Rationalizing Transport Fuels Pricing Policies and Effects on Global Fuel Consumption

Carol A. Dahl, Professor, Mineral and Energy Economics Program, 1500 Illinois St, Colorado School of Mines, Golden, Colorado, USA
ph: 1-303- 273-3921, fx: 1-303-273-3416, email: cadahl@mines.edu
and
Visiting Professor, Department of Economics, College of Business Administration, King Saud University, Riyadh, Saudi Arabia
and

Yahya Faissal Anouti, Ph.D Candidate, Mineral and Energy Economics Program, Colorado School of Mines, Golden, Colorado

Abstract:

Transport fuel taxes have arisen for various reasons. High transport fuel taxes in Western Europe originated from the need to fund post World War II reconstruction plans. Gasoline considered a luxury good with inelastic demand was highly taxed. Somewhat lower diesel taxes were aimed at keeping down freight transport rates and keeping local industry more competitive. In the U.S., gasoline taxes have been mainly earmarked for road maintenance and have been lower than in Europe and many other countries. In many major oil exporting countries, the provision of gasoline and diesel subsidies have often been considered to be a means of social transfer. Thus, the landscape of transport fuel policies has been shaped by countries' self-interests as well as their historical context. Today, a confluence of factors, such as social pressures and growing concerns about associated consumption externalities, is building the momentum towards rationalizing the pricing of transportation fuels to reflect direct and indirect costs. In this paper, we provide a historical context for transport fuel policies, layout rationalizing schemes, and build on Dahl (2011) to measure the change in demand induced by the migration to those schemes.

Introduction

Despite the run up in oil prices experienced over the last decade, global demand for gasoline and diesel in transportation has been on an increase. While this has been true at the global level, the picture varies widely across regions. Indeed, economic growth and transport fuel policies in place have shaped the varying responses to the increase in prices. To this end, countries can be segmented into three worlds:

- Industrial countries in the OECD experiencing a decline in demand for transport fuels. This is driven by slow economic growth with varying but generally high tax rates on transportation fuels and increasing policies centered around internalizing externalities. These countries tend exhibit somewhat more elastic price and somewhat less elastic income demand for gasoline.
- Large oil exporting countries, such as many OPEC countries and Russia, exhibiting increasing growth in demand for transport fuels. This is underpinned by a confluence of increasing growth from oil export revenues and domestic policies aimed at shielding local consumers from international price levels through subsidies or relatively low taxes. Those countries exhibit low price elasticities for transportation fuel demand.
- Emerging economies experiencing rapid economic growth with an increase in urbanization levels and standards of living. In these economies demand for passenger and freight transport burgeons with an accompanying increase in demand for fuel. Those economies generally exhibit higher income elasticities to transportation fuel demand and more often have taxes closer to those for Europe than the U.S. Table 1 reflects the resulting growth in road transport fuels by region through 2008.

Table 1. Year to year percentage change in road gasoline and diesel consumption

Region	2005	2006	2007	2008

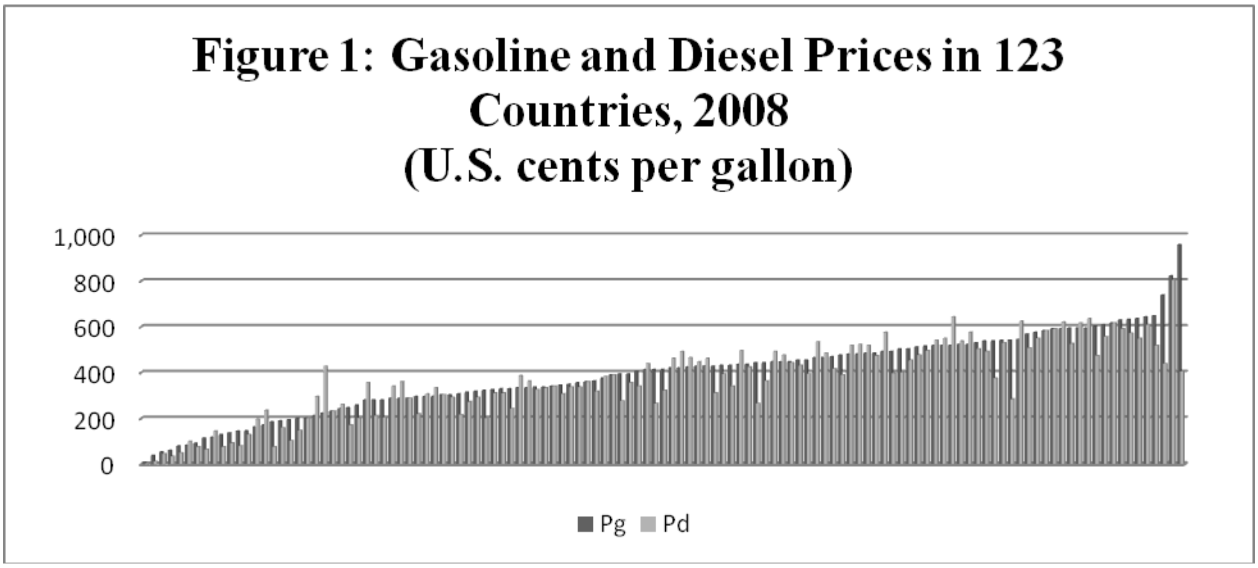
OECD North America	0.9%	0.7%	0.7%	-3.7%
OECD Pacific	-0.8%	-1.4%	-0.8%	-3.3%
OECD Europe	-0.1%	1.2%	1.1%	-2.8%
Africa	2.1%	2.4%	6.5%	5.2%
Latin America	1.4%	3.5%	4.1%	3.7%
Middle East	6.6%	6.8%	2.3%	6.3%
Non-OECD Europe	3.2%	2.4%	3.3%	7.3%
Former Soviet Union	-0.8%	5.2%	2.6%	9.5%
Asia (excluding China)	-0.9%	0.4%	6.7%	1.5%
China (including Hong Kong)	10.2%	11.1%	10.4%	19.0%
World	**1.2%**	**1.9%**	**2.3%**	**0.3%**

- *Source: IEA World Energy Balances*

Across the three worlds, the future demand for transportation fuels will depend not only on the demographic and socioeconomic trends exhibited in the countries in these regions, but also on related policies. In this paper, we present a historical perspective on such transport fuel policies in Section II. Then, we build on the Dahl (2011) to do a quantitative assessment of various fuel price subsidies and taxes in Section III.

Transport Fuels Policies

Since transport fuels tend to be the most heavily taxed energy product, differences in price across countries as seen in Figure 1 are largely the result of varying tax levels. With gasoline prices without taxes around 193 cents per gallon and diesel prices without taxes around 248 cents, Figure 1 suggests that around 30 countries were subsidizing gasoline, diesel fuel or both. However, more often countries were taxing fuels and sometimes quite heavily.



Source: GTZ (2009)

As noted above gasoline taxes in Europe have been relatively high with diesel fuel taxes a bit lower. This differential coupled with changing vehicle technologies has encouraged a major switch of the passenger fleet towards diesel engines in some countries. For instance, over two thirds of recent new passenger vehicle sales in France and just over half of new passenger cars in Western Europe in 2007 had diesel engines. (U.S. Energy Information Administration (2009)) In the U.S., transport fuel taxes have been much lower, and they have been more closely earmarked for highway funding. For instance, 90% of the Federal gasoline tax goes to the Federal Highway trust, 8.5% goes to Mass Transit, and 1.5% goes to the Leaky Underground Storage Trust. (U.S. Highway Administration (2010))

On the other side of the world, early energy subsidies for transport fuels were more often located in oil producing countries where they were considered to be social programs. Examples include

Venezuela and Saudi Arabia which have some of lowest gasoline prices in the world. However, even in non-oil exporting countries fuel subsidies may have had ulterior motives. For example, some recent subsidies for transportation bio-fuels are criticized as being more of a subsidy for farmers than an energy transportation policy. The U.S. is a case in point, where ethanol production is highly subsidized amounting to about a 50 cents per gallon tax break and the U.S. Energy Independence and Security Act of 2007 (EISA2007) mandates increasing use of renewables as transport fuels.

In more recent decades, concerns about transportation fuel use externalities in many importing countries (e.g. energy security, local pollution, climate change, sustainability) have led governments to target and re-enforce policies specifically aimed at total transport fuel use and mix. The U.S. Corporate Fuel Efficiency (CAFÉ) standards, enacted in 1975 after the first oil embargo, were aimed at increasing vehicle fuel efficiency and reducing fuel use. Those standards were increased in EISA2007. Brazil's ethanol vehicle program enacted in the late 1970's, which required ethanol to be blended into gasoline, had the goal of changing the fuel mix away from petroleum based fuels towards a domestic renewable fuel. More recently with the manufacture of flex fuel vehicles, now around one quarter of the Brazilian vehicle stock can burn multiple fuels. "Gas guzzler" taxes on less efficient vehicles, "Cash for Clunkers" to get the worst pollution offenders off the road, feebates that tax inefficient and give rebates to efficient vehicle purchases are examples of similarly adopted policies.

In addition, governments have considered urban policies that may have large effects to the extent of dwarfing those of direct transport fuel policies in many cases. Such local urban transport policies aimed at congestion and pollution that affect transport fuel use include: the choices and resources applied to urban transit, taxing private vehicles entering the central business district during peak traffic hours; limiting the number of publically available parking spaces, and providing free public transport on particularly bad air pollution days. Local land use policies that have no direct link to transportation services can also have a major effect on transportation energy use. For example, zoning regulations designed to maintain a quiet suburban lifestyle may severely limit population and jobs per square mile of a metropolitan area. Such suburban sprawl greatly reduces the feasibility of providing public transport services.

Obviously for the future, countries' self-interest will continue to influence transportation fuel and other policy choices. Across our three worlds:

- In some large energy exporting countries, like the UAE, policy makers kicked off the deployment of targeted social programs and started a gradual decrease in subsidies levels. In those countries, policy makers are not really concerned with domestic energy transportation consumption levels but are more concerned with export revenues from energy production.
- In industrial countries with transport and land use structures in place and a vehicle stock turnover of about 15 years, there is more concern with "sustainability" and adjustments are more likely to come from changes in the vehicle stock.
- Rapidly developing countries where the transport and land use structure will largely evolve in the coming decades are interested in development. Policies relating to transport systems and land use may have even more influence on transport fuel use than policies more directly relating to fuels.

Although quantifying the effect of all of the above mentioned policies on transport fuel demand is beyond the scope of this paper, we consider the effect of policies and economic drivers that operate through price elasticities in the sections below. Such analysis has been aided by Dahl (2011), which contains price and income elasticities for gasoline and diesel transport fuels for 124 countries based on analysis of historical studies. These elasticities are reproduced below in Table 2 for each country along with gasoline and diesel prices, taxes, and estimated subsidy levels in 2008. Although fuel efficiency standards are not directly considered in her paper, they are not totally ignored as they are embedded in the historical elasticities, and she indirectly accounts for country fuel switching policies by modifying some of the elasticities.

Table 2. Gasoline and Diesel Prices, Taxes and Subsidies across Countries.

Country	**P Gasoline** (2008, Cents/gallon)	**P Diesel** (2008, Cents/gallon)	**Tax/Subsidy (+/-) G** (2008, $/gallon)	**Tax/Subsidy (+/-) D** (2008, $/gallon)	ElasP_G	ElasP_D	ElasY_G	ElasY_D
Albania	515	496	321	236	-0.26	-0.13	1.26	1.34
Algeria	129	76	-65	-184	-0.45	-0.22	-0.59	1.87
Angola	201	148	7	-112	-0.22	-0.22	1.26	1.34
Argentina	295	220	96	-22	-0.08	-0.22	-1.09	1.34
Australia	280	356	132	134	-0.29	-0.65	0.55	0.69
Austria	519	541	299	251	-0.81	-0.16	-0.79	1.79
Azerbaijan	280	212	87	-47	-0.22	-0.22	1.26	1.34
Bahrain	79	49	-110	-179	-0.50	-0.19	1.04	1.34
Bangladesh	443	265	253	37	-0.09	-0.22	2.06	1.66
Belarus	503	401	310	142	-0.39	-0.22	-0.37	1.34
Belgium	568	507	355	222	-0.51	-0.38	-0.79	1.79
Benin	390	390	196	130	-0.26	-0.13	1.26	1.34
Bolivia	257	201	58	-41	-0.22	-0.22	1.26	1.34
Bosnia and Herzegovina	428	447	234	187	-0.26	-0.13	1.26	1.34
Botswana	333	386	140	127	-0.26	-0.13	1.26	1.34
Brazil	477	390	278	148	-0.39	-0.32	1.37	0.90
Brunei	144	79	-46	-149	-0.24	-0.27	0.90	1.34
Bulgaria	484	519	291	259	-0.39	-0.13	0.74	1.34
Cambodia	356	337	166	109	-0.26	-0.13	1.26	1.34
Cameroon	431	394	238	134	-0.26	-0.13	1.26	1.34
Canada	288	341	105	91	-0.48	-0.74	0.72	1.26
Chile	360	360	160	118	-0.38	-0.13	0.40	0.70
China	375	382	185	154	-0.26	-0.22	0.97	0.59
Colombia	394	276	195	35	-0.06	-0.22	-0.73	1.79
Congo, R. (Brazzaville)	307	216	113	-44	-0.26	-0.13	1.26	1.34
Costa Rica	469	416	270	175	-0.44	-0.13	1.26	1.34
Cote d'Ivoire	503	454	310	195	-0.14	-0.46	-1.07	1.19
Croatia	481	519	287	259	-0.48	-0.13	0.82	1.79
Cuba	632	572	433	330	-0.26	-0.13	1.26	1.34
Cyprus	484	473	291	214	-0.33	-0.38	0.72	1.34
Czech Republic	519	549	449	396	-0.32	-0.38	0.89	1.34
Denmark	583	583	273	204	-0.60	-0.20	-0.11	1.79
Dominican Republic	394	356	195	114	-0.29	-0.13	1.13	1.34
Ecuador	193	102	-6	-139	-0.18	-0.17	1.25	1.21
Egypt	185	76	-8	-184	-0.21	-0.22	1.36	0.86
El Salvador	295	307	96	65	-0.26	-0.13	1.95	1.34
Eritrea	958	405	764	146	-0.26	-0.13	1.26	1.34
Estonia	447	492	338	329	-0.32	-0.38	1.02	1.34
Ethiopia	348	337	155	77	-0.39	-0.22	0.74	1.79
Finland	594	526	348	232	-0.50	-0.05	0.56	1.35
France	575	549	343	262	-0.53	-0.24	-0.77	1.79
Gabon	431	341	238	81	-0.22	-0.22	1.26	1.34

Georgia	413	439	219	180	-0.26	-0.13	1.26	1.34
Germany	590	590	393	301	-0.42	-0.38	0.68	1.79
Ghana	341	341	147	81	-0.26	-0.13	1.26	1.34
Greece	466	534	271	249	-0.33	-0.44	1.89	1.18
Guatemala	326	310	126	69	-0.50	-0.22	1.43	1.34
Honduras	303	303	104	61	-0.30	-0.13	1.26	1.34
Hong Kong	738	439	548	211	-0.12	-0.36	0.42	0.50
Hungary	481	522	439	394	-0.32	-0.38	1.07	1.34
Iceland	435	496	242	236	-0.33	-0.38	0.66	1.34
India	413	265	223	37	-0.36	-0.13	1.37	1.12
Indonesia	189	159	-1	-69	-0.20	-0.38	1.89	1.58
Iran	38	11	-152	-217	-0.20	-0.15	1.11	1.68
Iraq	145	129	-45	-99	-0.09	-0.17	0.63	1.34
Ireland	590	621	258	226	-0.30	-0.38	0.81	1.41
Israel	519	643	341	291	-0.23	-0.19	1.20	0.46
Italy	594	617	358	291	-0.57	-0.24	-0.52	1.79
Japan	537	492	199	123	-0.15	-0.26	1.39	0.99
Jordan	231	231	41	3	-0.26	-0.22	0.42	1.05
Kazakhstan	314	273	121	13	-0.26	-0.22	1.26	1.34
Kenya	454	431	261	172	-0.26	-0.13	1.75	1.34
Korea, South	288	360	415	312	-0.90	-0.38	1.14	0.88
Kuwait	91	76	-99	-153	-0.09	-0.02	0.82	0.61
Latvia	424	466	231	206	-0.48	-0.13	1.21	1.79
Lebanon	288	288	98	59	-0.26	-0.22	0.74	1.34
Libya	53	45	-140	-214	-0.14	-0.22	-0.38	1.34
Lithuania	428	462	234	202	-0.48	-0.13	0.80	1.79
Luxembourg	530	503	246	178	-0.50	-0.38	0.14	1.34
Macedonia, FYR	435	424	242	165	-0.39	-0.13	-0.37	1.34
Malaysia	201	201	11	-28	-0.13	-0.22	0.95	1.61
Malta	628	590	435	331	-0.48	-0.13	-0.40	1.34
Mexico	280	204	57	39	-0.31	-0.30	1.25	0.86
Moldova	454	394	261	134	-0.26	-0.13	1.26	1.34
Mongolia	522	537	332	309	-0.26	-0.13	1.26	1.34
Mozambique	647	519	454	259	-0.26	-0.13	1.26	1.34
Myanmar	163	197	-27	-31	-0.22	-0.13	1.26	1.34
Namibia	295	333	102	74	-0.33	-0.38	0.90	1.46
Nepal	428	310	238	82	-0.26	-0.57	1.26	1.34
Netherlands	636	549	408	265	-0.34	-0.01	0.60	1.31
New Zealand	413	322	175	40	-0.10	-0.38	0.87	1.79
Nicaragua	329	310	130	69	-0.26	-0.22	1.26	1.34
Nigeria	223	428	30	168	-0.22	-0.22	1.65	1.34
Norway	617	617	319	264	-0.42	-0.07	-0.64	2.08
Oman	117	144	-73	-84	-0.52	-0.27	0.96	1.34
Pakistan	318	291	128	63	-0.41	-0.22	0.73	1.37
Paraguay	443	363	244	122	-0.22	-0.13	0.84	1.34
Peru	537	375	338	133	-0.37	-0.43	1.46	1.05
Philippines	344	307	154	78	-0.35	-0.13	0.57	1.34
Poland	541	530	483	374	-0.48	-0.13	-0.31	1.34
Portugal	609	556	470	326	-0.38	-0.29	0.99	1.79

Qatar	83	#N/A	-107	#N/A	-0.08	-0.15	0.66	1.34
Romania	420	462	227	202	-0.26	-0.13	1.26	1.34
Russia	337	326	143	66	-0.10	-0.22	0.23	1.79
Saudi Arabia	61	34	-129	-194	-0.09	-0.12	1.02	0.79
Senegal	511	477	318	218	-0.26	-0.13	1.26	1.34
Singapore	405	341	215	112	-0.33	-0.12	0.66	0.36
Slovakia	594	636	485	473	-0.48	-0.38	0.66	1.34
Slovenia	447	477	311	283	-0.50	-0.38	0.32	1.79
South Africa	246	170	53	-89	-0.26	-0.13	0.54	1.20
Spain	466	484	274	228	-0.36	-0.38	-0.64	1.79
Sri Lanka	541	284	351	56	-0.40	-0.17	1.02	1.04
Sudan	602	473	408	214	-0.26	-0.22	1.26	1.34
Sweden	522	575	322	279	-0.48	-0.25	-0.61	1.39
Switzerland	492	575	201	211	-0.37	-0.43	1.48	1.18
Syria	322	201	132	-28	-0.22	-0.22	1.26	1.96
Taiwan	242	261	52	33	-0.69	-0.28	2.02	0.43
Tanzania	420	492	227	233	-0.26	-0.13	1.26	1.34
Thailand	329	242	139	14	-0.16	-0.23	0.91	1.33
Togo	337	333	143	74	-0.26	-0.13	1.26	1.34
Trinidad and Tobago	136	92	-63	-149	-0.22	-0.27	0.80	1.34
Tunisia	363	318	170	59	-0.22	-0.28	0.75	1.21
Turkey	822	804	757	523	-0.29	-0.13	0.57	2.27
Ukraine	333	363	140	104	-0.26	-0.13	1.26	1.34
United Arab Emirates	170	235	-20	6	-0.14	-0.17	0.63	1.34
United Kingdom	545	625	384	388	-0.50	-0.38	-0.23	1.79
U.S.	212	295	51	53	-0.30	-0.07	0.63	1.00
Uruguay	447	443	248	201	-0.26	-0.13	1.06	1.34
Uzbekistan	#N/A	121	#N/A	-138	-0.39	-0.22	-0.37	1.34
Venezuela	8	4	-192	-238	-0.14	-0.17	0.70	1.65
Vietnam	303	291	113	63	-0.26	-0.22	1.26	1.34
Yemen	114	64	-76	-164	-0.22	-0.22	1.26	2.36
Zambia	643	609	450	350	-0.26	-0.13	1.26	1.34
Zimbabwe	492	397	299	138	-0.22	-0.22	1.26	1.34

Source: Dahl (2011), International Energy Agency, Online Database: *Oil Balances*, GTZ (2010) *Fuel Prices*. Note: #N/A = not available.

Policy Scenarios and Impact Analysis

Economic theory tells us that the socially optimal price is the marginal social production cost, which includes cost of production as well as externality affects. Gasoline consumption related externalities result from the combination of miles traveled and amount of fuels consumed. Among the long list of negative direct externalities, Parry and Small (2005) argue that quantitative estimates rank pollution, congestion and traffic accidents on top of the list. Existence of such externalities justifies corrective government intervention, ideally reflecting the context of each externality.

Within a global context, a survey of governmental policies dealing with the transport related externalities reveals that direct fuel tax is the most widely adopted instrument. While this is not first best policy instrument when it comes to allocation efficiency, it ranks high on other dimensions such as ease and cost of implementation.

Our scenarios for this draft will involve moving the market towards the optimal social price levels in a series of steps as follows:

1. Remove fuel subsidies, thus raising all subsidized gasoline prices to production cost;
2. Increase prices so that retail price equals at least the direct cost and indirect road maintenance cost;
3. Increase prices to include external costs so that all retail prices equal at least the direct, indirect and externality costs;

For each scenario, we will measure the change in demand induced by a change in price levels from the current retail prices (P_i) to the policy scenario price (P_{i2}). Holding constant all other variables such as income and population. Building on Dahl (2011) work, we take per capita demand elasticity estimates demand for fuel i (Q_i) that have been rearranged to:

$$Q_i = \beta P_i^{\beta_2} Y_i^{\beta_3} Pop_i^{(1-\beta_3)}$$

Where

The post policy scenario demand can presented as

$$Q_{i2} = \beta P_{i2}^{\beta_2} Y_{i2}^{\beta_3} Pop_{i2}^{(1-\beta_3)}$$

The ratio of post policy scenario demand to 2008 levels can be written as:

$$\frac{Q_{i2}}{Q_i} = \frac{\beta P_{i2}^{\beta_2} Y_{i2}^{\beta_3} Pop_{i2}^{(1-\beta_3)}}{\beta P_i^{\beta_2} Y^{\beta_3} Pop^{(1-\beta_3)}}$$

Holding income and population levels constant for our first four scenarios, predicted Q_2 can be represented as

$$Q_{i2} = Q_i \left(\frac{P_{i2}}{P_i} \right)^{\beta_2}$$

Using the elasticities reported in Dahl (2011) and taking 2008 as the base year, our analysis will cover 124 countries that represent over 98% of total transport fuel consumption. The gasoline and diesel price elasticities are adjusted relatively to the price levels in each scenario as proposed by Dahl (2011), Figures 7 and 8. She finds that as prices increase, demand price elasticities become more elastic. In this analysis we assume that the cross price elasticity between the two fuels is zero. Although there is not much systematic statistical evidence that quantitatively captures substitutions across the two fuels, we hope to join others in future research to quantify cross price effects. Preliminary results for our computations for our three scenarios are given in the next section.

<u>Scenario 1: Remove Fuel Subsidies</u>

We will use the direct cost of gasoline and diesel and remove subsidies to see the effect on fuel consumption. In order to identify the subsidy level by country, we will evaluate the direct cost of fuel i (i=g for gasoline and d for diesel) (C_i) being equal to the wholesale price (P_{iw}) for fuel i plus a transportation and distribution margin (m). The government transfer (T_i), subsidy level in this case, equals the retail price (P_i) or $T_i = P_i - (1+m)P_{iw}$. The wholesale price in November 2008 is measured at three international ports where products are traded and the price is very transparent – New York Harbor (NYH), Amsterdam/Rotterdam/Antwerp (ARA), and Singapore. Which for gasoline are (128, 119, 115 ¢/g) and for diesel are (239, 241, 235 ¢/g) in NYH, ARA, and Singapore, respectively.

The price at the closest port is taken as the reference wholesale price. Initially we added U.S. margins reported by U.S. EIA of around 12% to compute the retail price less tax. These margins were too small and implied taxes higher than actual available reported taxes, especially for small countries. We then picked margins that minimized the total squared error between available reported and computed tax and use them to compute taxes where taxes are not reported (The margins used are 38% for gasoline and 34% for diesel).

The computed subsidies are the negative numbers shown in Table 2, Columns 4 and 5 under T_g and T_d. With this technique, we find about 10% of world's gasoline and about 20% of the world's diesel fuel is subsidized. Removing these subsidies, we find the long-run effect of this policy would be a global decrease of 1.9% in gasoline consumption and 2.6% in diesel fuel consumption from 2008 levels. Given our space constraints more complete descriptions of all our scenarios as well as country level demand estimates are in a longer paper (Dahl and Anouti (2011)).

Scenario 2: Include highway maintenance costs

Next we consider indirect costs that might be attributed to fuels. Since charging for highway use in the past has been expensive, often highways have been funded from tax revenues. Since highway fuel use should be correlated with road use, fuel taxes can be a substitute for highway fees. A cost of 39 ¢/g is a rule of thumb number that should be sufficient to maintain trunk roads with an added cost of 12 - 20 ¢/g for urban road and transit needs. (GTZ (2007) values converted to real 2008 cents)) Under this scenario, we add in the road maintenance to the indirect cost. This average of 56.6 ¢/g is adjusted for each country by a purchasing power parity adjustment. When all prices are increased to at least this level global gasoline consumptions falls by 4.3% and diesel fuel consumption falls by 4.7%. (Prices higher than this level are left at the higher level)

Scenario 3: Add External Costs

The next case considers external costs of transport fuel consumption. Burning transport fuels creates local pollution - CO, NOx, VOC, and particulates and global externalities on the climate from CO_2 emissions. Local externalities are increasingly being internalized in the industrial countries, where regulations have reversed the increasing trend. For example, highway vehicle emissions of CO fell over 75% in the U.S. from 1970 to 2008. However, they still are on an upward trajectory in the emerging economies. For instance, Asian emissions of SO_2 from burning transportation fuels increased 50% and NOx emissions increased over 20% from 2000 to 2006. Local pollution values are taken from the National Research Council (2009). They are distributed over gasoline and diesel fuel, adjusted to each countries' values using purchasing power parity and GDP per capita. The ranges of values across countries are given in Table 3.

The value of CO_2 is taken to be \$21 per tonne as used in Parry (2011). It is distributed over gasoline and diesel fuel, adjusted to each countries' values using purchasing power parity and GDP per capita. The ranges of values across countries are given in Table 3.

The number of accidents by countries is available from the International Road Federation. The methodology used to convert these values to cents per gallon is adapted from Parry (2011) and adapted to each country using purchasing power parity and GDP per capita.

Table 3. Estimates of Gasoline Externality Costs (2008 ¢/gallon)

Country Ranges Diesel	**Low**	**High**
Local Pollutants: CO,NOx,VOC,Particulates,SO2	0	195
Global Pollutants: CO2	0	30
Accidents	0	226
Total	**2**	**259**
Country Ranges Diesel	**Low**	**High**
Local Pollutants: CO,NOx,VOC,Particulates,SO2	0	313
Global Pollutants: CO2	0	47
Accidents	0	257
Total	**3**	**322**

Source: Dahl and Anouti (2011)

When all prices are increased to include at least these external costs, gasoline consumption falls 7.9% from 2008 levels and diesel consumption falls by 5.2%.

Some also consider the costs of energy vulnerability associated with risks of oil disruptions and their effects on the macro economy as well as any extra military expenditures associated with protecting oil supplies to be negative externalities. Given the controversial nature of such costs and the difficulty of distributing them across countries, we have chosen to not formally evaluate such costs. However, if we take the maximum value for these costs given by Parry et al (2007) and prorate them as for highway maintenance we shave an addition 1.9% off of gasoline consumption and an additional 0.7% off of diesel consumption.

Bibliography

Dahl, Carol A. (forthcoming 2011) "Measuring Global Gasoline and Diesel Price and Income Elasticities," *Energy Policy, Special Issue on Transport Modelling.* doi:10.1016/j.enpol.2010.11.05.

Dahl, Carol A and Yahya Anouti (2011) "Rationalizing Transport Fuels Pricing Policies and Effects on Global Fuel Consumption," Draft, Mineral and Energy Economics Program, Colorado School of Mines.
(http://dahl.mines.edu/courses/dahl/D&A11).

GTZ (German Technical Cooperation), 2009. International Fuel Prices. On behalf of the German Federal Ministry for Economic Cooperation. http://www.gtz.de/en/themen/30005.htm.

International Road Federation (2008) *International Road Statistics*, Geneva, Switzerland, http://www.irfnet.org.

Parry, Ian W. H. (2011) Reforming the Tax System to Promote Environmental Objectives: An Application to Mauritius Fiscal Affairs Department, International Monetary Fund WP/11/124 , June

Parry, I. W. H. and K. A. Small. (2005) "Does Britain or the United States Have the Right Gasoline Tax?" *American Economic Review*, 95(4), 1276-1289.

Parry, Ian W. H., Margaret Walls and Winston Harrington (2007) Automobile Externalities and Policies, January 1, Resources for the Future Discussion Paper No. 06-2, Washington, DC. http://papers.ssrn.com/sol3/papers.cfm?abstract_id=927794.

U.S. National Research Council (2009) Global Sources of Local Pollution: An Assessment of Long-Range Transport of Key Air Pollutants to and from the United States, National Academy of Science, Washington, D.C. http://www.nap.edu/catalog.php?record_id=12743.,

U.S. Energy Information Administration (2009) Light-Duty Diesel Vehicles: Market Issues and Potential Energy and Emissions Impacts, Office of Integrated Analysis and Forecasting U.S. Department of Energy, Washington, D.C.,January

U.S. Federal Highway Adminstation (2010) *Highway Statistics.*U.S. Department of Transportatation, Washington D.C. http://www.fhwa.dot.gov/policyinformation/statistics.cfm.