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Into the Mire:
A closer look at fossil fuel subsidies

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Into the mire: A closer look at fossil fuel subsidies[1]

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Abstract

Stefanski (2014) develops a unique methodology to extract fossil-fuel subsidies from patterns in countries carbon emission-to-GDP ratios. This paper examines the regional, temporal and country-specific trends emerging from this 170 country, 30 year database. I find that: 1) Both the direct and indirect financial- as well as the environmental-costs of subsidies are very large and increasing; 2) The overwhelming majority of the world's subsidies come from only three countries: China, the US and the ex-USSR; 4) Whilst subsidies have been increasing almost everywhere, the vast majority of the increase comes from just two countries: China and the US.

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1 Introduction

An astonishing feature of international energy and climate policy is that fossil fuels - often seen as the primary contributor to global warming - receive enormous government support causing them to be artificially cheap and encouraging their greater use. Eliminating these distortionary policies could in principle improve efficiency, provide a reprieve to strained government budgets whilst - importantly - also lowering carbon emissions.[2] The first step towards reform however must be the transparent, comprehensive and systematic reporting of environmentally harmful subsidies. Surprisingly, a comprehensive database measuring energy subsidies directly does not exist at the international level. As argued by Koplow (2009), this is both because of political pressure from the direct beneficiaries of subsidies and because of the immense complexity of the task given the profusion and diversity of subsidy programs across countries.[3] Indirect measures of subsidies such as the ones constructed by the IMF (2013) or the IEA (2012) are based on the price-gap approach which infers national subsidies by comparing measured energy prices with an international benchmark price. The key limitations of this technique is that it does not account for government actions that support carbon energy without changing its final price (Koplow, 2009).[4] Furthermore, since estimates are based on energy prices measured 'at the pump', they incorporate significant non-traded components which bias estimated subsidies. Finally, these types of estimates exist only for a limited number of years.

In Stefanski (2014) 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 structural-transformation that generates this hump-shaped intensity and show that deviations from this pattern must be driven by distortions to sectoral-productivity and/or fossil-fuel prices. Finally, I use the calibrated model to measure these distortions for 170 countries for 1980-2010. The focus of Stefanski (2014) was 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 GDP, was largely restricted to broad, global trends and a few particular or interesting examples. In the present paper, I perform a more disaggregated exercise and take a closer look at the subsidies obtained using the above methodology and the implication of these subsidies for emissions, government spending and GDP at both the regional and country-specific level.

[2] See, for example, IEA (2012), OECD (2012), IMF (2013) or Koplow (2009).

[3] A limited attempt to directly calculate a subset of carbon subsidies has been performed by the OECD (2012). These estimates however, are only for a select number of countries and years, and more importantly, they are not comparable across countries.

[4] For example in the US, oil and gas producers receive support if they have older technology or access to more expensive reserves. As argued by Koplow (2009), "the subsidy is not likely to change the market price of heating oil or gasoline, simply because the subsidized producer is a very small player in the global oil market."

2 Context

Literature Review - Measuring Subsidies Directly measuring fossil fuel subsidies in a single country is a difficult and costly task due to the complexity of support mechanisms, their variety and the desire for opacity from the direct beneficiaries of these 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 (1952). It is based on comparing the retail price of fossil fuels in a given country to an appropriate reference price, which often takes the form of an international price adjusted for distribution and transportation costs estimated for each country. McCrone (1962) was one of the first to use this method to study agriculture subsidies in the UK. In terms of energy subsidies, papers such as OECD (1998, 2013), IEA (2006, 2008) or Coady et al. (2010) have used this method to examine the size of subsidies and study the impact of fossil fuels in selected countries. More recently Lin and Jiang (2011) use the price-gap approach to estimate China's energy subsidies whilst IMF (2013) 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 (2009). There are two key issues. First of all, 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. This is because the method requires accurate data on world reference prices, domestic taxes and transport costs. Even more importantly, the method assumes a reference price that is common across countries and does not take into account differences in non-tradable prices across countries that form an important component of fuel prices. 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 to drill in areas that would otherwise not be profitable; these will not be captured by the price-gap approach simply because the subsidized producer is small relative to the global oil market- even though an effective subsidy was paid (Koplow, 2009).

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 thus an attempt to directly quantify the 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 that it highlights the cost of particular policies and picks up the cost of programs that may not influence the price directly. The best example of this type of data construction is the recent OECD (2013) exercise which estimates the size of government support to both the production and consumption of fossil fuels in 24 OECD countries for 2005-2011.

The transfer approach also has important limitations discussed in OECD (2013), Koplow (2009) and Lin and Jiang (2011). First, there is the definitional 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 and the national context. Some countries that are more transparent than others, may in fact appear as providing more support than more opaque countries. What's more, differences in overall subsidy/tax levels may play a role. Countries with higher taxes, may provide greater support to energy, but the net level of support could be smaller. As is stated in OECD (2013), tax-expenditure accounting was not designed for international comparability. For this reason, cross-country comparisons of tax expenditures constructed in this way need to be interpreted with great caution.

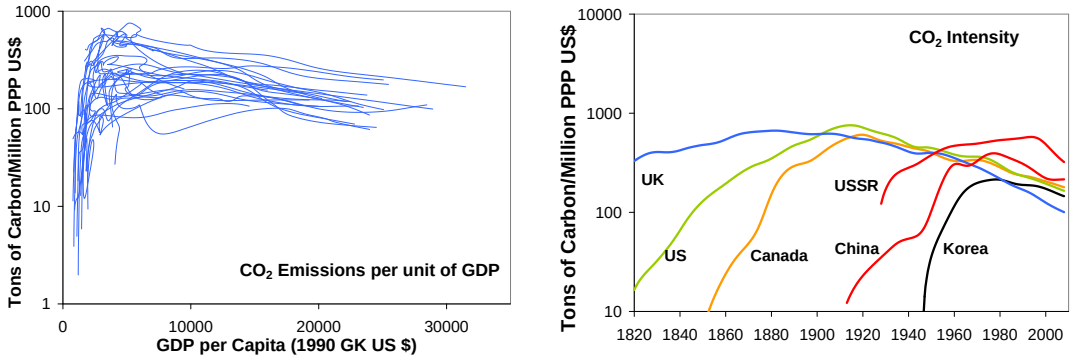
Literature Review- Theoretical Approach The method used in Stefanski (2014) (and expanded on in the next section) bypasses the above problems completely as it does not focus on energy prices, but rather on quantities of carbon dioxide emissions and on fossil-fuel energy use. These data - unlike prices or transfers - are easily measurable and freely available.[5] The suggested method is most closely related to work by Chari et al. (2007) and Duarte and Restuccia (2007). These two papers estimate the sources of business cycles and cross-country income differences respectively by estimating time-varying 'wedges' in the framework of traditional models. In particular, the authors point out that different types of distortions, imperfections, government policies etc. observed in the data can be accounted for and captured by parameters that appear like productivity, labor or investment taxes/subsidies in standard models. By

[5] 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 is 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.

matching other moments of the data, standard models can then be used to back out the size of these distortions. Chari et al. (2007) use this method to show that almost all the fluctuations in the US during the Great Depression and in 1982 stem from distortions in investment and productivity. Duarte and Restuccia (2007) on the other hand, use their model to measure sectoral labor productivity differences across countries and to assess their quantitative role on aggregate productivity outcomes across countries. The method suggested in this research agenda will thus follow the pattern and use a model to measure the size of a fossil-fuel subsidy 'wedge' in the data.

The research also ties into a long tradition of investigating the connection between emissions and economic development. This literature is huge and begins at least in the 1970's with work by Forster (1973), Solow (1973), Stiglitz (1974) and Brock (1977). The examination became more empirically orientated with work by Grossman and Krueger (1994) and Grossman and Krueger (1995) who argued that there was a hump-shaped relationship between total emissions and economic development within and across countries, which they dubbed the Environmental Kuznets Curve (EKC). Theoretical explanations for this phenomenon have been made by Lopez (1994), Copeland and Taylor (1994), Stokey (1998), Aghion and Howitt (1998), Jones and Manuelli (2001), Andreoni and Levinson (2001) and Brock and Taylor (2010). The authors have argued that a number of factors could drive the EKC such as changes in scale of production, changes in output and input mix, the current state of technology, improvements in production efficiency and emissions specific changes in processes. For a more complete review of the EKC literature see Chapter 2 of Copeland and Taylor (2003). However, as Stern (2004) argues, the problem with most of these papers is that they are strictly theoretical and do not bring their models to the data. In Stefanski (2014), not only do I propose a model theoretically capable of reproducing patterns in carbon emissions, I also bring the model to the data by demonstrating that it does a remarkably good job in reproducing patterns in carbon emissions.

The basis for my work is not the classical EKC - which was heavily criticized by Stern (2004) as lacking rigorous empirical support. Instead, I rely on the existence of a hump- shaped *emission intensity* curve (pollution per unit of GDP) with income and time. The hump-shaped pattern of emission intensity for carbon dioxide is relatively well known and very robust. Tol et al. (2009) examine this relationship for the United States for the 1850-2002 period. Lindmark (2002), Kander (2002) and Kander and Lindmark (2004) demonstrate that this relationship holds for Sweden. Bartoletto and Rubio (2008) find evidence of a similar pattern in Italy and Spain. Lindmark (2004) examines CO_2 emission intensity in forty six countries and finds that the hump shape is a feature in most of those economies. Finally, Stefanski (2013) demonstrates that a hump shape plays a key role in driving emissions in 149 countries between 1960 and 2005.



(a) OECD CO_2 Emission Intensity, 1751-2007

(b) Timing and Emission Intensity

Figure 1: Carbon Dioxide Emission Intensity Patterns

3 Methodology - A non-technical summary

The methodology used to infer subsidies in Stefanski (2014) takes an entirely different approach to previous work. In particular, it uses a method of so-called revealed preference to back out subsidies. Rather than looking at prices, which are difficult to measure, it examines the actual quantities of carbon that countries emit (and hence the amount of energy that they 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. The graph suggests that middle-income countries produce dirtier output than rich or poor countries. 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 UK - arguably the first country to start the modern development process - after which, their intensity tends to approximately follow the same path as that of the UK. An illustrative example of this envelope-pattern is shown in Figure 1(b). In the graph, the obvious exceptions are China and the former USSR, which greatly overshoot this pattern.[6] Stefanski (2014) 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. A simple model can then be used to disentangle and measure these distortions.

In particular, to do this, in Stefanski (2014) I construct a model of industrialization calibrated to the experience of the UK. The model reproduces the hump-shaped emission intensity by

[6] Notice that whilst the above are illustrative, the hump-shape and envelope patterns are statistically robust as is shown in the Appendix.

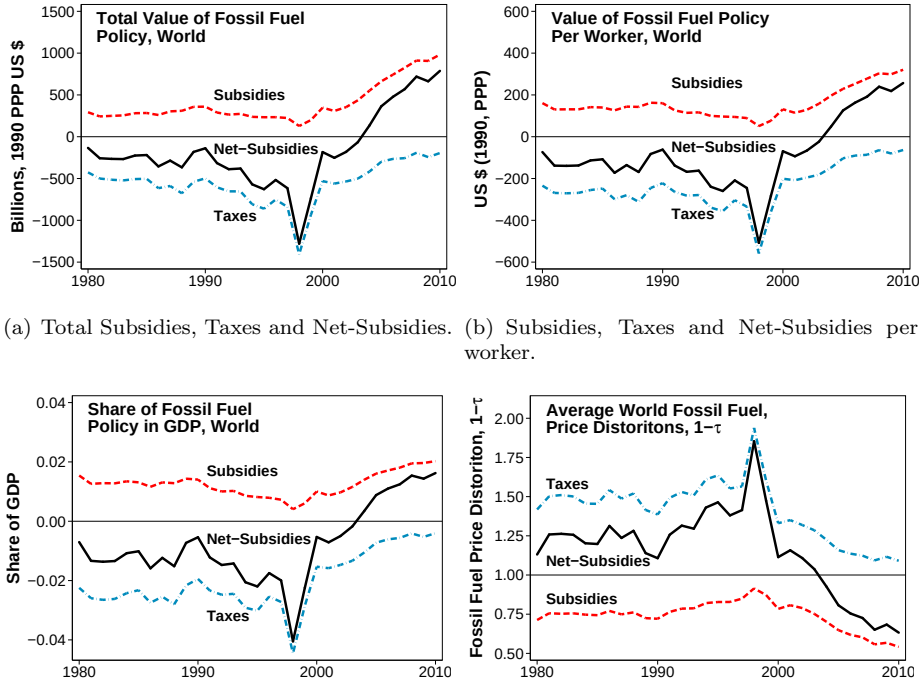
generating an endogenously changing fuel mix and energy intensity. I then examine cross-country differences in emission intensity through the lens of the model. In my framework, any deviation in a country's emission intensity from the hump shape pattern is indicative of one of three distortions or wedges within that economy: 1) a wedge to agricultural productivity, 2) a wedge to non-agricultural productivity and a 3) subsidy-like wedge to fossil fuel prices. Following the language of Chari et al. (2007) and Duarte and Restuccia (2007), these 'wedges' are objects that appear like shocks to productivity or prices in a standard model but in fact reflect a wider set of distortions, imperfections or government policies found in the data.

The contribution of Stefanski (2014) is to 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. Any other deviations from the hump-shaped pattern are symptomatic of either non-agricultural productivity wedges or subsidy-like wedges on fossil fuels. Given the calibrated, structural model data can then be used on a country's CO_2 intensity, the size of its agricultural sector and its GDP levels to measure the size of these three wedges - and in particular the size of the energy subsidy wedge across countries and over time can be inferred. In what follows, I examine in greater details the database obtained using the above technique.

4 Global Overview

I start by examining the trend of implicit fossil fuel subsidies, taxes and net-subsidies over time at a global level. The dashed red line in Figure 2(a) depicts the total value of all subsidies in the world calculated by summing over the value of subsidies in every country with positive subsidies 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. Looking at the dashed red lines in Figures 2(b) and 2(c) this translates to approximately 122 USD for every worker on the planet or 1.1% of global GDP (also measured in 1990 PPP terms). After the year 2000 subsidies grew even further. By 2010, global subsidies had increased more than three-and-a-half times and reached a level of 983 billion dollars a year - costing each worker on the planet 321 USD and comprising a stunning 2.03% of global GDP. Finally, the dashed red line in Figure 2(d) depicts the average (model implied) price of fossil fuels in subsidizing countries relative to the undistorted price.[7] In subsidizing countries, between 1980 and 2000, the relative price was approximately 78% of the undistorted price - implying an average subsidy rate on fossil fuels of 21% ($= 1 - 0.78$). By 2010, the relative price had fallen to 54% - implying subsidy rates had grown to 56%($= 1 - 0.54$).

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



(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.

Figure 2: Global Measures of Fossil Fuel Policies, 1980-2010.

Of course, whilst many countries subsidized fossil fuel, others carried out the opposite policy of taxing fossil fuels. These taxes have also been significant over the last thirty years. The dash-dotted, blue line in Figure 2(a) depicts the total value of all taxes in the world calculated by summing over the value of taxes in every country with positive taxation in a given year. Between 1980 and 2000 the value of implicit global taxes on fossil fuels was - on-average - 664 billion USD (measured in 1990 PPP terms) a year. The corresponding dash-dotted blue lines in Figure 2(b) and 2(c) indicate that this translates to approximately 294 USD for every worker on the planet or 2.6% of global GDP (also measured in 1990 PPP terms). The level of taxation however, fell dramatically after the 2000's just as the level of subsidization was rising. By 2010, global taxes had fallen by more than two-thirds and reached a level of 195 billion dollars a year - costing each worker on the planet 64 USD and comprising 0.4% of global GDP. Finally, the dash-dotted red line in Figure 2(d) depicts the average (model implied) price of fossil fuels in countries with positive taxes relative to the undistorted price.[8] In countries countries with positive taxes,

[8] 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.

between 1980 and 2000, the relative price was approximately 152% of the undistorted price - implying an average tax rate on fossil fuels of 52% ($= 1.52 - 1$). By 2010, the relative price had fallen to 109% - implying a 9% tax rate.

Finally, I examine the net-subsidies over the period. This measure subtracts the total taxes from total subsidies and examines the overall impact. From the black line in Figure 2(a), that according to this measure, between 1980-2000, fossil fuel taxes were larger than fossil fuel subsidies and that the value of net fossil fuel taxes globally was approximately 396 billion dollars. The corresponding solid black lines in Figure 2(b) and 2(c) indicate that this translates to approximately 172 USD for every worker on the planet or 1.5% of global GDP. After the year 2000 however, there was a massive reversal in these types of policies and by 2010, net-subsidies rose to 788 billion dollars (or 257 USD per worker and 1.6% of global GDP). Notice that increase was driven both by a massive surge in subsidies and a large decline if taxes. 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 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.

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 2000's. In the following sections, I will examine how regions and countries influenced the patterns observed in this section.

5 Regional Analysis

In this section I take a closer look at the above data by examining how subsidies vary across and within geographical regions around the world. In particular I examine the subsidy and tax data shown in Figure 2, but at the regional level. I divide the world into 12 geographical regions: 3 in Europe, 3 in Africa, 2 in the Americas and 4 in Asia and examine how different measures of subsidies evolve over time in these regions. Figure 3 shows the total value of subsidies, taxes and net-subsidies; Figure 4 shows per-worker subsidies, taxes and net-subsidies; Figure 5 shows the share of subsidies, taxes and net-subsidies in regional GDP and Figure 6 shows the price of fossil-fuels relative to the undistorted price in each region as well as only subsidizing or taxing parts of each region. In these graphs the red dashed line represents subsidies, the dashed-dotted blue

line represents negative subsidies (i.e. taxes) and the black thick continuous line represents net subsidies. 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 surprising, 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.

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 taxes on the planet. In 2010 the average Western European tax rate was 45% or approximately 85 billion USD in total, 422 USD per worker or 0.09% of GDP. In contrast, Former Soviet countries have had some of the highest subsidy rates in the world. In 2010 the average Soviet subsidy rate on fossil fuels was 56% or approximately 108 billion USD in total, 795 USD per worker or a staggering 6.2% of GDP. Central and Eastern European countries, lie somewhere in the middle. In the early 1980's these countries had subsidies 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 was 41% or approximately 18 billion USD in total, 406 USD per worker or 1.6% of GDP.

Whilst Western Europe has had generally high taxes on fossil fuels, it's rate of taxation has fallen by a massive 24 percentage points between 1980 and 2010, with practically the entire decline taking place after the late 1990s. Similarly, whilst not as extreme, the former Soviet Union 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 lower level in 2010 than in 1980.

Finally, notice the differences in dispersion between subsidizing and taxing countries within regions. Western Europe and the former Soviet Union had almost no countries that subsidized or taxed fossil fuels respectively. Central Europe on the other hand- although dominated by countries that subsidizing countries - had countries with more diverse policies.

Asia In Asia, implicit fossil fuel subsidies have tended to follow one of two scenarios. First, Southern and South-Eastern Asia, have seen some of the highest implicit taxes in the world that have gradually fallen over time. In particular, in 1980 the average fossil fuel tax was 181% in Southern Asia and 239% in South-Eastern Asia. By 2010 both regions were on-net slightly subsidizing fossil fuels. In particular, the average fossil fuel subsidy in Southern Asia in 2010 was 32%, 44 billion dollars in total, 71 dollars per worker or 1.2% of GDP whilst the corresponding figures in South-Eastern Asia were 32%, 24 billion dollars in total, 87 dollars per worker or 0.8% of GDP. Second, countries in Eastern Asia and Oceania tended to have near zero (net)

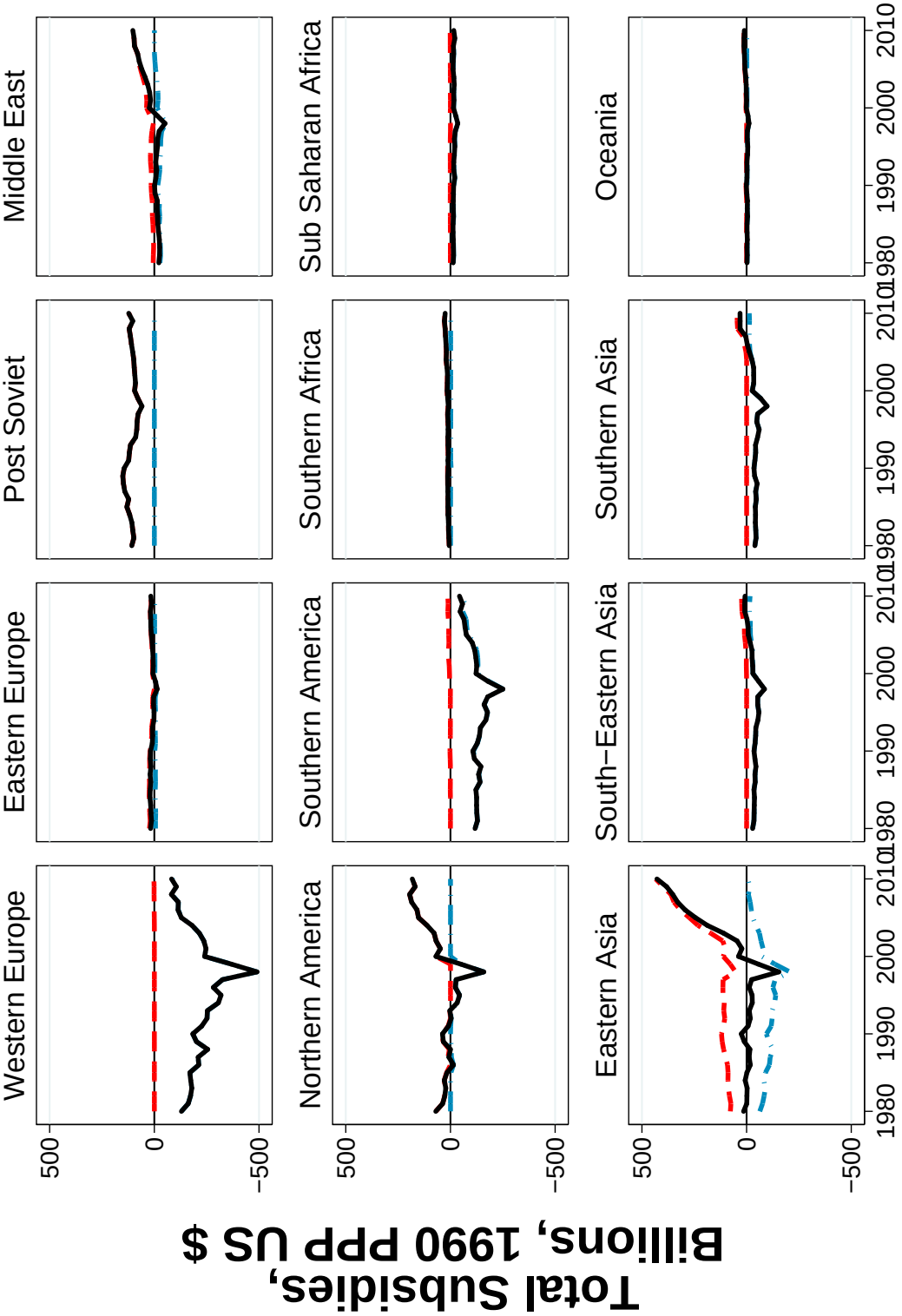


Figure 3: Regional total subsidies to fossil fuels, 1980-2010.

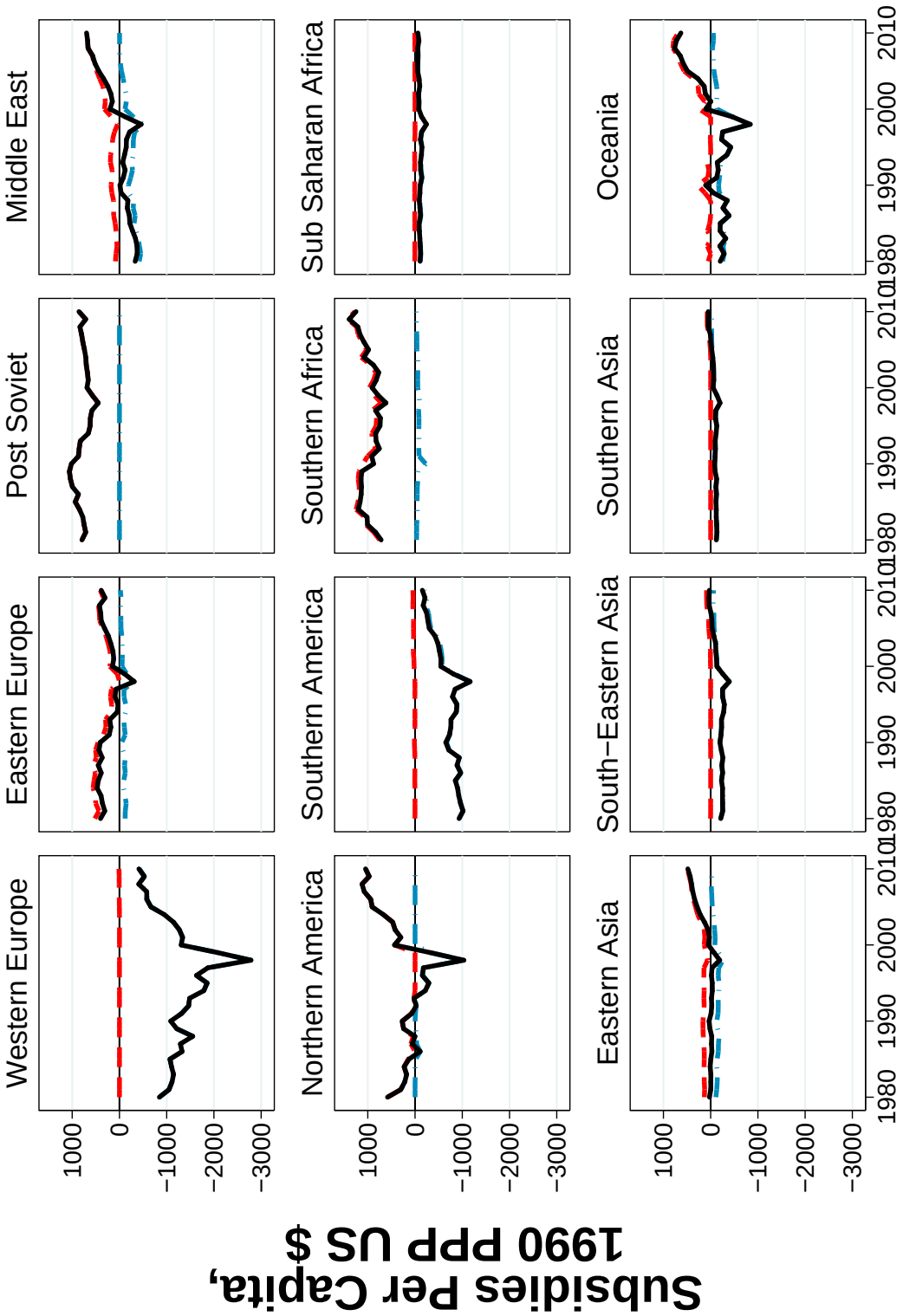


Figure 4: Regional total subsidies to fossil fuels, 1980-2010.

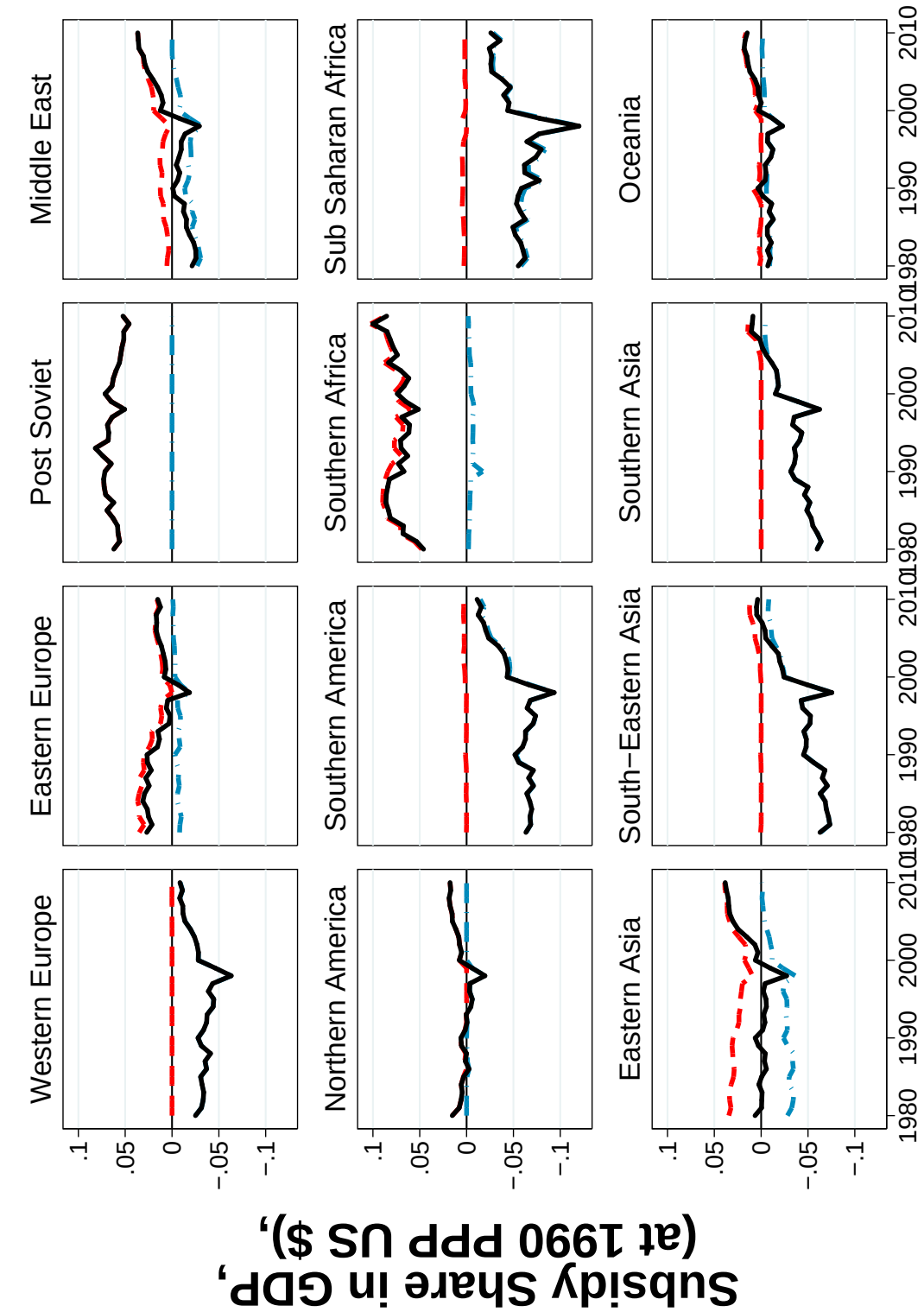


Figure 5: Share of subsidies is GDP (constant price), 1980-2010.

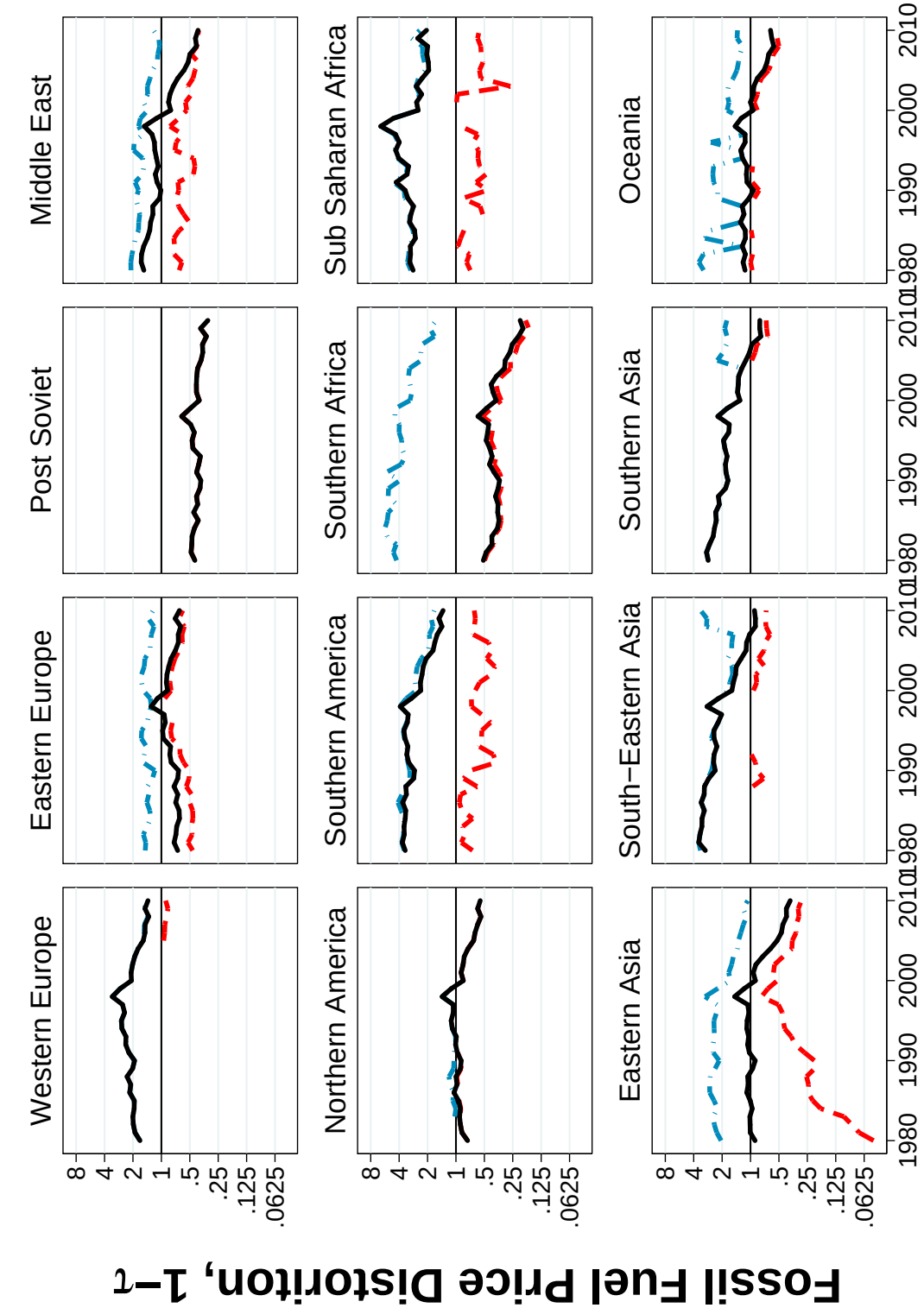


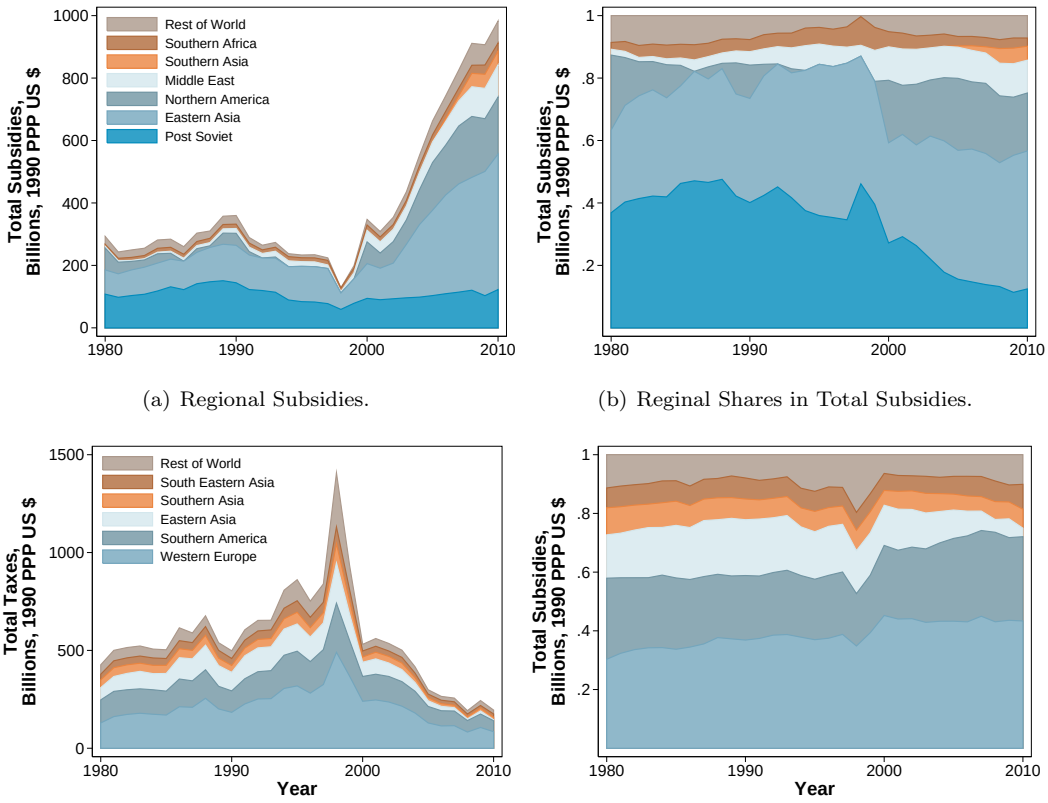
Figure 6: Regional prices of fossil-fuels relative to undistorted price, 1980-2010.

subsidies until the end of the 1990s after which both regions saw a massive increase in subsidies. In particular, in 2010 the average subsidy rate in Oceania was 46%, 12 billion USD in total, 685 USD for every worker of the region or 1.8% of the region's GDP. The 2010 average East Asian subsidy rate was 71% or a monumental 434 billion USD in total, 490 USD for every worker of the region or 3.9% 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 Southern 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 was 70%, taxes were 56 billion USD in total, 200 USD per worker or 1.5% of GDP. The Northern 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, 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 were on average 45%, 182 billion USD in total, 1048 USD per worker or 1.8% 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 (excluding Southern 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 was one of the highest in the world at 142% or 2.8% 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% in 1980 to a massive 82% and a monumental 8.7% of GDP. In absolute terms this amounts to 26 billion dollars total or 1275 dollars per worker spent on fossil fuel subsidies. Finally, the Middle East has seen fossil fuels policies change significantly over time. In 1980 it had high fossil-fuel taxes of approximately 110%. 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 was 60%, totalling 103 billion USD, 699 USD per worker or 3.7% of GDP.

Overview Finally, Figure 7, decomposes the information from Figure 2(a) by region and compares the different contribution of regions to global subsidies and taxes. In particular Figures



(a) Regional Subsidies.

(b) Reginal Shares in Total Subsidies.

(c) Regional Taxes.

(d) Reginal Shares in Total Taxes.

Figure 7: Regional Fossil Fuel Subsidies, Taxes and Net-Subsidies, 1980-2010.

7(a) and 7(c) plot the contribution of particular geographical regions to total world subsidies and taxes, whilst Figures 7(b) and 7(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% of the worlds 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 only from the Soviet region and Eastern Asia alone. Third, the total subsidies of the Soviet region have been relatively stable over time and hence its share to total subsidies has been falling. Most of the growth in subsidies seen in the 2000's has been driven by an explosion of subsidies in East Asia and Northern American and - to a lesser extent - the Middle East.

On the taxation side we observe a number of interesting parallels. First, four regions account for over 80% of the world's fossil fuel taxes: Western Europe, Southern America, Eastern Asia and Southern Asia. Second, among these regions between sixty and seventy percent of taxes

	1980				2010			
Region	Subs. Total	Subs. p.w.	Subs /GDP	Price ratio	Subs. Total	Subs. p.w.	Subs /GDP	Price ratio
Ex-Soviet	107.88	795	6.22%	.44	122.53	857	5.24%	.32
N. America	70.32	583	1.54%	.75	182.49	1048	1.77%	.55
E. Europe	16.25	580	4.45%	.54	16.7	379	1.51%	.65
E. Asia	14.65	25	0.65%	.9	428.41	484	3.84%	.38
S. Africa	6.1	718	4.60%	.52	25.37	1251	8.53%	.22
Oceania	-1.92	-202	-0.70%	1.14	10.87	630	1.49%	.61
SS Africa	-12.83	-106	-5.51%	2.71	-15.62	-60	-2.58%	2.09
Mid East	-21.31	-332	-2.13%	1.53	102.88	697	3.66%	.41
S.E. Asia	-28.49	-212	-6.28%	3.01	7.65	28	0.38%	.91
S. Asia	-39.34	-120	-5.97%	2.81	31.31	51	0.88%	.8
S. America	-117.33	-931	-6.33%	3.45	-42.95	-154	-1.12%	1.37
W.Europe	-129.24	-845	-2.50%	1.69	-82.3	-411	-0.85%	1.39

Table 1: Measures of Net Subsidies: Total Net Subsidies (in billions of 1990 PPP USD), Net Subsidies per worker (1990 PPP USD), Net Subsidies as a share of GDP (constant 1990 PPP prices), ratio of fossil fuel price to undistorted price (weighted average).

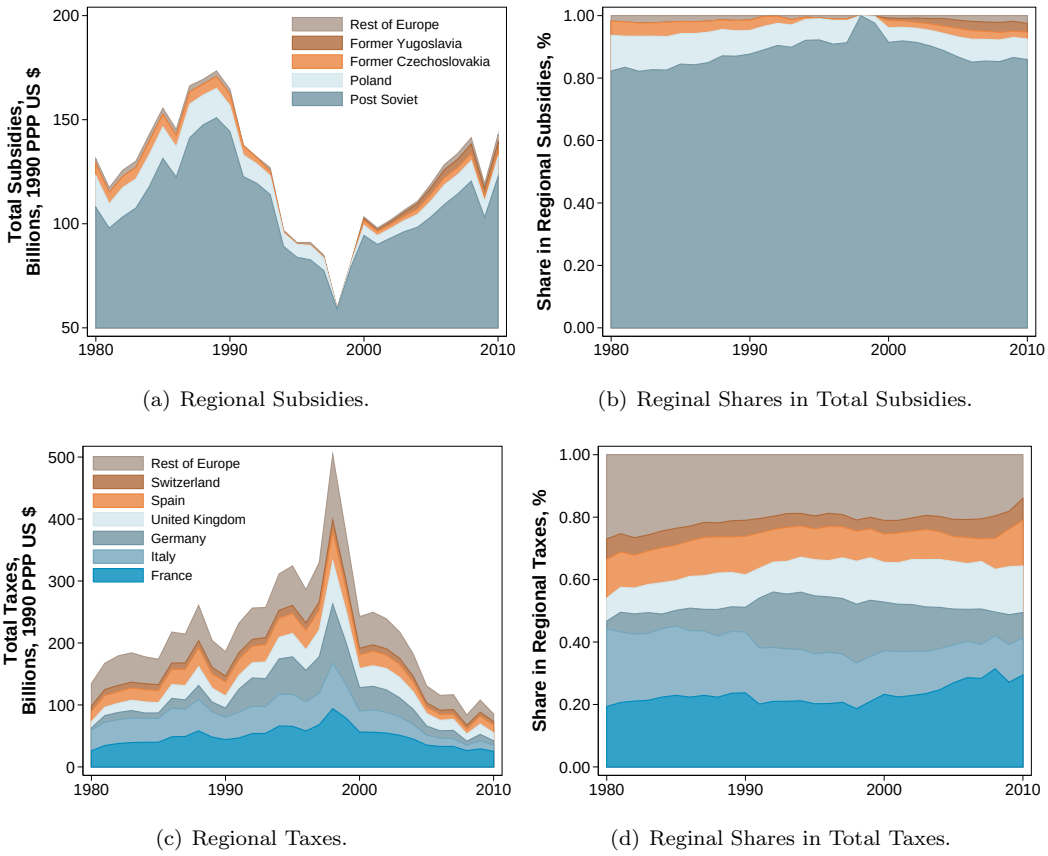
stem only from Western Europe and South America alone. Third, most of the decline in taxes after the year 2000 has come from declines in taxes in Western Europe and Eastern Asia and - to a lesser extent - Southern America. Finally, for ease of comparison Table 1 summarizes the various measures of subsidization and taxation across regions.

6 Country Analysis

In this section I examine the particular countries that were key drivers of the regional behavior described above.

Europe Figure 8 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% of the value of total subsidies which was on average 108 billion USD a year between 1980 and 2010. Poland and the former Czechoslovakia come a very distant second and third with average annual subsidies of 9 and 3.6 billion USD respectively.

In terms of taxation, there is far more diversity across European countries. The largest fossil-fuel taxes are to be found in France where they are an annual average of 48 billion USD or 23% of the total. Italy's subsidies have also been large - accounting for roughly 25% of the continent's subsidies in 1980, but have fallen steadily to roughly 12% or 10 billion dollars by 2010 - similar in size to Germany (7 billion USD), the UK (13 billion USD) and Spain (12 billion USD). Finally, and perhaps surprisingly, Switzerland also has high implicit taxes and in 2010 accounted for approximately 7% of European taxes - or 6 billion USD. All remaining countries



(a) Regional Subsidies.

(b) Reginal Shares in Total Subsidies.

(c) Regional Taxes.

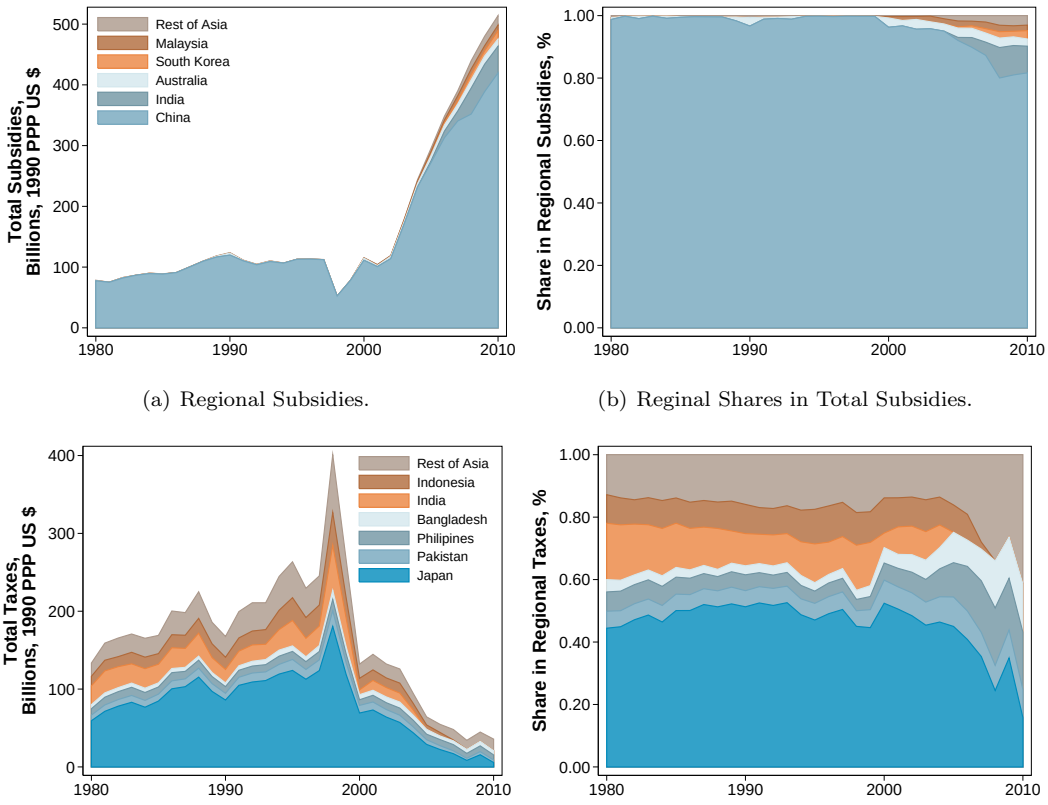
(d) Reginal Shares in Total Taxes.

Figure 8: Europe: Fossil Fuel Subsidies, Taxes and Net-Subsidies, 1980-2010.

in Europe have accounted for - on average - 21% of taxes over the entire period falling to a low 14% in 2010.

Asia Figure 9 shows the key contributors to Asian fossil-fuel subsidies and taxes. Before 2000, virtually all Asian subsidies of 97 billion dollar per year were from China. By 2010 China's share had fallen to 82% but in absolute terms its subsidies had risen to 420 billion dollars. In 2010, India accounted for 8.5% (44 billion dollars), South Korea for 2.7% (14 billion dollars) and Malaysia for 1.8% (9.1 billion dollars) with the rest of Asia accounting for only 5.1% (27 billion dollars). Finally, notice that the vast majority of the increase of subsidies in Asia seen after the 2000's has been driven by an explosion of Chinese subsidies - from approximately 111 billion dollars in 2000 to an enormous 420 billion dollars in 2010.

In terms of taxation, Japan contributed on average 49% of Asian taxes (or 92 billion dollars a year) between 1980 and the mid-2000's, after which it's share fell to only 16% and it's total



(a) Regional Subsidies.

(b) Reginal Shares in Total Subsidies.

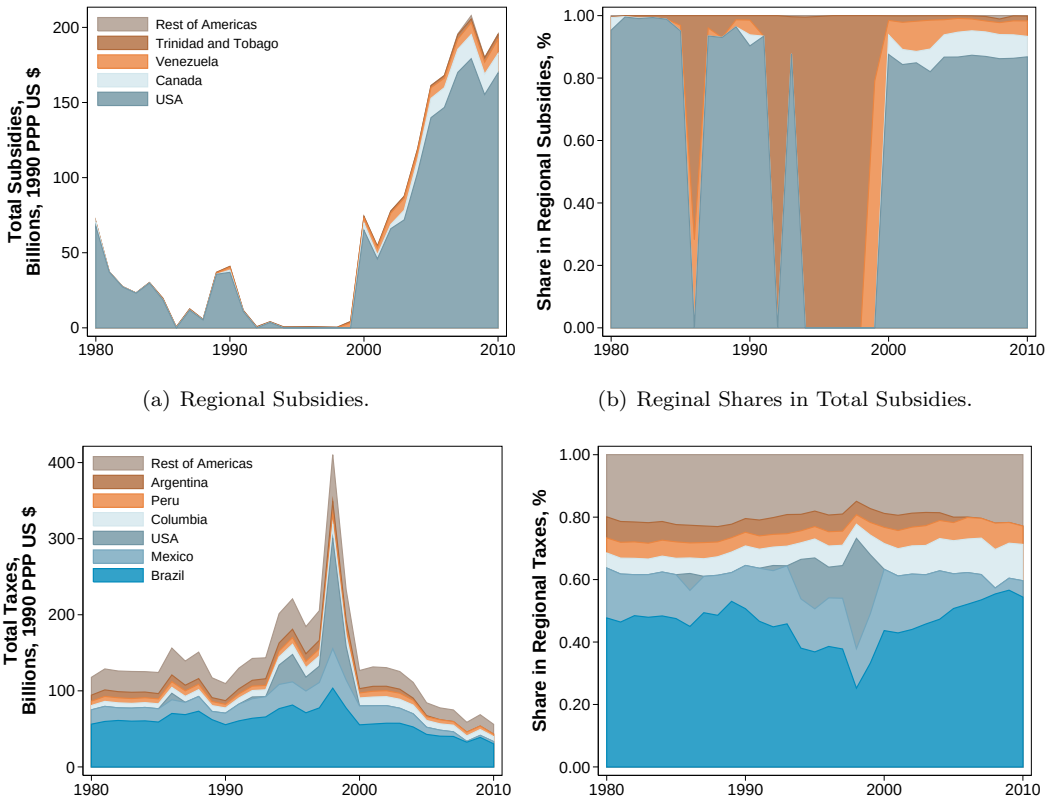
(c) Regional Taxes.

(d) Reginal Shares in Total Taxes.

Figure 9: Asia: Fossil Fuel Subsidies, Taxes and Net-Subsidies, 1980-2010.

taxes fell to 5.6 billion dollars. The other large contributor countries where the Philippines (18% or 6.5 billion dollars in 2010), Bangladesh (15% or 5.5 billion dollars) and Pakistan (9% or 3.2 billion dollars). Interestingly, until the mid-2000's India and Indonesia also had large implicit fossil fuel taxes but subsequently switched to pro-fossil fuel policies.

The Americas The evolution of subsidies and taxes in the Americas is shown in Figure 10. The dominant highest subsidies come from the US - although it has followed rather more volatile policies than most other subsidizing countries. Throughout the 1980's the US had largely positive subsidies of - approximately - 28 billion dollars per year. This also accounted for virtually all subsidies of the region for this period. Throughout much of the 1990's, the US did not subsidize fossil fuel subsidies, and the subsidies in the Americas were dominated by Trinidad and Tobago and Venezuela. Finally, in the late 1990's and throughout the 2000's there was an explosion of fossil fuel subsidies in the US from almost nothing in 1991 to to 170 billion dollars or 87% of



(a) Regional Subsidies.

(b) Reginal Shares in Total Subsidies.

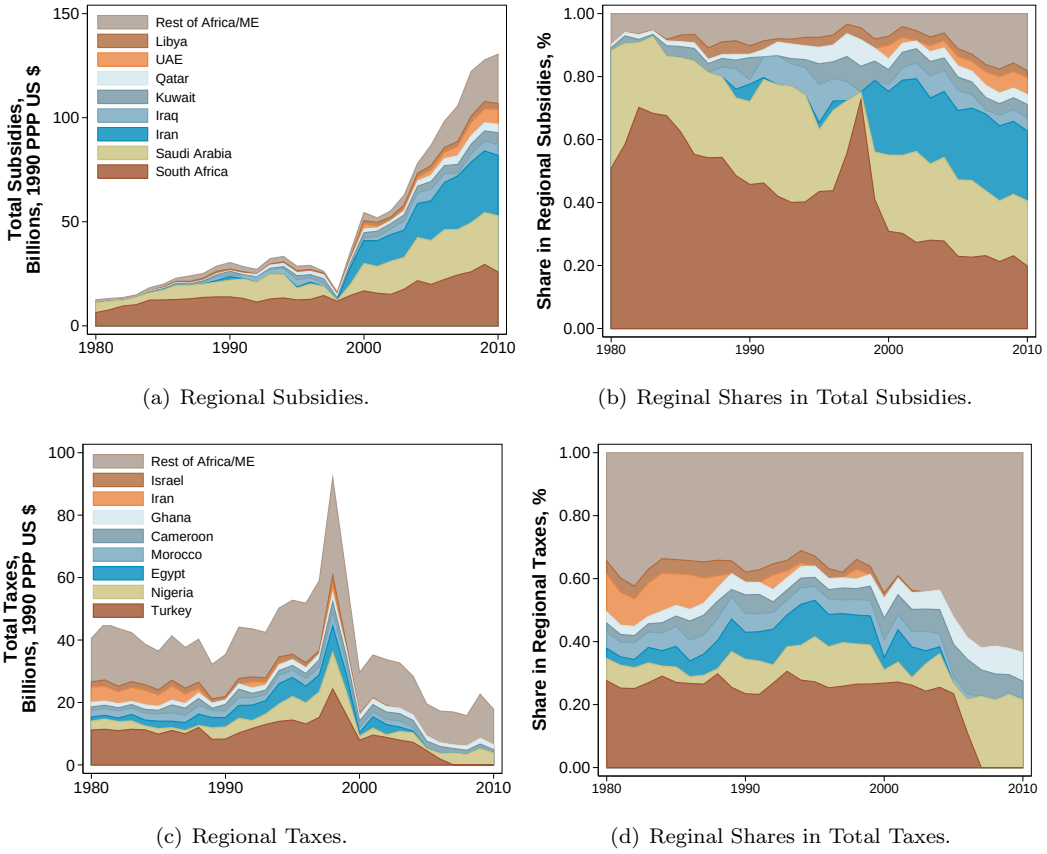
(c) Regional Taxes.

(d) Reginal Shares in Total Taxes.

Figure 10: The Americas: Fossil Fuel Subsidies, Taxes and Net-Subsidies, 1980-2010.

all subsidies in the Americas in 2010. During this period, virtually all remaining subsidies were accounted for by Canada (6.5% or 13 billion dollars) and Venezuela (5% or 9.7 billion dollars).

Fossil fuel taxes in the Americas were dominated by Brazil - where they numbered on-average 60 billion dollars a year and accounted for approximately 46% 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% of the total in 1980 - but this has fallen to only 2.9 billion dollars or 5% of the total by 2010. During the mid-to-late 1990's when the US was taxing fossil fuels, the US were also an important contributor to fossil fuels accounting for 17% and on annual average 48 billion dollars in taxes. Finally, Columbia and Peru have had high taxes on fossil fuels as well (accounting for approximately 12 and 6 percent of the total in 2010 respectively). Argentina also used to be a country with fossil fuel taxes (as high as 7% or 8 billion dollars of the region's total taxes in 1980) until 2005, but more recently it has began to subsidize fossil fuels. Taxes are very common in South and Central America, and thus the remaining countries of the Americas



(a) Regional Subsidies.

(b) Reginal Shares in Total Subsidies.

(c) Regional Taxes.

(d) Reginal Shares in Total Taxes.

Figure 11: Africa and the Middle East: Fossil Fuel Subsidies, Taxes and Net-Subsidies, 1980-2010.

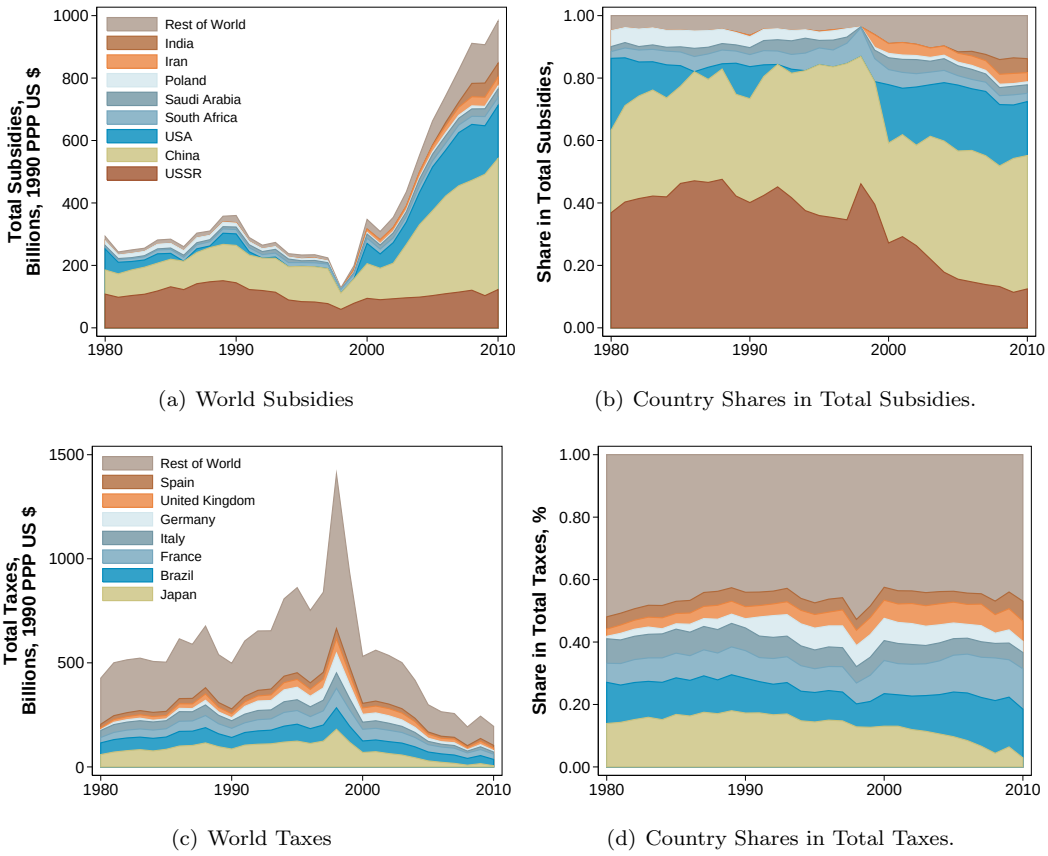
account for the other 20% of the region's taxes, with no one dominant country.

Africa and the Middle East Figure 11 shows the evolution of subsidies and taxes in the 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 subsidies of the region, at nearly 30 billion dollars or 22% of regional subsidies in 2010. Iran's dominance however, is relatively recent and as late as 1998 Iran was actually a country that taxed fossil fuels. Next is Saudi Arabia with - 27 billion dollars of subsidies or 21% percent 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 dollars on subsidies in 2010 alone - and accounted for 20% percent of the region's subsidies. At its peak however, South Africa accounted for 70% of the region's subsidies in 1982. The other large subsidizers of the region are Iraq, Kuwait, Qatar, the UAE and Libya, which together spent

25 billion dollars or 19% 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 dollars on subsidies in 2010 - or 18% of the total.

Taxation is far more diverse and wide-spread across countries of the region. Until the mid-2000's the country with the largest value of taxation of fossil fuels is Turkey - with an average of 11 billion dollars a year in taxes or 26 % of the total. However, subsequently, Turkey began subsidizing fossil fuels. Nigeria, is the region's second highest taxer - with taxes exploding after the mid 2000's and reaching 3.8 billion USD (or 22% 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, 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 9% of the regional total in 2010) and Cameroon (1 USD billion and 6% 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 2000's (for the first two countries) and the mid-2000's for the latter two countries, these policies reversed to subsidies. Altogether, the above countries only accounted for approximately 40% of the regions total taxes. 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 dollars and were thus relatively small on the global level.

Overview In Figure 12, I decompose the information from Figure 2(a) and 7 by country and compare the contribution of individual states to the evolution of global fossil fuel policy. As we saw above, in terms of subsidies, the spectrum is entirely dominated by the former Soviet Union, China and the US where, in 2010, subsidies amounted to 712 billion dollars or nearly 80% percent of total world subsidies. Furthermore, the massive increase in subsidies after the year 2000 is due primarily to the spectacular growth of subsidies in China and to a somewhat lesser extent in the US. In terms of taxes, the picture is less clear-cut. The country with the largest taxes has historically been Japan, although recently it's taxes have fallen and it has been overtaken by Brazil. Together Brazil and Japan account for 19% of world fossil-fuel taxes - or 36 billion dollars. Following these two countries are the "big-five" European countries of France, Italy, Germany, the UK and Spain. France here has the largest taxes among these countries - in 2010 its tax was approximately 25 billion dollars and accounted for 13% of global



(a) World Subsidies

(b) Country Shares in Total Subsidies.

(c) World Taxes

(d) Country Shares in Total Taxes.

Figure 12: Country Totals: Fossil Fuel Subsidies, Taxes and Net-Subsidies, 1980-2010.

fossil fuel taxes. In total, the five European countries account for 35% of world fossil-fuel taxes or approximately 67 billion dollars. Besides Japan, Brazil and European countries, taxes are quite evenly distributed - the remaining countries of the world account for approximately 47% of world taxes. Finally, for ease of comparison, Table 2 summarizes the various measures of subsidization and taxation across the top and bottom ten subsidizing countries (according to Total Net Subsidies in 1980).

7 The Indirect Costs of Subsidies

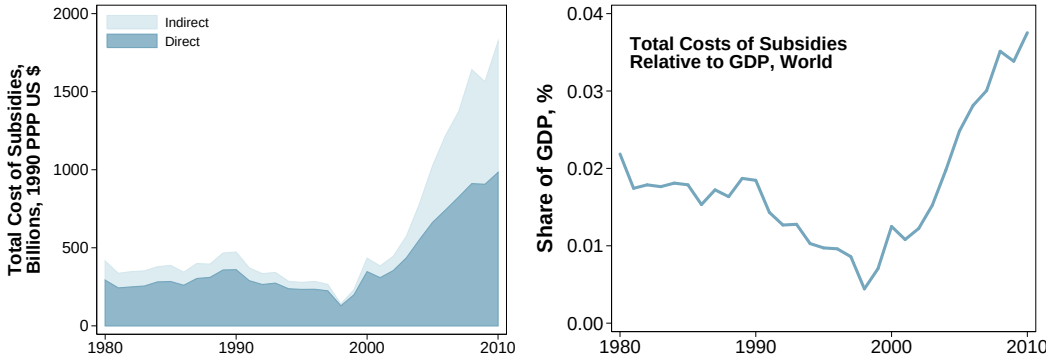
The above sections focused on examining the direct or - out-of-pocket - costs of subsidies. However, besides generating direct costs, subsidies also generate two types of indirect costs. First, since subsidies are distortions to energy prices, they result in individuals and firms mis-allocating resources and using 'too-much' energy and 'too-little' of other inputs. This in turn results in

	1980				2010			
Region	Subs. Total	Subs. p.w.	Subs /GDP	Price ratio	Subs. Total	Subs. p.w.	Subs /GDP	Price ratio
USSR	107.88	795	6.22%	.44	122.53	857	5.24%	.32
CHN	77.36	153	18.66%	.05	419.77	528	5.93%	.26
USA	67.47	622	1.62%	.74	169.67	1089	1.80%	.55
POL	14.97	864	6.49%	.42	9.39	531	1.95%	.57
ZAF	6.37	799	4.92%	.5	25.87	1450	9.55%	.18
SAU	4.67	1831	3.26%	.5	26.99	3012	9.26%	.16
CAN	2.85	238	0.68%	.88	12.82	703	1.42%	.63
BGR	2.32	516	6.59%	.46	1.35	405	2.34%	.56
AUS	.49	73	0.22%	.96	11.82	1029	1.88%	.54
DZA	.43	110	0.74%	.88	4.67	428	3.39%	.45
JPN	-59.29	-1052	-3.55%	2.13	-5.64	-86	-0.19%	1.07
BRA	-56.21	-1200	-8.95%	6.43	-30.43	-290	-2.47%	2.05
ITA	-33.5	-1464	-4.06%	2.56	-10.19	-403	-0.79%	1.36
FRA	-26.02	-1091	-2.98%	1.93	-25.15	-848	-1.68%	2.01
IND	-24.1	-95	-4.66%	2.25	43.91	97	1.47%	.68
MEX	-18.82	-869	-3.67%	2.27	-2.93	-60	-0.30%	1.1
ESP	-16.73	-1218	-3.90%	2.41	-12.46	-535	-1.35%	1.67
IDN	-12.2	-218	-7.24%	3.32	2.05	17	0.28%	.93
TUR	-11.18	-624	-6.37%	3.66	3.75	156	0.63%	.82
GBR	-9.87	-368	-1.45%	1.31	-12.72	-399	-0.82%	1.37

Table 2: Measures of Net Subsidies in top and bottom ten countries (according to Total Net Subsidies in 1980): Total Net Subsidies (in billions of 1990 PPP USD), Net Subsidies per worker (1990 PPP USD), Net Subsidies as a share of GDP (constant 1990 PPP prices), ratio of fossil fuel price to undistorted price (weighted average).

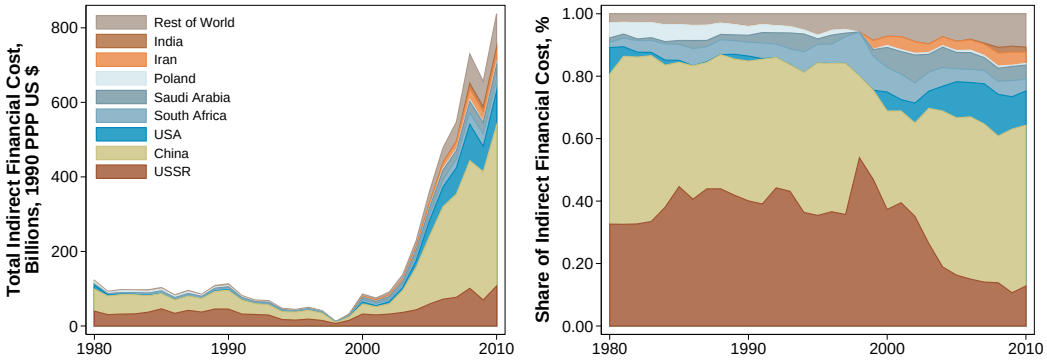
lower levels of GDP, since resources could otherwise be more efficiently used to produce more output. The difference in GDP between the observed world and the world without distortions, is thus the indirect financial cost of fossil fuel subsidies. Second of all, since we use more fossil-fuel energy when it is cheaper, we are also emitting 'too-much' carbon dioxide. The difference in emissions between worlds were we pollute 'too-much' and 'just-the-right' amount is the environmental cost of subsidies. A huge advantage of the model based methodology of extracting subsidies developed in Stefanski (2014) is that the model can be used to perform a counterfactual experiment generating a world that is identical to ours in all respects, but where fossil fuel subsidies are set to zero in subsidizing countries. Performing this experiment then allows me to calculate the additional indirect financial and environmental costs of subsidies. In the following section, I proceed to analyze these indirect costs.

First, Figure 13(a) 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 dollars which was approximately 42% of direct costs at the time. Their value falls to 12 billion dollars by 1998 when they constitute only 9.2% of direct costs. However, as subsidies



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

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



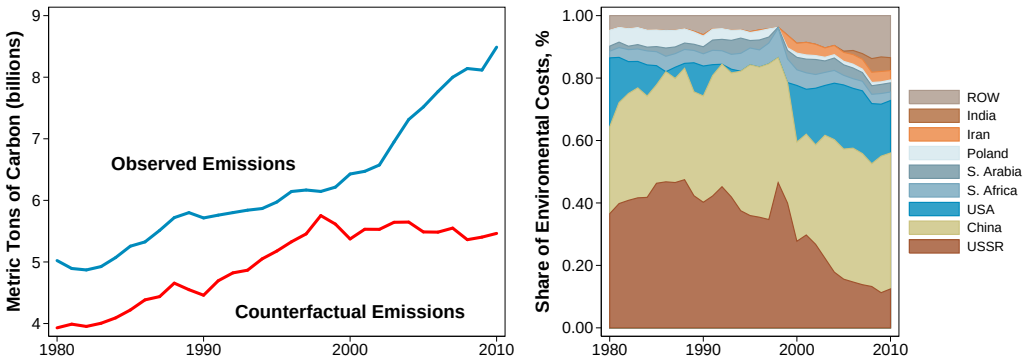
(c) World Indirect Financial Costs, by Country.

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

Figure 13: Indirect Financial Costs of Fossil Fuel Subsidies, 1980-2010.

explode in the 2000's so did the indirect costs of these subsidies. By 2010, the global indirect financial costs of subsidies reach 838 billion dollars - or 85% of global direct subsidies. Thus, in 2010, the combined direct and indirect financial costs were a stunning 1.82 trillion dollars. Figure 13(b), plots these total financial costs as a fraction of global GDP. The total financial costs of subsidies oscillate between 0.4% of global GDP in 1998, to an astounding 3.8% in 2010.

Second, Figures 13(c) and 13(d), decompose the indirect costs by country. Once more, we observe that China, the former Soviet Union and the US 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 US. Consequently, the extent of the mis-allocation in China is greater than in other countries.



(a) Indirect Environmental Costs of Subsidies, World.

(b) Indirect Environmental Costs relative to GDP, World.

Figure 14: Indirect Environmental Costs of Fossil Fuel Subsidies, 1980-2010.

Third, Figure 14(a) plots counterfactual and observed emissions. Notice that the environmental costs of subsidies - represented by the difference of the two lines in the graph - are also enormous. In particular, without subsidies total cumulative emissions over the entire period would be 21% lower. The extent of the environmental cost varies over time in a similar fashion to subsidies themselves and rises dramatically after the 2000's. In particular, by the year 2010 a world without subsidies would have emissions that were 36% lower than what was observed.

Finally, Figure 14(b) decomposes these environmental costs by country. Again - quite unsurprisingly - we observe that the same three countries: China, the Former Soviet Union and the USA are causing the most environmental damage - accounting for roughly 64% of environmental costs associated with positive subsidies.

8 Conclusion

In Stefanski (2014) I developed a novel methodology for inferring carbon subsidies and constructed a database of subsidies for 170 countries for the period 1980-2010. In the present paper, I have performed a disaggregated analysis of the resulting subsidies by examining policies at both the regional and country-specific level. Whilst many countries subsidize carbon fuels, I find that only three countries - China, the Former Soviet Union, and the USA - are responsible for an overwhelming majority of subsidies. Furthermore, I find that the massive increase in subsidies observed after the year 2000 is driven by an explosion of subsidies in just two countries: China and the US. Besides being vastly expensive, these subsidies have had a significant negative indirect impact. First, they have caused major mis-allocation of resources

which has resulted in sizably 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 policy makers interested in cutting global carbon emissions. Whilst reaching consensus on carbon emission reductions may be difficult at a global level, negotiation 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.

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