel efficiency, measured as miles/gal is given by a constant-elasticity formula:

$$\left(\frac{M}{F}\right) = \left(\frac{M^0}{F^0}\right)\left(\frac{q_F + t_F}{q_F + t_F^0}\right)^{-(\eta_{FF}-\eta_{MF})}$$

The effective (average) tax rate on labor is defined as $t_L = \alpha_G - (t_F/q_F)\alpha_F$, where α_G and α_F are the shares of government spending and gasoline expenditures in national output.

Table 2 and section 2.2 explains the remaining notation (all notation here is identical to Parry and Small (2005); '0' superscripts indicate initial values). Parameter values that are common for all countries are in parentheses in Table 2. When the values are country-specific, section 2.2 explains the sources.

2.2. Data sources for country-specific parameter values

(M^0/F^0) : **Initial motor fuel efficiency:** P-S use values of 20 miles/gal for U.S. and 30 miles/gal for U.K. From IEA (2007) we obtain values for OECD countries and from IEA (2008) we obtain motor fuel efficiency values for India, Brazil, China and transition countries, the latter we assume is equal to Russia's. A Korean government report[4] stated passenger cars motor fuel efficiency was 10.69 kilometers per liter in 2006.[5] For Mexico we obtain values of 28 miles/gal.[6] For the rest of the countries (Portugal, Spain, Switzerland, Austria, Belgium, Luxembourg, Hungary, Iceland, Poland, Turkey and Czech Republic) we used the median value for European countries, 31 miles/gal, and the sample median for South Africa (27 miles/gal).

E^C : **External congestion costs:** Congestion costs are highly variable across times and locations; thus P-S use central values of marginal congestion cost of 3.5 cents/mile

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[4] See http://www.highbeam.com/doc/1G1-143417929.html; article appeared in YON - Yonhap News Agency of Korea , March 19, 2006.

[5] http://www.highbeam.com/doc/1G1-143417929.html

[6] Results presented at a *Workshop on Sustainable Transport in Latin America* in Washington DC in 2005 http://www.autoproject.org.cn/english/new_advance_en/Mex%20TRB%20presentation.pdf

for the U.S. and 7 cents/mile for the U.K. From Carisma and Lowder(2008) we take values of deadweight loss European countries based on an INFRAS/IWW 2000 study. Transforming the 0.68% deadweight loss value for U.K. into 7 cents/mile, we compute the values in cents/mile for these other countries. From Carisma and Lowder(2008) we also obtain results for most of the other countries which the authors compile from separate studies. The Korea Transport Institute's latest estimate of congestion costs is of 2.97% of GDP in 2004 while the Ministry of Land, Infrastructure and Transport in Japan estimated congestion costs for this country at around 2% of GDP in 2000. For Sao Paulo, a cost of 2.4% of GDP was estimated by Willoughby (2000); for Mexico City, a cost of 2.65% of GDP by Ochoa and Radian (1997). We use the results for these cities for Brazil and Mexico. For India, we assume the numbers to be similar to those in Bangkok and Kuala Lumpur, 2.1 and 1.8% of GDP respectively according to a study on sustainable infrastructure in Asia completed by the United Nations Economic and Social Commission for Asia and the Pacific (2007). Creutzig and He (2009) estimate the congestion cost for China is 3.35% of GDP and the Russian government has estimated that congestion costs for Russia are about 3% of GDP.[7] We set the value of congestion cost at 2.15% of GDP. Finally, from Carisma and Lowder(2008) we obtain the cost of congestion for U.K. as a percent of GDP to be 3% from which we then transform the other figures into cents/miles. For the rest of the European countries for which we do not have data available (Hungary, Iceland, Slovak Republic, Turkey and Czech Republic), we use the median for all European countries, which is 2.4 cents/mile. For Canada and Australia, we use the median for the whole sample, which is 3.1 cents/mile.

E^A : **External accident costs:** P-S take 3.0 and 2.4 cents/mile as the central estimates for the U.S. and U.K., respectively. The difference, according to the authors is mainly based on the fact that the U.K. has about two-thirds as high a willingness to pay for reduction in injury and death, and a lower fatality rate in the U.K. For European countries we rely only on average accident costs in €/1,000 passenger per km estimated by INFRAS/IWW (2004). Accident costs for China are estimated to be 1.5 % of GDP.[8] For Russia the Government has estimated traffic accident costs to represent 2.55% of GDP.[9] for South Africa, the estimate is of 1% of GDP,[10] and for Australia, 2.3% of GDP. Mendoza *et al.* (1998). estimate that external accident costs for Mexico represent 0.35% of GDP. Mohan (2002) provides estimates of external crash cost for Brazil, Korea and India.

q_F : **Producer price (ex-tax) and initial gasoline tax rates (t_F^0):** Most of the ex-tax prices and taxes data are taken from the March 2009 issue of Energy Détente. For Brazil, India, Russia, South Africa and Norway we use ex-tax prices and taxes

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[7] http://www.latimes.com/news/nationworld/world/la-fg-russia-roads15-2009jul15,0,6188164.story

[8] http://www.car-accidents.com/country-car-accidents/china-car-accidents-crash.html

[9] http://www.kommersant.com/p-13563/r_500/Traffic_accident/

[10] http://findarticles.com/p/articles/mi_qa5327/is_291/ai_n29030852/

in 2005 from Energy Détente. For Iceland and Poland we used the median of pre-tax price and tax for all European countries, 473 cents and 327 cents respectively.

α_G : **Total government spending over GDP:** Parry and Small (2005) use central values of 0.35 for the U.S. and 0.45 for the U.K., based on summing average labor and consumption tax rates in Mendoza *et al.* (1994). We use two sources for data on general Government expenditure: the OECD stats and World Economic Outlook (WEO).[11] We averaged government expenditure for the period 2005–07 so as to smooth variability.

α_F : **Fuel production shares:** Using the the shares of gross domestic production spent on motor fuel, Parry and Small (2005) set values of 0.012 values for the U.S. and 0.009 for the U.K. The calculation is based on n 1999 consumption of motor fuel multiplied by the gasoline price/gal net-of-tax over GDP. For our estimates we use data for billions of barrels of Motor gasoline consumed by each country in 2006 from IEA. The gasoline price net of tax (q_F) that we use is from Energy Détente.

See Table 6 for country-specific parameter values, and Table 7 for the list of data sources.

3. Optimal Fuel Taxes for Selected Countries

In this section, we estimate the optimal motor fuel taxes for the group of countries considered in this study, which includes OECD members and the BRICs (Brazil, Russia, India and China) and South Africa. These countries, as a group, account for more than 80 percent of fossil-fuel related green house gas (GHG) emissions (see Fig. 2). Note that these emissions include coal emissions which may be the predominant source in some countries, like China.

Table 3 shows the estimated optimal motor fuel taxes, given the values of the benchmark parameters, for our group of countries. These results should be taken as broadly indicative and not as precise estimates of the optimal taxes. We shall discuss their sensitivity to key parameters below. In Table 3, the countries are sorted, in descending order, by the difference between the optimal tax on motor fuel (t_F) and the actual tax (t_F^0). Countries undertaxing motor fuel the most appear at the top of the table while countries that would be overtaxing motor fuel the most appear closer to the bottom of the table.

China and the USA, the two largest transport oil-related GHG emitters in 2006 according to data from the International Energy Agency (IEA) (see last column in Table 3) are among the six countries that are undertaxing fossil fuels. The rest of the countries that are undertaxing are among the few countries in the world that individually account for more than 2% of total transport oil-related emissions.[12] Note that the size of a country's

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[11] OECD.Stat includes data and metadata for OECD countries and selected non-member economies. The World Economic Outlook (WEO) database contains selected macroeconomic data series from the statistical appendix of the World Economic Outlook report, the result of analysis and projections carried out by IMF for many individual countries and country groups.

[12] In the table, only Germany, Japan, France Italy and India show transport oil related emissions of more than 2% of world total. Outside our list of countries, Iran and Saudi Arabia, each accounting for 2.1% ot total transport oil-related emissions are the only countries with comparable high fuel oil emissions in 2006

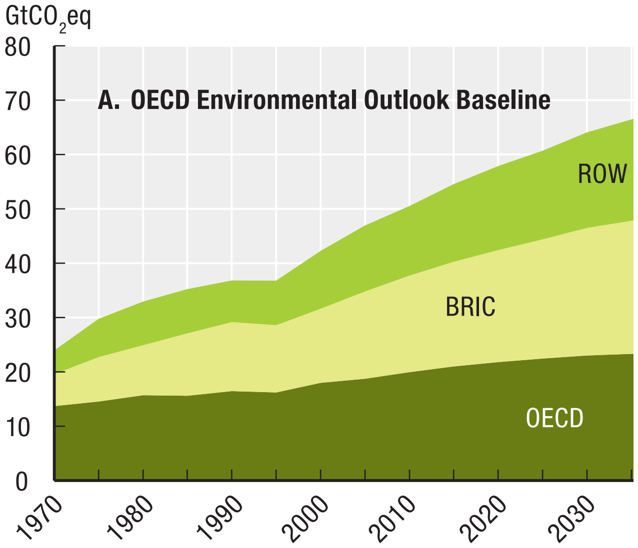

Fig. 2. Anthropogenic green house emissions: OECD, BRICs and Rest of the World. (Source: http://www.oecd.org/environment/outlookto2030)

emissions do not play any role in the determination of the optimal tax, t_F, in (1)–(3). However, obviously, the size of the tax does affect final prices and energy efficiency.

The Ramsey and Pigou components dominate the determination of t_F, with the Congestion Feedback component playing a very minor role (note that the congestion externality is part of the Pigou component). The relative importance of the Ramsey and Pigou components in Table 3 is driven mostly by differences in producer prices, q_F (Table 6). The lower q_F the lower the Ramsey component—*e.g.*, compare Germany and the UK in table 3, and note the difference in q_F in Table 6. Table 3 reports the implied excess burden of non-motor fuel taxation $(1 + MEB_L)$. (Remember that in this framework all other taxes are lumped into an aggregate labor tax.) These values are broadly in line with the lower-range of values used in the literature for the marginal cost of funds, between 1.1 and 1.25. Other things equal, the larger the MEB_L, the larger the optimal motor fuel tax.

Fig. 3 summarizes (using *box plots*[13]) the results in Table 4, which shows the impact of changes in the values of key parameters in the results, across the different countries. The size of the response to the variation in a particular parameter depends on the values of all others, so these results inform on what matters most, given the configuration of parameters. We consider changes of 0.1 in the values of the labor and motor fuel elasticities, and changes of ¢10 in the climate-change emissions damage.

There is large heterogeneity in the response across countries when altering three of the

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according to IEA.

[13] A box plot is a histogram-like method of displaying data. The quartiles Q_1 and Q_3 delimit the box, while the statistical median is represented by a horizontal line in the box. The "whisker" are extended to the farthest points that are within $\frac{3}{2}$ times the interquartile range of $(Q_3 - Q_1)$. Then, every point more than $\frac{3}{2}$ times the interquartile range from the end of a box, is represented by a dot, and it is considered an outlier.

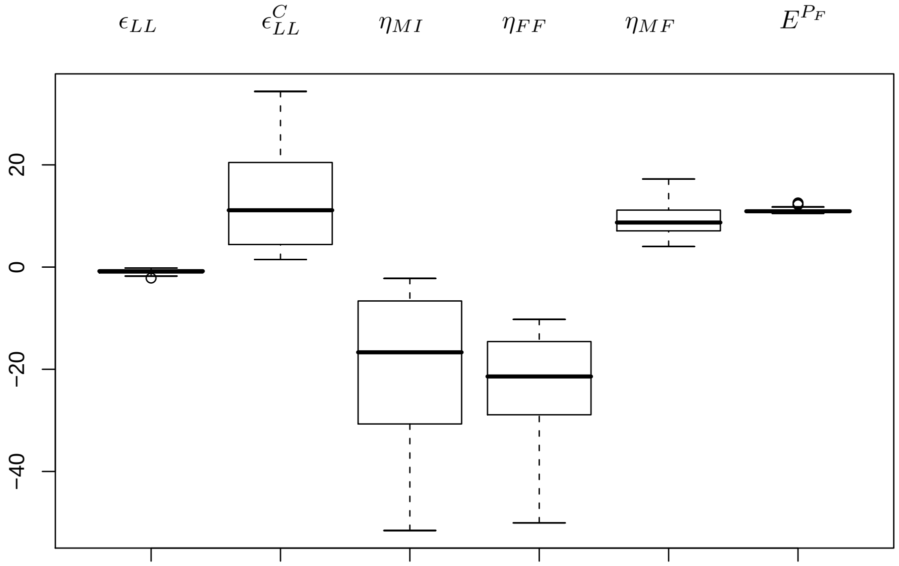

Fig. 3. Response of the Optimal Fuel Taxes to variations of 0.1 in the value of each elasticity, and of ¢10 in the value of the GHG emission externality (Δt_F in ¢/gal).

elasticities: the compensated labor elasticity, ϵ_L^C, the elasticity of demand of vehicle-miles traveled with respect to disposable income, η_{MI}, and the own-price elasticity of demand for gasoline, η_{FF} (note the spreads in Fig. 3). The range of responses when changing the elasticity of demand of vehicle-miles traveled with respect to gasoline price, η_{MF}, and the damage associated with emissions, E^{P_F} is much narrower. The uncompensated labor elasticity shows a rather unimportant effect, and little variation. The median (horizontal bar within each box) effects of $\Delta\epsilon_L^C$, $\Delta\eta_{MF}$, and ΔE^{P_F} are about ¢10/gal. The magnitude of the median effects to $\Delta\eta_{MI}$ and $\Delta\eta_{FF}$ is twice as large, about −20¢/gal.

Table 5 shows the optimal taxes when we increase the labor elasticities by 50 percent ($\epsilon_{LL} = 0.30$, and $\epsilon_{LL}^c = 0.53$, versus baseline of $\epsilon_{LL} = 0.20$, and $\epsilon_{LL}^c = 0.35$), bringing them to the upper bound of the 95 percent interval discussed in Parry-Small. While also increasing the value of the climate-change damage to $E^{P_F} = \$100$ per ton of carbon. In this case, now more than half of the countries would be undertaxing motor fuel. In terms of GHG emissions, however, the group of undertaxing countries accounts now for only 8 percent more than in the baseline calculation.

3.1. *Climate-Change Externality*

When considering the effects of the changes in the climate-change emissions damage, ΔE^{P_F}, we may be inclined to expect a less than 1:1 response Δt_F because of the marginal cost of funds adjustment. Indeed the first impact through the Adjusted Pigou component (1) will be less than 1:1 as long as $MEB_L > 0$. However, when a larger t_F enters into the Ramsey (2) and Congestion Feedback (3) components, there's a second round of adjustments and t_F must raise further to balance the left-hand side and right-hand side of (1)–(3). When the all the dust is settled, the final impact Δt_F exceeds ΔE^{P_F}, by about

10 percent (Table 4).

Note also, that even if there were an international agreement on the value of the climate-change externality, E^{P_F}, the impact of this component on the overall tax on motor fuel, t_F, varies in each country, as equations (1)–(3) make apparent.

4. Conclusions

The taxation of motor fuel displays a great variability across different countries. While these products are generally subject to broadly similar consumption taxes, the rates applied by individual countries, especially on the excise component, vary substantially. Parry and Small (2005) develop a model balancing the level motor fuel taxes against all other taxes. They show that the second-best optimal tax on motor fuel can be broken into several components: an adjusted Pigovian tax to account for the external effects of motor fuel; a general Ramsey-type consumption tax component; and a reduced-congestion feedback.

In this paper, we apply the Parry-Small framework to estimate the second-best optimal level taxation of motor fuel for OECD and BRICs, which jointly account for about 80 percent of fossil-fuel world GHG emissions. In the benchmark specification, we find that six countries, China, Russia, the U.S., Brazil, Mexico and Canada, accounting for more than 40 percent of transport oil GHG emissions, would be undertaxing fossil fuels. Increasing the shadow value on GHG emissions to $100 per ton of carbon (from the $25 benchmark value) and the size of the labor-leisure substitution response to wages result in more than half the considered countries undertaxing fossil fuels.

We evaluate the sensitivity of the results to the values of the elasticities and externalities that we use by computing numerical derivatives evaluated with each country's specific parameter values. We find that varying the values of these parameters—within the level of uncertainty reasonably associated with them—significantly affects the quantitative results although the qualitative results are more robust. This implies that, while informative, the results must be taken as indicative. The further analysis for a particular country must rely in a well-informed choice for the values of their country-specific parameters.

Table 3. Optimal Motor Fuel Taxes: Benchmark Case

Benchmark Values for Labor Elasticities and Climate-Change Externality

($\epsilon_{LL} = 0.20$, $\epsilon^c_{LL} = 0.35$, and $E^{P_F} = \$25$ per ton of carbon.)

	Optimal Fuel Tax (U.S. cents/gal)							
	Pigou	Ramsey	Cong.	Total t_F	Actual Tax t^0_F	Difference $(t_F - t^0_F)$	Excess Burden $(1 + MEB_L)$	% World GHG Motor Fuel Emissions 1/
Countries that undertax motor fuel ($t_F > t^0_F$); account for 41% of motor fuel GHG world emissions								
China	147	16	1	165	44	121	1.05	8.03
Russia	122	27	2	151	70	81	1.10	2.98
US	75	23	1	99	40	59	1.10	22.39
Brazil	80	73	2	156	100	56	1.19	2.28
Mexico	82	22	1	105	61	44	1.06	2.39
Canada	58	59	1	118	92	26	1.14	2.45
Countries that overtax motor fuel ($t_F < t^0_F$); account for 28% of motor fuel GHG world emissions								
Hungary	71	151	2	224	227	-3	1.24	0.17
Greece	96	117	2	216	241	-25	1.17	0.49
France	98	251	5	353	379	-26	1.28	2.16
Luxembourg	124	114	2	241	280	-39	1.15	0.07
Italy	104	204	4	312	362	-50	1.23	2.06
Australia	62	42	1	105	156	-51	1.12	1.04
India	81	28	1	110	184	-74	1.08	3.15
Czech Republic	72	126	1	199	276	-77	1.18	0.23
Belgium	78	203	1	282	374	-92	1.24	0.51
Germany	129	175	5	309	402	-93	1.19	2.76
Austria	53	159	0	213	308	-95	1.23	0.35
Spain	64	94	1	158	254	-96	1.14	1.77
Denmark	48	227	0	275	385	-110	1.26	0.20
Sweden	34	175	0	209	321	-112	1.25	0.32
Japan	67	42	1	110	233	-123	1.11	5.45
UK	109	43	3	155	280	-125	1.15	1.76
Poland	72	123	1	196	327	-131	1.17	0.56
Portugal	62	172	1	236	371	-135	1.21	0.32
Slovak Republic	73	100	1	174	323	-149	1.14	0.08
Finland	73	145	2	219	390	-171	1.18	0.25
Iceland	74	77	1	152	327	-175	1.11	0.02
Netherlands	71	184	1	256	432	-176	1.20	0.63
Switzerland	51	74	0	126	311	-185	1.13	0.31
Ireland	52	83	0	135	327	-192	1.12	0.24
Korea	107	22	1	131	327	-196	1.06	1.82
South Africa	53	13	1	67	266	-199	1.08	0.57
Norway	53	126	1	180	399	-219	1.14	0.21
New Zealand	48	28	0	76	385	-309	1.10	0.17
Turkey	61	34	1	96	491	-395	1.11	0.72

1/ Source: Authors' calculations and IEA (2006) CO_2 Emissions by Sector.

Table 4. Sensitivity of Optimal Motor Fuel Taxes to the values of several parameters

	Response (in cents) of optimal motor fuel tax (Δt_F) to increase of:					
	0.1 in					¢10 in
	ϵ_{LL}	ϵ^c_{LL}	η_{MI}	η_{FF}	η_{MF}	E^{P_F}
Australia	-0.6	4.8	-7.3	-12.6	7.2	10.9
Austria	-1.4	21.0	-31.4	-28.0	6.7	10.8
Belgium	-2.2	27.3	-41.0	-38.2	10.3	11.0
Brazil	-0.9	9.0	-13.6	-19.2	10.0	11.2
Canada	-0.6	6.9	-10.4	-13.6	6.5	10.8
China	-0.3	1.7	-2.5	-14.8	16.0	12.2
Czech Republic	-1.1	15.9	-23.8	-25.7	9.1	11.0
Denmark	-1.5	30.8	-46.2	-37.1	6.0	10.7
Finland	-0.8	17.7	-26.5	-27.9	9.1	10.7
France	-1.8	34.4	-51.6	-50.1	14.1	11.2
Germany	-1.2	21.5	-32.2	-40.7	17.2	11.0
Greece	-1.0	14.1	-21.2	-27.0	12.0	10.9
Hungary	-1.5	20.0	-30.0	-29.8	9.2	10.9
Iceland	-0.6	8.8	-13.3	-18.3	8.6	10.6
India	-0.4	3.1	-4.6	-13.9	9.8	11.3
Ireland	-0.7	9.8	-14.7	-16.1	5.8	10.5
Italy	-1.5	26.3	-39.4	-41.9	14.1	11.0
Japan	-0.5	4.8	-7.3	-14.2	8.2	11.0
Korea	-0.3	2.4	-3.6	-18.3	13.7	11.4
Luxembourg	-1.4	13.9	-20.9	-30.5	15.7	11.1
Mexico	-0.2	2.3	-3.4	-10.8	8.7	11.0
Netherlands	-1.2	23.3	-35.0	-33.3	9.0	10.7
New Zealand	-0.4	3.1	-4.7	-10.6	6.0	10.7
Norway	-0.7	15.0	-22.5	-21.8	6.1	10.6
Poland	-1.0	15.1	-22.6	-24.7	8.8	10.7
Portugal	-1.1	22.2	-33.3	-30.9	7.9	10.9
Russia	-0.7	3.1	-4.6	-16.3	14.9	12.6
Slovak Republic	-0.8	11.8	-17.8	-21.4	8.7	10.7
South Africa	-0.3	1.5	-2.2	-10.2	7.0	11.4
Spain	-0.7	11.1	-16.7	-19.2	7.5	10.7
Sweden	-1.0	23.4	-35.0	-27.7	4.0	10.7
Switzerland	-0.7	8.9	-13.3	-15.4	6.0	10.7
Turkey	-0.5	4.0	-6.0	-14.4	8.2	11.0
U.K.	-1.0	5.2	-7.7	-24.6	16.5	12.3
U.S.	-0.6	2.8	-4.1	-10.3	8.4	11.8
Mean	-0.9	12.8	-19.1	-23.1	9.6	11.0
Median	-0.8	11.5	-17.2	-21.6	8.8	10.9
Standard Deviation	0.5	9.3	14.0	10.2	3.5	0.50

Table 5. Optimal Motor Fuel Taxes: High-Tax Case

High Labor Elasticities and High Value for Climate-Change Externality

($\epsilon_{LL} = 0.30$, $\epsilon^{c}_{LL} = 0.53$, and $E^{P_F} = \$100$ per ton of carbon.)

	Optimal Fuel Tax (U.S. cents/gal)							
	Pigou	Ramsey	Cong.	Total t_F	Actual Tax t^0_F	Difference $(t_F - t^0_F)$	Excess Burden $(1 + MEB_L)$	% World GHG Motor Fuel Emissions 1/
Countries that undertax motor fuel ($t_F > t^0_F$); account for 50% of motor fuel GHG world emissions								
France	103	461	7	571	379	192	1.48	2.16
China	165	27	2	194	44	150	1.07	8.03
Hungary	80	269	3	351	227	124	1.40	0.17
Brazil	91	127	4	222	100	122	1.30	2.28
Russia	137	46	3	186	70	116	1.16	2.98
Italy	111	358	6	476	362	114	1.38	2.06
US	90	40	1	132	40	92	1.16	22.39
Denmark	57	411	1	468	385	83	1.45	0.20
Canada	71	99	1	172	92	80	1.22	2.45
Belgium	86	363	1	450	374	76	1.40	0.51
Mexico	98	35	1	135	61	74	1.09	2.39
Greece	107	197	4	308	241	67	1.27	0.49
Luxembourg	134	192	3	330	280	50	1.24	0.07
Germany	137	299	7	443	402	41	1.31	2.76
Sweden	44	315	0	360	321	39	1.43	0.32
Austria	63	282	1	346	308	38	1.38	0.35
Czech Republic	83	218	2	303	276	27	1.30	0.23
Portugal	72	303	2	377	371	6	1.34	0.32
Countries that overtax motor fuel ($t_F < t^0_F$); account for 19% of motor fuel GHG world emissions								
Australia	76	70	1	147	156	-9	1.18	1.04
Spain	76	157	2	234	254	-20	1.23	1.77
Netherlands	81	318	2	401	432	-31	1.33	0.63
Poland	83	209	2	293	327	-34	1.27	0.56
India	97	46	2	144	184	-40	1.13	3.15
Finland	83	246	3	333	390	-57	1.28	0.25
Slovak Republic	85	166	2	253	323	-70	1.22	0.08
UK	121	75	5	201	280	-79	1.24	1.76
Japan	81	71	2	154	233	-79	1.18	5.45
Iceland	88	126	1	215	327	-112	1.17	0.02
Norway	66	211	1	278	399	-121	1.23	0.21
Switzerland	65	124	0	189	311	-122	1.21	0.31
Ireland	66	137	0	203	327	-124	1.19	0.24
Korea	124	37	2	162	327	-165	1.09	1.82
South Africa	70	23	1	93	266	-173	1.11	0.57
New Zealand	64	46	1	110	385	-275	1.15	0.17
Turkey	76	58	1	135	491	-356	1.17	0.72

1/ Source: Authors' calculations and IEA (2006) CO_2 Emissions by Sector.

Table 6. Parameter Values

	Taxes and Producer Prices (U.S.$/Gallon)				Fuel Intensity		Congestion Costs		Accident Costs		Share of Fuel Production		Government Size	
	t_F^0	q_F	Sum	Source	α_{FM}^0	Source	E^C	Source	E^A	Source	α_F	Source	α_G	Source
Australia	1.56	2.12	3.68	(1)	21.57	(5)	3.10	(9)	2.63	(21)	0.01	(29)	0.35	(30)
Austria	3.08	4.52	7.60	(1)	31.00	(3)	3.81	(10)	2.30	(22)	0.01	(29)	0.49	(30)
Belgium	3.74	5.41	9.15	(1)	31.00	(3)	5.46	(10)	4.32	(22)	0.01	(29)	0.50	(30)
Brazil	1.00	2.12	3.12	(2)	21.38	(6)	5.60	(11)	2.29	(23)	0.02	(29)	0.45	(30)
Canada	0.92	2.57	3.49	(1)	20.45	(5)	3.10	(9)	2.10	(9)	0.02	(29)	0.39	(30)
China	0.45	1.19	1.64	(1)	26.72	(6)	7.82	(12)	1.71	(24)	0.01	(29)	0.20	(30)
Czech Rep.	2.76	4.43	7.19	(1)	31.00	(3)	2.40	(13)	2.24	(13)	0.02	(29)	0.44	(30)
Denmark	3.85	5.79	9.64	(1)	33.12	(5)	1.96	(10)	1.78	(22)	0.01	(29)	0.52	(30)
Finland	3.90	5.43	9.33	(1)	34.08	(5)	3.19	(10)	1.03	(22)	0.02	(29)	0.43	(30)
France	3.79	5.45	9.24	(1)	31.57	(5)	4.53	(10)	2.03	(22)	0.01	(29)	0.53	(30)
Germany	4.02	5.54	9.56	(1)	26.72	(5)	5.35	(10)	2.83	(22)	0.01	(29)	0.45	(30)
Greece	2.41	4.17	6.58	(1)	39.52	(5)	3.60	(10)	1.23	(22)	0.02	(29)	0.43	(30)
Hungary	2.27	3.85	6.12	(1)	31.00	(3)	2.40	(13)	2.24	(13)	0.02	(29)	0.50	(30)
Iceland	3.27	4.24	7.51	(3)	31.00	(3)	2.40	(13)	2.24	(13)	0.01	(29)	0.43	(30)
India	1.85	1.80	3.65	(2)	23.75	(6)	2.15	(14)	2.29	(23)	0.01	(29)	0.28	(30)
Ireland	3.27	4.79	8.06	(1)	26.88	(5)	0.82	(10)	3.10	(22)	0.01	(29)	0.35	(30)
Italy	3.62	5.53	9.15	(1)	34.58	(5)	5.15	(10)	1.85	(22)	0.01	(29)	0.49	(30)
Japan	2.33	2.12	4.45	(1)	21.77	(5)	4.67	(15)	2.10	(9)	0.01	(29)	0.35	(30)
Korea, Rep.	3.27	1.94	5.21	(1)	26.42	(7)	6.93	(16)	2.97	(23)	0.01	(29)	0.22	(30)
Luxembourg	2.80	4.53	7.33	(1)	31.00	(3)	4.63	(10)	4.60	(22)	0.02	(29)	0.40	(30)
Mexico	0.69	2.01	2.70	(1)	22.80	(8)	6.07	(17)	0.34	(25)	0.02	(29)	0.23	(30)
Netherlands	4.32	6.06	10.38	(1)	29.40	(5)	8.54	(10)	2.68	(22)	0.01	(29)	0.46	(30)
New Zealand	0.00	3.30	3.30	(1)	23.75	(5)	2.33	(18)	2.10	(9)	0.02	(29)	0.32	(30)
Norway	4.00	6.24	10.24	(2)	28.68	(5)	1.54	(10)	1.60	(22)	0.01	(29)	0.38	(30)
Poland	3.27	4.73	8.00	(3)	31.00	(3)	2.40	(13)	2.24	(13)	0.01	(13)	0.43	(30)
Portugal	3.71	5.53	9.24	(1)	31.00	(3)	2.16	(10)	1.69	(22)	0.02	(29)	0.46	(30)
Russian Fed.	0.70	0.82	1.52	(2)	23.52	(6)	7.00	(19)	2.86	(26)	0.01	(29)	0.33	(30)
Slovak Rep.	3.23	4.82	8.05	(1)	31.00	(3)	2.40	(13)	2.24	(13)	0.02	(29)	0.38	(30)
South Africa	0.83	2.66	3.49	(2)	27.00	(9)	3.10	(9)	1.14	(27)	0.03	(29)	0.28	(30)
Spain	2.54	4.28	6.82	(1)	31.00	(3)	4.53	(10)	1.41	(22)	0.01	(29)	0.39	(30)
Sweden	3.21	4.70	7.91	(1)	26.13	(5)	1.44	(10)	1.22	(22)	0.01	(29)	0.51	(30)
Switzerland	3.11	4.63	4.63	(4)	31.00	(3)	3.91	(10)	2.11	(22)	0.01	(29)	0.37	(30)
Turkey	4.91	1.83	6.74	(2)	31.00	(3)	2.40	(13)	2.24	(13)	0.00	(29)	0.33	(30)
U.S.	0.46	1.96	2.42	(1)	20.27	(5)	3.50	(20)	3.00	(20)	0.02	(29)	0.33	(30)
U.K.	4.07	1.97	6.04	(1)	30.94	(5)	7.00	(10)	2.40	(28)	0.00	(29)	0.41	(30)
Mean	2.66	3.66	6.38		28.37		3.93		2.20		0.01		0.39	
Median	3.11	4.25	6.82		30.94		3.50		2.24		0.01		0.40	
Standard Deviation	1.32	1.53	2.67		4.54		1.96		0.83		0.01		0.09	

Table 7. Sources of Data

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(1) Energy Détente (March, 2009)

(2) Energy Détente (December, 2005)

(3) N/A. Used median value for European countries.

(4) Price from (1) and tax from OECD stats

(5) IEA (2007) *Energy use in the New Millennium*

(6) http://www.indiaenvironmentportal.org.in/content/review-international-policies-vehicle-motor fuel-efficiency

(7) http://www.highbeam.com/doc/1G1'(1)43417929.html

(8) http://www.autoproject.org.cn/english/new_advance_en/Mex%20TRB%20presentation.pdf

(9) N/A. Use median for the whole sample.

(10) Carisma and Lowder (2008)

(11) Willoughby (2002) based on estimates for Sao Paulo.

(12) Creutzig and He (2009).

(13) N/A. Use median for European countries.

(14) Estimate similar to Bangkok and Kuala Lumpur from United Nations Economic and Social Commission for Asia and the Pacific (2007).

(15) Ministry of Land, Infrastructure and Transport (2000).

(16) Korea Transport Institute (KOTI).

(17) Ochoa and Radian (1997).

(18) Jayaram *et al.* (1995)

(19) http://www.latimes.com/news/nationworld/world/la-fg-russia-roads15-2009jul15,0,6188164.story

(20) Parry and Small (2005).

(21) Connelly and Supangan(2006.)

(22) INFRA/IWW (2004).

(23) Mohan (2002). Table found at http://www.vtpi.org/tca/tca0503.pdf

(24) http://www.car-accidents.com/country-car-accidents/china-car-accidents-crash.html

(25) Mendoza, Chavarría and Mayoral (1998).

(26) http://www.kommersant.com/p'(1)3563/r_500/Traffic_accident/

(27) http://findarticles.com/p/articles/mi_qa5327/is_291/ai_n29030852/

(28) (22) as average accident costs in €/1,000 passenger and tonne-kilometres.

(29) IEA World Energy Statistics and Balances.

(30) IMF WEO Database.

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