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INTO THE MIRE: A CLOSER LOOK AT FOSSIL FUEL SUBSIDIES*†

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SUMMARY

Threatened by climate change, governments the world over are attempting to nudge markets in the direction of less carbon-intensive energy. Perversely, many of these governments continue to subsidize fossil fuels, distorting markets and raising emissions. Determining how much money is involved is difficult, as neither the providers nor the recipients of those subsidies want to own up to them.

This paper builds on a unique method to extract fossil fuel subsidies from patterns in countries' carbon emission-to-GDP ratios. This approach is useful since it: 1) overcomes the problem of scarce data; 2) derives a wider and more comparable measure of subsidies than existing measures and 3) allows for the performance of counterfactuals which help measure the impact of subsidies on emissions and growth.

The resultant 170-country, 30-year database finds that the financial and the environmental costs of such subsidies are enormous, especially in China and the U.S.

The overwhelming majority of the world's fossil fuel subsidies stem from China, the U.S. and the ex-USSR; as of 2010, this figure was $712 billion or nearly 80 per cent of the total world value of subsidies.

For its part, Canada has been subsidizing rather than taxing fossil fuels since 1998. By 2010, Canadian subsidies sat at $13 billion, or 1.4 per cent of GDP.

In that same year, the total global direct and indirect financial costs of all such subsidies amounted to $1.82 trillion, or 3.8 per cent of global GDP.

Aside from the money saved, in 2010 a world without subsidies would have had carbon emissions 36 per cent lower than they actually were.

Any government looking to ease strained budgets and make a significant (and cheap) contribution to the fight against climate change must consider slashing fossil fuel subsidies. As the data show, this is a sound decision – fiscally and environmentally.

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DANS LE BOURBIER : UN EXAMEN PLUS APPROFONDI DES SUBVENTIONS POUR LES COMBUSTIBLES FOSSILES*†

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SOMMAIRE

Aiguillonnés par la menace du changement climatique, les gouvernements du monde entier tentent d'orienter les marchés dans la direction d'énergies à intensité carbonique réduite. Ironiquement, beaucoup de ces gouvernements continuent à subventionner les combustibles fossiles, faussant les marchés et provoquant l'augmentation des émissions. Il est difficile de déterminer les sommes d'argent en cause, personne ne souhaitant avouer être le fournisseur ou le bénéficiaire de ces subventions.

Le présent article est basé sur une méthode exclusive permettant d'extraire les subventions aux combustibles fossiles des tendances notées dans les ratios des émissions de carbone au PIB. Cette méthode est utile du fait qu'elle : 1) permet de surmonter le problème de la rareté des données; 2) assure une mesure plus large et plus comparable des subventions que les mesures actuelles; 3) permet l'exécution d'analyses hypothétiques qui aident à mesurer l'incidence des subventions sur les émissions et la croissance.

La base de données obtenue de 170 pays sur 30 ans permet de constater que les coûts financiers et environnementaux de telles subventions sont énormes, particulièrement en Chine et aux États-Unis.

L'écrasante majorité des subventions mondiales pour les combustibles fossiles a son origine en Chine, aux États-Unis et dans l'ex-URSS. En 2010, cette somme s'élevait à 712 milliards de dollars, c'est-à-dire près de 80 pour cent de la valeur totale des subventions mondiales.

Pour sa part, le Canada subventionne plutôt que d'imposer les combustibles fossiles depuis 1998. En 2010, les subventions canadiennes s'élevaient à 13 milliards de dollars, soit 1,4 pour cent du PIB.

La même année, les coûts financiers directs et indirects mondiaux de toutes ces subventions s'élevaient à 18,2 mille milliards de dollars, c'est-à-dire 3,8 pour cent du PIB mondial.

En plus de l'argent épargné, en 2010 un monde sans subventions aurait eu des émissions de carbone 36 pour cent moins élevées qu'elles ne l'ont été.

Tout gouvernement qui cherche à réduire la pression exercée sur le budget et à faire une contribution significative (et peu coûteuse) à la lutte contre le changement climatique doit envisager de réduire les subventions aux combustibles fossiles. Comme les données le démontrent, c'est une décision raisonnable, tant du point de vue fiscal que du point de vue environnemental.

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1. INTRODUCTION

A comprehensive database directly measuring fossil fuel subsidies does not exist at the international level. This is due both to political pressure from the direct beneficiaries of subsidies, as well as the complexity and variety of subsidy programs across countries. Indirect measures of subsidies, such as the ones constructed by the International Monetary Fund or the International Energy Agency, are based on the price-gap approach which infers subsidies by comparing local energy prices with an international benchmark price. The data used to construct indirect estimates however, are available for relatively few countries and years. The price-gap approach also has a number of other well-known drawbacks. For example, it misses subsidies that are too small to effect the energy price and attributes nearly all deviations from the benchmark price to subsidies, even though price differences can arise from unrelated forces like cross-country differences in income levels. Since fossil fuel subsidies are potentially an important driver of international carbon emissions and climate change, accurate and comprehensive information on the scope and evolution of subsidies is crucial to policymakers.

In one of my papers —referred to as RLS[1] from now on— I develop a novel methodology for inferring carbon subsidies by examining country-specific patterns in carbon emission-to-output ratios, known as emission intensities. First, I demonstrate that for most —but not all— countries, intensities tend to be hump-shaped with income. Second, I construct a model of industrialization that generates this hump-shaped intensity and show that deviations from this pattern must be driven by cross-country differences in sectoral productivity and/or fossil fuel prices. Finally, using the model I disentangle and measure these productivity and price deviations for 170 countries for 1980-2010. The implicit deviations in prices arising from this procedure are interpreted as net fossil fuel subsidies. In particular, they capture the net effects of all policies in each country associated with both the production and consumption of fossil fuels. The focus of RLS is primarily the development and testing of this novel methodology. However, in that paper, my analysis of the implied subsidies and their impact on emissions and Gross Domestic Product (GDP) is largely restricted to broad, global trends and a few particularly interesting examples. The present paper takes a closer look at the subsidy database obtained using the RLS methodology and the implications these subsidies have for carbon emissions, government spending and GDP at both the regional and country-specific levels.

In the following section, I review the literature on fossil fuel subsidies and economic models of carbon emissions. I then provide a non-technical summary of the methodology used in RLS to extract fossil fuel subsidies in Section 3, and compare my subsidy results with those arising from other approaches in Section 4. Sections 5-7 analyze the subsidy database I develop at the global, regional and country level, whilst Section 8 focuses on the extent of indirect costs of fossil fuel subsidies on emissions and output. Finally, Section 9, examines the subsidy regime in Canada implied by my methodology and considers some possible drivers of the implicit subsidies in that country.

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1 Stefanski (2014).

2. CONTEXT — MEASURING SUBSIDIES

There are a huge variety of government support mechanisms aimed at fossil fuels. Governments influence markets by "affect(ing) costs or prices, by transferring funds to recipients directly, by assuming part of their risk, by selectively reducing the taxes they would otherwise have to pay, and by undercharging for the use of government-supplied goods or assets."[2] It is also often the case that more than one support mechanism is used simultaneously. For example, on the consumer side of the market the government can provide tax breaks to consumers who purchase vehicles, whilst also placing price caps on gasoline. On the producer side, according to an example given by the IEA,[3] "a government may fund research at a national laboratory on how to convert coal into a liquid transport fuel, provide grants and loan guarantees to companies investing in synthetic fuels from coal, provide a tax credit linked to the production of such fuels, and exempt such producers from paying royalties on coal mined from state-owned lands. The national government may, in turn, pay the producer a higher price for the fuel than it could have paid for an imported, petroleum-derived fuel." To make things even more complicated, governments also often impose policies that are *negative* subsidies (i.e., taxes) on fossil fuels — such as additional value-added taxes (VAT) on gasoline. These policies often operate simultaneously with the above policies subsidizing fossil fuels.[4]

Directly measuring fossil fuel subsidies in a single country is thus a difficult and costly task due to their complexity, their variety and the desire for opacity from the direct beneficiaries of subsidies. The task becomes even more challenging when aiming to construct comparable measurements of subsidies across countries and over time. This difficulty has restricted subsidy measurement to using indirect methods or focusing only on selected subsidies and selected countries. In what follows, I summarize the two main strands of this fossil fuel subsidy measurement literature.

The first and most popular method is the so-called price-gap approach of estimating subsidies. The theoretical groundwork for this method was pioneered by Corden.[5] It is based on comparing the retail price of fossil fuels in a given country to an appropriate reference price. This reference price often takes the form of an international price adjusted for distribution and transportation costs estimated for each country. McCrone[6] was one of the first to use this method to study agriculture subsidies in the United Kingdom (U.K.). In terms of energy subsidies, papers by the Organisation for Economic Co-operation and Development[7] and others such as the IEA[8] or Coady et al.[9] have used this method to examine the size of subsidies and study the impact of fossil fuels in selected countries.

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2 IEA (2010).

3 Ibid.

4 For more detail on the taxonomy of fossil fuel subsidies, see Steenblik et al. (2010) or McKenzie and Mintz (2011).

5 Corden (1952).

6 McCrone (1962).

7 See OECD (1998); (2013a) op. cit.

8 See IEA (2006); (2008).

9 See Coady et al. (2010a).

More recently, Lin and Jiang[10] use the price-gap approach to estimate China's energy subsidies whilst the IMF[11] uses the approach to estimate pre-tax consumer subsidies for gasoline, diesel and kerosene for 176 countries between 2000 and 2011.

The limitations of the price-gap approach have been nicely summarized by the work of Koplow.[12] There are two key issues. First of all, a number of measurement challenges may reduce the accuracy of price-gap calculations and result in outcomes that are difficult to compare across countries, time and fuel types. In particular, the price-gap method requires accurate data, over time, on world reference prices, on domestic taxes and on transport costs — in many cases these data simply do not exist and must be estimated.[13] The method also assumes a common world reference price across countries. However, price levels can vary systematically across countries for reasons unrelated to subsidization policies or transport costs. For example, a well established economic fact —the so-called Balassa-Samuelson effect— states that goods and services tend to be more expensive in richer countries than in poorer countries.[14] Lower energy prices in poorer countries may thus be interpreted as a subsidy by the price-gap approach and higher energy prices in rich countries may be interpreted as a tax — even though they could be driven by the Balassa-Samuelson effect. The price-gap approach thus underestimates fossil fuel subsidies in rich countries and overestimates subsidies in poor countries. Second of all, by definition, the price-gap approach cannot capture government interventions that support industries or individuals, but do not affect the final price of the good. Hence, for example, subsidies to oil and gas producers that help them stay in business despite older technology, or drill in areas that would otherwise not be profitable, will not be captured by the price-gap approach simply because the subsidized producer is small relative to the global market and its actions do not impact prices, even though an effective subsidy was paid.[15]

The second method of estimating subsidies is more direct and examines the transfers from individual government programs in particular countries to consumers or producers of fossil fuels. This is an attempt to directly quantify transfers induced by programs that aim to support fossil fuel energy use regardless of whether they end up changing fuel prices. This approach has the obvious benefit of highlighting the cost of particular policies and picking up the cost of programs that may not influence the price directly. The best example

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10 Lin and Jiang (2011).

11 IMF (2013) op. cit.

12 Koplow (2009) op. cit.

13 For example consider the world reference price of energy against which domestic prices are to be compared. Whilst theoretically compelling, calculating this price is not so simple in practice. Even though a commodity like oil is traded globally, the actual price on delivery may vary substantially across countries. Establishing reference prices for less-traded commodities like natural gas, coal or electricity can be even harder.

14 One prominent explanation attributes this effect to differences in the prices of so-called non-tradable goods and services. These are goods and services that are not (or cannot be) traded across countries and thus have to be produced locally in a country, such as haircuts, taxi rides or prepared food. Since richer countries tend to have higher wages than poor countries, but the time taken to produce many non-traded goods is often similar in rich and poor countries, the cost of producing these non-tradable goods in richer countries will also be higher — and so will their price. This in turn will contribute to higher overall price levels in richer countries. Since the production of energy includes a number of non-tradable auxiliary services such as delivery, distribution or refining, the final consumer price of energy can vary across countries irrespectively of energy taxes or subsidies, based only on the variance of the price of those non-tradable services used in the production of energy.

15 Koplow (2009) op. cit.

of this type of data construction is the recent OECD exercise,[16] which estimates the size of government support to both the production and consumption of fossil fuels in 24 OECD countries for 2005-2011.

However, the transfer approach also has important limitations discussed in OECD,[17] Koplow[18] and Lin and Jiang.[19] First, there is the definitive question requiring the specification of what actually constitutes a subsidy to a particular industry, in a particular country at a particular point in time. This is non-trivial since a variety of different policies can potentially be seen as supporting carbon energy, even if they seem unrelated. Second, and in a similar vein, there is the question of the non-trivial cost of data collection. In principle, one may wish to be as broad in one's definitions of fossil fuel subsidies as possible. However, there is a question of practicality and budget. The OECD, for example, does not include support such as concessional credits, loan guarantees or injections of public funds into state-owned companies, as it would require too much time and funding to collect the necessary data. Third, there are serious questions of cross-country comparability largely driven by measurement error. For example, countries that are more transparent in reporting subsidies may appear to provide more support than countries that are more opaque in their reporting. Furthermore, differences in overall subsidy and tax levels in an economy may also play a role. In particular, two countries with identical carbon energy (gross) subsidy rates, but very different aggregate tax rates, will have different net levels of support for energy. Thus, the transfer approach will document the same value of (gross) subsidies even though the net level of support for fossil fuels in the high-tax country could be smaller than in the low- tax country. Subsidies calculated in this direct way are thus not necessarily internally valid in the sense that estimates from one country are not directly comparable to estimates from another country. For this reason, cross-county comparisons of subsidy estimates constructed in this way need to be interpreted with great caution.[20]

The method used in RLS (and expanded on in the next section) bypasses most of the above problems as it does not focus on energy prices, but rather on quantities of carbon dioxide emissions and on fossil fuel energy use. These data —unlike world reference prices or government transfers— are easily measurable and freely available.[21]

3. METHODOLOGY AND DISCUSSION

The methodology used to infer subsidies in RLS takes an entirely different approach to previous work. Rather than focusing on prices, which are difficult to measure, it examines the actual quantities of carbon that countries emit (and hence the amount of energy they

[16] OECD (2013a) op. cit.

[17] Ibid.

[18] Koplow (2009) op. cit.

[19] Lin and Jiang (2011) op. cit.

[20] OECD (2013a) op. cit.

[21] Whilst this might seem counterintuitive, the reason that we have excellent data on carbon emissions is that carbon emissions are almost entirely driven by the consumption of carbon fuels. Thus, there is a very tight, physio-chemical link between how much carbon fuels of a particular type are consumed and how much carbon is emitted into the atmosphere. Since we have excellent data on carbon fuel consumption, we implicitly have excellent data on carbon emissions as well.

use) to infer how cheap fossil fuels must be in those countries. The method is based on two observations about carbon emission intensity. First, emission intensities follow a robust hump-shaped pattern with income. Figure 1(a) plots total CO_2 emissions per dollar of GDP for 26 OECD countries versus each country's GDP per capita, for 1751-2010. Each line plots an emissions intensity for a single country against its per-capita income. Since per-capita income tends to increase over time, each line (roughly) represents the evolution of emission intensity of one country over time.[22] The graph suggests that countries with the dirtiest output are those in the middle-income phase of their development.[23] Second, the emission intensity of later developers tends to follow a so-called envelope pattern over time: the intensities of later developers rise quickly until they roughly reach the intensity of the U.K. —arguably the first country to start the modern development process— after which their intensity tends to approximately follow the same, hump-shaped path as that of the U.K. An illustrative example of this envelope pattern is shown in Figure 1(b).[24] In the graph, the obvious exceptions are China and the former Soviet Union (USSR),[25] which greatly overshoot this pattern. RLS shows that the extent to which countries like China deviate from the hump-shaped pattern is indicative of different types of distortions within those economies. Since variation in intensity can arise from numerous different sources, a model is needed to disentangle and measure these distortions.

In particular, to do this, in RLS I construct a model of industrialization matched to the experience of the U.K. and then examine cross-country differences in emission intensity through the lens of the model. The model generates a hump-shaped emission intensity by capturing the evolving fuel mix and energy intensity of economies. First, the increasing part of the hump shape is driven by a changing fuel mix as economies move away from relatively clean, predominantly biomass energy that characterizes agricultural economies to relatively dirty, predominantly carbon energy that characterizes industrialized economies.[26] Second, the declining part of emission intensity stems from falling *energy* intensity — the energy-to-GDP ratio of an economy. As economies grow richer, they tend to become more energy efficient, demanding less energy per unit of output and hence emitting less carbon per unit of output. Together, an increasingly dirty fuel mix and a falling energy intensity can give rise to a hump-shaped emission intensity.

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[22] See RLS for sources of all data. Notice that GDP is in constant 1990 U.S. dollars expressed in Purchasing Power Parity (PPP) terms. Purchasing Power Parity is a way to measure output adjusted for price differences across countries.

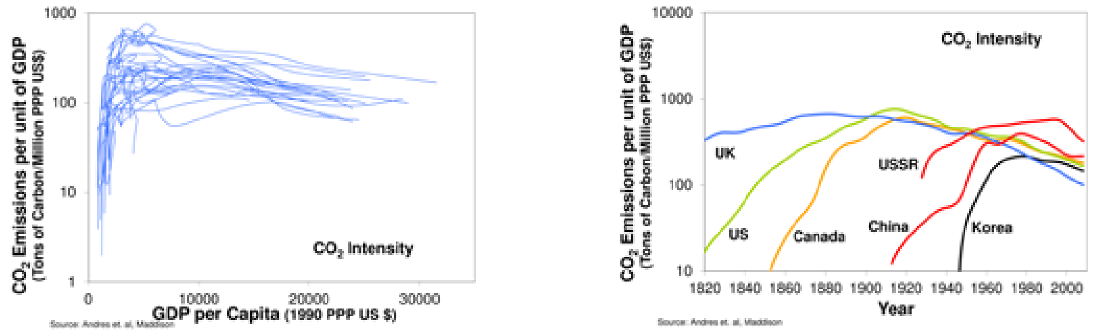
[23] I speak of poor, middle-income and rich countries in a broad sense and since I consider long periods of time, one country can belong to all three categories at one point or another. The exact cut-offs for being rich or poor are irrelevant and do not change the basic hump-shaped pattern with income.

[24] Notice that the particular choice of countries in the above is entirely illustrative. In Stefanski (2013) and RLS I demonstrate that the hump shape and envelope patterns are statistically robust to a far wider sample of countries and are a defining feature of a country's carbon emission cycles.

[25] The former Soviet Union (USSR) consists of: Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, the Kyrgyz Republic, Latvia, Lithuania, Moldova, Russia, Tajikistan, Turkmenistan, Ukraine and Uzbekistan.

[26] Both the Intergovernmental Panel on Climate Change (IPCC) and the U.S. Energy Information Administration (EIA) treat biomass emissions as carbon neutral and recommend that "reporters may wish to use an emission factor of zero for wood, wood waste, and other biomass fuels." See EIA (2001).

FIGURE 1 CARBON DIOXIDE EMISSION INTENSITY PATTERNS



(a) OECD CO_2 Emission Intensity, 1751-2007 (b) Timing and Emission Intensity

The model is chosen to match the growth, industrialization and fossil fuel net subsidy patterns (i.e., the difference between taxes and subsidies) of the U.K.[27] The U.K. is chosen for three reasons. First, it was the earliest country to start the industrialization process and thus it captures the evolution of emission intensity over all stages of development. Second, the U.K. has excellent long-run data which do not exist for many other countries and which allow for more accurate fit of the model. Finally, and perhaps most importantly, the U.K. has some of the smallest directly measured (gross) carbon subsidies in the OECD,[28] making it an excellent choice for the reference country.[29] The model does very well in reproducing economic aspects to which it has not been fitted, such as sectoral and energy price patterns observed in the data, which goes some way to demonstrate the external validity of the mechanism. Finally, since the model takes as an input the measured net subsidies from the U.K. data, in no way does it assume that the observed hump-shaped emission intensity pattern in the U.K. is efficient or optimal. Instead, the observed emission intensity in the U.K. is a consequence of the evolution of fuel mix and energy intensity, as well as measured energy policy in the U.K.

The resulting model can then be used as a lens through which to examine cross-country differences in intensities. In RLS I show that the envelope pattern in CO_2 emission intensities is a consequence of different starting dates of industrialization, which in turn are driven by cross-country wedges in agricultural productivity.[30] Any other deviations in intensity from the hump-shaped pattern are symptomatic of either non-agricultural productivity wedges or subsidy-like wedges on fossil fuels. In what follows, I examine in greater details the implicit subsidy database obtained using the above technique.

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27 Using data from the Institute for Fiscal Studies (IFS, 2013), the IEA (2012), British Petroleum (BP, 2014) and Mitchell (2011), I construct a measure of taxes on modern fuels in the U.K., which I then combine with data on modern energy subsidies from the OECD (2013a) op. cit. to create a measure of net subsidies on modern energy in the U.K. For more details see RLS.

28 OECD (2013a) op. cit.

29 Recall that OECD figures come from direct measurements of fossil fuel subsidies. That is, the OECD has examined detailed legislation and measured the (gross) value of all subsidizing policies that it could find within different countries. Whilst these data are not strictly internationally comparable, they nonetheless are strongly indicative of the limited extent of subsidization in the U.K.; the value of gross subsidies calculated in this way is among the lowest in the OECD.

30 A wedge in agriculture that results in low agricultural productivity will delay the beginning of industrialization. Countries that begin industrialization later will have access to more energy-efficient (and hence cleaner) technology than countries that industrialized earlier. This in turn will drive the envelope pattern in emission intensities observed in the data.

Strengths and Weaknesses

The fossil fuel subsidies that emerge from the methodology proposed in RLS have a number of crucial strengths and some potential weaknesses. Importantly however, almost all the weaknesses are shared by other indirect methods of subsidy measurement (such as the price-gap approach), whereas my methodology offers several improvements along a number of crucial dimensions. I start by considering four potential weaknesses of the methodology and then move on to its strengths.

1. Whilst the model identifies price wedges as being important drivers of cross-country emissions, it cannot tell us the specific sources of these wedges and hence it cannot pin down the exact policies driving energy price wedges. Furthermore, the methodology is used to measure subsidies and stays entirely silent on the political economy aspect of how to remove energy policies — an important feature of the debate and one that is discussed more in IMF, Koplow and IEA.[31] Whilst this is a weakness of the current setup, it is one that is also shared by the price-gap approach.

2. The implicit price wedges obtained from the model do not necessary exclusively represent distortions arising from government policies. In principle, price wedges could also include other factors that influence energy prices. For example, countries with higher natural resource endowments that are closed off to trade for geographical reasons might have a local glut of fossil fuels, resulting in lower prices and hence higher fossil fuel use and subsequently higher carbon emissions. The model could then — in principle— pick up these higher emissions as implicit subsidies even though they are geographical features of the country.[32] The implicit wedges should thus be viewed as aspects of individual economies that result in fossil fuels being used more intensively than they otherwise should be. Importantly however, the price-gap approach suffers from the exact same potential weakness (and as I explain below, this criticism applies to the price-gap approach even more strongly).

3. The above has implications for subsequent counterfactual exercises performed using the model. When performing counterfactuals, I assume that energy price wedges emerge entirely from government policies, and hence that those wedges can be removed or set to zero. If this is not the case (that is, if a part of the energy price wedge emerges from non-governmental policies that are not captured by productivity wedges), or if there is a cost to changing particular policies, then the assumption that the entire energy price wedge can be removed in the counterfactual may result in an overestimate of the role played by government policies in driving carbon emissions. Of course, neither the price-gap approach nor the direct method of measuring subsidies can be used to think about counterfactual outcomes at all — thus my methodology still provides useful insights.

4. Many governments simultaneously have policies that subsidize and tax fossil fuels.[33] The baseline version of the model however, only calculates net subsidies and hence

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[31] IMF (2013) op. cit.; Koplow (2009) op. cit.; IEA (2010) op. cit.

[32] However, if countries are closed off to trade because of government trade restrictions, the resulting implicit price wedges should in fact be interpreted as implicit (if arguably unintended) government subsidies/taxes to carbon energy.

[33] For example, Turkey has some of the highest taxes on gasoline at the pump in the world, but at the same time it provides massive subsidies to employees of the coal mining industry, which it sees as strategically important. See IEA (2010) op. cit.

considers net effects of all policies in a particular country combined. On the positive side, this gives a clear, one-figure summary of all policies carried out by a government. On the other hand, reporting a single number might miss large subsidies that occur in an economy but are netted out by corresponding taxes. This, however, again is a flaw that also exists in the price-gap approach, with observed energy prices in a country reflecting potentially varying government policies.

Thus, whilst the suggested methodology does have drawbacks, these are mostly shared by the price-gap approach. Importantly however, the proposed setup has a number of crucial strengths.

1. The method is not very data-intensive[34] and can be applied to a wide range of countries and used to obtain estimates of subsidies for states that would otherwise not be available. Thus, I provide new information for a far wider set of countries than is standard — 170 in total. For comparison, the estimates of subsidies provided by the IEA give data only for 37 countries.[35]

2. Subsidy estimates are also usually available only for select years. The earliest data estimated using the price-gap methodology are usually available only for 1991 or 1995, whilst afterwards the data are available only every two years from 1998.[36] The suggested methodology above can be used to determine annual subsidies going back to 1980 for almost all countries, and even further back for a substantial portion of the world's countries.

3. Since the suggested approach uses a uniform methodology and does not rely on country-reported data, the examination of individual tax codes or individual subsidy laws, it provides a database of *comparable* fossil fuel subsidies across a wide range of countries and time.

4. Since the methodology examines observed emissions rather than prices, unlike the price-gap approach it can capture subsidies that support carbon energy without changing carbon energy's final price due to their small size.[37]

5. The suggested methodology is robust enough to account for cross-country price differences arising from variation in productivity, without misattributing these differences to energy subsidies or taxes. Thus, for example, poorer countries tend to have lower price levels of services than richer countries (the so-called Balassa-Samuelson effect). In so far as this translates to lower energy prices at the pump, the

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34 To calculate subsidies in a country in a given year we only need data on the country's agricultural employment share, its constant price GDP and its total carbon emissions.

35 IEA (2010) op. cit.

36 This is due to the fact that the price-gap approach uses data on petrol prices at the pump provided by the Deutsche Gesellschaft fuer Internationale Zusammenarbeit (GIZ) on a biennial basis. These data are constructed from price surveys that started in 1991 in a restricted set of countries and then, over the years, expanded to include most countries around the world.

37 This can include a whole range of diverse subsidy mechanisms such as guaranteed loans to small oil drillers, subsidized loans to companies buying oil-bearing land, vouchers that entitle consumers to a certain amount of fuel at a discounted price or income tax codes that encourage employers to offer free fuel in place of higher salaries to their executives using company cars. See IEA (2010) op. cit.

price-gap approach would interpret these low prices as subsidies, even though they arose from productivity differences between rich and poor countries.

6. Since the methodology developed in RLS is model-based, it automatically allows me to perform counterfactuals to gauge the impact that subsidies have on the environment (by promoting too much fossil fuel consumption) or on GDP (by promoting a misallocation of resources). This allows for better estimates of the total opportunity costs of fossil fuel subsidies.

In short, whilst the proposed methodology admittedly possesses some of the same potential weaknesses of other indirect methods of subsidy estimation like the price-gap approach, it is more comprehensive both in scope (since it considers more countries over a longer period of time) and in completeness (since it captures a broader measure of subsidies), and importantly it is comparable across countries and time whilst offering the possibility of calculating total opportunity costs of fossil fuel subsidies. It thus provides essential information to academics and policymakers interested in understanding the role of fossil fuel subsidies in driving carbon emissions.

4. COMPARISONS WITH OTHER MEASURES

To aid comparisons, it is helpful to position the subsidies from RLS relative to other techniques in the literature. There are a multitude of disjoint subsidy definitions from numerous organizations[38] which can roughly be classified into ever-widening bands of support.[39] At the most basic level, there are direct budget expenditures (including tax expenditures), followed by market price support and market transfer mechanisms and uncollected or under-collected resource rents. These three levels of subsidies roughly correspond to the definition of subsidies used by the World Trade Organization (WTO).[40]

The IEA/OECD definition used in IEA[41] casts a wider net and classifies *any* government market intervention that support the consumption and production of fossil fuels as a subsidy.[42] Notice that this definition cites government market intervention as being necessary for a policy to be classified as a subsidy. A *lack* of government market intervention might arguably not be captured by this definition.[43] For example, a government choosing not to impose taxes on fossil fuels whilst imposing taxes on other energy carriers might encourage more fossil fuel use, but would arguably not satisfy the above definition of

38 For an excellent overview see Jones and Steenblik (2010).

39 Steenblik et al. (2010) op. cit.

40 The WTO defines subsidies as: (i) a government practice involving a direct transfer of funds; (ii) government revenue that is otherwise due is foregone or not collected; (iii) a government provides goods or services other than general infrastructure or purchased goods; and (iv) a government makes payments to a funding mechanism or instructs a private body to carry out one or more of the functions described in (i) through (iii). For more details see https://www.wto.org/english/docs_e/legal_e/24-scm.pdf.

41 IEA (2010) op. cit.

42 More specifically the IEA/OECD defines subsidies as government interventions in markets in a way to affect costs or prices, by transferring funds to recipients directly, by assuming part of their risk, by selectively reducing the taxes they would otherwise have to pay, and by undercharging for the use of government-supplied goods or assets. Ibid.

43 Although it remains an open question whether the lack of an action is an action in and of itself.

a subsidy.[44] This type of measure might also exclude non-market interventions. For example laxer environmental standards or lower health and safety requirements in manufacturing firms might arguably increase the number of manufacturing firms which use fossil fuels intensively, effectively encouraging fossil fuel use in the economy and thus acting as an implicit subsidy. Policymakers and economists however, might nonetheless be interested in quantifying the cost of government inaction and non-market interventions when thinking about subsidies.

In order to capture this type of support, the IMF's approach to defining subsidies involves examining differences in *outcomes* across countries.[45] Rather than pinpointing specific policies that may or may not count as subsidies based on an interpretation of a particular definition, the IMF defines pre-tax subsidies in terms of price outcomes — as the difference between the price paid by consumers (i.e., firms and households) for energy and the cost of supplying that energy.[46] This approach in principle is wider than either the WTO or the IEA/OECD definitions and captures the impact of all policies influencing the price of fossil fuels. In particular, it would include the influence of cap and trade programs, tax benefits for research and development investment aimed at developing cleaner production technologies and any other policy that influences retail fossil fuel prices. My approach is closest to this pre-tax price-gap approach, but casts an even wider net as it includes policies that support fossil fuel consumption, but —as explained in the Introduction— might not necessarily be reflected in the price of fossil fuels.

Finally, the widest (and perhaps most controversial) measure of subsidies is the so-called post-tax price-gap approach also used by the IMF.[47] In this measure, a country has a fossil fuel subsidy if the price paid by consumers is below the supply cost of energy *plus* an appropriate Pigouvian (or corrective) tax that reflects the environmental damage associated with energy consumption and an additional consumption tax that should be applied to all consumption goods for raising revenues. This is a very broad and incredibly sensitive measure that rests largely on the assumptions of what the damages and externalities of fossil fuels are and hence what the right corrective tax is. My measure is significantly tighter than this post-tax subsidy estimate and does *not* consider the cost of potential externalities associated with fossil fuel consumption.

I finish this section by comparing my measure of subsidies with the (pre-tax) price-gap estimates from the IMF and the IEA.[48] It is, however, important to point out a number of difficulties with this comparison. First, the IEA and the IMF[49] left-censor their data. This means that when they find local prices of carbon energy that are higher than the international benchmark price, instead of reporting the corresponding negative subsidy (i.e., a tax), they report a subsidy of zero instead. Given that their positive subsidy estimates capture net subsidies, this left-censoring of the data is somewhat arbitrary, results in a loss of information and introduces an upward bias in the average levels of their subsidies.

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[44] Arguably though, this type of subsidy might fall under point (ii) of the WTO definition.

[45] IMF (2013) op. cit.

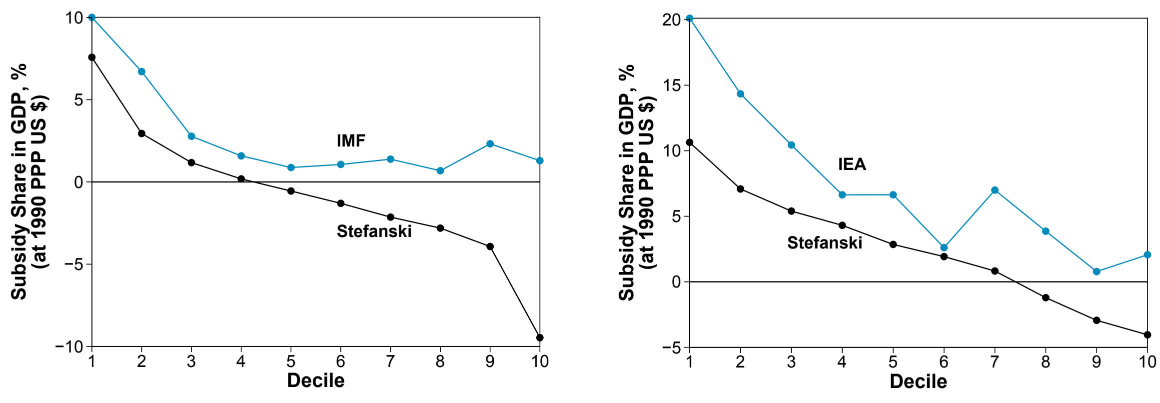
[46] In other words, this is the standard price-gap approach discussed above.

[47] IMF (2013) op. cit.; Coady et al. (2015).

[48] Ibid; IEA (2010) op. cit.

[49] Ibid; Ibid.

FIGURE 2 VALUE OF SUBSIDIES AS A SHARE OF GDP (AT 1990 PPP USD) BY DECILE



(a) IMF and this paper (2010/2011) (b) IEA and this paper (2009 and 2010)

Second, the IMF[50] price-gap subsidy measure is only carried out for the year 2011, but my subsidy dataset extends only up to 2010.[51] Thus, the IMF and my measures do not coincide for a particular year. As to the IEA data,[52] they offer information for only 31 countries for the years 2009 and 2010. Third, neither the IEA nor the IMF[53] provide data on subsidy *rates*. Instead, both papers only publish total subsidies in (current year) U.S. dollars. Since these are not unitless measures of subsidies and depend on the year of measurement, the quantity of energy used in a country and the level of the undistorted price of energy, this makes a clean comparison harder since their data need to be transformed into comparable units. Despite these difficulties, I now present a direct comparison of measures of my subsidies and those of the IMF and the IEA.[54]

Since the IMF (2013) data[55] are for 2011 and my data series stops at 2010, for the IMF exercise I compare 2011 IMF data with my 2010 data for the 140 countries available in the IMF database. For the IEA exercise, I compare my data to the 31 countries in the IEA exercise in 2009 and 2010. Since data from the IMF and the IEA are in current U.S. dollars, to make them comparable with my data, I transform the value of subsidies into 1990 PPP dollars, using exchange rates from the World Development Indicators (WDI). Then, I convert the resulting values into subsidy shares of GDP (measured in constant 1990 U.S. dollars) in order to make the subsidy measures unitless. I then calculate the corresponding measure of subsidy shares of GDP in my model. Finally, I sort my subsidy-share data from highest to lowest and divide resulting data into deciles. I then compare the average subsidy share of each decile in my data with the corresponding IMF and IEA data. I present my findings for the IMF data in Figure 2(a) and for the IEA data in Figure 2(b).

Subsidy shares estimated using my technique tend to be lower than those of either the

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50 IMF (2013) op. cit.

51 This is largely because a number of databases that I make use of in my model, such as the comparable, global carbon emission data from the CDIAC, stop in 2010.

52 IEA (2010) op. cit.

53 Ibid; IMF (2013) op. cit.

54 See Ibid; IEA (2010) op. cit. In RLS I construct my own price-gap measure that avoids the above problems and show that it performs remarkably well in matching subsidy rates across countries and over time.

55 IMF (2013) op. cit.

IMF or the IEA. In the highest decile, my measures predict that subsidies constitute approximately 7.5 per cent of GDP versus 10 per cent of GDP in the IMF data and 11 per cent versus 20 per cent in the IEA data. The difference is greater in the lowest deciles, where I find net subsidy shares of GDP of on average -9 per cent versus 1.3 per cent for the IMF and -4 per cent versus 2.1 per cent in the IEA data. Neither of these facts is particularly surprising, since the IEA and the IMF left-censor their data and I do not. Thus whilst I include negative subsidies amongst my estimates, the lowest estimates in the IMF and IEA data will be zero. Thus, if anything, my data tend to underestimate mean subsidy shares across countries in comparison to those from the IMF/IEA. Importantly however, there is a strong correlation between my measure of subsidies and those in the IMF and the IEA. Thus, in general, both methodologies are picking up similar trends in cross-country subsidies.

Finally, even though I find that subsidy shares generally tend to be lower using my methodology, I nonetheless find that the value of total global subsidies (in dollar terms) are comparable or even higher than in the IMF/IEA data. The reason for this is that I find subsidy shares in three key countries that are substantially higher than those predicted by the IMF/IEA. In particular, the IMF finds total subsidies in China, Russia and the U.S. to be $46 billion in 2011 (in 1990 PPP U.S. dollars), whilst in the rest of the world they find subsidies to be $583 billion (in 1990 PPP U.S. dollars). On the other hand, I find subsidies in China, Russia and the U.S. to be $673 billion (62 per cent of which comes from China) and subsidies in all remaining countries considered by the IMF to be $273 billion in 2010. Similarly the IEA paper finds that China and Russia (the IEA does not have data on the U.S.) spent $62 billion (in 1990 PPP U.S. dollars) on subsidies in 2010 whilst the remaining 29 countries spent $555 billion (in 1990 PPP U.S. dollars). My measure of subsidies in China and Russia was $503 billion (in 1990 PPP U.S. dollars) whilst subsidies in the remaining 29 countries of the IEA data totalled $220 billion (in 1990 PPP U.S. dollars). Thus, whilst my methodology predicts far lower subsidies in most countries than the methodology of the IMF or the IEA, my methodology picks up on a host of hidden subsidies in China, Russia and the US that the price-gap approach may have missed.

5. GLOBAL OVERVIEW

Next, I turn to an in-depth analysis of the subsidies that emerge using my technique. To illustrate the evolution of fossil fuel policies around the world, I separate countries into two groups and examine how the total value of subsidies, the value of subsidies per worker, the share of subsidies in GDP and the size of fossil fuel price distortions evolved over time in each group. The first group consists of countries where net subsidy rates are positive. These are countries which tend to have policies that, on the whole, subsidize rather than tax fossil fuels. Later, when I refer to total global fossil fuel subsidies or say that global subsidies have risen, I will be referring to the net subsidies in this group of countries. The second group consists of countries where net subsidy rates are negative. These are countries that, on the whole, tend to have policies that tax fossil fuels more than they subsidize them. Later, when I refer to total global fossil fuel taxes or say that global taxes have risen, I will be referring to this second group of countries. Notice that neither of these groups are composed of a fixed set of countries. The countries entering each group will change depending on each country's net subsidy rate at a given point in time. Finally, I also consider the evolution of fossil fuel policies for the entire world taken as a whole.

I start by examining the trend of implicit fossil fuel subsidies over time for countries that had positive net subsidies. The dashed red line in Figure 3 depicts the total value of all positive net subsidies in the world at a point in time calculated by summing over the value of subsidies in every country where subsidies were positive in a given year. From the figure it emerges that subsidies are enormous. Between 1980 and 2000 the world spent on average \$268 billion USD (measured in 1990 PPP terms) a year on implicit fossil fuel subsidies in countries that were net subsidizers.[56] Looking at the dashed red lines in Figures 3(b) and 3(c) this translates to approximately \$122 USD per worker per year or 1.1 per cent of global GDP every year (also measured in 1990 PPP terms) between 1980 and 2000.[57] After the year 2000, subsidies grew even more. By 2010, the value of global subsidies in countries that were net subsidizers had increased more than three and a half times and reached a level of \$983 billion a year — costing each worker on the planet \$321 USD every year and comprising a stunning 2.03 per cent of global GDP per year.[58] Finally, the dashed red line in Figure 3(d) depicts the average (model implied) price of fossil fuels in countries with positive net subsidies relative to the undistorted price.[59] In subsidizing countries, between 1980 and 2000, the relative end-user price of carbon energy was approximately 78 per cent of the undistorted price, implying an average subsidy rate on fossil fuels of 22 per cent (=1−0.78). By 2010, the relative price had fallen to 54 per cent, implying subsidy rates had grown to 46 per cent (=1−0.54).

Next, I examine the trend of implicit fossil fuel subsidies over time for countries that had negative net subsidies or taxes. These taxes have also been significant over the last 30 years. The dash-dotted blue line in Figure 3 depicts the total value of all taxes in the world calculated by summing over the value of taxes in every country with positive taxation (i.e., negative subsidization) in a given year. Between 1980 and 2000 the value of implicit global taxes on fossil fuels in countries that taxed fossil fuels on net was, on average, \$664 billion USD (measured in 1990 PPP terms) a year. The corresponding dash-dotted blue lines in Figure 3(b) and 3(c) indicate that this translates to approximately \$294 USD per year for every worker on the planet or 2.6 per cent of global GDP (also measured in 1990 PPP terms) per year. The level of taxation, however, fell dramatically after 1998 — indicating the same increase in net subsidies that was also observed among the group of subsidizing countries. By 2010, the value of global taxes of fossil fuels in countries that had positive fossil fuel taxes had fallen by more than two-thirds and reached a level of \$195 billion a year, costing each worker on the planet \$64 USD per year and comprising 0.4 per cent of global GDP per year. Finally, the dash-dotted blue line in Figure 3(d) depicts the average (model implied)

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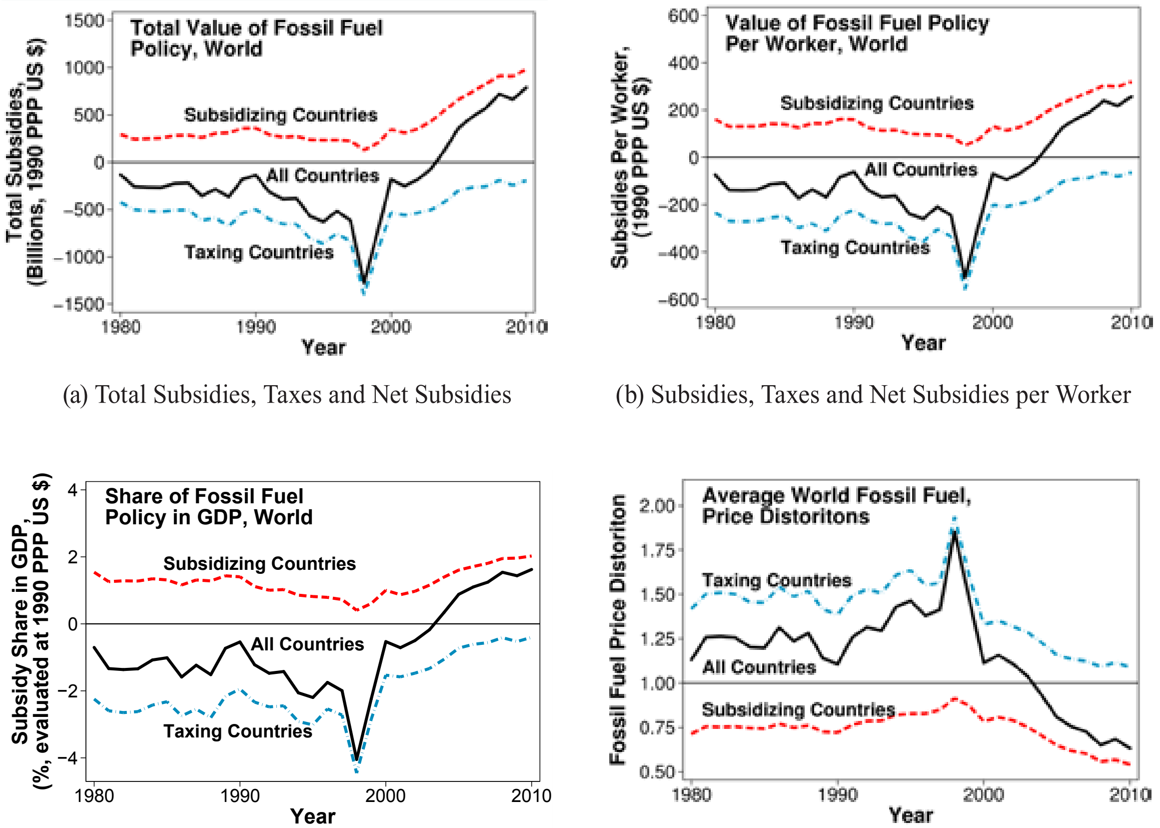
[56] All quantities are given in 1990 PPP dollars. To convert to 2010 dollars, multiply by a factor of approximately 1.514.

[57] Data for GDP and labor force come from Penn World Tables version 7.1. See Heston et al. (2012). In the setup of the model, the relevant variable is the labor force, rather than the population. To maintain consistency, I maintain per-worker measures instead of per-capita measures. This makes very little difference to the qualitative and quantitative results of the model.

[58] To put this into perspective, a rough estimate by the Global Subsidies Initiative (GSI) indicates around \$100 billion USD (2007 current) were spent in 2007 globally to subsidize alternatives to fossil fuels; see GSI (2010). The OECD estimates that agricultural subsidies in OECD countries were close to \$400 billion USD (2008 current) in 2008; see OECD (2009).

[59] This ratio is calculated as a carbon-emission weighted average. Very similar results are obtained if I weigh by GDP or population.

FIGURE 3 GLOBAL MEASURES OF FOSSIL FUEL POLICIES, 1980-2010



(a) Total Subsidies, Taxes and Net Subsidies

(b) Subsidies, Taxes and Net Subsidies per Worker

(c) Share of Subsidies, Taxes and Net Subsidies in Global GDP

(d) Price of Fossil Fuels Relative to Undistorted Price

price of fossil fuels in countries with positive net taxes relative to the undistorted price.[60] In countries with positive taxes, between 1980 and 2000, the relative price was approximately 152 per cent of the undistorted price, implying an average net tax rate on fossil fuels of 52 per cent (=1.52−1). By 2010, the relative price had fallen to 109 per cent, implying a nine per cent net tax rate.

Finally, I examine the evolution of net subsidies in all countries over time. This measure simply sums country-level net subsidies of all countries in the world at each point in time. From the black line in Figure 3(a), between 1980-2000 globally fossil fuel taxes were larger than fossil fuel subsidies and the value of net fossil fuel taxes globally was approximately $396 billion. The corresponding solid black lines in Figure 3(b) and 3(c) indicate that this translates to approximately $172 USD for every worker on the planet or 1.5 per cent of global GDP. After the year 1998, however, there was a massive reversal in these types of policies and by 2010, the value of subsidies on a global level rose to $788 billion (or $257 USD per worker and 1.6 per cent of global GDP). Notice that the global increase was driven by a massive surge in net subsidies (corresponding to an increase in subsidies and/or a decrease in taxes) in both groups of countries. It is also important to point out that looking at the net effect may be somewhat misleading. If one country's subsidies are exactly offset

60 As in the case of subsidies, this is an emission-weighted average, and the results remain largely unchanged if I use other sensible weighing schemes.

by another country's taxes, the net measure of subsidies will be zero. Nonetheless, both countries will still have the corresponding economic and environmental distortions of their respective policies.[61]

A clear pattern emerges from the above analysis. Global net subsidies have increased dramatically and steadily since approximately 1998. This seems especially striking, as it is at clear odds with the declared efforts of almost all the world's countries to cut carbon emissions in an effort to combat climate change. Intriguingly, other studies on fossil fuel subsidies like those by Coady et al., the IMF or the IEA ,[62] whilst focusing on much shorter periods than the current study, also find rising fossil fuel subsidies in the post-2000 period. Whilst the model developed in RLS can be used to measure subsidies and potentially examine the impact that they have on the economy and the environment, one of its drawbacks (like all the literature on indirect subsidy estimation, including the price-gap approach) is that it is unable to tell us the specific policies that result in subsidies following the path that they do. Coady et al., the IEA[63] and others have speculated that the increase in subsidies has been closely linked to rising energy prices after 1998 driven by a significantly low pass-through rate of international prices to local consumers.[64] According to the above, built-in momentum in the tax systems of various countries results in increasing subsidies when energy prices rise and increasing taxes when energy prices tend to fall. Such momentum may arise, for example, from the desire of governments to insulate consumers from rising oil prices or because governments wish to maintain stable levels of tax revenue in the face of falling energy prices. Thus, the massive rise of fossil fuel prices between 1998 and 2010, in combination with governments' desire to insulate consumers from rising energy prices by reducing fossil fuel taxes or regulating below market prices, could perhaps explain the increase in observed net subsidies over the period. Nonetheless, pinpointing the policies that drive implicit subsidies is still an open and interesting question and more research needs to be done on the subject.

The above global analysis of fossil fuel subsidies demonstrates that subsidies have been very large and hence must have played an enormous role in policy and carbon emissions over the last 20 years. To understand these global policies and how to counteract them, it is important to understand which regions and countries have been driving the bulk of global fossil fuel taxation and subsidization over the period. It is particularly important to know which countries have been driving the massive build-up of subsidies and the large decline in taxes seen in the 2000s. In the following sections, I will examine how regions and countries influenced the global patterns observed in this section.

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61 Notice, however that the same can be said of my estimate of net subsidies for a given country. If one country has two policies that exactly offset each other, the net measure of subsidies will be zero but the country will still have the corresponding economic and environmental distortions of both respective policies. I discuss this negative aspect of my policy in Section 2.

62 Coady et al. (2010b); IMF (2013) op. cit.; IEA (2010) op. cit.

63 Coady et al. (2010b) op. cit; IEA (2010) op. cit.

64 Indeed, using the world average subsidy rates between 1980-2010 arising from my methodology, I find that a percentage increase in the real oil price is associated with a 0.43 percentage point increase in fossil fuel subsidies; see BP (2014) op. cit.

6. REGIONAL ANALYSIS

In this section I take a closer look at the above data by examining how net subsidies vary across and within geographical regions around the world. In particular, I repeat the above global exercise but at a regional level. I divide the world into 12 geographical regions: three in Europe, three in Africa, two in the Americas and four in Asia and examine how different measures of subsidies evolve over time within these regions.[65] As before, at each point in time, I separate countries in each region into two groups: countries with positive net subsidies and countries with negative net subsidies. As before, when I refer to the value of subsidies of a region, I will mean the total value of net subsidies of all countries within that region that have positive net subsidies. When I refer to the value of taxes of a region, I will mean the total value of net taxes of all countries within that region that have negative net subsidies. I then examine how the total value of subsidies, the value of subsidies per worker, the share of subsidies in GDP and the size of fossil fuel price distortions evolved over time in each group of each region. I also consider the evolution of fossil fuel policies for each region taken as a whole.

For each group of countries and each geographical region, Figure 4 shows the total value of net subsidies; Figure 5 shows per-worker net subsidies; Figure 6 shows the share of net subsidies in regional GDP and Figure 7 shows the price of fossil fuels relative to the undistorted price (which is a measure of the subsidy rate). In these graphs the red dashed line represents countries that positively subsidized fossil fuels, the dashed-dotted blue line represents countries that taxed fossil fuels and the black thick continuous line represents all countries.[66] Unsurprisingly, I find that there is a fair amount of variation in both the magnitude and the direction of distortions across regions. Perhaps somewhat more surprisingly, there is also significant variation within regions over time: several regions make large swings towards or away from implicitly pro- or anti-fossil fuel policies.[67]

Europe

European fossil fuel policies vary across the continent along the former east-west division. Western European countries have had some of the highest implicit energy tax rates on the planet. In 2010 the average Western European tax rate (in countries that had positive net taxes) was 45 per cent or approximately $85 billion USD in total, $422 USD per worker or 0.09 per cent of GDP. In contrast, former Soviet countries have had some of the highest subsidy rates in the world. In 2010 all former Soviet Union countries had positive net subsidies and the average Soviet subsidy rate on fossil fuels was 56 per cent or approximately $108 billion USD in total, $795 USD per worker or a staggering 6.2 per cent of GDP. Eastern European countries lie somewhere in the middle. In the early 1980s

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[65] For a detailed description of each region and why this particular regional division was chosen, see the Appendix.

[66] Notice that in the Fossil Fuel Price Distortion graphs *only* (Figure 7), the price distortion is *not* shown if there are no countries that belong to a particular group. Thus, for example, if a geographical region has no countries that have positive net subsidies, whilst it is still correct to say that the regional total subsidies, the subsidies per worker and the subsidy share in GDP are all zero (as shown in Figures 4-6), we nonetheless *cannot* calculate and graph the average fossil fuel price distortion in the group of countries with positive net subsidies, since there are no countries within that group. As such, in Figure 7, a missing line is indicative of a region not having countries belonging to a particular group.

[67] All values in this section are in 1990 PPP U.S. dollar terms.

these countries had subsidy rates that were only slightly below Soviet levels, but since then subsidies have fallen. In 2010 the average implicit Eastern European subsidy rate on fossil fuels (in countries with positive net subsidies) was 41 per cent or approximately $18 billion USD in total, $406 USD per worker or 1.6 per cent of GDP.

Whilst Western Europe has had generally high taxes on fossil fuels, its taxation rate has fallen by a massive 24 percentage points between 1980 and 2010, with practically the entire decline taking place after 1998. Similarly, whilst not as extreme, the former USSR has also seen a continued shift towards more pro-fossil fuel policies: between 1980 and 2010, subsidies rose by 12 percentage points. The only European region to see a decline in subsidies was Eastern Europe. By the late 1990s, subsidies had fallen from record highs to near zero, but started rising after, nonetheless finishing at a lower level in 2010 than in 1980.

Finally, notice the differences in dispersion between subsidizing and taxing countries within geographical regions. Western Europe and the former Soviet Union had no or almost no countries that were net subsidizers or net taxers of fossil fuels respectively. Eastern Europe on the other hand, although dominated by subsidizing countries, had countries with more diverse policies.

Asia

In Asia, implicit fossil fuel subsidy rates have tended to follow one of two scenarios. First, Southern and Southeastern Asia have seen some of the highest implicit tax rates in the world that have gradually fallen over time. In particular, in 1980 the average fossil fuel tax rate (in countries with positive net taxes) was 181 per cent in Southern Asia and 239 per cent in Southeastern Asia. By 2010 both regions were, on net, slightly subsidizing fossil fuels. In particular, the average fossil fuel subsidy rate in Southern Asia in 2010 was 32 per cent, which amounted to $44 billion in total, $71 per worker or 1.2 per cent of GDP, whilst the corresponding figures in Southeastern Asia were 32 per cent, $24 billion in total, $87 per worker or 0.8 per cent of GDP. Second, countries in Eastern Asia and Oceania tended to have near zero (net) subsidy rates until the end of the 1990s, after which both regions saw a massive increase in subsidy rates. In particular, in 2010 the average subsidy rate in Oceania (in countries with positive net subsidies) was 46 per cent, $12 billion in total, $685 USD for every worker of the region or 1.8 per cent of the region's GDP. The 2010 average East Asian subsidy rate (in countries with positive net subsidies) was 71 per cent or a monumental $434 billion USD in total, $490 USD for every worker of the region or 3.9 per cent of GDP. Interestingly, Oceania had relatively limited dispersion in taxes and subsidies across countries of the region whereas Eastern Asia had some of the highest quantities of both taxes and subsidies in the world, generating the initial low net subsidies seen in the figures.

The Americas

Fossil fuel wedges in the Americas can also largely be divided by geographical region. The South American region, with a few exceptions, has tended to have very high tax rates, which have declined somewhat since the late 1990s. In particular, by 2010 the average South American tax rate (in countries with positive net taxes) was 70 per cent, taxes were $56 billion USD in total, $200 USD per worker or 1.5 per cent of GDP.[68] The North American region however, has had a far more pro-fossil fuel policy. In particular, until the 1990s the policy was fairly neutral with a slight tendency towards subsidization. Subsequently however, the total value of fossil fuel subsidies exploded and the region became the second highest subsidizing region after East Asia. In particular, by 2010 the average North American subsidies (in countries with positive net subsidies) were on average 45 per cent, $182 billion USD in total, $1048 USD per worker or 1.8 per cent of GDP.

Africa and the Middle East

The regional evolution of subsidies in Africa and the Middle East has followed three very distinct paths. First, Sub-Saharan Africa has had consistently very high levels of fossil fuel taxes between 1980 and 2010. In particular, in 2010 the average tax rate in Sub-Saharan Africa (in countries with positive net taxes) was one of the highest in the world at 142 per cent or 2.8 per cent of GDP. However, due to the low income levels in this part of the world, this translated to only $17 billion USD in total taxes or $65 USD per worker. Next, Southern Africa has consistently had the highest subsidy rates from all other regions in the world, rising from approximately 50 per cent in 1980 to a massive 82 per cent and a monumental 8.7 per cent of GDP in 2010 (in countries with positive net subsidies). In absolute terms this amounts to $26 billion total or $1275 per worker spent on fossil fuel subsidies. Finally, the Middle East has seen fossil fuel policies change significantly over time. In 1980 it had high fossil fuel tax rates of approximately 110 per cent (in countries with positive net taxes). By 2010, this high taxation had disappeared and had been replaced by enormous subsidies. In particular, in 2010 the average subsidy rate in the Middle East (in countries with positive net subsidies) was 60 per cent, totalling $103 billion USD, $699 USD per worker or 3.7 per cent of GDP.

Overview

Finally, Figure 8 decomposes the information from Figure 3 by region and compares the different contributions of each region to global subsidies and taxes. In particular, Figures 8(a) and 8(c) plot the contribution of particular geographical regions to the value of total world fossil fuel subsidies and taxes, whilst Figures 8(b) and 8(d) show the corresponding shares that these regions represent. On the subsidy side of policy, three facts emerge. First, only four sub-regions account for over 90 per cent of the value of the world's fossil fuel subsidies: the former Soviet Union, Eastern Asia, North America and the Middle East. Second, even among these sub-regions, between two-thirds and nine-tenths of subsidies stem from the Soviet region and Eastern Asia alone. Third, the total value of subsidies in the Soviet region have been relatively stable over time and hence its share in the total value of subsidies has been falling. Most of the growth in the value of subsidies seen in the 2000s has been driven by an explosion of subsidies in East Asia and Northern America and —to a lesser extent— the Middle East.

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[68] As noted in the Appendix, Mexico and some Central American countries are included in the South American region.

FIGURE 4 REGIONAL TOTAL NET SUBSIDIES TO FOSSIL FUELS, 1980-2010

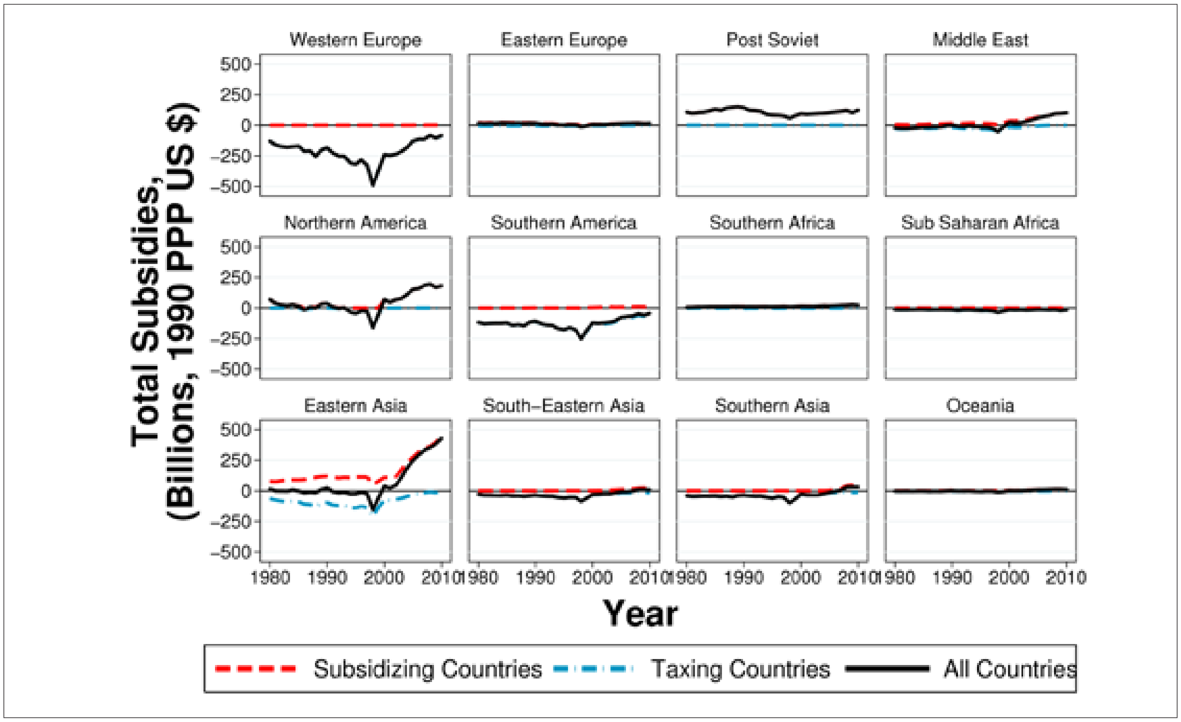
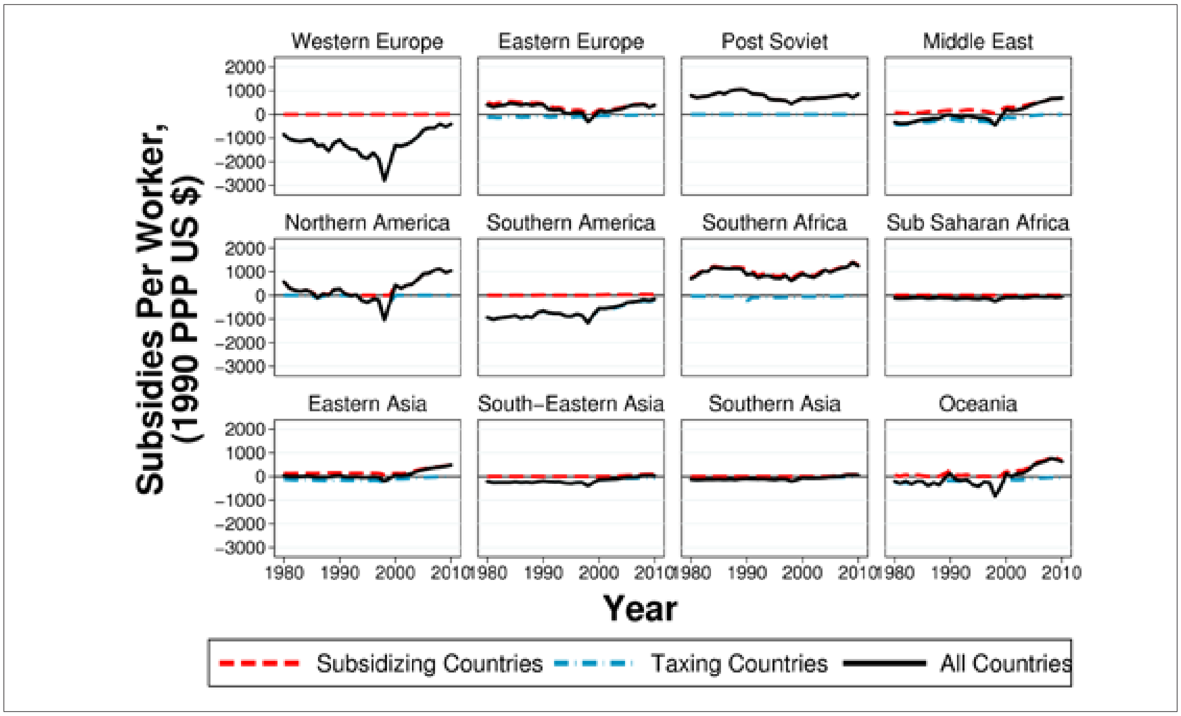


FIGURE 5 REGIONAL TOTAL NET SUBSIDIES TO FOSSIL FUELS, 1980-2010



On the taxation side, we observe a number of interesting parallels. First, four regions account for over 80 per cent of the world's fossil fuel taxes: Western Europe, Southern America, Eastern Asia and Southern Asia. Second, among these regions between 60 and 70 per cent of taxes stem only from Western Europe and South America alone. Third, most of the decline in taxes after 1998 has come from declines in taxes in Western Europe and East Asia and —to a lesser extent— Southern America.

FIGURE 6 SHARE OF NET SUBSIDIES IN GDP (CONSTANT PRICE), 1980-2010

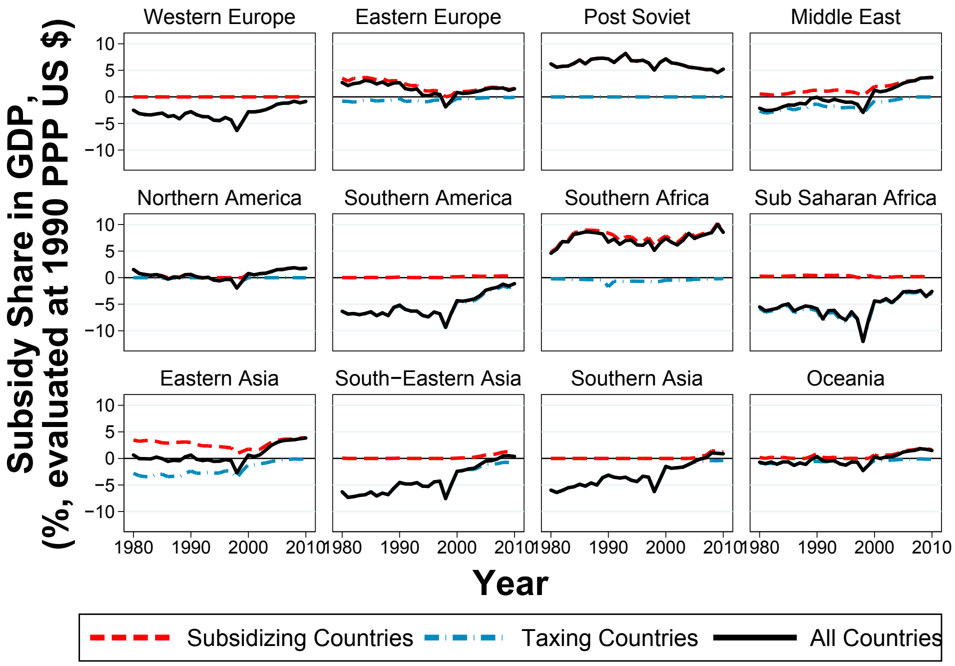


FIGURE 7 REGIONAL PRICES OF FOSSIL FUELS RELATIVE TO UNDISTORTED PRICE, 1980-2010

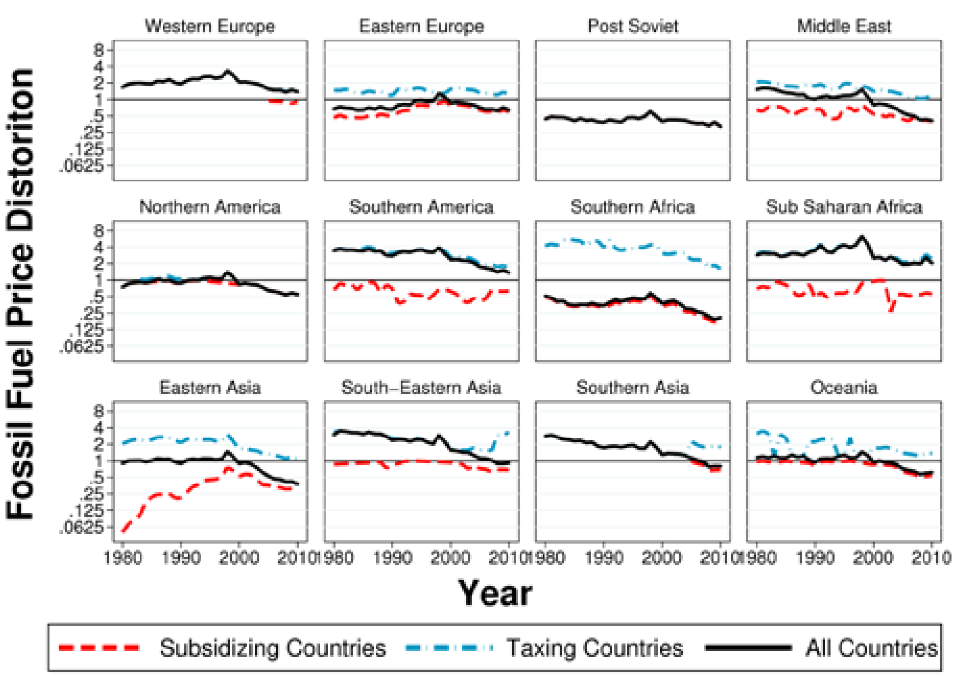
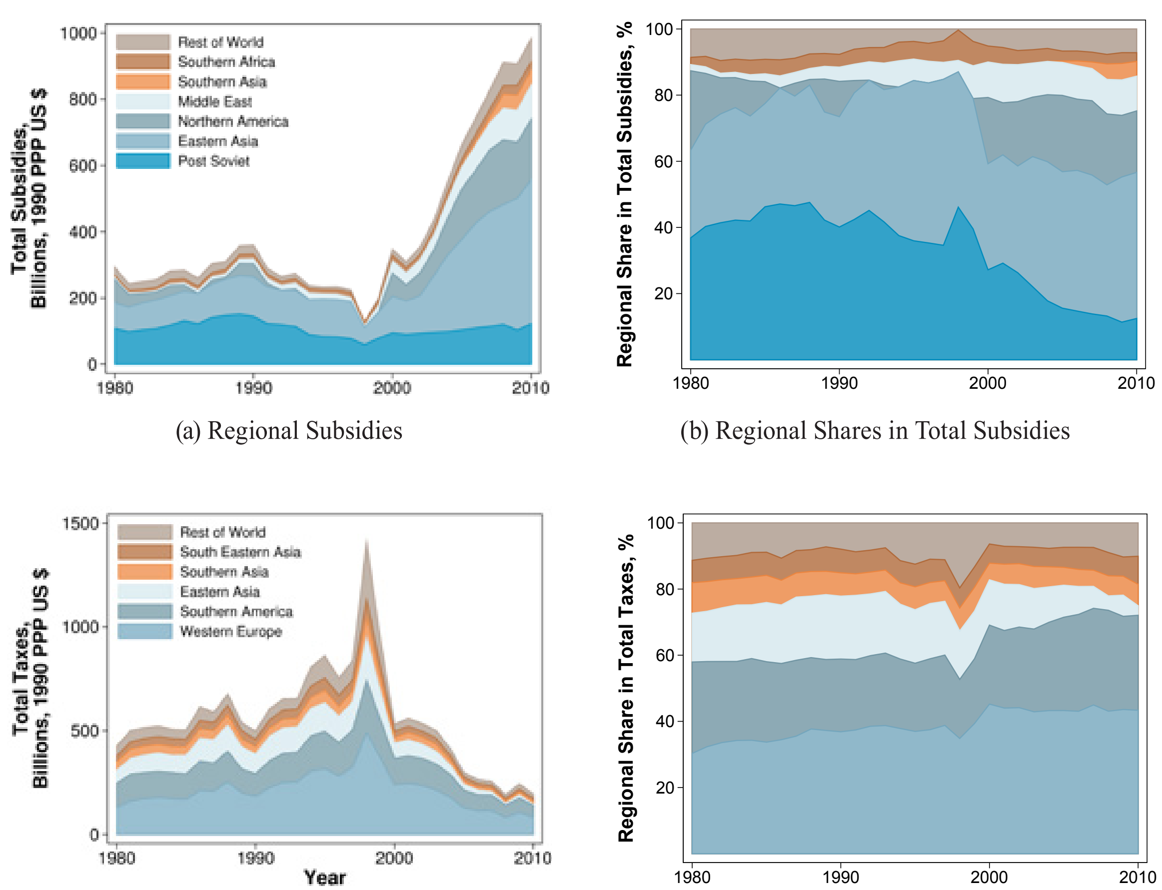


FIGURE 8 REGIONAL FOSSIL FUEL NET SUBSIDIES AND NET TAXES, 1980-2010



(a) Regional Subsidies

(b) Regional Shares in Total Subsidies

(c) Regional Taxes

(d) Regional Shares in Total Taxes

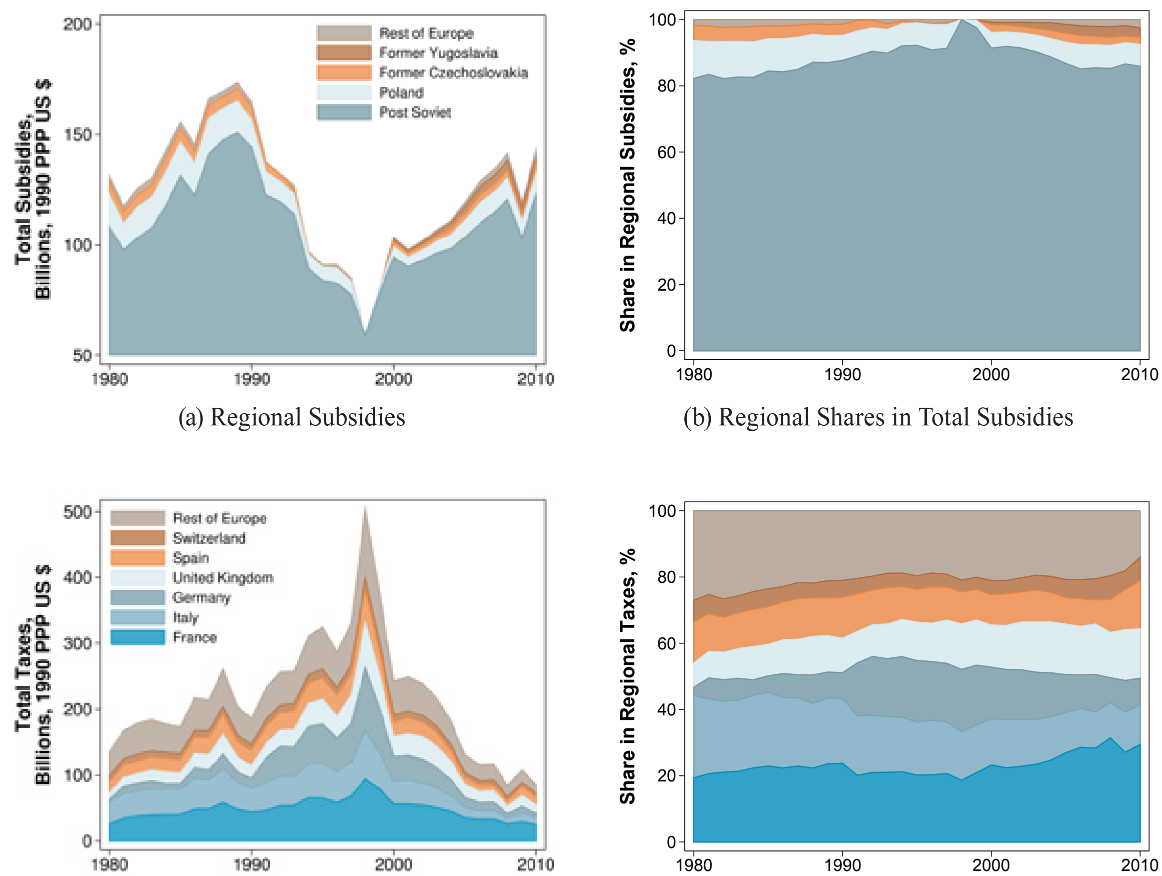
7. COUNTRY ANALYSIS

Next, I turn to the role in international fossil fuel policies played by individual countries. Recall that the total value of subsidies either globally or regionally is the sum of the value of net subsidies of all countries (globally or regionally) that have positive net subsidies. The total value of taxes either globally or regionally is the sum of the value of net subsidies of all countries (globally or regionally) that have negative net subsidies. In this section I will examine the particular countries that were key drivers of the regional and global subsidy behavior described above.

Europe

Figure 9 shows the key contributors to European fossil fuel subsidies and taxes. The (ex-) Soviet Union accounts for the vast majority of all subsidies on the continent — contributing between 82-100 per cent of the value of total subsidies, which was on average $108 billion

FIGURE 9 EUROPE: FOSSIL FUEL NET SUBSIDIES AND NET TAXES, 1980-2010



(a) Regional Subsidies

(b) Regional Shares in Total Subsidies

(c) Regional Taxes

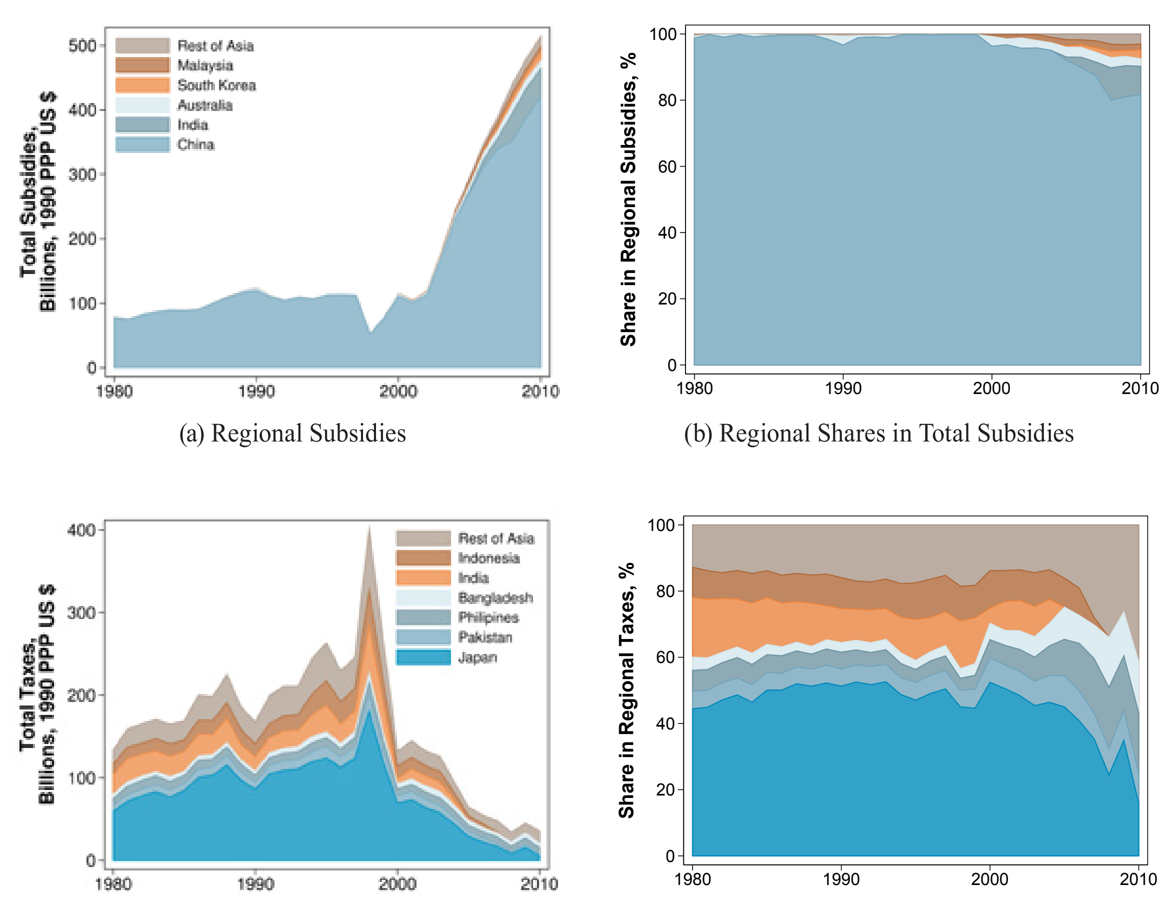
(d) Regional Shares in Total Taxes

USD a year between 1980 and 2010. Poland and the former Czechoslovakia come a very distant second and third with an average annual value of net subsidies of $9 billion and $3.6 billion USD respectively. In terms of taxation, there is far more diversity across European countries. The largest value of fossil fuel taxes is to be found in France, where they are an annual average of $48 billion USD or 23 per cent of the regional total. The value of Italy's net taxes has also been large, accounting for roughly 25 per cent of the continent's taxes in 1980, but it has fallen steadily to roughly 12 per cent or $10 billion by 2010 — similar in size to Germany ($7 billion USD), the U.K. ($13 billion USD) and Spain ($12 billion USD). Finally, and perhaps surprisingly, Switzerland also has high implicit net taxes and in 2010 accounted for approximately seven per cent of European taxes or $6 billion USD. All remaining countries in Europe have accounted for, on average, 21 per cent of taxes over the entire period, falling to a low of 14 per cent in 2010.

Asia

Figure 10 shows the key contributors to Asian fossil fuel subsidies and taxes. Before 2000, virtually all Asian subsidies of $97 billion per year were from China. By 2010, China's share had fallen to 82 per cent but in absolute terms its subsidies had risen to $420 billion. In 2010, India accounted for 8.5 per cent ($44 billion), South Korea for 2.7 per cent ($14

FIGURE 10 ASIA: FOSSIL FUEL NET SUBSIDIES AND NET TAXES, 1980-2010



(a) Regional Subsidies

(b) Regional Shares in Total Subsidies

(c) Regional Taxes

(d) Regional Shares in Total Taxes

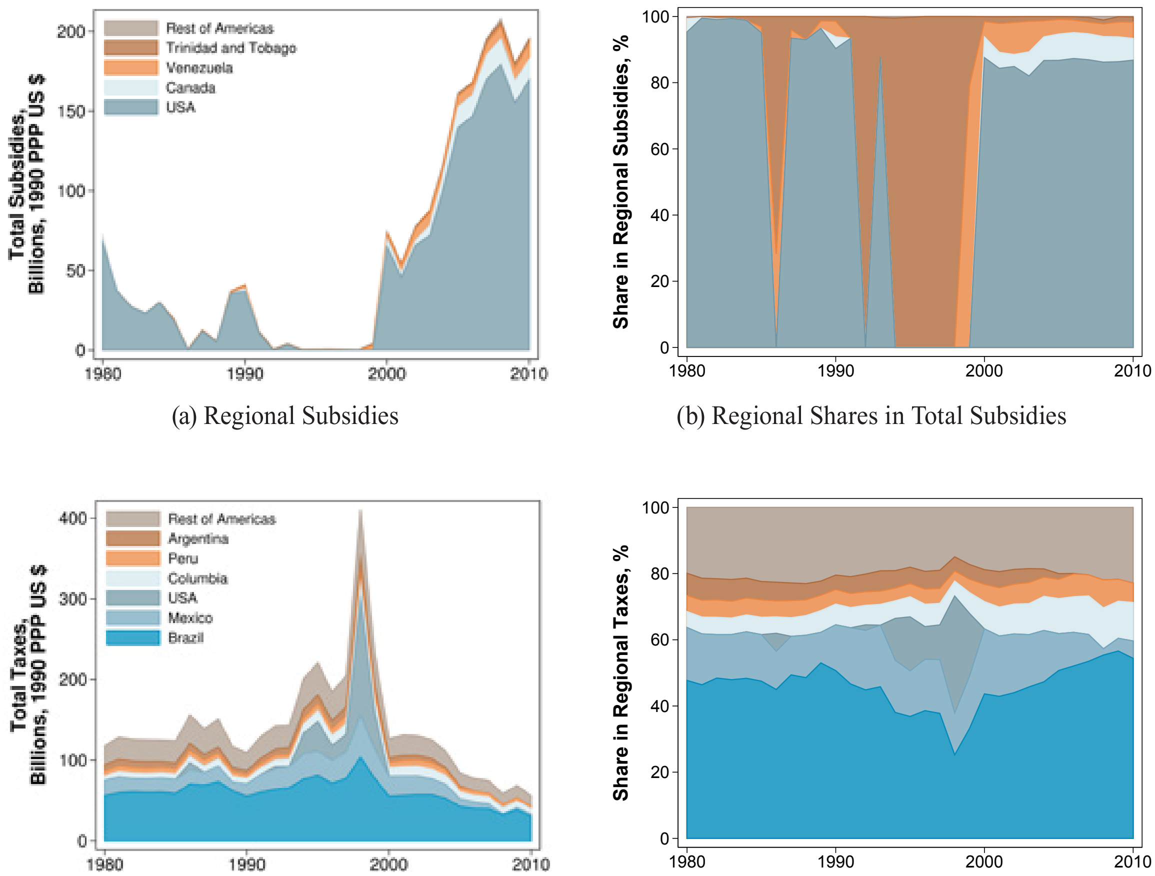
billion dollars) and Malaysia for 1.8 per cent ($9.1 billion) with the rest of Asia accounting for only 5.1 per cent ($27 billion). Finally, notice that the vast majority of the increase in the value of subsidies in Asia seen after 1998 has been driven by an explosion of Chinese subsidies — from approximately $111 billion in 2000 to an enormous $420 billion in 2010.

In terms of taxation, Japan contributed on average 49 per cent of Asian taxes (or $92 billion a year) between 1980 and the mid-2000s, after which its share fell to only 16 per cent and its total taxes fell to $5.6 billion. The other large contributor countries were the Philippines (18 per cent or $6.5 billion in 2010), Bangladesh (15 per cent or $5.5 billion) and Pakistan (nine per cent or $3.2 billion). Interestingly, until the mid-2000s India and Indonesia also had large implicit fossil fuel taxes but subsequently switched to pro-fossil fuel policies.

The Americas

The evolution of the value of subsidies and taxes in the Americas is shown in Figure 11. In general, the highest subsidies by far have come from the U.S., although it has followed rather more volatile policies than most other subsidizing countries. Throughout the 1980s the U.S. had largely positive net subsidies of approximately $28 billion per year. This accounted for virtually all net subsidies of the region for this period. Throughout much of

FIGURE 11 THE AMERICAS: FOSSIL FUEL NET SUBSIDIES AND NET TAXES, 1980-2010



(a) Regional Subsidies

(b) Regional Shares in Total Subsidies

(c) Regional Taxes

(d) Regional Shares in Total Taxes

the 1990s, the U.S. had negative net subsidies and hence did not contribute to the region's measure of subsidies. During this period most net subsidies in the Americas came from Trinidad and Tobago and Venezuela. Finally, in the late 1990s and throughout the 2000s there was an explosion of net fossil fuel subsidies in the U.S. from almost zero in 1991 to $170 billion or 87 per cent of all subsidies in the Americas in 2010. During this period, virtually all remaining subsidies were accounted for by Canada (6.5 per cent or $13 billion) and Venezuela (five per cent or $9.7 billion).

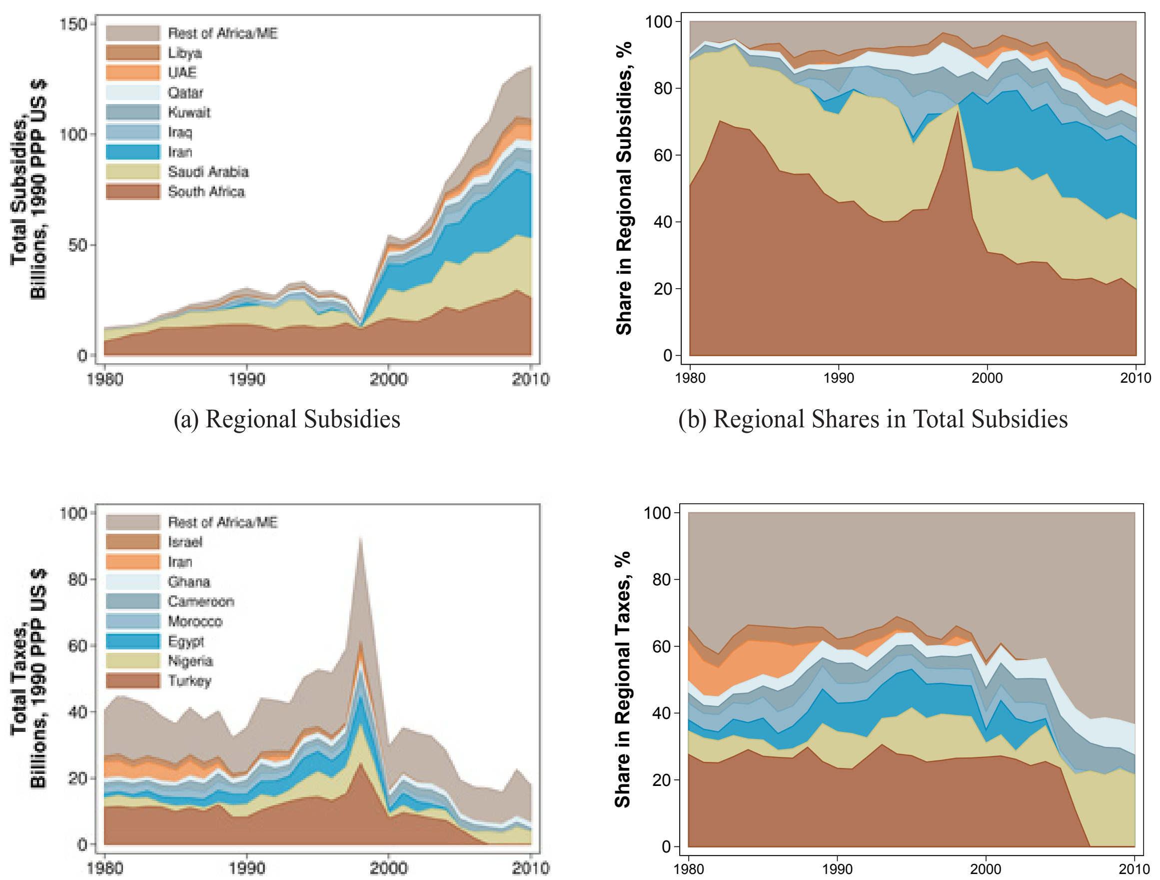
Fossil fuel taxes in the Americas were dominated by Brazil, where they numbered on average $60 billion a year and accounted for approximately 46 per cent of the region's total fossil fuel taxes. Historically, Mexico has also had high levels of taxation of fossil fuels, approximately $19 billion dollars or 16 per cent of the total in 1980, but this has fallen to only $2.9 billion or five per cent of the total by 2010. During the mid-to-late 1990s the U.S. had positive net tax rates on fossil fuels and was an important contributor to the total value of fossil fuel taxes in the region. In particular, it accounted for approximately 17 per cent of the region's total taxes or approximately $48 billion a year in taxes over this period. Finally, Columbia and Peru have had high values of taxes on fossil fuels as well (accounting for approximately 12 and six per cent of the regional total in 2010 respectively). Argentina also used to be a country with net fossil fuel taxes (as high as seven per cent or $8 billion of the region's total taxes in 1980) until 2005, but more recently it has become a net subsidizer of fossil fuels. Taxes are very common in South and Central America, and thus the remaining countries of the Americas account for the other 20 per cent of the region's taxes, with no dominant country.

Africa and the Middle East

Figure 12 shows the evolution of subsidies and taxes in Africa and the Middle East. This is perhaps the most diverse region with respect to fossil fuel policies and numerous countries have either large subsidies or taxes. Iran has the highest value of net subsidies of the region, at nearly $30 billion or 22 per cent of regional subsidies in 2010. Iran's dominance however, is relatively recent and as late as 1998 Iran was actually a country that (on the net) taxed fossil fuels. Next is Saudi Arabia with $27 billion of subsidies or 21 per cent of the region's subsidies in 2010. Somewhat surprisingly, historically (and in almost every other year since 1980), the largest subsidizer of the region has been South Africa, which spent $26 billion on net subsidies in 2010 alone and accounted for 20 per cent of the region's subsidies. At its peak however, South Africa accounted for 73 per cent of the region's subsidies in 1998. The other large subsidizers of the region are Iraq, Kuwait, Qatar, the United Arab Emirates (UAE) and Libya, which together spent $25 billion or 19 per cent of the regional total. Notice also that the absolute value of subsidies has been increasing in each of these countries over time. Finally, the rest of the region spent $24 billion on subsidies in 2010 or 18 per cent of the total.

Taxation is far more diverse and widespread across countries of the region. Until the mid-2000s, the country with the largest value of taxation of fossil fuels was Turkey, with an average of $11 billion a year in taxes or 26 per cent of the total. However, subsequently, Turkey became a net subsidizer of fossil fuels. Nigeria is the region's second highest taxer, with the value of taxes exploding after the mid 2000s and reaching $3.8 billion USD (or 22 per cent of the total) in 2010. Whilst this may seem surprising since Nigeria is a country that is often associated with high levels of subsidies, recall that the measure of subsidies used in this paper is broad and includes both direct and indirect measures of subsidization. Thus, the measure of subsidies captured here includes a whole host of other indirect policies or circumstances that result in Nigeria consuming disproportionately less fossil fuels than it otherwise should. Afterwards, there is Ghana ($1.6 billion USD and nine per cent of the regional total in 2010) and Cameroon ($1 USD billion and six per cent of the regional total in 2010). Historically, both Iran and Israel, as well as Egypt and Morocco, also had high levels of taxes, however in the early 2000s (for the first two countries) and the mid-2000s for the latter two countries, these policies reversed to (net) subsidies. Altogether, the above countries only accounted for approximately 40 per cent of the value of the region's total taxes in 2010. Unlike other regions (and besides Turkey), there were thus no dominant countries in the sphere of taxation. This reflects both the large number of countries in the region and the fact that each country tended to have a relatively similar policy of taxing fossil fuels with respect to the rest of the region. Notice, however, that on a global scale, the value of taxes in the remaining countries amounted to approximately $11 billion and was thus relatively small on the global level.

FIGURE 12 AFRICA AND THE MIDDLE EAST: FOSSIL FUEL NET SUBSIDIES AND NET TAXES, 1980-2010



(a) Regional Subsidies

(b) Regional Shares in Total Subsidies

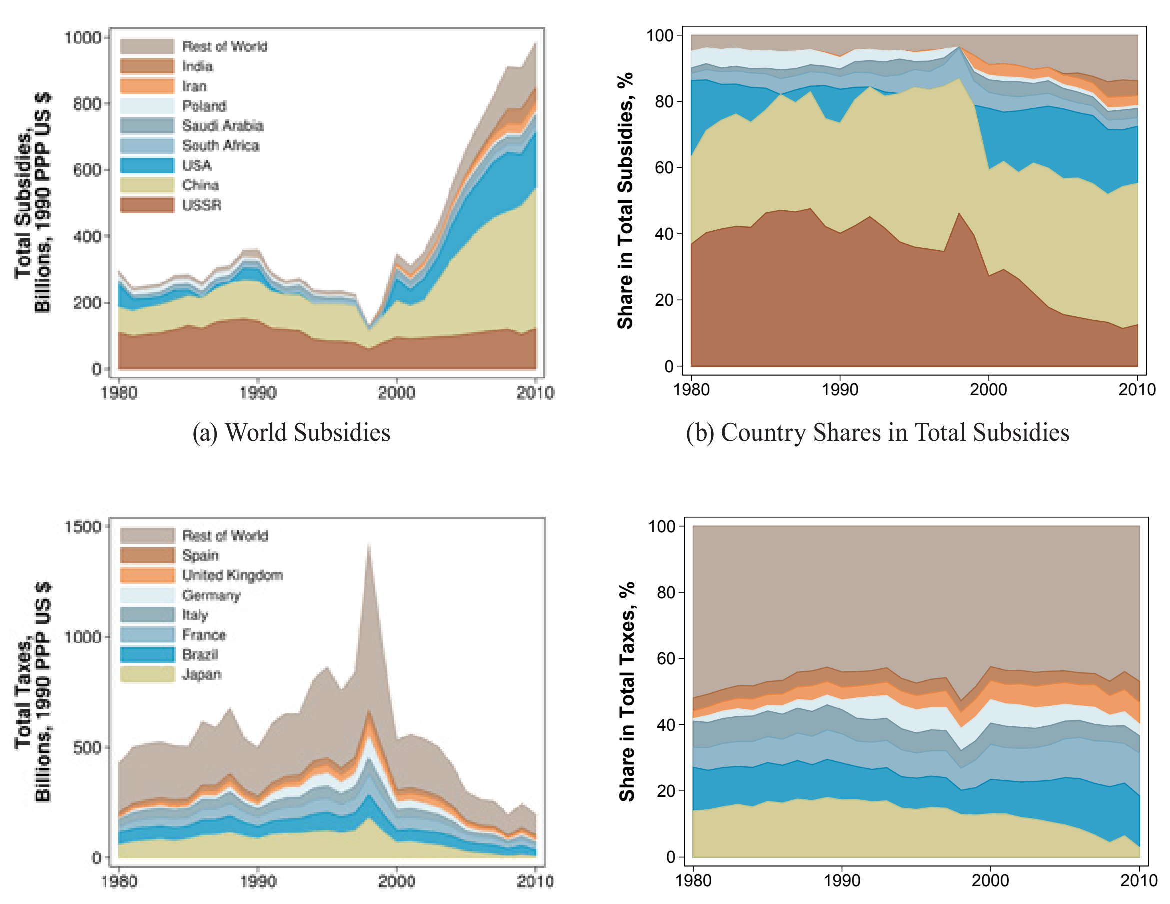
(c) Regional Taxes

(d) Regional Shares in Total Taxes

OVERVIEW

In Figure 13, I decompose the information from Figure 3(a) and 8 by country and compare the contribution of individual states to the evolution of global fossil fuel policy. As we saw above, subsidies are entirely dominated by the former Soviet Union, China and the U.S. where, in 2010, the value of subsidies amounted to $712 billion or nearly 80 per cent of the total world value of subsidies. Furthermore, the massive increase in the value of subsidies after 1998 is due primarily to the spectacular growth of the value of subsidies in China and to a somewhat lesser extent in the U.S. In terms of taxes, the picture is less clear-cut. The country with the largest taxes has historically been Japan, although recently its taxes have fallen and it has been overtaken by Brazil. Together, in 2010, Brazil and Japan account for 19 per cent of the value of world fossil fuel taxes or $36 billion. Following these two countries are the big five European countries of France, Italy, Germany, the U.K. and Spain. France here has the largest value of taxes among these countries; in 2010 its tax was approximately $25 billion dollars and accounted for 13 per cent of the value of global fossil fuel taxes. In total, the five European countries account for 35 per cent of the value of

FIGURE 13 COUNTRY TOTALS: FOSSIL FUEL NET SUBSIDIES AND NET TAXES, 1980-2010



(a) World Subsidies

(b) Country Shares in Total Subsidies

(c) World Taxes

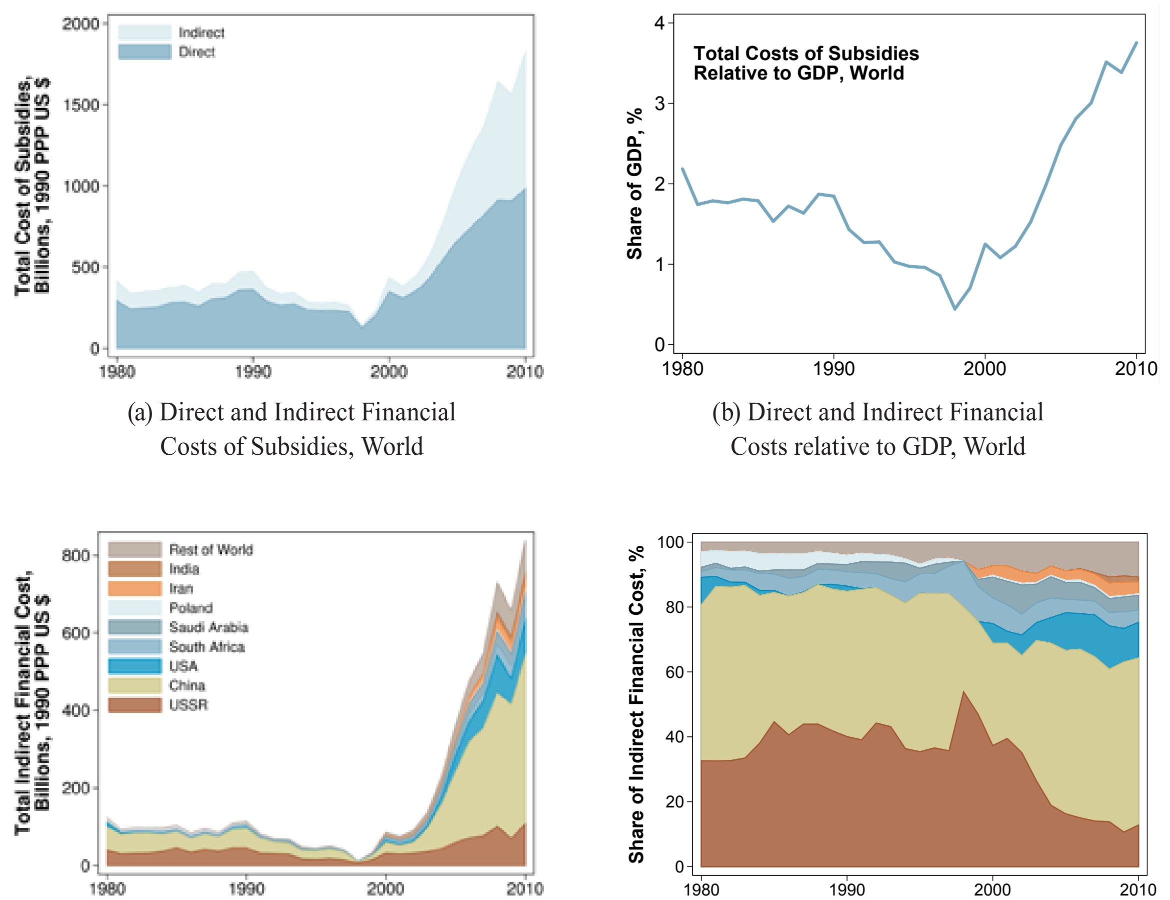
(d) Country Shares in Total Taxes

world fossil fuel taxes or approximately $67 billion. Besides Japan, Brazil and the European countries, taxes are quite evenly distributed; the remaining countries of the world account for approximately 47 per cent of world taxes.

8. THE INDIRECT COSTS OF SUBSIDIES

The above sections focused on examining the direct or out of pocket costs of subsidies. However, besides generating direct costs, subsidies also generate two types of indirect costs. First, since subsidies are distortions to energy prices, they result in individuals and firms misallocating resources and using too much energy and too little of other inputs. This in turn results in lower levels of GDP, since resources could otherwise be more efficiently used to produce more output. The difference in GDP between the observed world and the world without distortions is thus the indirect financial cost of fossil fuel subsidies. Second of all, since we use more fossil fuel energy when it is cheaper, we are also emitting too much carbon dioxide. The difference in emissions between scenarios where we pollute too much and the right amount is the environmental cost of subsidies. A huge advantage of the model-based methodology of extracting subsidies developed in RLS is that the model can be used to perform counterfactual experiments. In particular, (net) fossil fuel subsidies can

FIGURE 14 INDIRECT FINANCIAL COSTS OF FOSSIL FUEL SUBSIDIES, 1980-2010



(a) Direct and Indirect Financial Costs of Subsidies, World

(b) Direct and Indirect Financial Costs relative to GDP, World

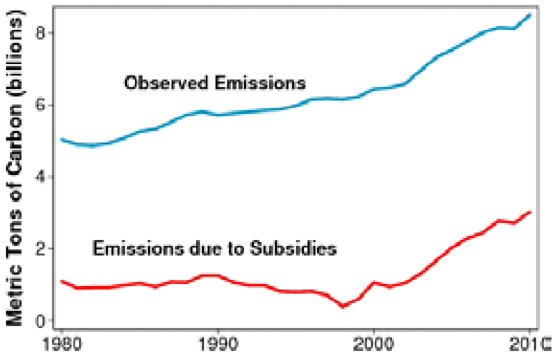
(c) World Indirect Financial Costs, by Country

(d) Share of World Indirect Financial Costs, by Country

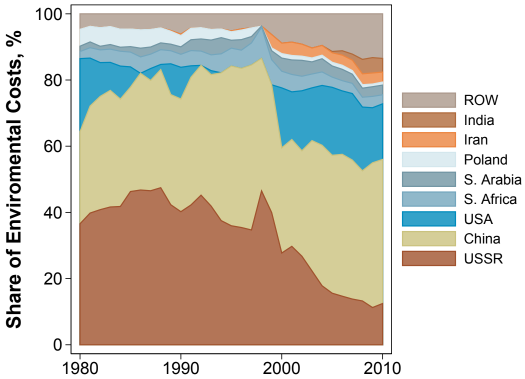
be set to zero in all countries where they are positive, whilst keeping all other aspects of the countries unchanged. This then allows me to calculate a measure of the additional indirect financial and environmental costs of positive net subsidies by seeing the implications that the model with zero subsidies would have on emissions and GDP.[69] In the following section, I proceed to analyze these indirect costs. First, Figure 14 plots the total financial costs of subsidies calculated as the sum of direct costs (from the previous section) and indirect financial costs of subsidies, which are simply the difference between GDP measures in a world with and without subsidies. Notice that indirect costs are massive and follow a similar pattern to direct costs. In 1980, they amounted to $122 billion, which was approximately 42 per cent of direct costs at the time. Their value falls to $12 billion by 1998 when they constitute only 9.2 per cent of direct costs. However, as subsidies exploded in the 2000s, so did the indirect costs of these subsidies. By 2010, the global indirect financial costs of subsidies reached $838 billion or 85 per cent of global direct subsidies. Thus, in 2010, the combined direct and indirect financial costs were a stunning $1.82 trillion. Figure 14(b),

[69] Notice, that since I am focusing on the indirect costs of *positive* net subsidies, I leave negative net subsidies entirely unchanged in the counterfactual. This is not meant to imply that positive net subsidies are considered to be distortionary, while negative net subsidies are treated as optimal corrective mechanisms. Instead, the exercise is an attempt to quantify the indirect cost of positive net subsidies *only*, rather than also considering the distortive costs of negative net subsidies.

FIGURE 15 INDIRECT ENVIRONMENTAL COSTS OF FOSSIL FUEL SUBSIDIES, 1980-2010



(a) Indirect Environmental Costs of Subsidies, World



(b) Share in Indirect Environmental Costs, World

plots these total financial costs as a fraction of global GDP. The total financial costs of subsidies oscillate between 0.4 per cent of global GDP in 1998, to an astounding 3.8 per cent in 2010.

Second, Figures 14(c) and 14(d), decompose the indirect costs by country. Once more, we observe that China, the former Soviet Union and the U.S. account for the vast majority of indirect subsidies. Interestingly, China bears a disproportionately greater share of the indirect costs than the direct costs. The reason is that China's subsidy rates are higher than those of the U.S. Consequently, the extent of the misallocation in China is greater than in other countries.

Third, Figure 15(a) plots total global observed emissions, as well as the emissions caused by positive net subsidies. Notice that this environmental cost of subsidies is enormous. In particular, without subsidies total cumulative emissions over the entire period would be 21 per cent lower. The extent of the environmental cost varies over time in a similar fashion to subsidies themselves and rises dramatically after 1998. In particular, by the year 2010 a world without subsidies would have carbon emissions that were more than 3 billion metric tons or 36 per cent lower than what was observed.

Finally, Figure 15(b) decomposes these environmental costs by country. Again, quite unsurprisingly, we observe that the same three countries, China, the former Soviet Union and the U.S., are causing the most environmental damage, accounting for roughly 73 per cent of environmental costs associated with positive subsidies in 2010.

From the above analysis it is especially interesting to note that rising fossil fuel subsidies were responsible for nearly all the increase in global carbon emissions after 1998. Ironically, this coincided with the global adoption of the Kyoto protocol in December 1997, which bound many countries to reduce greenhouse emissions based on the premise that global warming both exists and is caused by man-made carbon emissions. The dirty little secret of international energy policy seems to be that the world is addicted to fossil fuel subsidies. Even though many governments publicly proclaimed (and continue to proclaim) their desire to cut carbon emissions, my model suggests that their words have not been backed up by concrete actions and that existing governmental policies are not only part of the problem but have in fact been making matters worse.

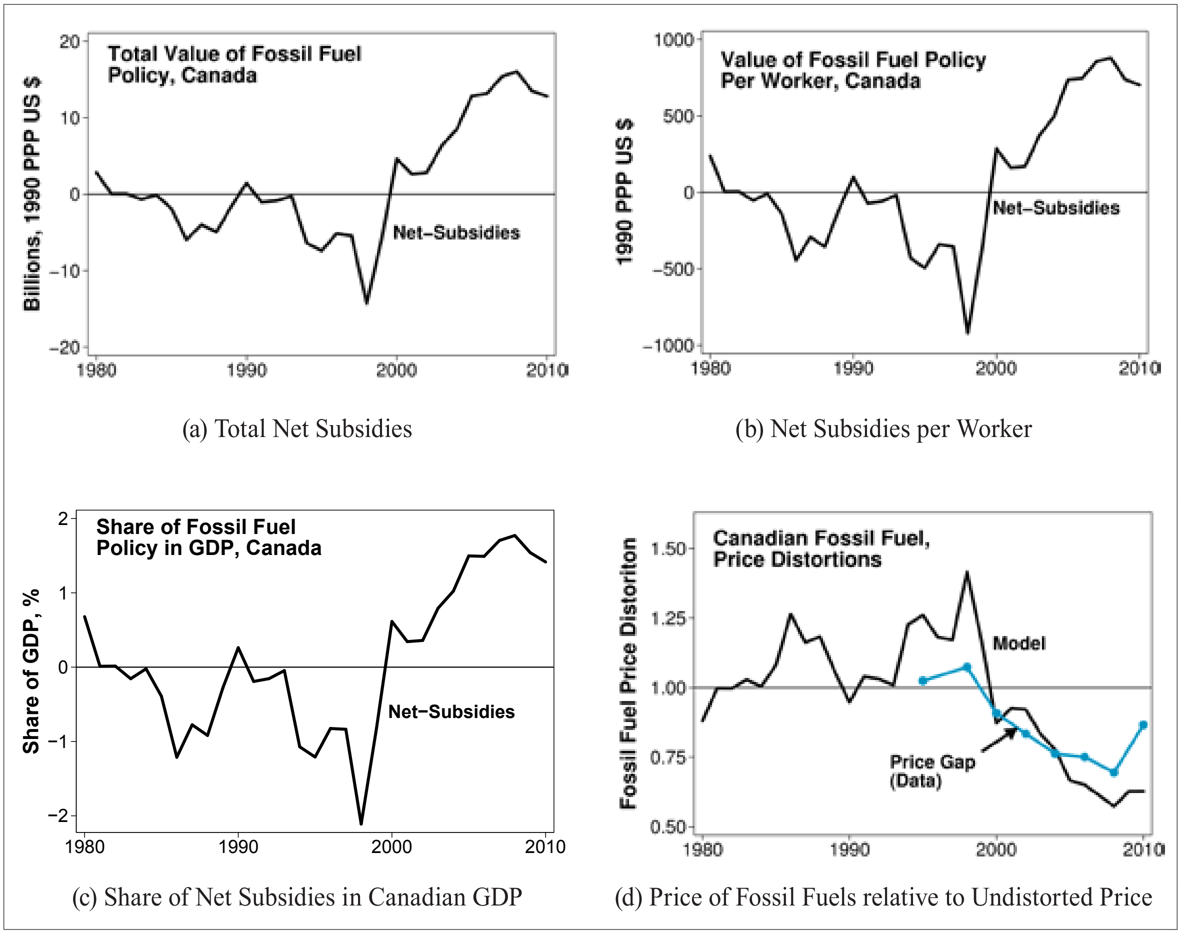
Policy makers interested in capping carbon emissions should thus not only focus on reaching multilateral agreements, but perhaps more importantly they should seek ways of making such agreements enforceable, besides acknowledging the role that governments (in addition to businesses and consumers) play in driving global emissions. The contribution of RLS in this direction is to shine a bright light on government subsidies by providing a new methodology and new data to help hold governments to account. By providing a comprehensive, clear, comparable and transparent summary of country-level estimates of the value of government subsidies, the database developed in the above paper makes it much harder for governments to publicly claim a certain action whilst continuing a business-as-usual subsidy regime in practice.

9. CANADA

In this section I focus on Canada and examine its (net) subsidies on fossil fuels, their direct and indirect costs and the impact they have had on the environment and GDP. Finally, I also examine specific policies that could potentially be driving subsidies. The black line in Figure 16 depicts the total value of net subsidies to fossil fuels in Canada over time. From the figure it emerges that until the end of the 1990s Canada largely taxed fossil fuels —on average $3 billion a year until 1998 (measured in 1990 PPP terms)— and that the value of taxes until 1998 was generally increasing. After 1998, taxes turned into subsidies which peaked in the year 2008 at approximately $16 billion (1990 PPP terms). This then fell back to $13 billion by 2010. From Figures 16(b) and 16(c) notice that at their maximum in 2008, subsidies cost each Canadian worker $880 (1990 PPP terms) a year and comprised 1.7 per cent of GDP. This amount then declined to $703 (1990 PPP terms) by 2010 or a corresponding 1.4 per cent of GDP. From the black line in Figure 16(d), notice that between 1980 and 2000 the relative implicit price of carbon energy was approximately 110 per cent of the undistorted price — implying an average tax rate on fossil fuels of 10 per cent (=1−1.10). In 2008, when subsidies reached their peak, the relative price had fallen to 57 per cent of the undistorted price, implying subsidy rates of 43 per cent (=1−0.57). By 2010, relative prices had risen to 63 per cent of the undistorted price, implying subsidy rates of 37 per cent (=1−0.63). In this last figure the blue line depicts the corresponding relative price ratio calculated using the price-gap approach from the data described earlier in Section 3. Notice that in general, the model and the data match relatively well. In the most recent years, the implicit model predicts subsidies that are larger than the price-gap subsidy estimates. This seems to match well with the fact that price-gap subsidy estimates tend to underestimate true subsidies.[70]

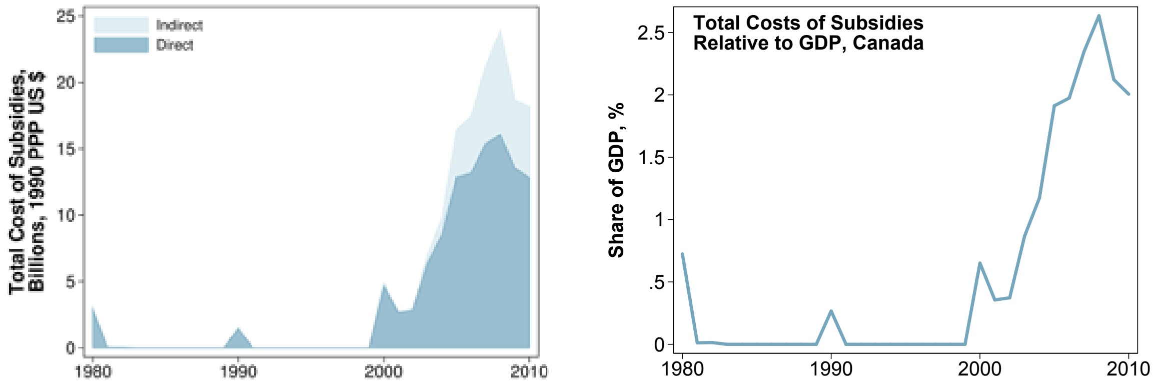
[70] See Koplow (2009) op. cit. I also calculate Canadian subsidies from other sources and convert them in comparable units (share of GDP evaluated at constant 1990 PPP prices). Again, I find that my method finds larger subsidies in Canada than subsidies from other sources. Subsidy estimates from the Auditor General (Sloan, 2012), are on-average 0.05 per cent of GDP a year between 2006-2010. According to the GSI (GSI, 2010), provincial and federal governments are providing the equivalent of 0.17 per cent of GDP in 2008 in subsidies to the oil sector in Alberta, Saskatchewan and offshore Newfoundland and Labrador alone. Both of the above figures refer to direct expenditure estimates. Using data from the IMF (2013, op. cit.) pre-tax price-gap approach, I find that subsidies in 2010 are 0.001 per cent of GDP. Finally, directly measured consumer and producer subsidies from the OECD (2013, op. cit.) are found to be approximately 0.41 per cent, 0.22 per cent and 0.28 per cent of GDP (evaluated at 1990 PPP dollars) in 2008, 2009 and 2010 respectively. However, since these represent gross rather than net subsidies, this last measurement is not really comparable to my estimates of subsidies. Finally, in my paper, I find that fossil fuel subsidies were on average 1.58 per cent of GDP (at 1990 PPP prices) per year between 2006 and 2010. Thus, estimates of subsidies vary widely across sources and my estimates tend to be the largest.

FIGURE 16 CANADA: MEASURES OF FOSSIL FUEL POLICIES, 1980-2010



As I argued above, besides generating direct costs, subsidies generate both financial and environmental indirect costs. I now examine these for the case of Canada. Figure 17(a) plots the total financial costs of subsidies in years in which net subsidies are positive, calculated as the sum of direct costs (from above) and indirect financial costs of subsidies, which are simply the difference between GDP measures in a world with and without subsidies. Notice that after 1998 indirect costs are sizable and tend to follow a similar pattern to direct costs. By 2008, indirect costs constituted 33 per cent of all financial costs associated with fossil fuel subsidies, or approximately $7.8 billion (1990 PPP terms). By 2010, this fell back to 29 per cent of all financial costs or $5.3 billion (1990 PPP terms). Thus, at their peak in 2008, total financial costs of subsidies (both direct and indirect) were approximately $24 billion (1990 PPP terms) and fell back down to $18.2 billion in 2010. According to Figure 17(b) these total financial costs corresponded to 2.6 per cent of GDP in 2008 and two per cent in 2010.

FIGURE 17 CANADA: INDIRECT FINANCIAL COSTS OF FOSSIL FUEL SUBSIDIES, 1980-2010



(a) Direct and Indirect Financial Costs of Subsidies, Canada

(b) Direct and Indirect Financial Costs Relative to GDP, Canada

Figure 18 plots counterfactual and observed emissions. Notice that the environmental costs of subsidies —represented by the difference of the two lines in the graph— are very large, especially in the post-2000 period. In particular, without subsidies total cumulative emissions between 2000 and 2010 in Canada would be 20 per cent lower. The extent of the environmental cost varies over time in a similar fashion to subsidies themselves. The cost is highest in 2008 when a Canada without subsidies would have had emissions that were 32 per cent lower than what was observed, whilst by 2010 Canada's emission would have been 28 per cent lower.

As emphasized throughout this paper, the current methodology is not designed to pinpoint specific policies that drive the evolution of fossil fuel subsidies. Nonetheless, since in this section I focus on only one country, I can more easily speculate on possible drivers of fossil fuel net subsidies in Canada. Fossil fuel net subsidy rates are driven by the evolution of both fossil fuel tax and subsidy rates. The evolution of taxes is relatively easy to document. Whilst there are numerous energy taxes in Canada, I focus on gasoline taxes since gasoline constitutes an important part of Canadian energy demand and since these taxes are relatively easy to measure. Figure 19 shows the average tax rate of gasoline at the pump in Canada between 1980 and 2010. These data come from the Canadian Taxpayers Federation (pre-1987) and from Natural Resources Canada (post-1987),[71] and document the contribution of the federal excise tax, the federal sales tax, the goods and services tax, the harmonized sales tax as well as provincial fuel taxes, transportation taxes and carbon taxes on the average retail price of a liter of gasoline. Notice that this is directly measures data and is *not* calculated using a price-gap approach. Quite strikingly, there is a steady increase in the tax rates until 1998, after which tax rates tumble by nearly 60 per cent by 2010. This closely follows the evolution of net subsidy rates found using my methodology as seen Figure 16(d). This suggests that changes in the rates of fuel tax were a key component of changing implicit net subsidies found in this paper. Figure 19 also shows the evolution of the real oil price in Canada over the period. Notice the strong negative correlation between the real oil price and gasoline tax rates. This is evidence that suggests Canadian provincial

[71] See https://www.taxpayer.com/media/20.pdf and http://www.nrcan.gc.ca/energy/fuel-prices/4593. For the pre-1987 data, to calculate tax rates, I used average retail prices of unleaded gasoline from Statistics Canada (Table 326-0009) in conjunction with tax data from the Canadian Taxpayers Federation.

FIGURE 18 CANADA: INDIRECT ENVIRONMENTAL COSTS OF FOSSIL FUEL SUBSIDIES, 1980-2010

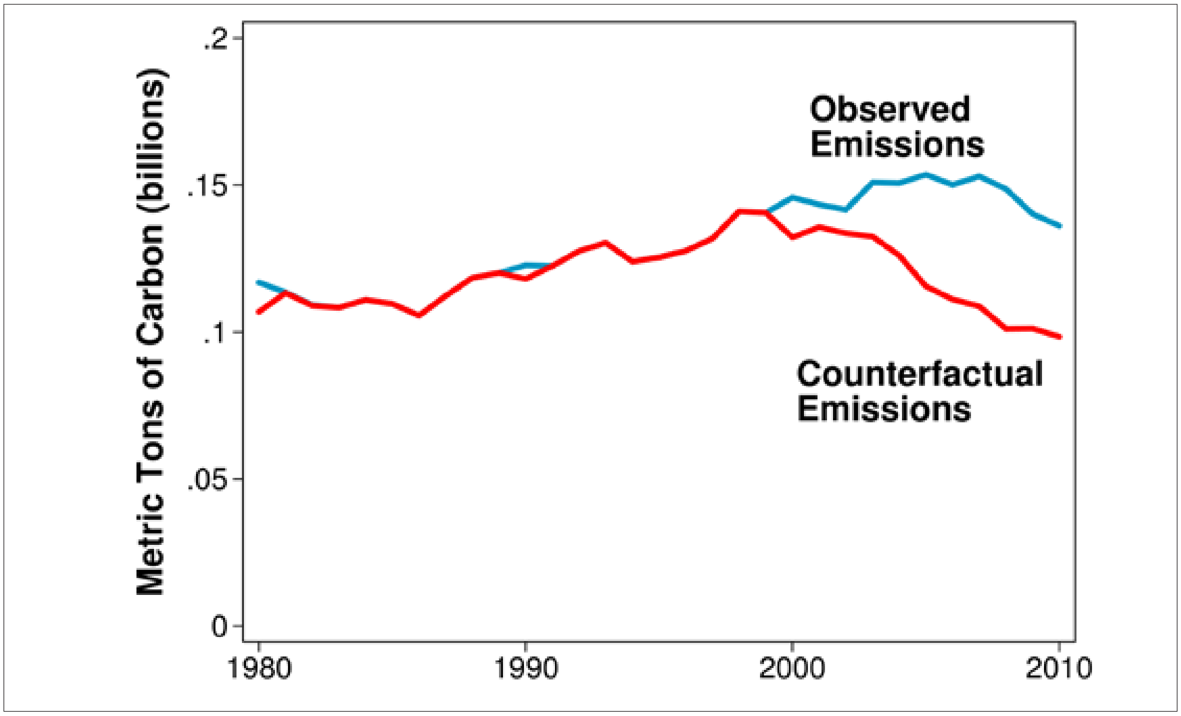
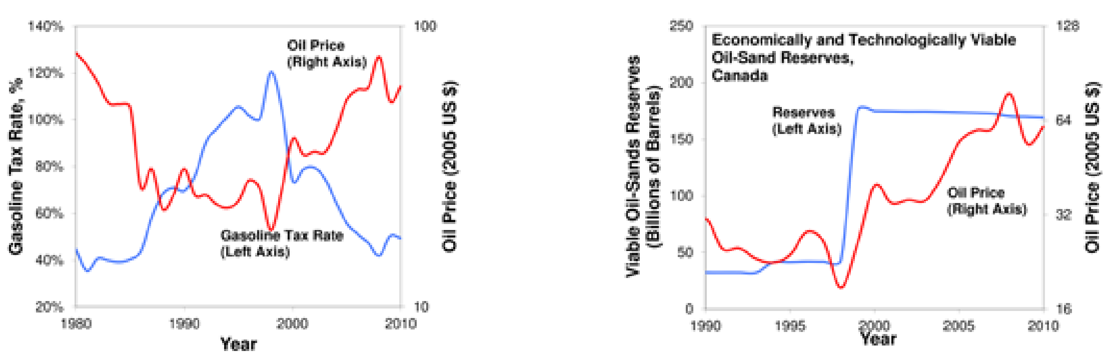


FIGURE 19 CANADA: GASOLINE TAXES, OIL SANDS RESERVES AND THE REAL OIL PRICE, CANADA



(a) Gasoline Taxes in Canada

(b) Economically and Technologically Viable Oil Sands Reserves, Canada

and federal governments set tax rates that move in the opposite direction to the oil price — perhaps wishing to cushion consumers from a rising oil price on the one hand, and attempting to maintaining steady flows of tax revenue when the oil price fell on the other hand.[72]

The analysis of gross subsidies is much harder; this is exactly the reason why indirect methods exist in the first place. The OECD[73] has documented a number of subsidy

[72] Notice that changes in tax rates are not necessarily discretionary. Most of the gasoline taxes in Canada are set as a nominal, per-liter charge that is independent of the price of gasoline. When prices of gasoline increase or fall, the implicit tax rate automatically moves in the opposite direction.

[73] OECD (2013a) op. cit.

programs in Canada. They find that oil, natural gas and electricity prices tend to be regulated in some provinces, that income tax treatment for the oil, gas and mining sectors is not neutral compared to other sectors and that exploration activity of oil, oil sands, gas, and shale gas benefits from significant tax deductions and exemptions, especially in Alberta. Furthermore, they find that some provinces also provide support to farmers and to households for energy consumption. The GSI confirms these findings and documents dozens of government programs that "seek to increase exploration and development activity with a focus on reducing the costs of exploration, drilling and development through a mix of tax breaks and royalty reductions."[74]

One particularly interesting example of a subsidization policy that can help explain the rise in implicit net subsidy rates after 1998 are the major tax breaks for the oil sands sector introduced in 1996. These tax breaks took the form of an accelerated capital cost allowance (ACCA) deduction which rose from 25 per cent to 100 per cent and allowed companies to write off their entire capital investment in a single year, contributing to a large reduction in income taxes payable.[75] This change in regulations coincided with new technological breakthroughs and a rising oil price, which contributed to greatly increasing the economic and technological viability of oil sands production as shown in Figure 19(b), which depicts a massive increase in the size of economically and technologically viable oil sands reserves in 1999 (BP, 2014).[76] The continued increase in the oil price over the next 12 years meant that oil production from the abundant oil sands reserves became ever more profitable and resulted in the oil sands share in total oil production rising from 25 per cent in 1997 to 54 per cent in 2010.[77] As an ever greater proportion of Canadian oil production shifted from a less to a more subsidized sector, the implicit subsidy rates on fossil fuels increased. Whilst the above example is illustrative, it nonetheless demonstrates another mechanism through which rising oil prices can contribute to rising implicit energy net subsidy rates without the need for additional government intervention.

10. CONCLUSION

In RLS I developed a novel methodology for inferring carbon subsidies and constructed a database of subsidies for 170 countries for the period 1980-2010. This methodology is useful for three reasons. First, it overcomes the problem of scarce data. Second, it captures a wider and more comparable measure of subsidies than existing methods. Finally, because the method is model-based, it allows me to perform counterfactuals measuring the impact of subsidies on emissions and growth. In the present paper, I presented a non-technical description of this new methodology and I performed a disaggregated analysis of the resulting subsidies by examining policies at both regional and country-specific levels. Whilst many countries subsidize carbon fuels, I find that only three countries —China,

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[74] GSI (2010) op. cit.

[75] For more detail see https://www.nrcan.gc.ca/mining-materials/taxation/mining-taxation-regime/8892.

[76] This figure refers to so-called proven oil reserves, which are defined as the amount of oil that geological and engineering information indicates with reasonable certainty can be recovered from known reservoirs *under existing economic* and operating conditions.

[77] Alberta Energy Regulator (2014).

the former Soviet Union and the U.S.— are responsible for an overwhelming majority of subsidies. Furthermore, I find that the massive increase in subsidies observed after 1998 is driven by an explosion of subsidies in just two countries: China and the U.S. Besides being vastly expensive, these subsidies have had a significant negative indirect impact. First, they have caused major misallocation of resources, which has resulted in sizeably lower levels of GDP. Second, they have also contributed to enormous additional usage of fossil fuels, which has resulted in enormous additional emissions of carbon. The concentration of fossil fuel subsidies in just a few countries also raises an interesting opportunity for policymakers interested in cutting global carbon emissions. Whilst reaching consensus on carbon emission reductions may be difficult at a global level, negotiations in a limited, trilateral setting may realistically be expected to achieve more. This is especially true as the removal of fossil fuel subsidies would be accompanied by significant increases in GDP and lower governmental expenditures.

11. APPENDIX

Regional Classifications

This section gives details on the regional classification used in this paper. The following is a list of countries in each region of my classification.

1. **Western Europe:** Andorra, Austria, Belgium, Denmark, Finland, France, Faroe Islands, Germany, Gibraltar, Greece, Ireland, Iceland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom.

2. **Eastern Europe:** Albania, Bulgaria, Bosnia and Herzegovina, Croatia, Czechoslovakia, Czech Republic, Hungary, Macedonia, Malta, Poland, Romania, Slovak Republic, Slovenia, Yugoslavia.

3. **Post-Soviet:** Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgyz Republic, Latvia, Lithuania, Moldova, Russia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan.

4. **Middle East:** Algeria, Bahrain, Cyprus, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Qatar, Saudi Arabia, Sudan, Syria, Tunisia, Turkey, United Arab Emirates, Western Sahara, Yemen.

5. **Northern America:** Bermuda, Canada, Greenland, United States.

6. **Southern America:** Anguilla, Antigua and Barbuda, Argentina, Aruba, Bahamas, Barbados, Belize, Bolivia, Brazil, Cayman Islands, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, Falkland Islands, French Guiana, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Mexico, Montserrat, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, Turks and Caicos Islands, Uruguay, Venezuela, British Virgin Islands.

7. **Southern Africa:** Botswana, Lesotho, Namibia, South Africa, Swaziland.

8. **Sub-Saharan Africa:** Angola, Benin, Burundi, Burkina Faso, Cameroon, Central African Republic, Chad, Cote d'Ivoire, Cape Verde, Comoros, Congo, Democratic Republic of the Congo, Djibouti, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Equatorial Guinea, Kenya, Liberia, Madagascar, Mali, Mauritania, Mauritius, Malawi, Mozambique, Niger, Nigeria, Reunion, Rwanda, Saint Helena, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, Tanzania, Togo, Uganda, Zambia, Zimbabwe.

9. **Eastern Asia:** China, Hong Kong, Japan, Macau, Mongolia, North Korea, South Korea.

10. **SouthEastern Asia:** Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, Vietnam.

11. **Southern Asia:** Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, Sri Lanka.

12. **Oceania:** Australia, Cook Islands, Fiji, Kiribati, Marshall Islands, Micronesia, Nauru, New Caledonia, New Zealand, Niue, Palau, Papua New Guinea, French Polynesia, Samoa, Solomon Islands, Tonga, Vanuatu, Wallis and Futuna.

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