

How much can CO₂ emissions be reduced if fossil fuel subsidies are removed?

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Abstract

This paper analyzes consumers' price elasticities of demand for fossil fuels, and how a reduction of fossil fuel subsidies can lead to important reduction in CO₂ emissions for various groups of countries that have relatively high fossil fuel subsidies and notably on diesel, including the countries in the Middle East and North Africa (MENA). These countries continue to maintain significant levels of fuel subsidies, with Iran and Saudi Arabia being the largest contributors to CO₂ emissions. This paper illustrates that fuel price policy reforms by these countries would be an important instrument for both climate and economic policy. We estimate that a reduction in subsidies to both gasoline and diesel by about 20 US\$ cents per liter will lead to significant decreases in CO₂ emissions, both in the MENA region and globally. In Iran, for example, the reductions could be up to 90% and 50% of current emissions generated from diesel and gasoline consumption, respectively, and for Saudi Arabia, approximately 70% and 40%, respectively.

1. Introduction

The goal of the 2015 Conference of Parties (COP21), or the 2015 Paris Climate Conference, was to formalize a worldwide mandate that permits global warming to be kept below 2°C. The Intergovernmental Panel on Climate Change (IPCC (2014)) has documented that there are multiple mitigation pathways that are likely to limit warming to below 2°C relative to pre-industrial levels. Any of these pathways will, however, require substantial CO₂ emission reductions over the next few decades and near-zero emissions of CO₂ by the end of the century.¹ CO₂ emissions should concern us because, as Matthews and Salomon (2013) show, the rising temperatures due to CO₂ emissions are essentially permanent.

It is now widely recognized that any target to reduce global CO₂ emissions cannot be achieved without a commitment from developing countries. Chakravarti et.al (2009), the International Energy Agency (IEA) (2014), and Parry et al. (2014a,b) have documented that the developing world now emits more than half of the global CO₂ emissions, and these emissions are increasing faster than those in the developed world under “business as usual” (BAU) standards.² Nonetheless, there exists no proper analysis of the major potential role that removing fossil fuels subsidies, which many developing countries implement, can have in reducing CO₂ emissions. We pursue such an analysis here by presenting a very simple scenario that answers the following question: How much can CO₂ emissions be reduced through a reduction in fossil fuel consumption, if subsidizing countries increase their gasoline and diesel prices by 20 US\$ cents per liter?

¹ Here, we do not focus on greenhouse gases (GHGs), and we note that the term “GHG emissions” refers to a large collection of GHGs that include CO₂, methane, and many others. Methane is more potent than CO₂, but the warming it causes fades quickly. In this paper, the term “carbon emissions” only refers to CO₂. Note also that the warming effect of GHGs does not accumulate like CO₂ (IPCC (2014)).

² One example of the many propositions to reduce CO₂ emissions is the work of Chakravarti et.al (2009), which consists of reducing CO₂ emissions by identifying the world’s high-emitting individuals across countries, and not all the countries. In short, they suggest that once the world agrees to a global CO₂ emission reduction target, the universal cap should be imposed on the global individual emission distribution (i.e., corresponding to their income distribution), such that eliminating all emissions above that cap achieves the target.

Many developing countries, including a few in Latin America and Asia but a great majority in the Middle East and North Africa (MENA) region, subsidize fossil fuels substantially for socio-political reasons. As shown below, gasoline and diesel subsidy rates have increased over time in the MENA region. This has resulted in a rapid increase in the demand for such fuels and considerable fiscal losses for these governments (Coady et al. (2015)). Taghvaei and Hajiani (2014) found that gasoline consumption in Iran has surpassed the Iranian production level, leading Iran to import gasoline. It is also well recognized that low fuel retail prices (i.e., high fuel subsidies) also has various other negative effects. For example, increases in negative externality costs are associated with fossil-fuel consumption; investment in energy efficient products is discouraged; and the renewable energy industry is made less competitive (Parry et al. 2014b). Mundaca (2016) found on the other hand that a country that initially subsidizes its fossil fuels, and then eliminates or reduces these subsidies, will, as a result, experience higher economic gross domestic product (GDP) per capita growth, higher employment, and greater levels of labor force participation, especially among the youth. These effects are strongest in countries where fuel subsidies are high, such as those in the MENA region. Our main message here is that it is imperative to move away from the two-tier world defined by the 1992 United Nations Framework Convention on Climate Change (UNFCCC): that only developed countries should take the lead in reducing CO₂ emissions while developing countries, in light of their relatively low economic development, should be treated differently. We think that the removal of energy subsidies should apply to all (developed or developing) countries, and be part of any international agreement to reduce CO₂ emissions. We recognize that achieving substantial reductions in CO₂ emissions will require substantial technological, economic, social, and institutional challenges; however, the removal of fossil fuel subsidies does not involve immediate technological challenges. Fossil fuel price reforms, together with the provision of economic safety nets to the poorest countries, will benefit the subsidizing countries overall in terms of higher economic growth and welfare as Mundaca (2016) shows.

Note that detailed estimates of price elasticities are not available for many of the countries with very high fuel subsidies. Our goal here is to estimate fuel price and income elasticities for these countries for the purpose of concurrently achieving our other important

goals: i) assessing the amount of CO₂ emissions that can be reduced by decreasing subsidies; ii) measuring how the demand for fuels responds to price changes and, consequently, how effective any fuel subsidy reform could be. It is imperative to properly specify a demand model for fossil fuels, and estimate as precisely as possible the price elasticities of fossil fuels, such as gasoline and diesel, for subsidizing countries if we want to provide policy recommendations to substantially reduce CO₂ emissions.

One of the main contributions of this paper is an improved understanding of the demand for fossil fuels by developing countries, particularly by those that today subsidize fossil fuels. We remark that the objective of most related studies in the literature have been simply to estimate the price and income elasticities of demand for fuels, with focus on developed countries or those that are part of the Organization for Economic Cooperation and Development (OECD). Much less research has been done on developing countries. Exceptions include the work of Alves and Bueno (2003) for Brazil, Lin and Zeng (2013) for China, Sita et al. (2012) for Lebanon, Sene (2012) for Senegal, and Taghavee and Hajiani (2014) for Iran. More crucially, even less attention has been given to the analysis of one of the most important externalities caused by fuel consumption in these countries, carbon dioxide (CO₂) emissions.

A large number of reviews and surveys attempt to synthesize and compare the results of fuel price elasticity estimates. For examples, see Drollas (1984), Blum (1988), Dahl and Sterner (1991a,b), Goodwin (1992), Sterner and Dahl (1992), Dahl (1995), Espey (1998), Graham and Glaister (2002, 2004), Dargay et al. (2004), Basso and Oum (2007), and Lin and Prince (2009). Dahl (2012) uses the existing econometric estimates to evaluate whether income and price elasticities are constant across countries with different incomes and prices. Based on that evaluation, Dahl (2012) approximates (but does not estimate) the price and income elasticities for gasoline and diesel demand for over 100 countries, based on a static equation without any right-hand-side lagged variables. She further argues that these estimates can be interpreted as intermediate-run estimates. Here, we emphasize that we are not aware of work that estimates short- and long-run gasoline and diesel price elasticities, short- and long-run income elasticities, and CO₂ emissions for specific countries and regions of the World Bank, in particular, the highly fossil fuel subsidizing countries that we are focusing on in this paper.

The objectives of this paper are then: i) to estimate the price and income elasticities of demand for gasoline and diesel for the different World Bank regions, but also for other categories of countries according to their fossil-fuel subsidy policies; ii) to assess the breadth of the CO₂ emissions by these groups of countries in the state of Business As Usual (BAU); and iii) to estimate potential demands for fuels (gasoline and diesel) and the corresponding reductions in CO₂ emissions for these countries assuming an increase in fossil fuel prices by 20 US\$ cents per liter.

The paper is organized as follows. Section 2 presents basic data, some stylized facts, and our methodology for determining the different country categories according to their fossil fuel policies. Section 3 presents our estimations of fuel demand relationships for the different categories of countries, including World Bank regions, and for comparison purposes, for the OECD countries. The World Bank regions are MENA, East Asia Pacific (EAP), Latin America and the Caribbean (LAC), Africa (AFR), and Europe and Central Asia (ECA), excluding the OECD countries. In Section 4, we calculate impacts on future fossil fuel (gasoline and diesel) demand and carbon emissions in response to a 20 US\$ cents per liter increase in the prices of gasoline and diesel for our categories of countries. Section 5 concludes.

2. The data, stylized facts, and characterization of the countries

The data set has been gathered by the Environment and Energy Team at the Development Research Group of the World Bank (DECEE), and also contains relevant and important political and economic variables for this study taken from the World Bank Data Depository, IMF, Penn World Tables, Road Federation, World Road Statistics, the U.S. Energy Information Administration (EIA), International Energy Agency (IEA (2015)), and Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ). The data are on an annual basis for the period between 1998 and 2013.

The scatter plots in Figures 1 and 2 show negative sample correlations between fuel prices and fuel consumption for diesel and gasoline, taking into consideration all the client countries of the World Bank.³ Thus, the *higher* the fuel price, the *lower* the demand for diesel and gasoline.

³ The list of countries is presented in the Appendix.

This means that countries that subsidize or under-tax diesel and gasoline are the most likely candidates to reduce fuel demand and CO₂ emissions (as we will show).

Figure 1. World Bank countries excluding OECD

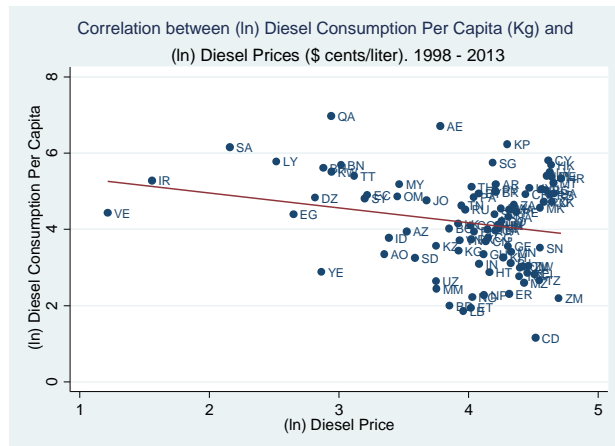
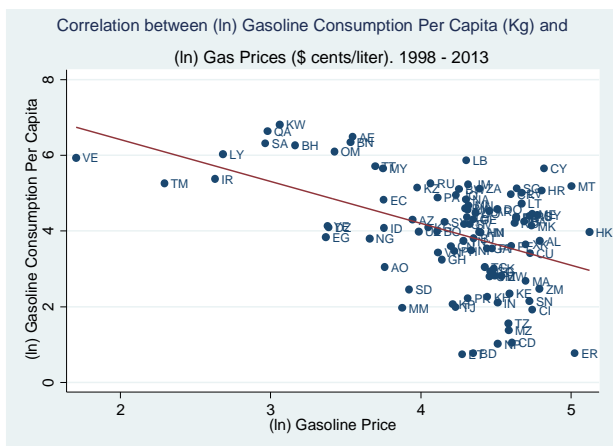


Figure 2. World Bank countries excluding OECD



To characterize the client countries of the World Bank according to their different fossil fuel policies, we use Koplow's (2009) definition of subsidies or "price gap." For fossil fuel importers, Koplow's price gap is equal to the domestic fuel retail price minus the average U.S. retail price, minus 10 US\$ cents per liter (which corresponds to the average U.S. gasoline or diesel tax). For the fossil fuel exporters, the price gap is equal to the domestic fuel retail price minus the average U.S. retail price, but now minus 20 US\$ cents per liter. The price gap is *negative* when fuel is *subsidized*, or *positive* when fuel is *taxed*. As we will show, several countries tax their consumption of fossil fuels, but many subsidize fossil fuels, which means that their domestic fossil fuel prices are too low relative to international prices.⁴

Our focus is to single out these subsidizing countries and to estimate how much their demand for fossil fuels (gasoline and diesel) and CO₂ emissions would decrease by decreasing their fossil fuel subsidies, thereby increasing their domestic fossil fuel prices. Note that we cannot follow Davis and Kilian's (2011) methodology, which consist in testing whether or not the response of

⁴ Our measure of subsidy is somewhat related to the IMF's measure of "pre-tax" subsidy, which is calculated as the transfer to bridge the gap between domestic and supply cost. Coady et al. (2016) argue that since petroleum products are international tradable products, the supply cost is the international price of the product adjusted for transport and distribution costs. The IMF also calculates the post-tax subsidy that includes in addition an estimate of negative externalities from energy consumption, that is the Pigouvian tax. See also Parry and Small (2005) and Clements et al. (2013) for further details. We have not used the IMF's data on taxes because there are no data before 2003.

gasoline or diesel consumption to changes in these fossil fuel prices is different from response to changes in fossil fuel subsidies. There are two important reasons for not being able to do so:

- i) To follow Davis-Killian's (2011) methodology, it is crucial to have observable data on fossil fuel subsidies, but the data on subsidies for developing countries are not available.
- ii) In contrast to U.S. gasoline taxes, which Davis and Kilian (2011) analyze, in most developing countries, which we here analyze, changes in fossil fuel subsidies are not determined by any formal legislation to make them clearly distinguishable from the changes in prices.

Therefore, we cannot easily disentangle the sources of the retail fossil fuel price changes, including subsidies. Instead, we estimate the fossil fuel subsidies, taking into consideration the countries' retail fuel prices and their relation to the international prices as well as whether the country in question is an exporter or importer of oil. As indicated, we thus follow Koplow's methodology.

There are several ways to group and analyze the subsidizing countries. We now explain our methodology in doing so. First, we group the countries by World Bank regions: MENA, ECA, LAC, EAP, SAR, and AFR.⁵ Thus, let us observe two contrasting regions with respect to fossil fuel prices/subsidies.

Figure 3a. Diesel price gap. MENA countries

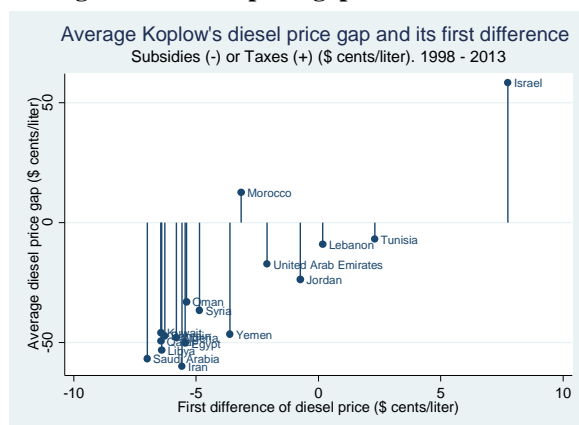
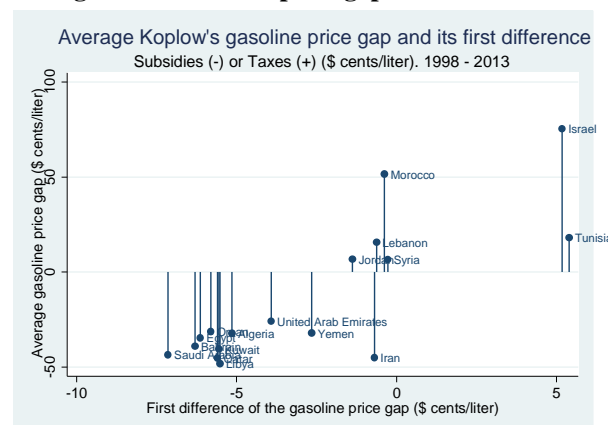


Figure 3b. Gasoline price gap. MENA countries



⁵ The Appendix has the countries in each of the regions we consider in this paper.

Figure 4a. Diesel price gap. ECA Countries

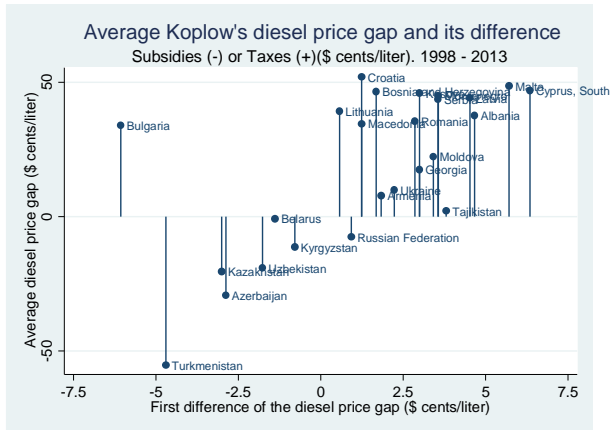
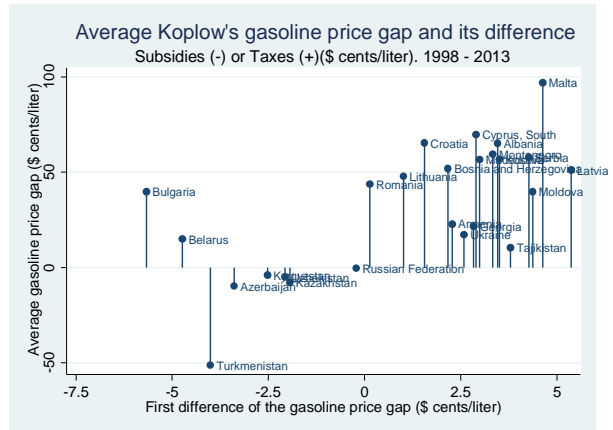


Figure 4b. Gasoline price gap. ECA Countries



Figures 3a and 3b (from Mundaca (2016)) display both the average price gaps (y-axis), and the average first-differences (x-axis) in these price gaps both expressed in US\$ cents/liter for diesel and gasoline, respectively, over the period of 1998 to 2013 for countries in the MENA region. A contrasting fossil fuel pricing policy is shown in Figures 4a and 4b with the corresponding gaps and their first-differences for the countries in the ECA region. It is noticeable that a large number of MENA countries have had much higher negative price gaps, or *higher average levels of subsidies* to diesel and gasoline, than most ECA countries where these fuels are typically taxed. The exceptions in ECA are Azerbaijan, Kyrgyzstan, Kazakhstan, Turkmenistan, and Uzbekistan, especially with respect to diesel. Moreover, between 1998 and 2013, the MENA countries have had higher levels of fuel subsidies, and the subsidy levels have become larger over time. The *average first-differences* of their fuel price gaps have been negative. Thus, most MENA countries have not attempted to seriously improve their fuel pricing situation over these years.

The MENA countries are not the only ones that subsidize fossil fuels. To draw firm conclusions about fuel demand elasticities and CO₂ emissions for fossil-fuel subsidizing countries in the world, we define the following country categories depending on the fossil-fuel pricing policies:

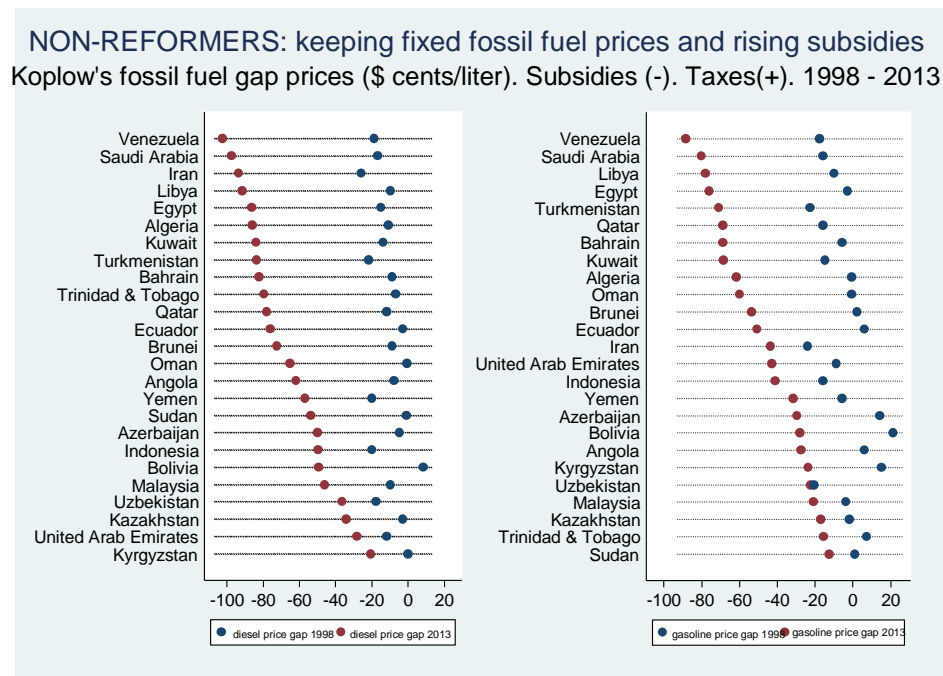
- i) Countries that have kept their fossil fuel prices fixed between 1998 and 2013. We call these countries *NON-REFORMERS*. Since gasoline and diesel prices in the U.S. (which are reference prices to calculate the Koplow's price gap), one can also argue that fuel subsidies must then have been increasing in these countries. Their gasoline and diesel

subsidies rose 142% and 164%, respectively over the period. In most of the cases, these countries' average price gaps were more negative in 2013 than in 1998 (see Figure 5). The list of these countries is also in the Appendix A.

- ii) Countries that have subsidized either diesel or gasoline (i.e., only one negative fossil fuel price gap) over our period of study. The list of these countries, which we call *PARTIAL REFORMERS*, is given in Figure 6 and in the Appendix A. Figure 5 shows that these countries have not only subsidized gasoline or diesel, but some of them have either kept their fossil fuel price gaps unchanged or they have become more negative.

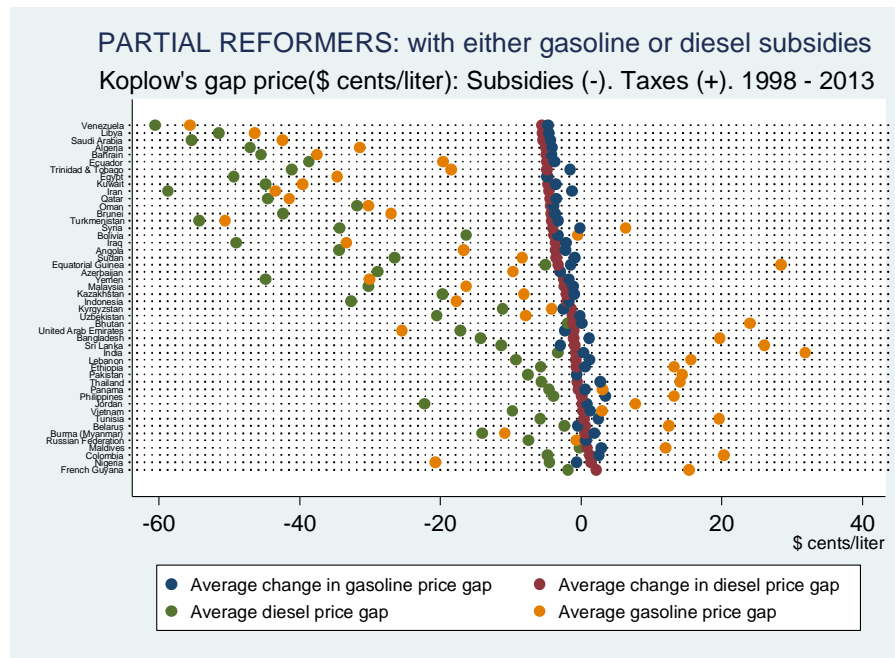
Figures 5 and 6 illustrate that diesel has been subsidized more often than gasoline in these countries. The same can be said in general for all World Bank client countries, as can be seen in Tables A2 and A3 in the Appendix A. This contrasts with the OECD countries, except for Mexico, see Table A1 in the Appendix A.⁶ A factor that could explain this is that public transportation heavily uses diesel; many of these governments might prefer to subsidize diesel to prevent hikes in public

Figure 5. NON-REFORMERS OF FOSSIL FUEL PRICES



⁶ European countries have put fossil fuel taxes into practice even though they have had policies promoting fuel switching away from gasoline toward diesel.

Figure 6. PARTIAL REFORMERS OF FOSSIL FUEL PRICES



transportation prices which would directly harm the poor.

Our next step is to estimate the average price and income elasticities for these groups of countries. We think it is important to determine the degree to which the patterns of fossil fuel consumption as well as price and income elasticities differ among the country groups that are high fossil fuel subsidizers (*NON-REFORMERS*) from those that have implemented some (but limited) degree of fossil-fuel pricing reform (*PARTIAL REFORMERS*), and those that tax fossil fuels (e.g. OECD countries).

Our final goals are thus to answer the following questions: i) how different are the price elasticities for country groups that subsidize their fossil fuels heavily from those that have implemented energy price reforms like the OECD countries? and ii) for given estimates of these elasticities, how much could the demand for fossil fuels and carbon emissions CO₂ be reduced if countries reduce, or even eliminate, their fossil fuel subsidies?

As indicated, the Appendix A presents the list of countries for the different categories according to their fossil fuel price policies and the World Bank regions they belong to, as well as for the OECD with their corresponding GDP per capita in USD and fossil fuel price gaps in prices of 2010.

3. Fossil fuel demand elasticities in the presence of fuel subsidies

3.1 The empirical model

We empirically analyze the demand for fuel i (= gasoline, diesel) in country j at time t for each of the country groups categorized in the previous section: *NON-REFORMERS*, *PARTIAL REFORMERS*, and the OECD excluding Mexico, since Mexico subsidizes heavily fossil fuels. Following previous literature (Archibald and Gillingham (1980), Hausman and Newey (1995), and Basso and Oum (2007)), we estimate the translog model as the baseline model structure:

$$\ln Q_{ijt} = \alpha_i + \beta_{1,i} \ln P_{ijt} + \beta_{2,i} \ln Y_{jt} + \beta_{3,i} \ln Q_{ijt-1} + \tau_t + c_{ij} + \varepsilon_{ijt} \quad (1)$$

In (1), the demand per capita for fossil fuel i (i = diesel and gasoline) in country j at time t , Q_{ijt} , is a function of the price of fuel i (US\$ cents per liter in 2010 USD) in country j at time t , P_{ijt} , and the per capita disposable income in country j at time t , Y_{jt} . For each type of fuel i , we include time and country fixed effects, which are denoted by τ_{it} and c_{ij} , respectively; the error term ε_{ijt} . $\beta_{1,i}$, $\beta_{2,i}$, and $\beta_{3,i}$, are the parameters of the model. $\beta_{1,i}$ and $\beta_{2,i}$ are respectively the short-run elasticities for prices and income. The long-run elasticities of prices and income for each region are represented by $(\beta_{1,i})/(1-\beta_{3,i})$ and $(\beta_{2,i})/(1-\beta_{3,i})$, respectively.

Our structural dynamic model then allows us to measure the cumulative (persistent) effect of prices P onto Q , which consists in summing up the instantaneous effect and all the delayed effects all the way to the infinite future, and is exactly measured by $(\beta_{1,i})/(1-\beta_{3,i})$. Moreover, we here assume, in contrast to Davis and Kilian (2011) who analyze U.S. gasoline taxes, that changes in fossil fuel prices can be expected to have the same effects on fossil fuel demand as changes in fossil fuels subsidies. This is because we study fossil fuel consumption in developing countries, and in most of these countries, changes in fossil fuel subsidies are not determined by any formal legislation that would make them clearly distinguishable from other changes in prices. Consumers in these countries are then most likely not able to distinguish between changes in fuel prices that are due to subsidies, and those that are due to other factors. Therefore, our modelling, and our countries of study permit us to take care of the concern of Davis and Kilian's (2011), about analyzing the persistent effect of fossil fuel price changes, but not to distinguish

the effect of changes in fossil fuel prices due to other factors than changes in fossil fuel prices on fossil fuel consumption.

3.2 Applying the empirical model to World Bank regions

We also estimate the demand for fuel i (i = gasoline, diesel) in country j at time t , for the countries of the different regions of the World Bank: MENA, ECA (excluding the OECD countries), EAP, SAR, AFR, and LAC. We modify the translog model specified above as follows:

$$\ln Q_{ijt} = \alpha_{ij} + \beta_{1,i} \ln P_{ijt} + \beta_{2,i} \ln Y_{jt} + \beta_{1,i,region} \ln P_{ijt} \times region + \beta_{2,i,region} \ln Y_{jt} \times region + \beta_{3,i} \ln Q_{ijt-1} + \tau_t + c_{ij} + \zeta_{ijt} \quad (2)$$

In contrast to equation (1) above, P_{ijt} and Y_{jt} enter now interactively with *region dummies* in order to obtain the elasticities of P_{ijt} and Y_{jt} , per individual region. Thus, “*region*” is a dummy variable for each of the regions: MENA, ECA, EAP, SAR, AFR, and LAC. We use the ECA countries as our reference region because as pointed out above, the great majority of the ECA countries impose fossil fuel taxes (see Figures 4a and 4b). We would like to determine how the countries in the other regions differ from the ECA countries with respect to their fossil fuel price policies. Note that the intercept and the effect of the lagged fossil fuel consumption per capita are not modeled to differ across country-regions in the same way as the slopes do.⁷ $(\beta_{1,i} + \beta_{1,i,region})$ then indicates how the effect of the price of fossil fuel i differs across regions, in which $\beta_{1,i}$ is the effect solely for the ECA countries. Similarly, $(\beta_{2,i} + \beta_{2,i,region})$ indicates how the effect of income per-capita differs across regions, and $\beta_{2,i}$ represents the effect for the ECA countries. The long-run elasticities for prices and income for each *region* are represented by $((\beta_{1,i} + \beta_{1,i,region}))/ (1 - \beta_{3,i})$ and $((\beta_{2,i} + \beta_{2,i,region}))/ (1 - \beta_{3,i,j})$, respectively.

For comparison purposes, we also estimate equation (1) for all World Bank client countries jointly without distinguishing their region, which yields average elasticities for all the countries. The results from the latter specification are presented in Table 3, while the results considering regions separately are shown in Table 4. Note that an attempt to estimate a separate model for

⁷ We could have chosen to have the intercept and $\beta_{3,i,j}$, differing across regions but we trade off fewer degrees of freedom and cumbersome interpretation of the estimates with a “more constrained” model.

each region could result in loss of statistical power; additionally, we would have not an optimal number of observations for each region.

3.3 The empirical methodology

The estimation of our demand equations might result in biased and inconsistent parameter estimates since price and quantity are jointly determined through shifts in both supply and demand. We deal with this econometric problem by instrumenting for price. The ideal instrumental variable for gasoline and diesel demand is one that is highly correlated with the price of gasoline and diesel, but not with unobserved shocks to the demand for gasoline and diesel. Finding good instrumental variables for gasoline and diesel demand is challenging. Given that the prices of gasoline and diesel are highly influenced by the type of governance in each country⁸, gasoline and diesel prices should be correlated with the effectiveness of the regulatory system and the development of the institutions in each country. This implies, theoretically, that indicators of governance might serve as instruments for fuel prices. However, we do not need to be concerned about the exogeneity of such instruments, since it is unlikely that governance will directly influence fossil fuel consumption. We can then safely argue that our governance variables will be uncorrelated with the error terms, ε_{ijt} (in equation (1)) and ζ_{ijt} (in equation (2)). We thus use some of these indicators constructed by Kaufmann et al. (2010)), as instruments. In addition, when we estimate the demand for diesel (gasoline), we also use the gasoline (diesel) price as an instrument. Thus, any effect that gasoline prices could have on diesel consumption, for example, would go through the high correlation between gasoline prices and diesel prices. We also used certain indicators of economic development. For instance, governments might be forced to keep the retail fossil fuel prices low in order to avoid dissatisfaction among the public.

We test the validity of the instruments with the Sargan test when using the System Generalized Method of Moments (GMM) (Arellano-Bover (1995)/Blundell-Bond (1998)) for our panel data as an estimation method. Importantly, the GMM corrects for possible endogeneity and non-stationarity of the regressors or explanatory variables. In particular, diesel and gasoline prices are most likely endogenous, affected by both demand and supply conditions.

⁸ See Strand and Beers (2013)

All our Tables with the estimates report both of the two-step estimates (which yield theoretically robust results, Roodman (2009)). Since we use the two-step estimator, we can obtain a robust Sargan test (same as the robust Hansen J-test). This is crucial for testing the validity of the instruments (or over-identifying restrictions). We test the presence of first- and, in particular, second-order autocorrelation in the error term to shed light on the validity of the model (De Hoyos and Sarafidis (2006)). These statistical diagnostics are also presented together with the estimated parameters. In our empirical models, the Sargan tests of over-identifying restrictions do not reject the null hypothesis (of correct model specification and valid over-identifying restrictions) at any reasonable level of significance, indicating that our econometric strategy has valid instruments. The tests of autocorrelation indicate that we cannot reject the null hypothesis (e.g. the cross-section dependence is homogeneous across pairs of cross-section units after including time dummy variables). Hence, the inclusion of time-dummies in our specification has removed the time-related shocks from the error term in our empirical model.

3.4 Estimation results for country groups by fossil fuel subsidy policies

First, we present the group of countries that kept their fossil fuel prices fixed between 1998 and 2013 (our period of study) and upheld higher fossil fuel subsidies in 2013 than in 1998. This set of countries is shown in Figure 5 and is listed in the Appendix A. These countries have worsened their fossil fuel policies as they have subsidized fossil fuels consistently and increasingly over time. These are our *NON-REFORMERS*. The price and income elasticities for these countries are shown in Table 1.

In this group of countries, both their short- and long-run price elasticities are higher for diesel than for gasoline. Thus, for equal and persistent price hikes for diesel and gasoline, households in this group of countries can, in the short- and long-run, respond by changing their fuel-mix of consumption toward more environmentally friendly fuel, such as gasoline, by hopefully acquiring more efficient vehicles. Of course, the lower the diesel price (i.e. the greater the subsidy), the greater will be the preference for consuming diesel, the more polluting fuel and the desire to keep the more polluting vehicles. These countries' income elasticities are all statistically insignificant but they are still numerically larger for diesel, both in the short run and the long run.

TABLE 1. PRICE ELASTICITIES OF GASOLINE AND DIESEL CONSUMPTION FOR COUNTRIES WITH UNCHANGED FOSSIL FUEL PRICES AND INCREASING SUBSIDIES: NON-REFORMERS
Dependent variable (ln) fuel consumption per capita. 1998 – 2013.^a GMM ESTIMATES.

NON-REFORMERS	DIESEL		GASOLINE	
<i>Explanatory variables</i>	<i>Short-run elasticities</i>	<i>Long-run elasticities</i>	<i>Short-run elasticities</i>	<i>Long-run elasticities</i>
ln(real income_t)	0.2452 (0.1999)		0.0789 (0.0819)	
ln(fuel price_t)	-0.3368*** (0.1380)	-0.9848	-0.1361* (0.0812)	-0.4840
(ln) fuel consumption p.c._(t-1)	0.6580*** (0.2185)		0.7188*** (0.1418)	
Constant	0.1509 (1.3789)		1.2488 (0.3716)	
H₀: No 1st autocorrelation	z = -2.4196 Prob>z = 0.0155		z = -2.4089 Prob>z = 0.0160	
H₀: No 2nd autocorrelation	z = 0.6838 Prob>z = 0.4941		z = 1.6307 Prob>z = 0.11	
H₀: over-identifying restrictions are correct. Sargan Test	chi2(77) = 6.4190 Prob>chi2 = 0.9999		chi2(34) = 5.3596 Prob>chi2 = 0.9999	
# of observations	341		359	

^aStandard errors in parentheses. *** Significant at the 1% level; ** significant at the 5% level; *significant at the 10% level

We can now present the estimates for the price and income elasticities for the group of countries that have upheld negative price gaps for either diesel or gasoline on average. These are the *PARTIAL REFORMERS*, since they have made a price reform for at least one of the two analyzed fossil fuels. The countries' fossil fuel price attributes are shown in Figure 6 above, and the estimation results are displayed in Table 2.

For countries that have subsidized either diesel or gasoline, their short-run price elasticity is both statistically significant and larger for diesel than for gasoline. The long-run price and income elasticities are also remarkably larger for diesel. Thus, higher fossil fuel subsidies (i.e. lower prices) and incomes per-capita lead to a relatively larger increase in consumption for diesel than for gasoline in the long run. Thus, richer households tend to consume more diesel than gasoline. The point here is that when fossil fuel subsidies are high, the consumer will be tempted to minimize costs and not necessarily use the fuel that is most beneficial for society.

**TABLE 2. PRICE ELASTICITIES OF GASOLINE AND DIESEL CONSUMPTION
COUNTRIES SUBSIDIZING EITHER DIESEL OR GASOLINE: PARTIAL REFORMERS**
Dependent variable (ln) fuel consumption per capita. 1998 – 2013.^a GMM ESTIMATES

<i>PARTIAL REFORMERS</i>	<i>DIESEL</i>		<i>GASOLINE</i>	
<i>Explanatory variables</i>	<i>Short-run elasticities</i>	<i>Long-run elasticities</i>	<i>Short-run elasticities</i>	<i>Long-run elasticities</i>
ln(real income_t)	0.0923*** (0.0362)	0.9819	0.1224*** (0.0479)	0.6191
ln(fuel price_t)	-0.1041*** (0.0502)	-1.1074	-0.0337** (0.0158)	-0.1705
(ln) fuel consumption p.c._(t-1)	0.9060*** (0.0430)		0.8023*** (0.0662)	
Constant	0.0261 (0.2317)		0.0673 (0.1361)	
H₀: No 1st autocorrelation	z = -3.488 Prob>z = 0.0005		z = -3.799 Prob>z = 0.0001	
H₀: No 2nd autocorrelation	z = 0.5409 Prob>z = 0.5886		z = 1.0719 Prob>z = 0.2837	
H₀: over-identifying restrictions are correct. Sargan Test	chi2(116) = 21.8017 Prob>chi2 = 0.9999		chi2(64) = 29.644 Prob>chi2 = 0.9999	
# of observations	597		617	

^aStandard errors in parentheses. *** Significant at the 1% level; ** significant at the 5% level;
*significant at the 10% level

Since these countries generally subsidized diesel more than gasoline, our results indicate that there will be much more to gain, in terms of demand reduction, in the short run and long run from increasing the price of diesel (through reducing/eliminating subsidies). In the long run, demand impacts are still much greater for diesel than for gasoline

The most important message from these results is that authorities of these two groups of countries should eliminate their subsidies on diesel and gasoline in order to reduce the demand for these fuels. This is more crucial for diesel and for countries that have not yet made any type of fossil fuel price reform. Demand effects are again even larger and more desirable for the long-run demand for diesel. This will also help them to contribute to the Paris Agreement with respect to CO₂ emission reductions.

One of our objectives for this paper is to determine whether the sizes of the price elasticities depend on the fossil fuel policies and whether countries impose taxes or subsidies. This is important for disentangling which countries might have the largest potential for decreasing their demand for fossil fuels and CO₂ emissions. Having this well-defined objective

will help these countries to set goals and policies to reduce the CO₂ emissions as necessary to meet the Paris agreement (due to enter into force in 2020) and avoid dangerous climate change by limiting global warming below 2°C.

Therefore, for comparison purposes, we present the results of estimating equation (1) for all of the OECD countries today, with the exception of Mexico, which has been imposing fuel taxes rather than subsidies. Our estimates for the OECD countries are presented in Table 3, and OECD countries are listed in the Appendix A.

The average short-term price elasticities for diesel and gasoline for the OECD countries are -0.0159 and -0.0206, respectively. These are very low, but they fall in the range of the EIA's estimates of the price elasticity of motor gasoline in the short term for the US (see also Lin and Prince (2013)). Thus, a 10% rise in diesel and gasoline prices would lead to an average of 0.16% and 0.21% decline in diesel and gasoline consumption, respectively, over the short-run among OECD countries. In the long run, the figures are significantly larger, especially for gasoline. For the same rise in these fuel prices, there could be a 3.52% and 16.89% average reduction for the same countries, respectively.

Note then that, in contrast to the *NON-REFORMER* and *PARTIAL-REFORMER* countries, the short-run impacts of price changes on the demand for diesel and gasoline are smaller in the OECD than for the former countries. However, in the long run the effects of changes to gasoline prices on the demand for this fuel are significantly larger in the OECD countries. This can be explained by the fact that, even though the OECD countries do not subsidize fossil fuels, until quite recently, many European countries have implemented policies promoting fuel switching from gasoline toward diesel fuel. As a consequence, OECD consumers will have good incentives to drastically reduce their gasoline consumption in the long run in response to price hikes.

With respect to diesel, we observe that in both the short run and long run, there is a significantly more elastic diesel fuel price response in the *NON-REFORMER* and *PARTIAL-REFORMER* countries which have high diesel subsidies, as noted, than in OECD countries. Households in countries that maintain fuel subsidies are more willing to switch to diesel and take greater advantage of the higher diesel subsidies when prices decrease and income rises than the OECD consumers. However, if there are equal increases in the prices of gasoline and diesel, it will

become more important for the households in the subsidizing countries to switch to a more efficient fossil fuel. This result contrasts the conclusions of Dahl (2012), who found that lower-price countries have a less elastic price response than higher-priced countries, and lower-income countries have a less elastic price response than higher-income countries. Here, we argue that households in these high-subsidizing countries have gotten used to taking full advantage of the high subsidies for diesel, but scale down their use of inefficient fuels when subsidies are reduced. As long as these governments maintain (or increase) their fossil fuel subsidies, fuel consumption will only rise, especially for diesel.

TABLE 3. PRICE ELASTICITIES OF GASOLINE AND DIESEL CONSUMPTION FOR OECD COUNTRIES (excluding Mexico)

Dependent variable (ln) fuel consumption per capita. 1998 – 2013.^a GMM ESTIMATES.

<i>OECD</i>	<i>DIESEL</i>		<i>GASOLINE</i>	
<i>Explanatory variables</i>	<i>Short-run elasticities</i>	<i>Long-run elasticities</i>	<i>Short-run elasticities</i>	<i>Long-run elasticities</i>
ln(real income_t)	0.0043 (0.0241)		0.0284* (0.0168)	2.3279
ln(fuel price_t)	-0.0159*** (0.0077)	-0.3525	-0.0206*** (0.0009)	-1.6885
(ln) fuel consumption p.c._(t-1)	0.9549*** (0.0296)		0.9878*** (0.0161)	
Constant	-0.3944*** (0.1356)		-0.1771** (0.0966)	
H₀: No 1st autocorrelation	z = -2.6652 Prob>z = 0.0077		z = --3.6319 Prob>z = 0.0003	
H₀: No 2nd autocorrelation	z = -0.5273 Prob>z = 0.598		z = -1.5165 Prob>z = 0.1294	
H₀: over-identifying restrictions are correct. Sargan Test	chi2(77) = 15.1897 Prob>chi2 = 0.9999		chi2(37) = 16.063 Prob>chi2 = 0.9989	
# of observations	495		495	

^aStandard errors in parentheses. *** Significant at the 1% level; ** significant at the 5% level; *significant at the 10% level

3.5 Estimation results for World Bank regions

The results of estimating equation (2), allowing for differences across regions, are presented in Table 5. In addition, for comparison purposes, we estimate equation (1) for all the World Bank countries as a group and without distinguishing the region they belong to. Results of the latter are presented in Table 4. They indicate that for the World Bank countries, the average short-run

price elasticities for both diesel and gasoline are much smaller than for the same categories in the countries we analyzed above.

The estimation results for all World Bank countries in Table 4 also indicate that the short- and long-run price elasticity is larger in absolute terms for diesel than for gasoline. Moreover, both the short- and long-run income elasticities are much larger for diesel than for gasoline as well. This is similar to the pattern for *NON-REFORMERS* and *PARTIAL REFORMERS*, above. That is, the average household in these countries, for given prices of diesel and gasoline, would consume more diesel than gasoline as their incomes increase. This result on income elasticity contradicts the “energy ladder” hypothesis proposed by Heltberg (2004) and highlighted by Dahl (2012), which suggests that as households get richer, they would change their fuel mix away from diesel and toward gasoline. The reason for our result could be that as countries subsidize more diesel than gasoline (see Figures 5 and 6 and Tables A2 and A3 in the Appendix A), households are provided with more incentive to further increase their consumption of diesel relative to gasoline since diesel is made cheaper by the higher subsidies.

Table 5 shows that price and income elasticities differ across country-regions when estimating equation (2). Here, we aim to take into account the important heterogeneities across the country-regions of the World Bank, both with respect to the levels of income per capita and the fossil fuel Koplow’s price gaps. Our reference region is ECA, with its corresponding estimates in row 6: the short-run diesel price elasticity ($\beta_{1,diesel}$) is in column 2; the short-run income elasticity for diesel demand ($\beta_{2,diesel}$) is in column 5; and the same for gasoline ($\beta_{1,gasoline}$) in column 8 and ($\beta_{2,gasoline}$) column 11, respectively. We use the ECA elasticities and the estimates for each of the regions in columns 1 ($\beta_{1,diesel,region}$); 4 ($\beta_{2,diesel,region}$); 7 ($\beta_{1,gasoline,region}$); and 10 ($\beta_{2,gasoline,region}$) to find the *net*⁹ price and income short-run elasticities for each region. The long-run elasticities for diesel and gasoline are shown in columns 3 and 6; and columns 9 and 12, respectively.

⁹ The net is the actual effect of changes in prices on the demand for fossil fuels. Note that columns 1, 4, 7, and 10 indicate the differential effect that changes in fossil fuel prices (and income per capita) have on their respective demands in the different country regions in contrast to the countries of the ECA region.

**TABLE 4. PRICE ELASTICITIES OF GASOLINE AND DIESEL CONSUMPTION
WORLD BANK COUNTRIES**

Dependent variable (ln) fuel consumption per capita. 1998 – 2013.^a GMM ESTIMATES

	DIESEL		GASOLINE	
<i>Explanatory variables</i>	<i>Short-run elasticities</i>	<i>Long-run elasticities</i>	<i>Short-run elasticities</i>	<i>Long-run elasticities</i>
ln(real income_t)	0.1391*** (0.0111)	1.0750	0.0889*** (0.0086)	0.8785
ln(fuel price_t)	-0.0586*** (0.0096)	-0.4529	-0.0251*** (0.0068)	-0.2480
(ln) fuel consumption p.c._(t-1)	0.8706*** (0.0126)		0.8988*** (0.0095)	
Constant	-0.1706*** (0.0655)		-0.1662*** (0.0345)	
H₀: No 1st autocorrelation	z = -4.3221 Prob>z = 0.0001		z = -4.151 Prob>z = 0.0001	
H₀: No 2nd autocorrelation	z = 0.2126 Prob>z = 0.8316		z = -1.3969 Prob>z = 0.1624	
H₀: over-identifying restrictions are correct. Sargan Test	chi2(156) = 85.94 Prob>chi2 = 0.9999		chi2(117) = 88.128 Prob>chi2 = 0.9786	
# of observations	1383		1432	

^aStandard errors in parentheses. *** Significant at the 1% level; ** significant at the 5% level; *significant at the 10% level

For example, our estimations in Table 5 show us that, with respect to the demand for *diesel* and *gasoline*, the long-run price elasticities are often twice or three times the short-run values for each of the World Bank regions. The short-run price elasticities are still numerically significant, except for the ECA region, and many fall within the range of previous studies as documented by Lin and Prince (2009). The short-run income elasticities for the demand for diesel and gasoline were all found to be positive, and numerically and statistically significant. These results indicate that diesel and gasoline must be normal goods. The long-run income elasticities are also 3 times larger or more than the short-run ones for all the regions.

We also find that for an equal increase in the household income in our two contrasting regions, as pointed out above, MENA, with a large number of countries that highly subsidize fossil fuels, and ECA, with much fewer countries that are fossil fuel subsidizers (i.e. Azerbaijan, Kyrgyzstan, Kazakhstan, Turkmenistan, and Uzbekistan), households in the MENA region will have a much larger response (twice as much) in their consumption of diesel and gasoline than households in the ECA region in both the short- and long-run. The former households maximize

their utilities (or minimize their costs) by consuming more of the cheaper but more polluting fossil fuel, diesel, in both the short-run and the long-run, to take advantage of the less expensive fossil fuels. Note that this is the case not only for MENA but also for the other regions that highly subsidize fossil fuels.

On the basis of these results, we can conclude that fuel price reforms in most of the regions of the World Bank, will be highly effective in affecting fuel demands, and that the governments should take advantage of this if they want to reduce fossil fuel demands and CO₂ emissions. From Table A3 (and Figures 3a and 3b for MENA), it is clear that many countries of the MENA, EAP, and SAR regions have significant diesel subsidies, and that they would reduce their fossil fuel consumption drastically if subsidies were eliminated.

These results for the countries in the World Bank regions (except ECA) and the *NON-REFORMER* and *PARTIAL REFORMER* countries indicate a great potential reduction in fossil fuel consumption and CO₂ emissions in these countries if their fossil fuel subsidies are reduced, relative to what can be gained from increased fossil fuel prices in the OECD and ECA countries. Recall that the latter countries' demand response is low for both diesel and gasoline. Higher fossil fuel prices will then lead to large reductions in fossil fuel consumption among countries that are high subsidizers. Implementing fossil fuel price increases or reductions in fossil fuel subsidies may require drastic reforms and planning. Mundaca (2016) finds that, whereas these countries might experience a reduction in GDP in the very short-run (as subsidies are removed), their economies will ultimately adjust and reallocate resources more effectively in response to higher fossil fuel prices. Additionally, with simultaneous enhanced public spending on infrastructure and public services with the freed resources from subsidy reductions, employment and GDP per capita can increase substantially in subsequent years. Finding a mechanism for these fossil fuel price reforms to occur faster may indeed be a key goal of all stakeholders in the near future.

TABLE 5. PRICE ELASTICITIES OF GASOLINE AND DIESEL CONSUMPTION. BY WORLD BANK REGIONS. ECA IS THE REFERENCE REGION
GMM ESTIMATES. Dependent variable: (ln) fuel consumption per capita. 1998 – 2013 ^a

	Elasticity to diesel real price			Elasticity to real income			Elasticity to gasoline real price			Elasticity to real income		
	(1) Estimates	(2) Net SR: $\beta_{1,diesel} +$ $\beta_{1,diesel,region}$	(3) LR	(4) Estimates	(5) Net SR: $\beta_{2,diesel} +$ $\beta_{2,diesel,region}$	(6) LR	(7) Estimates	(8) Net SR: $\beta_{1,gasoline} +$ $\beta_{1,gasoline,region}$	(9) LR	(10) Estimates	(11) Net SR: $\beta_{2,gasoline} +$ $\beta_{2,gasoline,region}$	(12) LR
MENA (1)	-0.3929*** (0.0626)	-0.2551	-0.9104	0.1596*** (0.0246)	0.2761	0.9853	-0.1141*** (0.0389)	-0.0824	-0.6994	0.0575*** (0.0163)	0.0811	0.6884
LAC (2)	-0.1964*** (0.0445)	-0.0586	-0.2091	0.0992*** (0.0240)	0.2157	0.7698	-0.0640** (0.0338)	-0.0323	-0.2742	0.0396** (0.0176)	0.0632	0.5365
AFR (3)	-0.4157*** (0.0663)	-0.2779	-0.9918	0.1852*** (0.0455)	0.3017	1.0767	-0.1921*** (0.0328)	-0.1604	-1.3616	0.1138*** (0.0182)	0.1374	1.1664
EAP (4)	-0.2519*** (0.0726)	-0.1141	-0.4072	0.1362*** (0.0377)	0.2527	0.9018	-0.2206*** (0.0632)	-0.1889	-1.8727	0.1175*** (0.0319)	0.1411	1.1978
SAR (5)	-0.5668*** (0.1874)	-0.429	-1.5310	0.2749*** (0.1056)	0.3914	1.3968	-0.5124*** (0.1222)	-0.4807	-4.0806	0.2758*** (0.0730)	0.2994	2.5416
ECA (6)		$\beta_{1,diesel}$ 0.1378 (0.1417)			$\beta_{2,diesel}$ 0.1165*** (0.0362)	0.4158		$\beta_{1,gasoline}$ 0.0317 (0.0225)			$\beta_{2,gasoline}$ 0.0236*** (0.0101)	0.2003
(ln) fuel consumption pc_(t-1)	0.7198*** (0.0289)						0.8822*** (0.0167)					
Constant	-0.0848 (0.2089)						0.1812* (0.1100)					
H₀: No 1st autocorrelation	z = -4.3805 Prob>z = 0.0001						z = -4.1041 Prob>z = 0.0002					
H₀: No 2nd autocorrelation	z = 0.4269 Prob>z = 0.6695						z = -1.3715 Prob>z = 0.1702					
H₀: correct over-identifying restrictions. Sargan Test	chi2(107) = 59.24 Prob>chi2 = 0.9999						chi2(81) = 75.86 Prob>chi2 = 0.9595					
# of observations	1383						1432					

^aStandard errors in parentheses. *** Significant at the 1% level; ** significant at the 5% level; *significant at the 10% level

4. How will lower fuel subsidies in the highly subsidizing countries reduce fossil fuel consumption and CO₂ emissions? Projections.

In this section, we present a scenario predicting how much CO₂ emissions can be reduced by increasing the gasoline and diesel prices by 20 US\$ cents per liter. Here, we pay special attention to the countries of the MENA region, as well as the group of countries that we categorize as *NON-REFORMERS*, because of the prominent feature of their energy markets. The latter countries subsidize both diesel and gasoline, and have increased their subsidies over the years. In the MENA region, most countries have very high fuel subsidies. Similar scenarios will be presented in the next section for the SAR and EAP regions, given the importance of China and India with respect to their levels of fossil fuel consumption. In the Appendix B we present similar scenarios assuming an increase of 40 US\$ cents per liter in the fossil fuel prices. By comparing the different scenarios, we conclude that as price increases become larger, the reduction in CO₂ emissions (and fossil fuel demands) will be larger but less than proportional to the price changes.

These assessments are worthwhile to pursue since we know from the analysis in the previous section that the long-run elasticities are statistically highly significant and large in size both for diesel and gasoline, and especially for countries that are high fossil fuel subsidizers. As mentioned, these estimates have important implications for fuel taxation policy and reforms: the higher the elasticities, the larger the likelihood that the policies will be effective and have greater effects. As Figures 3a, 3b, 5 and 6 above indicate, the fuel subsidies are not only very high in many countries but also have been increasing over time.

We use our estimated elasticities to calculate the equilibrium consumption for diesel and gasoline as well as the potential reductions in these fossil fuel consumptions and CO₂ emissions for each country of our defined categories, under the scenario of an increase of US\$ 20 cents per liter in fuel prices. For these calculations, we need to assume the same long-run fossil fuel price elasticity across the countries within each of our different categories. Consider then that the consumption of fuel *i* (*i*=gasoline, diesel) in country *j* at time *t*, Q_{ijt} , is influenced by its domestic per capita income Y_{jt} , and its domestic fuel price at time *t*, P_{ijt} , and the long-run price elasticities $(\beta_1)/(1-\beta_3)$. (A similar approach has been followed by Sterner (2007)).

By considering a one-time rise of 20 US\$ cents/liter in the fossil fuel prices in these countries that will prevail for a sufficiently long time, we can estimate the hypothetical annual demand for each of the considered fuels for the next 16 years.¹⁰ We denote this estimated *hypothetical* demand as HQ_{ijt} for fuel i in country j at time t , and will be obtained from the following relationship, following Sterner (2007) and others:

$$HQ_{ijt} = Q_{ijt} \left(\frac{P_{ijt} + 20}{P_{ijt}} \right)^{\beta_{1,j} / (1 - \beta_{3,j,j})} \quad (3)$$

We present our projections for the NON-REFORMER and MENA countries, respectively in Figures 7a-b and 8a-b. These figures illustrate both the *total actual* (from 1998 to 2013) and *hypothetical* (projected) CO₂ emissions for the next 16 years. They show the considerable impact of subsidy reforms (i.e. an increase of 20 US\$ cents per liter in the diesel and gasoline price) on CO₂ from the resulting reductions in fossil fuel consumption. The explanation for these large effects is that these countries heavily subsidize fossil fuels, and their price elasticities are relatively large, at least in comparison to OECD countries with no fossil fuel subsidies.

Thus, the reductions in CO₂ emissions can be very significant from this simple change in energy policy, and its implementation should not require complicated international agreements. However, these countries would need to implement social safety programs, financed with the subsidy savings, to protect the poor and those affected by the increases in fossil fuel prices.

Figure 7a. CO₂ from diesel. NON-REFORMERS

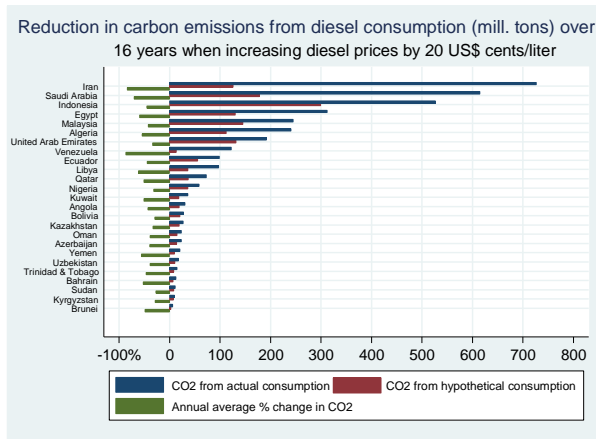
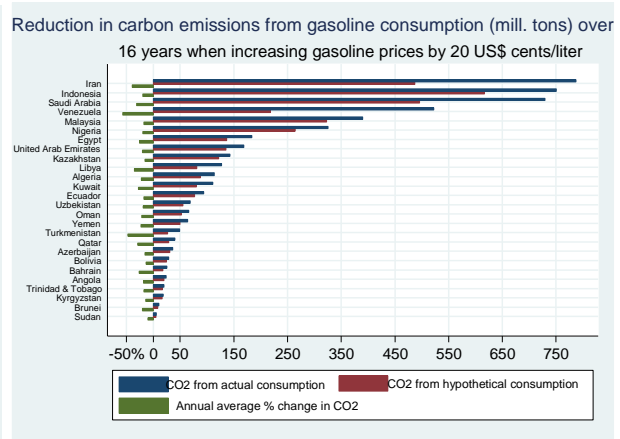


Figure 7b. CO₂ from gasoline. NON-REFORMERS



¹⁰ Our empirical study uses 16 years of data, from 1998 to 2013.

According to the EIA (2014) the MENA region's total CO₂ emissions have increased by approximately 200% from 1990 to 2013, and an average of 40% of these emissions come from the consumption of all petroleum products. There are, however, possibilities for potential reductions in CO₂ emissions as demonstrated by our estimates for the NON-REFORMERS and MENA (see Figures 7a-b and 8a-b).

Figure 8a. CO₂ from diesel. MENA

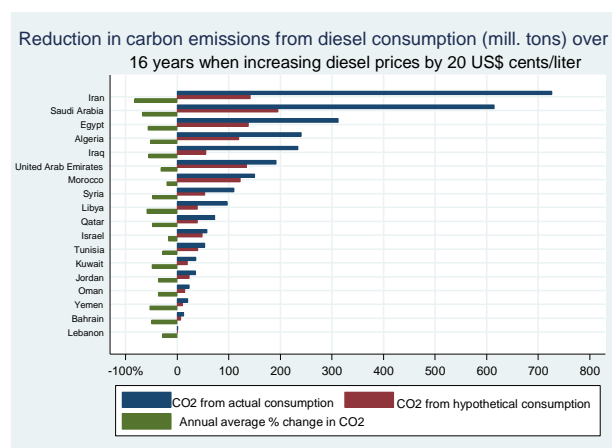
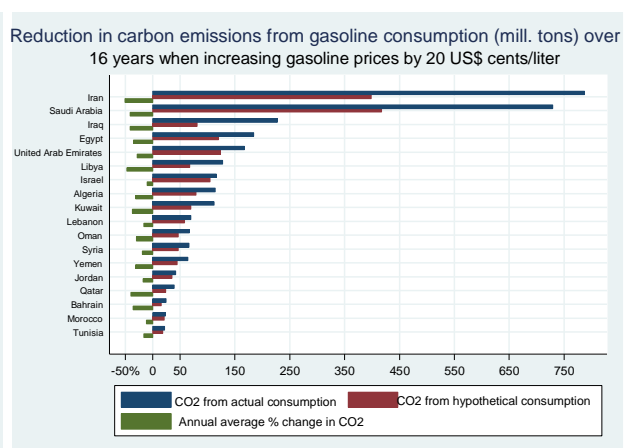


Figure 8b. CO₂ from gasoline. MENA



It should be pointed out that our estimates on fossil fuel consumption, not shown here due to space limitations, indicate that the average annual diesel consumption could be reduced by 90% and 70% for Iran and Saudi Arabia, respectively, with an increase of 20 US\$ cents/liter. Such annual reduction in consumption would permit Iran to decrease its consumption of diesel by about 170 million tons in the next 16 years, and Saudi Arabia by about 130 million tons. On the other hand, the reduction in gasoline consumption over 16 years would be 140 million tons for Iran and 100 million tons for Saudi Arabia for average annual reductions of 50% and 40% in consumption in the respective countries.

These results are important in view of the recent Conference of Parties (COP21) in Paris in December 2015. While commitments are still being discussed and negotiated, there is no reason for policy makers to disregard the implications of eliminating energy subsidies, something which is also beneficial in other respects for the subsidizing countries. It will be meaningful to extend

mitigation obligations to all countries, both developed and developing, and with a particular obligation for those countries which today substantially subsidize energy.

5. Estimation of impacts on CO₂ emissions for the OECD, EAP, and SAR countries. Projections.

The IEA (2014) reports that China, United States, India, Russia, Japan, Germany, Korea, Canada, Iran, and Saudi Arabia together emit two-thirds of global CO₂ emissions. We shall therefore extend our suggested scenario of increasing 20 US\$ cents per liter in the diesel and gasoline prices in order to reduce future CO₂ emissions to the EAP region (which includes China and Korea); the SAP region (which includes India); and the OECD countries (excluding Mexico). Recall that the estimations of the demand for fossil fuels for the OECD countries are presented in Table 3.

Here, we argue that for the EAP, SAR, and OECD countries, this increase of 20 US\$ cents per liter of diesel and gasoline should be interpreted as a “post-tax” or environmental tax, as defined in the IMF, to take into consideration the negative externalities from energy consumption, and which are not properly charged for by these regions today. See Perry and Small (2005), Clements et al. (2013) and Parry et al. (2014) for further details.

From our estimates, we found that, although no figures are presented due to space constraints, the largest gains could be obtained from increasing the price of gasoline by 20 US\$ cents per liter and especially in countries like China and Japan. Each of these two countries, for example, could reduce its gasoline consumption to less than 500 million tons of gasoline over the next 16 years in response to a hike in the price of gasoline. In this EAP region, the effects of increasing diesel prices would have a more modest effect on consumption. We should therefore expect bigger reductions in CO₂ from price increases for gasoline prices than for diesel.

As before, we use equation (3) to estimate the equilibrium diesel and gasoline consumptions and CO₂ emissions for the countries in the EAP and SAR regions, assuming an increase of 20 US\$ cents per liter in fossil fuel prices. The estimates for the EAP region are shown in Figures 9a and 9b. China is the largest emitter of CO₂ in this region, ahead of Japan; these two together emit more than 60% of all regional emissions. Here, the relative reductions for the next 16 years will be smaller than for the MENA region, as fossil fuels are here not subsidized as much as in the MENA region. Still, considering an increase of a mere 20 US\$ cents per liter of fossil fuels

as an environmental tax can have a substantial impact on CO₂ emissions, with a total reduction in the next 16 years from 10% to almost 70%, depending on the type of fossil fuel and country.

Figure 9a. CO₂ from diesel. EAP

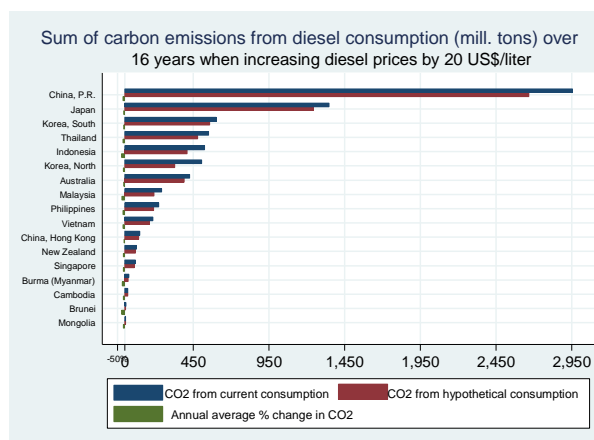


Figure 9b. CO₂ from gasoline. EAP

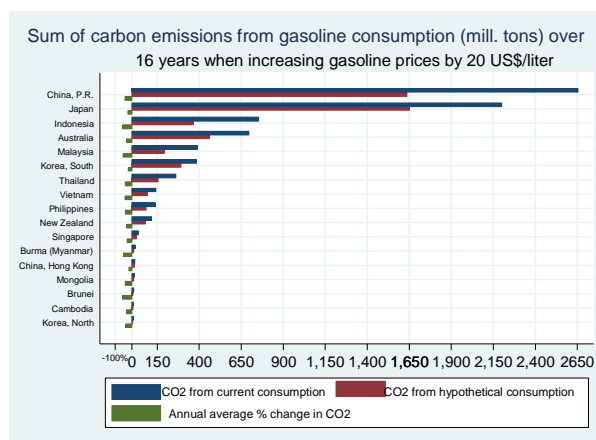


Figure 10a. CO₂ from diesel. SAR

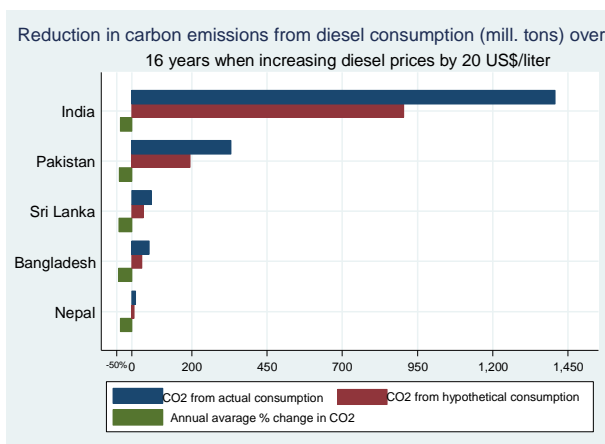
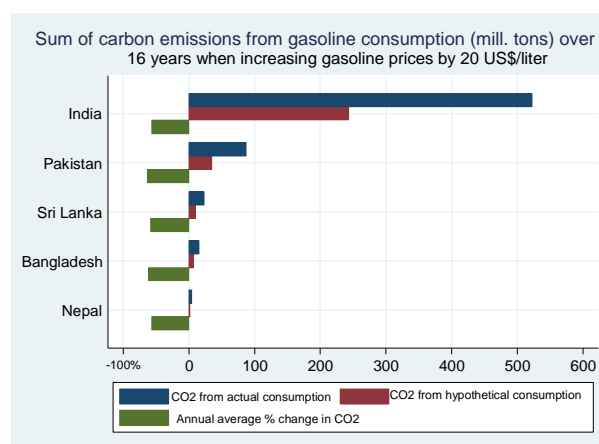


Figure 10b. CO₂ from gasoline. SAR



Figures 10a and 10b show that countries in the SAR region could also contribute to the avoidance of climate change disasters by reducing their CO₂ emissions in response to an increase in fuel prices of 20 US\$ cents per liter. This is especially noteworthy for India, since it is the largest consumer of fossil fuels in its region, and one of the largest in the world, as pointed out above.

The United States is the OECD's largest emitter of CO₂. An increase in the prices of gasoline and diesel by a meager 20 US\$ cents per liter of diesel and gasoline can lead, according to our estimates to reductions of CO₂ emissions for the next 16 years of about 10% and 35%, respectively. The estimates for the other OECD countries are not modest either, especially for

gasoline, and note that we only suggest an increase of 20 US\$ cents per liter. This should be taken into account when implementing the climate agreements in Paris 2015. See Table 6.

Table 6. OECD (excluding Mexico): Reductions in CO₂ emissions from increasing diesel and gasoline prices by 20 US\$ cents per liter.

Country <i>from</i>	CO ₂ reduction diesel	CO ₂ reduction gasoline	Country <i>from</i>	CO ₂ reduction diesel	CO ₂ reduction gasoline	Country <i>from</i>	CO ₂ reduction diesel	CO ₂ reduction gasoline
Australia	-7.60	-31.11	Greece	-6.43	-24.19	Norway	-4.39	-17.74
Austria	-5.74	-22.35	Hungary	-5.65	-23.10	Poland	-6.50	-24.68
Belgium	-5.52	-19.60	Iceland	-6.90	-20.23	Portugal	-6.17	-20.87
Canada	-8.87	-32.74	Ireland	-5.33	-22.07	Slovakia	-13.72	-37.70
Chile	-9.39	-29.17	Israel	-6.78	-21.70	Slovenia	-6.16	-25.36
Czech Republic	-5.99	-23.78	Italy	-5.06	-19.42	Spain	-6.17	-23.93
Denmark	-5.12	-19.43	Japan	-6.5	-22.74	Sweden	-5.07	-20.12
Estonia	-7.27	-28.65	Korea, South	-6.89	-21.44	Switzerland	-5.08	-22.98
Finland	-5.49	-19.11	Luxembourg	-6.47	-23.83	Turkey	-5.75	-19.34
France	-5.53	-20.03	Netherlands	-5.44	-18.54	United Kingdom	-4.21	-19.05
Germany	-5.42	-20.06	New Zealand	-10.28	-29.27	United States	-10.25	-39.71

We observe that for the OECD countries, it is also crucial to motivate higher fossil fuel prices as a way to implement optimal environmental taxes, if these countries want to contribute significantly to global reductions in CO₂ emissions. In addition, as Schipper (2011) argues, it is also important to bring into play new technology that reduces the fuel required for cars with given horsepower and weight. It may, in addition, be necessary to downsize both the average power and weight of new cars. Schipper (2011) further suggests that “... as long as the numbers of cars and the distances cars are driven keep creeping up, technology alone will have a difficult time offsetting all of these trends to lower fuel use and CO₂ emissions ...”. Higher fuel taxes will also help to keep driven distances in check.

6. Conclusion and Policy Implications

In this paper we have focused principally on: i) determining whether countries’ fossil fuel price policies, especially subsidies, influence the price and income elasticities of demand for gasoline and diesel; and ii) assessing the impacts of fossil fuel price increases (i.e. reduction of fossil fuel subsidies) on the fossil fuel demand and CO₂ emissions. We have considered different groups of

countries depending in particular on the degree to which they today subsidize fossil fuels, including an analysis of the World Bank regions, which vary with respect to their level of subsidies and consumption of fossil fuels. In contrast to previous literature, we present evidence on how price and income elasticities can differ by the types of fossil fuel price policies followed by the different countries.

We find that the long-run price elasticity for *diesel* and *gasoline* are at least three times the short-run values for countries in almost all the regions of the World Bank, and among the countries that have particularly high fossil fuel subsidies. Nonetheless, we find that the short-run price elasticities are not negligible, especially when high fossil fuel subsidies are present. Consequently, fossil fuel reforms are likely to have substantial effects also in the short-run. On the basis of these results, we can conclude that fuel price reforms will be highly effective in reducing the demand for fossil fuels. This is especially noticeable for the countries of the MENA region, which predominantly subsidize fossil fuel consumption, but also for other developing and emerging countries that currently have high subsidies to fossil fuels.

We also find that in countries that have made little attempt to implement fossil fuel price reforms and even increased their level of subsidies over time, and that are not necessarily poor, short- and long-run income elasticities for diesel demand are significantly larger than those for gasoline demand. We argue that households in these countries have probably become used to taking full advantage of the high subsidies to diesel, scaling up their use of inexpensive (but polluting) fuels not only when the subsidies are high (i.e. low fossil fuel prices) but also when their income rises. As long as governments keep maintaining or even increasing fossil fuel subsidies, the consumption of fossil fuels will only rise, especially for diesel.

This study has also aimed to show that it is possible to achieve important reductions in fuel consumption and consequently CO₂ emissions by reducing fuel subsidies, and thus increasing domestic fuel prices. Such fuel policy reforms can be a significant instrument of climate policy. This is especially crucial for countries with high energy subsidies. Assuming a scenario with an increase in the price of diesel and gasoline by 20 US\$ cents per liter, the reductions in the consumption and CO₂ emissions can be from 90% to 10%, depending on the country and type of fuel. Iran and Saudi Arabia are the countries that seem to be able to achieve the largest

reductions in their CO₂ emissions. Currently, these two countries are some of largest emitters of CO₂ in the world. These estimates are not in contradiction with Coady et al. (2015), who find that the MENA region as a whole could reduce CO₂ by 36%.

This is an important issue, and it is now time to think seriously and constructively about how to implement energy reforms in the countries that still maintain fossil fuel subsidies, and encourage these countries to use any resulting fiscal savings for increased public investments in health, education, and infrastructure, so as to also attain higher economic growth (Mundaca (2016) has demonstrated such effects). This is crucial for these countries, which are currently experiencing low growth rates and many other economic difficulties.

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APPENDIX A

**Table A1. Categories of countries according to their fossil fuel policies and OECD countries
GDP per capita in 2010 USD (GDPpc); diesel price gap (dpg); gasoline price gap (gpg)**

NON-REFORMERS ¹¹		PARTIAL REFORMERS		OECD COUNTRIES			
Countries	GDP pc	Countries	GDPpc	Countries	GDPpc	dpg	gpg
Algeria	2884.06	Algeria	2884.06	Austria	37086.63	57.93903	72.15508
Angola	1884.57	Angola	1884.57	Belgium	35448.77	63.60804	97.1729
Azerbaijan	1884.38	Azerbaijan	1884.38	Canada	35134.44	13.16212	23.03971
Bahrain	17739.15	Bahrain	17739.15	Chile	7627.37	10.8682	37.67261
Bolivia	1176.97	Bangladesh	438.25	Czech R.	12473.04	60.17469	68.19897
Brunei	25706.64	Belarus	3256.13	Denmark	46364.22	73.6115	96.76361
Ecuador	3003.24	Bhutan	1358.04	Estonia	9566.57	42.59202	46.10697
Egypt	1305.95	Bolivia	1059.20	Finland	36330.96	64.86805	98.07367
Indonesia	1315.82	Brunei	25706.64	France	33359.77	64.85189	89.47023
Iran	2741.77	Colombia	3507.04	Germany	34341.12	68.85469	93.95854
Kazakhstan	3671.41	Ecuador	3003.24	Greece	20422.83	56.19235	69.05125
Kuwait	31214.7	Egypt	1305.95	Hungary	10245.78	60.80875	68.50954
Kyrgyzstan	490.40	Equatorial Guinea	11594.42	Iceland	51432.32	59.89927	86.46349
Libya	7322.93	Ethiopia	176.50	Ireland	45045.75	68.40001	78.19753
Malaysia	5545.86	India	779.15	Israel	20040.86	58.88059	75.46184
Nigeria	774.37	Indonesia	1315.82	Italy	30149.1	75.40625	97.02896
Oman	13034.22	Iran	2741.77	S. Korea	18582.99	42.72231	77.79839
Qatar	55909.04	Iraq	2172.66	Luxembourg	77429.05	45.41235	65.13044
Saudi Arabia	14001.1	Jordan	2359.11	Mexico	7850.985	-8.301922	5.04152
Sudan	785.7	Kazakhstan	3671.41	Netherlands	39227.95	66.53639	108.6918
Trinidad & Tobago	11931.39	Kuwait	31214.7	Norway	63760.15	95.06081	114.4228
Turkmenistan	2632.42	Kyrgyzstan	490.40	Poland	8269.51	49.10907	63.10406
United Arab Emirates	37732.1	Lebanon	5890.33	Portugal	18144.95	55.26308	90.1039
Uzbekistan	584.33	Libya	7322.93	Slovakia	11734.91	35.52267	42.59316
Venezuela	5625.45	Malaysia	5545.86	Slovenia	17426.89	54.64188	59.97233
Yemen	802.60	Maldives	4663.38	Spain	25040.53	49.13726	62.02941
		Mexico	7850.98	Sweden	39967.59	76.3762	89.65864
		Nigeria	774.37	Switzerland	52132.07	73.54592	69.22089
		Oman	13034.22	Turkey	6979.04	76.32581	15.4775
		Pakistan	677.68	U.K.	36692.45	99.29644	97.24088
		Panama	5029.14	U.S.A. ¹²	42892.43		
		Philippines	1220.03				
		Qatar	55909.04				
		Russian Federation	5250.44				
		Saudi Arabia	14001.1				
		Sri Lanka	1308.74				
		Sudan	686.61				
		Syria	1499.32				
		Thailand	2674.06				
		Trinidad & Tobago	11931.39				
		Tunisia	3262.94				
		Turkmenistan	1939.50				
		United Arab Emirates	37732.1				
		Uzbekistan	584.33				
		Venezuela	5625.45				
		Vietnam	711.92				
		Yemen	802.60				

¹¹ Diesel and gasoline price gaps for the Non-Reformers of Type A and B are presented in Tables A2 and A3 below.

¹² We do not display the diesel or gasoline price gaps for the U.S.A. because the Koplow's gap price, which we use here, uses the fossil fuels of the U.S.A. as reference.

Table A2. List of countries by World Bank Region
GDP per capita in 2010 USD (GDPpc); diesel price gap (dpg); gasoline price gap (pgg)

AFRICA (AFR)				EAST ASIAN PACIFIC (EAP)				EASTERN AND CENTRAL EUROPE (ECA)			
Country	GDPpc	dpg	pgg	Country	GDPpc	pgd	pgg	Country	GDPpc	pgd	pgg
Angola	1884.57	-34.62	-16.94	Brunei	25706.64	-44.46	-27.23	Albania	2870.58	38.58	66.00
Benin	535.39	16.10	0.26	Cambodia	471.64	11.02	27.14	Armenia	1565.52	7.94	23.08
Botswana	5460.94	10.19	13.16	Hong Kong	26492.14	41.77	109.93	Azerbaijan	1884.38	-29.05	-8.61
Burkina Faso	402.96	35.24	53.18	China, P.R.	1925.91	1.57	9.10	Belarus	3256.13	-0.76	15.69
Burundi	150.17	48.51	56.32	Fiji	3501.68	19.92	38.08	Bosnia and Herzegovina			
Cameroon	908.17	23.22	28.21	Indonesia	1315.82	-32.64	-15.69		2812.52	47.04	52.52
Cape Verde	2114.00	36.11	91.76	Korea, S.	18582.99	42.72	77.79	Bulgaria	3680.18	41.07	46.85
Central African R.	375.67	62.66	73.99	Lao PDR	494.39	1.66	18.49	Croatia	9678.3	53.38	66.57
Chad	560.66	37.39	47.78	Malaysia	5545.86	-30.82	-17.58	Cyprus	22138.17	47.41	70.35
Congo (Brazzaville)	1716.79	2.55	28.48	Mongolia	1050.87	16.95	19.14	Georgia	1478.36	17.55	21.70
Congo, D. R.	231.32	28.75	41.20	Philippines	1220.03	-3.47	11.13	Kazakhstan	3671.41	-20.30	-5.72
Eritrea	223.99	14.77	102.09	Singapore	29185.74	4.91	44.71	Kosovo	2293.01	46.07	56.76
Ethiopia	176.50	-5.36	13.98	Thailand	2674.06	-7.28	18.00	Latvia	6629.77	44.28	51.11
Gabon	6454.38	5.48	26.64	Vietnam	711.92	-10.52	3.01	Liechtenstein	106731.2	70.97	66.35
Gambia	437.39	28.50	36.61					Lithuania	7556.04	42.30	51.34
Ghana	528.48	.97	6.52					Macedonia	2959.18	35.51	57.70
Guinea	300.43	24.71	32.20					Malta	15126.24	48.78	97.11
Ivory Coast	968.28	31.58	58.37					Montenegro	3873.11	45.43	59.54
Kenya	535.48	25.17	40.74					Romania	4658.58	38.93	47.42
Lesotho	739.95	17.25	19.85					Russian F.	5250.44	-7.39	0.31
Madagascar	277.66	27.85	52.76					Serbia	3294.75	44.59	58.06
Malawi	227.46	56.87	67.51					Tajikistan	333.69	2.32	11.49
Mali	443.33	29.09	52.14					Turkmenistan	1939.50	-55.34	-51.12
Mauritania	716.55	11.08	34.64					Ukraine	1716.53	10.12	17.53
Mozambique	313.08	23.98	42.69					Uzbekistan	584.33	-18.17	-2.86
Namibia	3588.09	14.09	16.18								
Niger	267.38	26.84	38.19								
Nigeria	774.37	-3.47	-20.55								
Rwanda	281.35	52.52	56.92								
Senegal	751.88	36.33	56.49								
Sierra Leone	325.40	22.56	25.41								
South Africa	5203.75	17.34	23.96								
Sudan	686.61	-27.24	-8.32								
Swaziland	2318.77	22.49	23.87								
Tanzania	377.63	33.31	39.90								
Togo	396.64	21.59	26.81								
Uganda	327.73	37.72	56.36								
Zambia	645.58	56.76	71.22								
Zimbabwe	512.35	27.79	45.20								

Table A3. List of countries by World Bank Region
GDP per capita in 2010 USD (GDPpc); diesel price gap (dpg); gasoline price gap (pgg)

LATIN AMERICA AND CARIBBEAN (LAC)				MIDDLE EAST AND NORTH AFRICA (MENA)				SOUTH ASIA (SAR)			
Country	GDPpc	dpg	pgg	Country	GDPpc	pgd	pgg	Country	GDPpc	pgd	pgg
Argentina	5428.47	5.32	22.94	Algeria	2884.06	-48.04	-32.00	Bangladesh	438.25	-15.10	19.93
Barbados	14118.62	24.08	44.03	Bahrain	17739.15	-47.67	-38.79	Bhutan	1358.00	-7.76	23.96
Bolivia	1059.20	-17.71	-0.62	Egypt	1305.95	-50.39	-32.35	India	779.15	-2.28	33.55
Brazil	4893.55	7.35	4.46	Iran	2741.77	-59.95	-46.92	Nepal	329.76	0.85	34.47
Chile	7627.37	10.86	37.67	Israel	20040.86	58.88	75.46	Pakistan	677.68	-4.90	16.22
Colombia	3507.04	-5.44	0.22	Jordan	2359.11	-22.01	10.50	Sri Lanka	1308.74	-11.52	29.95
Costa Rica	4749.45	14.48	33.12	Kuwait	1214.7	-45.85	-40.39				
Cuba	3811.82	22.24	58.1	Lebanon	5890.33	-8.89	15.26				
Dominican Republic				Libya	322.93	-53.10	-48.24				
	3899.29	10.98	33.83	Morocco	1995.46	13.11	51.78				
Ecuador	3003.24	-39.61	-18.73	Oman	13034.22	-33.02	-31.25				
El Salvador	2788.76	6.27	16.05	Qatar	55909.04	-49.31	-44.69				
Grenada	6084.12	16.87	28.26	Saudi Arabia							
Guatemala	2183.71	2.03	14.46		14001.1	-56.71	-42.98				
Guyana	1119.88	0.58	11.91	Syria	1499.32	-39.09	4.62				
Haiti	467.54	-1.43	27.88	Tunisia	3262.94	-9.82	14.41				
Honduras	1392.46	7.47	22.57	United Arab Emirates							
Jamaica	4189.65	9.33	16.05		37732.1	-18.13	-25.91				
Mexico	7850.98	-8.30	5.04	Yemen	802.60	-45.99	-31.53				
Nicaragua	1156.63	7.10	17.27								
Panama	5029.14	-4.95	0.63								
Paraguay	1560.93	7.53	29.65								
Peru	2856.47	18.51	41.76								
Suriname	3584.83	17.63	27.81								
Trinidad & Tobago											
	11931.39	-39.88	-9.97								
Uruguay	5692.98	29.96	60.44								
Venezuela	5625.45	-62.32	-57.28								

APPENDIX B

Projections of reductions in CO₂ emissions as a result of increasing diesel and gasoline prices by 40 US\$ cents per liter.

Figure B1: NON-REFORMERS. CO₂ emissions from diesel and gasoline

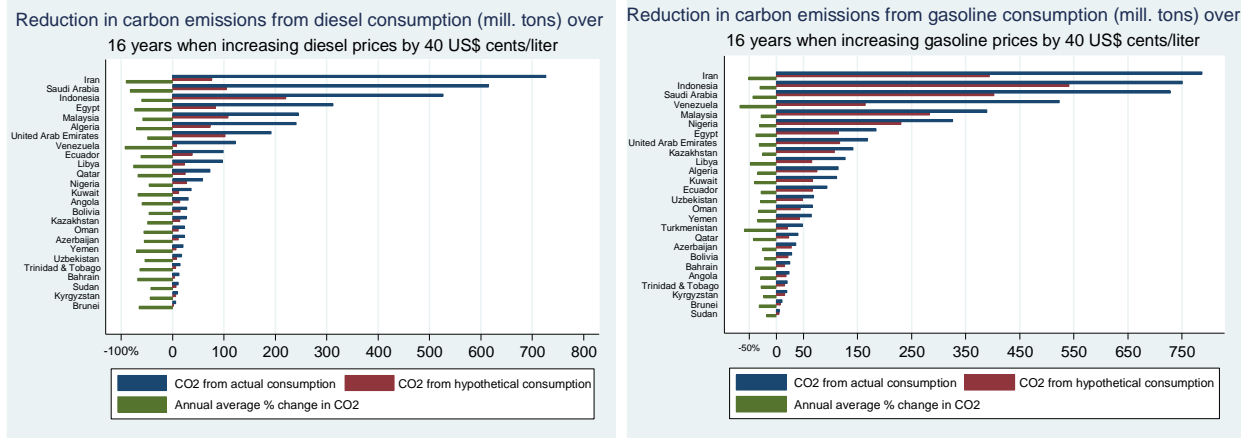


Figure B2: MENA countries. CO₂ emissions from diesel and gasoline

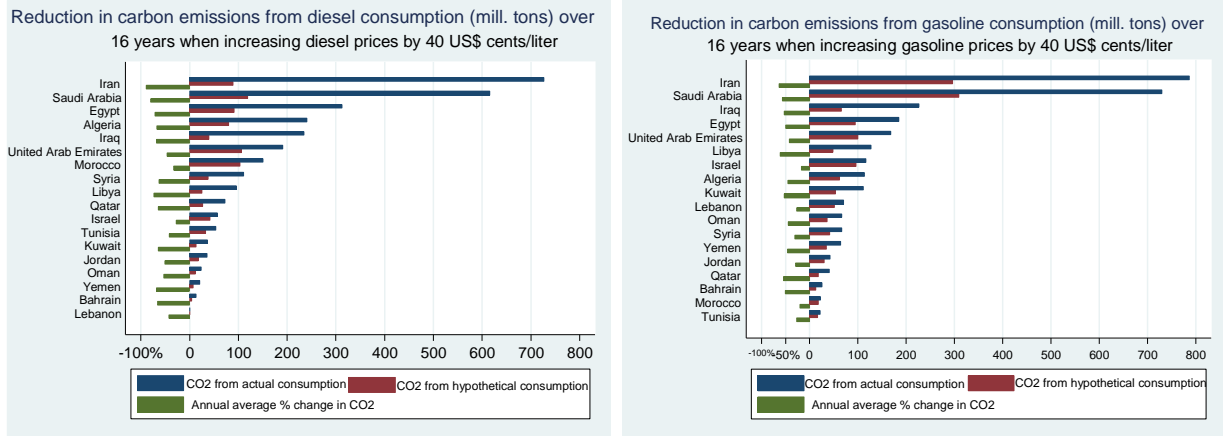


Figure B3: EAP countries. CO₂ emissions from diesel and gasoline

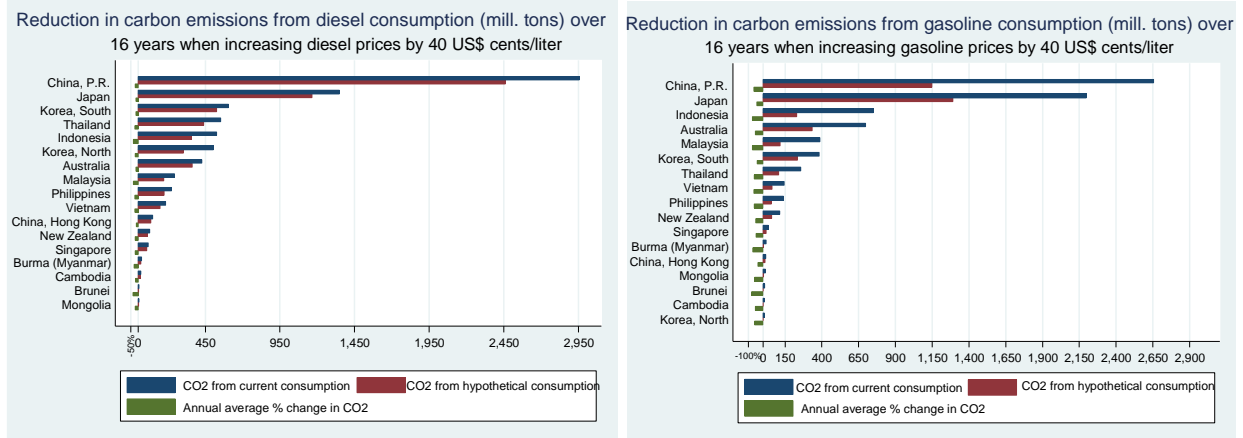


Figure B4: SAR countries. CO₂ emissions from diesel and gasoline

