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Comparability of Effort in International Climate Policy Architecture

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The goal of the Harvard Project on Climate Agreements is to help identify and advance scientifically sound, economically rational, and politically pragmatic public policy options for addressing global climate change. Drawing upon leading thinkers in Argentina, Australia, China, Europe, India, Japan, and the United States, the Project conducts research on policy architecture, key design elements, and institutional dimensions of domestic climate policy and a post-2015 international climate policy regime. The Project is directed by Robert N. Stavins, Albert Pratt Professor of Business and Government, Harvard Kennedy School. For more information, see the Project's website: http://belfercenter.hks.harvard.edu/climate

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Comparability of Effort in International Climate Policy Architecture

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Abstract

The comparability of domestic actions to mitigate global climate change has important implications for the stability, equity, and efficiency of international climate agreements. We examine a variety of metrics that could be used to evaluate countries' climate change mitigation effort and illustrate their potential application for large developed and developing countries. We also explain how transparent measures of the comparability of effort can contribute to the design of international and domestic climate change policy along several dimensions. For example, such measures can facilitate participation and compliance in an agreement if they can illustrate that all parties are doing their "fair share." Second, these measures can inform the bilateral linking of domestic cap-and-trade programs in a manner akin to how nations negotiate the lowering of trade barriers more generally in trade policy. Third, assessments of the comparability of effort can affect whether to implement and, if necessary, the stringency of unilateral border measures (e.g., a border tax). Finally, such assessments demonstrate the need for a well-functioning policy surveillance regime.

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1. Introduction

The comparability of domestic actions to mitigate global climate change has important implications for the stability, equity, and efficiency of international climate agreements. Much of the game theory literature on international environmental agreements highlights the need for institutions to support broad and typically comparable emission mitigation efforts by countries in order to avoid the free-riding that can trigger the unraveling of a global agreement (e.g., Barrett 2003). Like actions and effort among like countries would likely be consistent with most notions of equity and contribute to a "fair" deal. Implementing mitigation programs that reflect comparable effort are more likely to deliver cost-effective and potentially efficient abatement. So, what constitutes the comparability of effort among countries?

To address this question, we develop a set of principles to inform consideration of an array of comparability metrics.[1] Guided by these principles, we evaluate metrics of mitigation effort in three broad categories: emissions, prices, and costs. We present illustrations of each metric for a set of large developed and developing countries, drawing from published statistics and public domain research. Given the intractable challenge of completely mapping the complexity of any domestic greenhouse gas mitigation program to a metric, we conclude that no single metric can serve as a comprehensive, summary statistic for mitigation effort. Instead, we recommend consideration of a suite of metrics for comparing effort among nations, akin to an evaluation of multiple economic statistics in assessing the health of the macroeconomy.

Based on our assessment of existing environmental, energy, and economic statistics, a suite of comparability metrics could be applied in an evaluation of countries' greenhouse gas mitigation programs. Thus, comparability of effort analysis could be conducted for all countries, in line with the call for mitigation actions by all countries under the Durban Platform for Enhanced Action. Such analysis could permit for differentiation in the use of benchmarks (i.e., reference points for evaluating performance on given metrics). For example, the benchmark for comparing metrics among nations could take the form of historic measures of the metric, forecast future levels, or an agreed global standard. It may also vary among nations on the basis of a variety of factors, such as their population, incomes, past emissions, or forecast future emissions. Fundamentally, it is this benchmark that addresses how the burden of mitigating climate change is to be shared, how much past progress is rewarded, how future growth is accommodated, and how countries with different resources are treated differently.

Comparable effort has frequently been considered a necessary condition for international agreements. Indeed, assessing countries' respective effort under proposed commitments in an agreement is often a key determinant of whether the agreement would represent a fair deal. In the context of international trade, the related concept of reciprocity has characterized successful negotiations. Brown and Stern (2007) note that "fairness appears to be met when certain conditions are satisfied – like reciprocity in bargaining situations or equality of treatment in the application of common rules" (pp. 294-295). Finger et al (1999) conclude that "a sense of fairness, of appropriate contribution, was an important concept" (p. 7) in the success of the Uruguay Round of trade talks. In Simmons' (1998) review of the literature on compliance with international agreements, she notes that compliance is likely

[1] In this paper, we focus on emission mitigation. Comparability of effort could be important in other international climate policy contexts as well, such as adaptation, international climate finance, geo-engineering, and research and development.

better under rules "prescribing reciprocal rather than uni-obligational behavior" (p. 87). Methods for comparing effort inform an assessment of the reciprocity of action. Ostrom (1998) focuses on the importance of norms in guiding individual efforts toward collective action, and she recognizes that "all reciprocity norms share the common ingredients that individuals tends to react to the positive actions of others with positive responses and the negative actions of others with negative responses" (p. 10).

This kind of reciprocity is evident in the international climate talks. Under the 2009 Copenhagen Accord and the 2010 Cancun Agreements, the European Union (EU) announced that it would take on a 1990 -20% target by 2020 and would be willing to implement a -30% target "provided that other developed countries commit themselves to comparable emission reductions and that developed countries contribute adequately according to their responsibilities and respective capabilities."[2] Japan likewise conditioned its -25% target under these agreements on ambitious emission targets by all major economies. This focus reflects the decision in the 2007 Bali Action Plan that, among developed countries, "comparability of efforts" (1(b)(i)) should guide consideration of their emission mitigation efforts. Of course, given how much the world has changed since 1992, it is antiquated and counterproductive to maintain a developed/developing country distinction in analyzing and comparing effort (Aldy and Stavins 2012a). Indeed, negotiations in practice will likely reveal an appetite for information on the comparability of effort among developed, emerging, and even lower-income countries. For example, at the 2013 Warsaw Conference of the Parties, the decision to advance work on the Durban Platform opens by requesting the exploration of options that would reflect "the highest possible mitigation efforts by all countries" (paragraph 1).

With emergence of the Copenhagen Accord in 2009 and subsequent developments in the UN climate change negotiations, the question of comparability of action on climate change arises as far more than an academic question. The Copenhagen Accord and the Cancun Agreements included a varying array of emission mitigation policies, actions, and goals submitted by a much broader set of nations to contribute to the global effort to combat climate change. This Copenhagen model represents a new framework in which nation-states propose or pledge actions, policies, and goals unilaterally. In this context, there is considerable scope for stakeholders and other countries to critique a given country's pledge as inadequate and/or to attempt to inspire greater action. Absent some notion of comparability and a credible system of transparency and review, this new model could break down. The kind of analysis we describe in this paper can both inform the debate ex ante over countries' proposed mitigation commitments that could facilitate an agreement and then inform the ex post evaluation of countries' efforts delivering on what they agreed to.

We should also note that the comparability of effort impacts the design of domestic climate change policies in several important ways. Some countries pursuing more serious mitigation activities may take actions, including imposition of border measures on those viewed as making insufficient action, warranted or not, in order to protect their domestic industries. This primarily unilateral effort demands some objective measure of whether countries are doing "enough." The cooperative evolution of bottom-up coordination also requires an assessment of comparability. Take two examples. First, countries that may consider harmonizing domestic carbon taxes would seek assurance that such efforts are, in practice, comparable in light of other policy instruments, including other energy taxes or policies, that could undermine any explicit carbon tax. Second, countries seeking to link their domestic cap-and-trade programs need to make judgments about whether proposed partners would unfairly benefit from

2 http://unfccc.int/resource/docs/2011/sb/eng/inf01r01.pdf. Last accessed October 14, 2013.

the linkage. An analog to each of these examples is consideration of the reciprocity of lower tariffs and non-tariff trade barriers in the context of negotiating bilateral free trade agreements.

To illuminate the consideration of the comparability of effort in the design of international climate change policy, we propose a set of principles for comparing effort in the next section. We review various metrics for comparing effort in section three, including illustrations of potential metrics with current, historic, and forecast emissions, price, and cost statistics. These illustrations provide a basis for comparing the effort to date by countries participating in the UNFCCC. In the fourth section, we apply these insights on metrics in a discussion of how explicit demonstration of the comparability of effort can facilitate both international climate policy coordination and domestic policy design, and ultimately stronger international agreements. The final section concludes.

2. Principles for Comparability Metrics

Principles can inform the consideration of various metrics for comparing mitigation effort by countries. We should note at the outset that there may be trade-offs among some principles in identifying and constructing metrics. For example, as we note below, emission levels may be measurable and applicable in all countries, but this measure may not comprehensively represent mitigation effort. With this in mind, let us consider a non-exhaustive set of principles.

- Comprehensive: An ideal metric would capture the entire effort actively undertaken by a country to achieve its mitigation commitment. Such a metric would clearly reflect policies and measures and exclude non-policy drivers of climate outcomes. As a result, this single measure could suffice for comparing effort among countries.

- Measurable: A metric for comparing effort should focus on the observable characteristics of effort. This creates an incentive for countries to undertake and publicize emission mitigation actions that other countries can easily observe, thereby facilitating transparency. Metrics that allow quantitative ex ante estimates – to inform the current round of talks – and quantitative ex post assessments – to inform the next round of talks – could serve the international climate negotiations well. An exception could be for a “categorical” metric, to represent mitigation commitments of a specific type or category, such as a uniform carbon tax or uniform elimination of fossil fuel subsidies.

- Replicable: Individual countries as well as stakeholders should be able to replicate a metric given (a) the inputs used by analysts; and (b) available public information. This would ensure the legitimacy of such comparability analysis. It also requires a transparency of method that permits third party review of reviewers, which could also increase trust in the process. As a result, simple, less complex metrics would be preferred.

- Universal: Given the global nature of the climate change challenge, the metric should be constructed for and applicable to as broad a set of countries as possible.

Implicit in the notion of a "comprehensive" metric is that it would allow one to sort countries and provide some indication of which countries are doing more or less than others. That is, while the appropriate performance benchmark for individual countries may be endlessly debated, the "natural" benchmark of who scores relatively higher or lower on a comprehensive metric should be informative.

This raises the question of how performance benchmarks should be set for a particular metric or set of metrics. While we provide many examples below, we do not identify preferred benchmarks. We recognize that the preference of a benchmark for any given metric could vary among countries due to different normative positions, self-interest, and other factors.

3. Metrics for Comparing Effort

Given the history of international climate negotiations, we begin our review of metrics with a discussion of emissions. We then turn to an assessment of price-based metrics, with a focus on carbon prices and energy prices. Then we conclude our review of metrics with a description and analysis of cost-based measures.

3.1 Emissions

The 1997 Kyoto Protocol (and the recent extension of the second period emission commitments for some Annex I parties) delivered an agreement on emission targets, but provided parties to that agreement the discretion to design their own domestic policies necessary to realize those goals. The clear metric for comparison is the explicit commitment – the level of emissions. Since the Kyoto negotiations, efforts to broaden participation to emerging economies and other developing countries have resulted in greater variation in the forms of emission commitments. Under the Copenhagen Accord and Cancun Agreements, nations reached agreement on commitments structured as economy-wide emission goals, economy-wide emission intensity goals, emission reductions relative to a forecast business-as-usual emission level ("BAU"), as well as energy efficiency programs, transportation projects, forestry conservation investments, and wind and solar power capacity goals, among other forms. We review emission metrics in the forms of emission levels versus a historic base year, emission abatement versus a forecast of future emissions, and emission intensity goals in this sub-section.

3.1.1 *Emission Levels versus Historic Base Year*

Measuring a country's territorial emissions is a relatively straightforward exercise, especially for fossil fuel carbon emissions, which requires only an accounting of oil, gas, and coal consumption for energy.[3] Certain classes of greenhouse gas emissions are more difficult to measure, such as those related to land-use change or fugitive emissions. Industrialized countries currently report their annual total greenhouse gas emissions to the UNFCCC typically within two years. A number of independent experts produce estimates of fossil carbon emissions for most countries in the world each year (e.g., International Energy Agency, U.S. Energy Information Administration, and the Global Carbon Project).

The benchmark in the Kyoto context, and a benchmark some countries have maintained through recent rounds of negotiations, is a country's emissions level in 1990. Establishing a base year for some period of time that predates the negotiations removes the prospect that a country could game the system by increasing its emissions during negotiations to create a higher benchmark level for evaluation.

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[3] In contrast to territorail emissions (or what Aldy [2007] referred to as production emissions), consumption-based emissions represent an adjustment to territorial emissions based the embodied carbon in net imports (Peters et al. 2011). As world trade expands, accounting for the carbon content of traded goods and services could become an important aspect of future assessments of mitigation effort—or could become the basis for extensive border measures by importers or exporters. We leave this topic for future work.

However, the question of choosing benchmarks among countries is, in part, a question of rewarding leaders or supporting followers. That is, how does or should a benchmark differentiate among countries that have already undertaken significant efforts that reduce emissions and those that have not?

Importantly, emission levels relative to a base year may not comprehensively represent mitigation effort—in fact, it may have nothing to do with effort. Emission trends vary from country to country for a number of reasons beyond respective government policies and efforts to mitigate greenhouse gas emissions. For example, significant heterogeneity in economic and population growth among countries suggests that the effective stringency of a common percentage reduction from a common base year could differ dramatically among countries. Table 1 illustrates the change in emissions for a set of large developed and developing countries over 1990-2010 and 1997-2010. One could reach the inappropriate conclusion that Russia is the world's leader in combating climate change, with its 2010 emission levels for all greenhouse gases 28% below their 1990 levels. Russia's emissions, however, do not reflect an extensive climate change mitigation program, as evident by the 7% increase in emissions over 1997-2010. Instead, the 1990-2010 emissions decline is a product of dramatic economic restructuring after the cold war.

Indeed, very few countries implemented meaningful emission mitigation policies before the 1997 Kyoto Conference. Employing emission levels in 1997 as a benchmark yields some interesting differences from a 1990 benchmark. EU emission mitigation effort would appear to be about 40% less, while U.S. emission growth of 15% under a 1990 benchmark becomes a smaller growth of 5% under the 1997 benchmark. In either case, China's and India's carbon dioxide emissions have increased by more than 100%. [4] Refer to Appendix Table 1 for an extension of Table 1 for most countries in the world.

Another downside is that this emission level approach by itself does not promote learning about policy effectiveness. A variety of factors beyond the control of government policies could typically impact national emissions. Therefore, an assessment of effort using such a measure as the sole metric would do little to identify sources of emission growth and the impact of current policies. The status quo system of policy surveillance of industrialized countries' mitigation programs—which focuses largely on emissions—provides little useful information along these lines (Thompson 2006; Aldy 2013).

3.1.2 Emission Intensities

Emission intensities, such as tons of carbon dioxide per unit of economic output have long been heralded as a way to divorce discussions of reducing emissions from concerns that absolute emission limits constrain growth in a practical way. In the run-up to the 2009 Copenhagen talks, China and India each proposed emission goals structured as percentage improvements in emissions to GDP. The George W. Bush administration proposed such an intensity-based emission goal for the United States in 2002. Finally, the Government of Argentina proposed in 1999 an emission commitment specified as a function of economic output and requested consideration for joining Annex B of the Kyoto Protocol with this emission target. Such an approach can ensure that a country does not appear as a climate leader simply

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[4] The UNFCCC does not receive timely information on greenhouse gas emissions from developing countries. Some of the largest developing countries have reported no more than one emission inventory per decade to the UNFCCC since the 1992 Earth Summit (e.g., in 2004, China submitted an emission inventory for 1994, and in November 2012, China submitted an emission inventory for 2005). The outstanding question is whether this reflects technical obstacles or political obstacles. We have employed the World Resources Institute Climate Analysis and Indicators Tool (CAIT) database for greenhouse gas emissions.

because of economic decline, or that another country does not appear as a climate laggard simply because of faster economic growth.

Emissions and GDP are each fairly straightforward to measure. A variety of related data collected in numerous contexts (UN collection of fossil fuel data, IMF collection of economic data, private collection of financial and economic data, etc.) can be used to verify the quality of emissions and GDP data reported by countries.

Of course, emissions will continue to grow unless the reduction in emission intensity exceeds the economic growth rate. Further, many countries naturally experience a decline in emission intensity as their economies grow – reflecting a natural tendency towards lower energy intensity and higher efficiency. This means that a declining emission rate target could be set such that it requires no effort for compliance. Finally, some analysis has shown that emission intensity targets become more stringent if a country grows slower than expected and less stringent if it grows faster than expected. From a policy design perspective, it would be more appealing to design a policy that requires more emission mitigation effort for those countries that grow faster, and hence are wealthier, than they expected to be, instead of the opposite (Aldy 2004). This could lead to an "indexed" rather than intensity based approach (Newell and Pizer 2008).

Implementing a process to compare emission intensities requires decisions about the measurement of economic output. For example, comparing emission intensities among countries at a point in time involves conversion of local currencies into a single currency. Table 2 illustrates how the choice of market exchange rate or purchasing power parity affects bilateral comparisons. Under market exchange rates, China's emission intensity is about five times that of the United States and about 60% greater than that of India. India's intensity is about triple that of the United States. Under purchasing power parity exchange rates, China's intensity is about double that of the United States and India, which have identical intensities under this measure.

As an alternative approach, the comparison could focus on changes in intensity over time. Given the interest in intensity improvements over the 15-year period of 2005-2020 by China and India, figure 1 presents the change in intensity over 1996-2011, the most recent 15-year period for public domain data on fossil carbon emissions. Each country in each panel has its 1996 value indexed to 1.0, so a given country's trend over time represents the percentage of 1996 intensity for each of these years. The top panel presents the change in intensity in real market exchange rate terms while the lower panel presents the change in intensity based on nominal local currency. The change over 15 years is dramatically different across panels for each country, with the exception of Japan, which experienced very little inflation over the past two decades.

If the past is a guide to the stringency of future emission intensity goals, then the Copenhagen pledges by China and India require mitigation effort if gross domestic product is measured in real terms and no mitigation effort if gross domestic product is measured in nominal terms. The ranking of countries could also differ quite significantly between a comparison of intensity levels (Table 2) and a comparison of changes in intensity over time (Figure 1). Refer to Appendix Tables 2 and 3 for an extension of Figure 1 and Table 2 for most countries in the world.

3.1.3 Emission Abatement – Emission Levels Versus Future Emission Forecast

In recent years, interest among some large developing countries has turned to emission goals specified as percentage reductions from a reference case or forecast level in a future year. For example, Brazil, Indonesia, Korea, and South Africa have established emission targets relative to their forecast business-as-usual levels under the Copenhagen Accord. Such an approach requires an estimated business-as-usual emission forecast to calculate the estimated emission abatement. Estimated emission abatement could represent a much more precise measure of mitigation *effort* than emission levels, since it takes into account what emissions would have been in the absence of the greenhouse gas mitigation program. Compared to emission levels, it does not automatically penalize countries that have growing population or economies, nor reward those in economic decline.

Given the uncertainty in forecasting business-as-usual emissions, especially for developing countries that are expecting faster but more volatile economic growth, it is easy to imagine how such efforts might be gamed. Countries would certainly have the incentive to assume faster economic growth to ensure a higher baseline emission level.

The use of such forecasts also raises philosophical questions about the basis for entitlement to a particular emission level or limit: is the basis for an emission target tied to population or a level of economic attainment? Is it tied to some effort to deviate from a notional "business-as-usual?" Hearkening back to our discussion of historic base year benchmarks, what defines "business-as-usual"? Does it include existing mitigation efforts, helping laggards relative to leaders, or not? Regardless of the preference for base years or future forecasts, future forecasts are harder in practice to establish. They cannot be measured and they change. Different experts may make different but equally plausible modeling assumptions and produce significantly different emission forecasts. Of course, one might view the debate over how to differentiate performance benchmarks in a base-year approach as akin to a debate over future emission forecasts.[5]

To illustrate the potential practice – and pitfalls – to evaluating effort in terms of emission reductions versus a business-as-usual forecast, we present percentage emission reductions in 2010 versus a year-2000 forecast for 2010 for a set of developed and developing countries in Figure 2. This figure presents estimated emission reductions for territorial emissions. The U.S. EIA (2000) produced these "BAU" forecasts in 2000 assuming no new climate change or other energy policies in forecasting 2010 CO2 emissions. For example, the effort reflected by the EU Emission Trading Scheme ("ETS") is not included in this baseline for the European nations since EU member states agreed on the ETS after the publication of this forecast.

One can draw several insights from this figure. First, the forecasts could be quite erroneous, as evident with the China and India estimates. These countries did not implement aggressive policies intending to increase greenhouse gas emissions. Their emissions grew much faster and grew faster in energy-intensive sectors than forecast. These figures do not highlight or identify the causes for the changes from BAU. Increasing energy prices and a decreasing natural gas-coal price ratio helped reduce U.S. emissions relative to BAU.[6] Second, these figures do not illustrate the heterogeneity in BAU

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[5] In the Kyoto Protocol, national targets were expressed as a percentage deviation from 1990 levels, ranging from -8% for the EU to +10% for Iceland.

[6] Note that realized 2010 GDP was higher than the GDP incorporated in the forecast for the United States.

forecasts across models. Finally, such forecasts can help illuminate the effect of new, incremental actions but do not characterize necessarily the total effort by a country. That is, policies currently in operation are typically included in forecast scenarios (e.g., more recent forecasts by the U.S. EIA for European countries would include the EU ETS). It is challenging to construct a baseline that strips away past and current energy and climate policies, and doing so requires even more and difficult assumptions than typical forecasting exercises.

3.2 Prices

In the context of climate policy, most industry stakeholders and those concerned with the economy focus on the price of fossil energy and electricity. Ultimately the delivered price of fossil energy reflects a combination of global and local resource costs, other tax and subsidy policies, and any explicit carbon price. This leads us to consider not just explicit carbon prices but energy prices and energy taxes more broadly.

3.2.1 Carbon Prices

An observed carbon price is a natural benchmark for effort, as it measures the marginal cost levied in the name of climate change mitigation. A carbon price represents the marginal cost for emitting a ton of carbon dioxide among those emission sources covered by a country's climate change program. All mitigation opportunities that are less expensive than the carbon price should be undertaken by households and firms. In this way a national carbon price measures the degree to which a country is undertaking less expensive or more expensive mitigation efforts. Comparing carbon prices across countries provides an indicator of how hard each country is trying to reduce emissions, at the margin. If countries face similar opportunities to reduce emissions, e.g., similar marginal cost schedules, this would also be an indicator of a country's total expenditures to reduce emissions. One obvious challenge is that, because countries implement domestic carbon taxes in their local currencies, it is unclear how to address valuations in these different currencies. Market exchange rates are the most relevant for competitiveness concerns and traded goods. However, purchasing power parity exchange rates allow a comparison of domestic costs in terms of domestic goods.

There are a number of reasons why *explicit* carbon prices may not reflect mitigation effort. First, an explicit carbon price may be too narrow a measure of a country's efforts to mitigate greenhouse gas emissions. It may only cover a subset of a country's emissions (e.g., only large emitters, as in the EU ETS). It may fail to account for the effect of other, non-price policies that reduce greenhouse gas emissions. Efficiency standards or regulations supporting renewable energy can have significant emission consequences and represent significant effort, but are not reflected in carbon prices (or energy prices, for that matter). There is also the risk that a country may undermine the effectiveness of the carbon price by adjusting taxes downward (or increasing subsidies) for firms covered by the carbon price (what is typically referred to as fiscal cushioning). Finally, the effort represented by a carbon price – in terms of resources expended – depends on both the price and the amount of emissions reduced. For a country with particularly inelastic demand – and relatively few opportunities to reduce emissions – a high carbon price may amount to a within-country wealth transfer without affecting behavior or changing emissions.[7]

[7] McKibbin et al. (2011) find differences in the ranking of effort based on carbon prices versus economic costs (foregone consumption) in their analysis of the Copenhagen mitigation commitments.

Alternatively, one could also consider *implicit* carbon prices that summarize the effective penalty to carbon dioxide emissions (or subsidy for emission reductions) being applied by a specific policy or in a particular sector. Such implicit prices have the advantage of potentially being applied more broadly, but the disadvantage of not being directly observed. There is also an important difference between taxes and subsidies, as subsidies to reduce emissions will tend to lower the price of final goods that continue to emit carbon, distorting various margins in the supply chain for mitigation. This, in turn, raises another question: where in the supply chain do you measure an implicit price? For example, do you measure the implicit carbon price from a renewable subsidy, or from its effect on the final price for electricity, or from its effect on the price of electricity-intensive manufactured goods?

In contemplating benchmarks for carbon prices, there is a natural question of whether to expect the same carbon price for every country and how one might explain or accommodate differences. For example, should countries with relatively high fossil energy prices – either due to resource constraints or policies – be asked to seek even higher prices to reflect carbon content, or should countries with low prices be first asked to raise theirs? Europe, for example, currently faces much higher consumer petroleum prices than the United States. How should we view a policy that raises gasoline prices in the U.S. even as they remain below European levels? Is the U.S. doing more or less than Europe? Finally, assuming a decision to compare policies based on market exchange rates, how would an analysis of the carbon price metric address currency devaluation? For example, in the Mexican peso crisis, Mexico's currency devalued by 1/3; Korea's currency devalued by ½ during the Asian financial crisis.

Explicit and implicit carbon prices currently vary quite significantly among and within countries. Table 3 presents a subset of carbon prices based on carbon tax, cap-and-trade, and renewable subsidy and regulatory mandate policies. Consider the within-country variation. Several northern European countries implemented carbon taxes starting in the early 1990s. For example, Norway's carbon tax in 2009 set prices of \$58/tCO2 for gasoline, \$34/tCO2 for diesel, \$31-\$33/tCO2 for natural gas, and exempted coal (Aldy and Stavins 2012b). In Germany, the EU ETS has imposed a carbon price that has varied over time, but fell within the range of €5-10/tCO2 in 2012. In contrast, German wind feed-in tariffs effectively impose a carbon price an order of magnitude greater at €44/tCO2 and solar feed-in tariffs impose a carbon price another order of magnitude greater at €537/tCO2 (Marcantonini and Ellerman 2013).

The two-order of magnitude variation holds across countries as well. Firms in some parts of the world face low carbon prices, such as about US\$2/tCO2 in New Zealand and the northeast United States (Regional Greenhouse Gas Initiative). Moderate prices occur in Australia (A\$23/tCO2) and British Columbia (C\$30/tCO2) and high prices cover some firms in Sweden (US\$135/tCO2). Of course, the table omits the many parts of the world in which firms face no carbon price. This suggests the possible merits of constructing an economy-wide average carbon price, somehow weighting implicit and explicit carbon prices by fuel consumption throughout the value chain, in order to produce a single measure for comparison purposes. The challenge is in designing transparent, replicable methods, since some of the implicit carbon price estimates will require extensive statistical or simulation modeling analysis.

3.1.2 *Energy Prices and Taxes*

Energy prices are what matter for both the supply and demand for energy as well as investment in energy technologies by businesses and households. Higher overall energy prices will drive more investment in energy efficiency, and higher relative prices for more carbon-intensive energy sources will spur investment in low- and zero-carbon technologies. Energy prices are transparent and measurable with high frequency. Energy prices permit a net assessment of all policies, and thus can mitigate concerns that a country engages in fiscal cushioning by simultaneously imposing a carbon tax and source-specific tax relief. Energy prices could capture some effects from some non-price regulations that get built into the cost of developing and producing energy, such as a power plant emission standard or a low-carbon fuel standard for gasoline. Focusing on energy prices would not generally capture regulatory policies, such as those intended to reduce energy consumption (including appliance efficiency and fuel economy standards). Such policies reflect substantial political and economic effort and can yield important reductions in greenhouse gas emissions without being fully reflected in energy prices.[8]

Of course, not all energy price differences across countries or over time represent policy choices. Different resource endowments coupled with transportation constraints lead to significant regional disparities in coal and natural gas prices. Meanwhile, changes over time can reflect fundamental supply and demand shifts unrelated to policy changes. While there is a tendency to focus energy price comparisons across countries on the current policy and tax differences, it is useful to note that emissions comparisons are often based on changes vis-à-vis an historic base year without applying an explicit policy filter. One might therefore contemplate a price comparison that included a matrix of price levels and changes over time, differentiated by policy- and non-policy related elements.

Among price-based metrics, examining fossil energy prices will be necessary, at a minimum, to ensure fiscal cushioning does not occur; that is, to ensure that a carbon tax is not offset by changes in other energy taxes or subsidies. Fossil energy prices will also be useful in diagnosing any initial energy price distortions, as well as the progress of a carbon tax in changing the things that really matter – the prices of the underlying fuels delivered to end-users. An "effective carbon price" could attempt to take into account all policies impacting fossil energy prices, as well as electricity prices, to represent the net effect of national programs on the pricing of carbon.

What is the right benchmark for energy prices? First, we should care about the relative prices of different energy sources in different sectors, as well as the overall level of energy prices versus other productive inputs. Second, as noted above, it might be reasonable to think about a range of metrics measuring both changes from the status quo as well as absolute price levels, and decomposing both levels and changes into policy- and non-policy components. Third, it may be necessary to consider the path of future expected prices, both stated and revealed. A country with a high but fixed price may be less forward leaning than a country with a low but rising price.

Table 4 illustrates the average energy prices and taxes as well as the percentage changes in prices and taxes, respectively, over the 1997-2010 period for a set of OECD countries (the kind of matrix envisioned above). The average energy prices vary by a factor of two while average energy taxes vary by more than a factor of ten. Relatively low energy price countries, such as the United States and Canada, experienced greater growth in energy prices over 1997-2010 than other countries. This reflects, in large part, the fact that the underlying fuel prices are a greater share of retail energy prices in these countries than in many European countries. The average energy tax grew significantly over 1997-2010 in some countries, such as Canada and Germany, while failing by a third or more in other countries, such as the United Kingdom, France, and Mexico. Refer to Appendix Table 4 for an extension of Table 4 to all OECD countries and for data on gasoline prices for most countries in the world.

[8] The energy price metric is also less relevant for some countries in which a large fraction of their greenhouse gas emissions occur beyond the energy sector (e.g., Brazil and Indonesia due to land use change or New Zealand due to agriculture). In these cases, additional metrics to compare action will be necessary.

3.3 Costs

The mitigation costs of any domestic climate policy are typically most closely aligned with economists' notion of mitigation effort. For that reason, it is an intrinsically appealing metric. Expressed as a share of national income, or per capita, it could be scaled to be comparable across countries of vastly different sizes. The concern about the costs of combating climate change represents one of, if not the most, significant impediments to serious action by countries around the world. A metric to compare effort based on costs could promote confidence that the international effort is fair by ensuring that comparable countries bear comparable costs from their actions. Coupled with information about emission reductions, it could also highlight the potential advantages of some policies (with lower mitigation costs) over others.[9]

Of course, just as emissions are easily observed but reductions are not, prices are easily observed but costs are not. But even more than estimating reductions, cost estimation requires additional economic assumptions and detailed frameworks for evaluating economic changes in specific sectors and national economies.

One approach would be to use simple partial equilibrium analyses of mitigation costs associated with different policies. This would combine estimates of emission reductions with marginal costs revealed by observed prices to produce estimates of total costs.[10] This somewhat simple-minded combining of price and emission metrics could be a useful complement if such information is already being assembled.

Alternatively, one could pursue a more integrated modeling approach. A significant energy-economic modeling literature has produced emission mitigation cost estimates of climate change policy for more than two decades.[11] Such modeling tools provide important insights on policy design (e.g., the economic gains to trading among countries and across time) that have informed real-world policy debate and implementation. There are two limitations to extending such modeling analyses to a comparability of effort exercise. First, most models focus on a small set of large countries and regions. For example, the McKibbin et al. (2011) assessment of Copenhagen commitments employed the G-Cubed Model that represents the world economy with six countries and five regions. Such models in their current set-up can only highlight effort for a small set of countries.

Second, these models are best designed to evaluate economy-wide carbon price policies. In practice, countries implement a myriad of sectoral, overlapping policies. The UNFCCC (2011) reports that Annex I countries have implemented more than 1,000 mitigation policies. It may be beyond the capacity of these models to fully incorporate the entirety of these instruments, although recent efforts through the Stanford Energy Modeling Forum have attempted to include small combinations of policy

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[9] We presume that the domestic political incentives to minimize cost of mitigating greenhouse gas emissions would dominate the potential incentive to undertake cost-ineffective policies with the aim of highlighting high costs and hence high levels of effort in international negotiations.

[10] That is, assuming linear marginal costs rising from zero to the observed carbon price level, one could estimate costs as ½ × (marginal costs) × (emission reductions).

[11] See Gaskins and Weyant (1993) for a modeling comparison exercise of U.S. mitigation costs, Weyant and Hill (1999) for a modeling comparison exercise of Annex I mitigation costs under the Kyoto Protocol, and McKibbin et al. (2011) for a recent assessment of Copenhagen mitigation commitments

instruments (such as carbon pricing, fuel economy standards, and power sector renewables mandates). It also begs the questions whether analysis should focus on an evaluation of the observed mix of possibly cost-ineffective policies, or on an assessment of a cost-minimizing effort to achieve the same reductions. The former would measure actual effort but would reward countries for poor policy choices. Undertaking the latter could highlight a notion of effort that abstracts from these choices (and perhaps inform countries about the efficacy of their mitigation programs). However, such analysis also poses legitimacy challenges as in this case both the counterfactual BAU and the policy scenario are unobserved and unobservable.

A last question is how to view policies with negative costs. Consider two examples. First, suppose a country implements a tax swap – imposing a tax on carbon while reducing tax rates on labor and/or capital. Depending on the distortions of the pre-existing factor taxes and the nature of the tax swap, a country could experience greater economic growth while reducing emissions. Second, suppose a country eliminates fossil fuel consumption subsidies. For some countries, this could significantly reduce emissions while contributing to faster economic growth (IEA et al. 2010). Should such economic benefits reduce how we view a country's contribution to climate change mitigation?

3.4 Synthesis of Metrics

Table 5 summarizes our assessment of the various metrics against the four design principles identified in section 2. None of the six types of metrics evaluated here satisfy the Comprehensive principle. As noted above, measures based on emissions can result in erroneous assessments of effort since many factors can influence emissions that are unrelated to emission mitigation policies. Emission abatement and abatement costs are the metrics that probably best represent effort, but they fair poorly on other principles – these metrics require sophisticated modeling tools for implementation, and thus it is challenging to measure them. Credible differences in opinion on modeling assumptions could produce different results for abatement and costs, suggesting that estimated measures may not be replicable. Further, few modeling tools exist to address more than the largest developed and developing countries. Potential negative cost abatement policies (such as eliminating fossil fuel subsidies) raise additional questions about how to value efforts that may be politically quite significant but provide net economic gains.

Explicit carbon prices and energy prices and taxes are measurable and replicable, and they provide some information about effort, primarily in the energy sectors of an economy. Energy prices and taxes are also universal, although data collection protocols could be improved for some countries. The challenge lies with the fact that there are not many explicit carbon pricing policies in effect around the world, and implicit carbon price metrics require detailed analyses in order to construct an estimate. Just as with abatement and costs, different plausible assumptions in such analyses could result in non-replicable measures. This also requires an extension of current analytic tools to many more countries in order to produce a universal measure of implicit carbon prices.

4. Use of Metrics of Comparability for International Climate Policy

These metrics could play a variety of roles in the design and implementation of international climate policy. The relative importance of different principles and features will inevitably depend on the particular use, perhaps leading to preferences for different metrics in different situations.

4.1 Benchmarking for Comparability

Any metric will create a natural tendency to sort countries based on who has high versus low measures—essentially a default benchmark. However, a fair comparison likely requires a more explicit and nuanced benchmarking to adjust for differences not captured by the metric alone. That is, benchmarking various metrics is what truly facilitates comparisons among countries; are countries doing their fair share *relative* to one another? Certain benchmarks could also inform an assessment of whether the *absolute* effort called for in an agreement could deliver sufficient progress. For example, a carbon price metric could be compared to a social cost of carbon benchmark as a measure of progress. Of course, we recognize that it may be much easier to reach agreement on estimating and comparing implicit carbon prices than to reach agreement on the social cost of carbon benchmark.

While we have illustrated metric design and application as a positive exercise in this paper, we believe that the choice of benchmarks is a normative one. Thus, we do not attempt to make the case for explicit benchmarks for given metrics. Nonetheless, we identify a few considerations of benchmarks drawn from the UNFCCC. First, a benchmark could reflect an assessment of the adequacy of collective effort in realizing the long-term objective to limit warming to no more than 2°C as called for in the Copenhagen Accord and Cancun Agreements.[12]

Second, benchmarks could reflect the principle of common but differentiated responsibilities and respective capabilities. For example, it may appear odd to compare any metric concerning China's mitigation efforts to those of Chad, since the former's emissions are four orders of magnitude greater than the latter's. Or, it may appear odd to compare metrics describing Singapore's mitigation program to that of Ethiopia, since the former's per capita emissions are three orders of magnitude greater than the latter's. Or, it may be odd to compare effort metrics for Qatar to metrics for Bangladesh, since per capita income in the former is two orders of magnitude greater than in the latter. As a result, a metric could be universally applied but include differentiated benchmarks that apply to specific peer groups of nations. Even by itself, the creation of peer groups along various dimensions could be viewed as a form of comparative benchmarking.

For example, if the international community agreed on benchmarks for a few metrics, then the comparability of effort exercise could be designed in a way that would allow for comparisons among the largest economies, e.g., Major Economies Forum on Energy and Climate membership. Indeed, to demonstrate feasibility and applicability of a comparability of effort process, the MEF countries could voluntarily take on metrics and present data and analysis regarding their future emission commitments.

This type of differentiation naturally raises obvious questions of how benchmarks should be adjusted to reflect national circumstances. On the one hand, the larger the needed adjustments, in some sense, the more problematic is the metric. On the other hand, underlying the choice of metrics or the adjustments are fundamental questions about what sorts of concerns are valid. For example, countries like the United States, Canada, and Australia have all faced annual population growth on the

[12] It should be noted that our two examples of linking a benchmark for individual country effort derived from an aggregate measure of adequacy – the social cost of carbon and a 2°C warming limitation – may yield two different sets of benchmarks. For example, Nordhaus (2008) shows that a 2°C warming limitation is inconsistent with setting a globally harmonized carbon tax equal to the social cost of carbon.

order of 1% per year. Europe and Japan have not. China, India, and other emerging economies are not as wealthy on a per capita basis as the United States; how should their benchmarks be recalibrated? Some countries are endowed with plentiful fossil resources; others are not. Some countries have taken significant actions to mitigate actions, while others are regarded as policy laggards. How should decisions about benchmark differentiation (or about the metrics themselves) balance rewarding the first movers versus providing an incentive to the laggards to increase their participation? This is one of the thorniest issues that will have to be sorted out as metrics are put into practice.

4.2 Policy Surveillance

Distinct from the ultimate use metrics for comparison among countries is the process to produce and validate them. Many nations do not have the resources or capacity to evaluate other nations' commitments and performance, and they may be suspicious of self-assurances by nations themselves. Thus, an independent cadre of experts could provide a legitimate assessment of the effort pledged – and outcomes achieved – by nations to mitigate greenhouse gas emissions. To be effective, ensuring comparability requires a professional, regular, and independent assessment of countries' policies, actions, and emissions that can inform the periodic rounds of international climate negotiations.

Several models for such policy surveillance exist (see summary and review in Aldy, 2013). The International Monetary Fund undertakes so-called Article IV consultations of member governments' economic, fiscal, and monetary policies. Under the World Trade Organization, the Trade Review Policy Board evaluates the trade policies of WTO members, with greater frequency for the largest trading nations. While these treaty organizations created professional bureaucracies to undertake such policy surveillance, the G-20 tasked international organizations (the World Bank, OECD, International Energy Agency, and OPEC) to identify fossil fuel subsidies and evaluate the performance of G-20 nations in reducing their fossil fuel subsidies pursuant to the 2009 Pittsburgh G-20 Leaders' Agreement. Under the UNFCCC, ad hoc groups of experts evaluate the emission inventories submitted by industrialized nations and their national communications.

Given the absence of a single metric that satisfies our comprehensive principle, we recommend consideration of a policy surveillance mechanism focused on a suite of metrics to provide a richer characterization of effort. Just as an economic analyst would review a suite of data to understand the strength of a national economy (e.g., GDP, unemployment rate, interest rates, business investment, etc.), a climate policy analyst could also benefit from a more comprehensive assessment of emission mitigation effort.

Such surveillance could play an important role in ex ante and ex post assessments of mitigation commitments (or contributions). In the former, countries could propose their mitigation commitments to facilitate the comparability of effort exercise (as well as an aggregate ambition assessment). Countries could be required to submit their own data and analyses to demonstrate the effort they expect to undertake in delivering the commitment. A cadre of experts could process, compile, analyze, and construct comparisons based on submitted data and analyses as well as third party data and analyses. This could inform the negotiators as they finalize commitments. A similar process could focus on ex post assessments of countries' efforts to deliver on their pledged commitments. Again, such an assessment would benefit from a synthesis of country- and third party-provided data and analyses.

4.3 Improving the Structure of Emission Mitigation Commitments

The first two uses of metrics—for comparison and surveillance—could be combined in order to enhance mitigation action under an international agreement. National governments are more likely to take stronger action within an international agreement to combat climate change if they have stronger assurances that they will be making a fair contribution to the global effort alongside others' efforts. In light of the evolution in Copenhagen and Cancun to a pledge and review approach to emission mitigation commitments, one way to operationalize this process could be a modified approach to what constitutes a legally binding commitment.

For example, an international climate policy architecture could require all countries to submit two-part emission commitments. In the first part, each country pledges emission mitigation goals, policies, and/or actions – such as an economy-wide emission goal versus a base year, elimination of fossil fuel subsidies, a carbon tax, etc. In the second part, each country would produce data and analysis to characterize the impacts of its pledged commitment and thereby facilitate the comparison with other countries' pledged commitments.[13] Since some countries and some stakeholders continue to call for "legally-binding" commitments, this two-part approach could permit the second part – the provision of data and analysis to promote transparency and facilitate comparisons – could be deemed "legally binding."

In addition, evaluating emission mitigation commitments ex ante and ex post through various metrics can provide the baseline and performance measures necessary to ascertain the effectiveness of various policy approaches. Thus, a systematic approach to employing metrics can facilitate learning that could drive improvements in the design and implementation of future commitments. Such an adaptive learning approach may also promote the revision of metrics to increase their information content.

4.4 Linking Domestic Policies

Moving beyond the considerations of multilateral agreements, an important practical use of comparability metrics is whether individual jurisdictions will choose to link trading systems or explicitly coordinate carbon taxes or other policies. In this context, carbon prices are an obvious metric. Absent similar carbon prices, linking two trading systems will lead to significant flows of allowances in one direction and payments in the other. To the extent this kind of exchange is palatable that may make sense. For example, a rich country might be willing to be a significant net buyer from a poor country. Or, a small country might be willing to be a net buyer in exchange for the improved liquidity that arises from linking to a larger market. In other situations, significant price differences and the implied trade flows would be a sign of imbalance and may elicit political opposition.

Similarly, the explicit nature of the carbon price in a carbon tax regime suggests that efforts to harmonize carbon prices will need to explicitly tackle why those prices might deviate. Perhaps, some countries are expected to lead (based, say, on per capita income). Perhaps there is a recognition of an unequal starting point, in terms of underlying fossil energy prices or other policies. In either case, this could be a useful role for an explicit benchmarking exercise.

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[13] Such analysis could be subject to agreed guidelines to facilitate comparability. We should note that past guidelines for reporting through national communications have been inadequately rigorous to permit comparisons of effort across countries or even within countries over time (Thompson 2006).

4.5 Border Measures

A second practical arena for metrics is the potential for border measures to arise in the context of domestic policy debates when jurisdictions are worried about emission leakage. As this typically arises in relation to the status quo, the question is tied quite closely to *new* carbon pricing or other regulation. Here, the benchmark is a bit more obvious – namely, changes against levels in the recent past. Among carbon prices, fossil energy prices, and / or electricity – it is electricity and fossil energy prices that matter the most. Electricity prices might be the most amenable to allowing comparisons across policies; electricity is what matters for many manufacturing activities and – for regulations in the power sector – summarily measures the impact on end users. Since international trade occurs in markets, it is clear that market exchange rates, as opposed to purchasing power parity, are relevant for comparing prices in different currency.

To the extent that border measures are viewed not as a vehicle to address emission leakage but as a penalty to laggards in order to encourage action, the metric and benchmark becomes less obvious for justifying action. This could reflect the general array of metrics and adjusted benchmarks discussed throughout.

5. Conclusions

Metrics and benchmarks to compare climate change actions across countries are increasingly relevant as we transition to unilateral pledges of domestic action and policy within international negotiations. The negotiations no longer provide a revealed preference for particular choices; instead countries will state what they intend to do, other countries and various stakeholders must make decisions about adequacy, and then everyone will react accordingly. This reaction may be in the formal venue of top-down international negotiations; it may also relate to more ad hoc, bottom-up decisions to cooperate, harmonize, or link domestic systems; and it may arise in situations where countries unilaterally (or mini-laterally or multi-laterally) decide to act against laggards.

When we contemplate metrics for comparability, a number of relatively deep differences emerge. First, some metrics are relatively easy to observe and measure—total emissions and explicit emission prices—but may be one or more steps removed from the key concepts of effort and underlying incentives. Meanwhile, the concepts that are closer to effort—emission *reductions*, implicit prices, and costs—are harder to observe and measure directly, leading to more subjective and likely divergent estimates. Finally, there are a variety of ways that metrics can be benchmarked that may or may not make adjustments for resource endowments, historic behavior, or future growth. These benchmarks can be further differentiated in an ad hoc or formulaic matter.

Developing metrics and benchmarks for assessing comparability of effort, compiling data and related information in light of these metrics, and reporting the results of the assessments will require a serious, professional, transparent, and legitimate mechanism. This is particularly true for policy surveillance purposes. Moreover, the identification of benchmarks for either relative or absolute comparisons inherently reflects value judgments, and thus could involve extensive negotiations among countries. In the meantime, an array of metrics, such as those presented in section three, could be developed and data collected by existing international organizations to facilitate comparisons in the near term—in advance of any official policy surveillance or benchmarking. Feedback on the feasibility, integrity, and precision of various metrics could be solicited to enable further refinement of metrics and to inform the deliberations over metrics and benchmarks going forward.

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Tables and Figures

Table 1. Change in Emissions over 1990-2010 and 1997-2010

	1990-2010		1997-2010	
Country	Fossil CO2, Percentage Change	All GHGs, Percentage Change	Fossil CO2, Percentage Change	All GHGs, Percentage Change
United States	+12%	+15%	+1%	+5%
United Kingdom	-12%	-17%	-7%	-7%
European Union	-12%	-17%	-7%	-10%
China	+267%	+209%	+156%	+138%
India	+177%	+116%	+87%	+64%
Japan	+13%	+7%	+2%	-3%
Russia	-31%	-28%	+18%	+7%

Sources: U.S. Energy Information Administration (n.d.); World Resources Institute (n.d.). Russia 1990 data from Le Quéré et al. (2013) and UNFCCC (n.d.).

Table 2. Emissions Intensity (CO2-GDP ratio), 2010

Country	CO_2/ GDP(2012$, market exchange rate)	CO_2/ GDP(2012$, purchasing power parity)
United States	0.37	0.37
United Kingdom	0.20	0.21
China	1.81	0.75
India	1.11	0.37
Japan	0.22	0.26

Source: U.S. Energy Information Administration (2000, n.d.); World Resources Institute (n.d.).
Notes: CO_2 based on fossil fuel combustion CO_2 emissions only. Measures represent a metric ton of carbon dioxide per $1000 of GDP.

Table 3. Carbon Prices under Various Energy and Climate Policies

Country	Program	$/tCO2	Source/Date
EU ETS	Cap-and-trade	€8	Average daily price, 2012, (Datastream International BlueNext Series)
Germany	Wind feed-in-tariff	€62	Average abatement cost, 2010, Marcantonini and Ellerman, 2013 (2011€)
Germany	Solar feed-in-tariff	€547	Average abatement cost, 2010, Marcantonini and Ellerman, 2013 (2011€)
Australia	Cap-and-trade/tax hybrid	A$23	2012 fixed price (EDF/IETA 2013)
New Zealand	Cap-and-trade	NZ$3.15	January 3, 2014 closing spot price (Point Carbon 2014)
Regional Greenhouse Gas Initiative	Cap-and-trade	$2.67	September 2013 auction clearing price (RGGI 2013)
California	Cap-and-trade	$11.75	December 2013 futures price (November 22, 2013) (CME Group 2013)
Shenzen, China	Cap-and-trade	US$7	August 2013 (The Climate Group 2013)
Quebec	Cap-and-trade	C$10.75	Auction price floor 2013, (Government of Quebec n.d.)
British Columbia	Tax	C$30	2013 (Government of British Columbia n.d.)
Alberta	C performance standard	C$15	2012 (Government of Alberta n.d.)
Denmark	Tax	€3 - €90	2009, Industry, varies by type of industry and voluntary agreement (Aldy and Stavins 2012b)
Finland	Tax	€20	2009 (Aldy and Stavins 2012b)
Norway	Tax	NOK92 - 363	2009 (Aldy and Stavins 2012b)
Sweden	Tax	€114	Households and services, 2012 (Aldy and Stavins 2012b)

Table 4. Energy Prices and Energy Taxes, 2010, and Change since 1997, Select OECD Countries

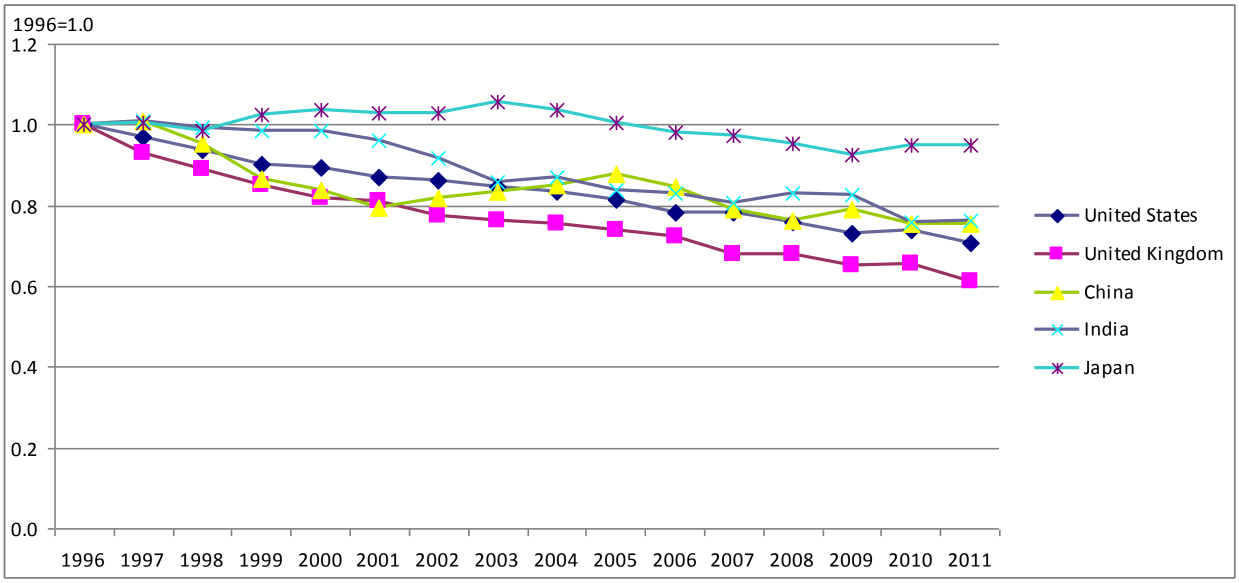
Country	Average Energy Price (2012US$/MMBTU)	1997-2010 Change in Energy Price (percentage)	Average Energy Tax (2012US$/MMBTU)	1997-2010 Change in Energy Tax (percentage)
United States	24.1	+72%	1.0	-2%
United Kingdom	61.5	+29%	6.4	-30%
France	58.4	+28%	5.9	-34%
Germany	59.7	+51%	9.2	+29%
Japan	47.5	+34%	1.9	+12%
Canada	33.6	+77%	2.7	+86%
Australia	37.8	+67%	2.4	+9%
Mexico	24.0	+33%	0.6	-56%

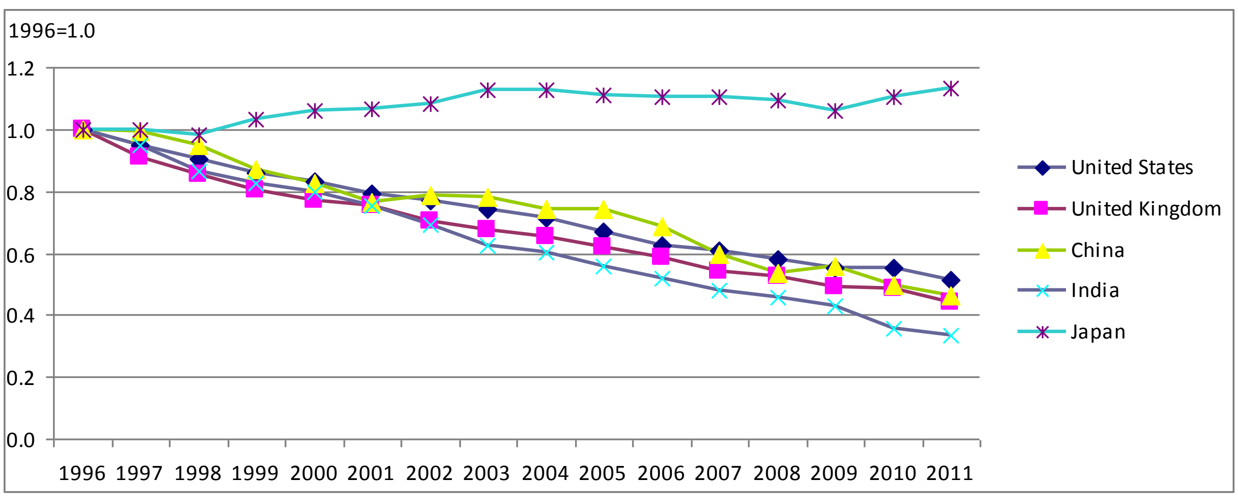
Notes: The average energy price (tax) reflects a consumption-weighted measure of end-user prices on a market exchange rate 2010 dollars per million British thermal units (MMBTU) basis.
Source: IEA (n.d.).

Table 5. Synthesis of Metrics and Principles for Comparability of Effort

	Principle			
Metric	**Comprehensive**	**Measurable**	**Replicable**	**Universal**
Emission Levels	A poor estimate of effort because it conflates natural trends	Yes	Yes; public domain data for energy and fossil CO2 available	Fossil CO2 data exist for all countries; additional work needed for all GHGs
Emission Intensities	Better than emission levels as it controls for economic trends, but a noisy signal	Yes	Yes; public domain data for energy and fossil CO2 available	Yes for fossil CO2/GDP; additional work needed for GHG/GDP
Emission Abatement	Most comprehensive among emission-related metrics	Challenging – requires modeling tools / subjective choices to determine counterfactuals	Different model structures with different assumptions could yield different outcomes	No, few modeling platforms evaluate more than ~10 countries
Carbon Prices	Incomplete C pricing undermines explicit measure;	Explicit, yes; implicit requires detailed analyses	Yes for explicit prices; implicit prices may depend on analytic assumptions	No, given few explicit C pricing policies; modeling tools necessary for implicit C prices
Energy Prices and Taxes	Inadequate for non-energy emissions; fails to account for some regulatory instruments	Yes, but unclear how to aggregate	Yes	Yes, but requires more detailed data collection than currently in public domain
Abatement Costs	Best measure of effort, still requires benchmarking	Challenging – requires modeling tools / subjective choices to determine counterfactuals and model costs	Different model structures with different assumptions could yield different outcomes	No, few modeling platforms to comprehensively evaluate more than ~10 countries

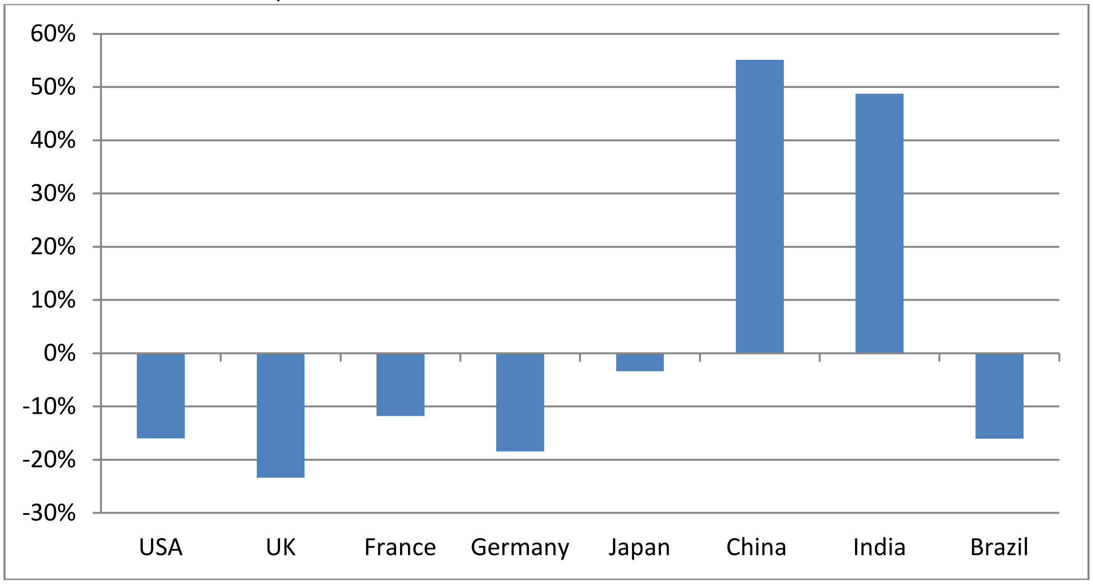
Figure 1. Change in Emission Intensity (CO2-GDP Ratio), 1996-2011, (A) Market Exchange Rate 2005-Year Dollars, (B) Nominal Local Currency Units





Notes: Each country's year 1996 intensity is indexed to 1.0.
Source: U.S. Energy Information Administration (n.d.); World Bank (n.d.).

Figure 2. Estimated Fossil Carbon Emission Reductions Relative to "Business-as-Usual" Forecast for 2010, Territorial and Consumption-based CO2 Emissions



Sources: Le Queré et al. 2013; U.S. Energy Information Administration 2000.

Appendix Table 1: Percentage Change in Emissions, Various Time Periods and Versus Business-as-Usual Forecast for 2010

Country	CO2, 1990 - 2010	CO2, 1997 - 2010	GHG, 1990 - 2010	GHG, 1997 - 2010	Realized 2010 v. BAU 2010 CO2
Afghanistan	5	365	66	71	N/A
Albania	-37	98	-43	27	N/A
Algeria	35	39	62	55	N/A
American Samoa	-51	-51	N/A	N/A	N/A
Angola	271	105	50	49	N/A
Antigua and Barbuda	58	35	N/A	N/A	N/A
Argentina	70	34	24	13	N/A
Armenia	N/A	39	-41	119	N/A
Aruba	75	14	N/A	N/A	N/A
Australia	58	28	75	59	N/A
Austria	24	8	12	6	N/A
Azerbaijan	N/A	-23	-29	44	N/A
Bahamas, The	21	2	83	100	N/A
Bahrain	114	66	167	114	N/A
Bangladesh	282	140	103	62	N/A
Barbados	8	-2	25	26	N/A
Belarus	N/A	9	-47	13	N/A
Belgium	9	-6	17	8	N/A
Belize	50	7	80	62	N/A
Benin	761	349	13	9	N/A
Bermuda	6	34	N/A	N/A	N/A
Bhutan	168	24	-12	-18	N/A
Bolivia	162	66	22	19	N/A
Bosnia and Herzegovina	N/A	131	N/A	N/A	N/A
Botswana	86	59	61	69	N/A
Brazil	90	39	6	1	-16
Brunei	85	130	42	23	N/A
Bulgaria	-40	-16	-51	-26	N/A

Country	CO2, 1990 - 2010	CO2, 1997 - 2010	GHG, 1990 - 2010	GHG, 1997 - 2010	Realized 2010 v. BAU 2010 CO2
Burkina Faso	247	61	48	32	N/A
Burma (Myanmar)	155	73	-9	-13	N/A
Burundi	-32	-46	670	371	N/A
Cambodia	777	120	29	19	N/A
Cameroon	149	24	1	0	N/A
Canada	16	0	28	9	-11
Cape Verde	294	222	305	413	N/A
Cayman Islands	103	64	N/A	N/A	N/A
Central African Republic	38	14	-19	-8	N/A
Chad	-25	44	41	30	N/A
Chile	149	47	195	60	N/A
China	267	156	209	138	55
Colombia	59	5	26	10	N/A
Comoros	86	56	16	16	N/A
Congo, Rep.	495	83	12	4	N/A
Congo, Dem. Rep.	-14	-16	-18	-8	N/A
Cook Islands	54	53	-68	-78	N/A
Costa Rica	156	57	-44	-56	N/A
Cote d'Ivoire	42	27	29	23	N/A
Croatia	N/A	5	-51	9	N/A
Cuba	-20	-15	-17	32	N/A
Cyprus	74	31	87	44	N/A
Czech Republic	N/A	-5	-40	-26	N/A
Denmark	-20	-39	-13	-26	N/A
Djibouti	-33	-37	103	76	N/A
Dominica	122	60	-16	-21	N/A
Dominican Republic	106	53	114	25	N/A
Ecuador	117	62	20	11	N/A
Egypt	106	70	119	79	N/A

Country	CO2, 1990 - 2010	CO2, 1997 - 2010	GHG, 1990 - 2010	GHG, 1997 - 2010	Realized 2010 v. BAU 2010 CO2
El Salvador	147	26	55	15	N/A
Equatorial Guinea	4421	242	364	163	N/A
Eritrea	N/A	-55	29	-5	N/A
Estonia	N/A	6	-45	36	N/A
Ethiopia	114	276	73	52	N/A
Falkland Islands	89	36	N/A	N/A	N/A
Faroe Islands	N/A	9	N/A	N/A	N/A
Fiji	27	20	53	50	N/A
Finland	3	1	9	-5	N/A
France	6	1	2	7	-12
French Guiana	44	2	N/A	N/A	N/A
French Polynesia	19	54	N/A	N/A	N/A
Gabon	-21	-19	-9	-5	N/A
Gambia, The	150	116	84	47	N/A
Georgia	N/A	8	-66	13	N/A
Germany	N/A	-11	-21	-12	-18
Ghana	201	138	6	1	N/A
Gibraltar	196	53	N/A	N/A	N/A
Greece	14	2	21	10	N/A
Greenland	N/A	20	N/A	N/A	N/A
Grenada	119	28	24	13	N/A
Guadeloupe	47	24	N/A	N/A	N/A
Guam	-51	-75	N/A	N/A	N/A
Guatemala	200	63	72	16	N/A
Guinea	-3	15	15	11	N/A
Guinea-Bissau	45	28	23	18	N/A
Guyana	143	45	5	-3	N/A
Haiti	185	47	59	29	N/A
Honduras	178	98	-9	-13	N/A

Country	CO2, 1990 - 2010	CO2, 1997 - 2010	GHG, 1990 - 2010	GHG, 1997 - 2010	Realized 2010 v. BAU 2010 CO2
Hong Kong	129	100	N/A	N/A	N/A
Hungary	-23	-13	-27	-12	N/A
Iceland	39	16	31	39	N/A
India	177	87	116	64	49
Indonesia	166	68	-17	-24	N/A
Iran	179	94	187	79	N/A
Iraq	64	63	39	23	N/A
Ireland	49	11	15	4	N/A
Israel	102	29	103	35	N/A
Italy	0	-2	6	-1	-13
Jamaica	22	-13	25	5	N/A
Japan	13	2	7	-3	-3
Jordan	103	50	46	23	N/A
Kazakhstan	N/A	50	-30	33	N/A
Kenya	85	77	27	30	N/A
Kiribati	183	180	219	156	N/A
Korea, North	-48	-3	-39	0	N/A
Korea, South	140	36	126	38	N/A
Kuwait	212	64	163	58	N/A
Kyrgyzstan	N/A	3	-76	-15	N/A
Laos	535	149	21	20	N/A
Latvia	N/A	-8	-67	-14	N/A
Lebanon	308	25	178	17	N/A
Lesotho	253	208	45	27	N/A
Liberia	-7	33	2	3	N/A
Libya	45	41	49	38	N/A
Lithuania	N/A	-13	-56	2	N/A
Luxembourg	13	41	15	47	N/A
Macau	39	1	N/A	N/A	N/A

Country	CO2, 1990 - 2010	CO2, 1997 - 2010	GHG, 1990 - 2010	GHG, 1997 - 2010	Realized 2010 v. BAU 2010 CO2
Macedonia	N/A	-22	-42	-2	N/A
Madagascar	96	45	52	28	N/A
Malawi	81	30	41	42	N/A
Malaysia	193	87	102	45	N/A
Maldives	987	237	460	163	N/A
Mali	49	28	43	37	N/A
Malta	237	187	242	212	N/A
Martinique	71	32	N/A	N/A	N/A
Mauritania	98	-40	11	-1	N/A
Mauritius	141	92	168	100	N/A
Mexico	43	24	49	30	-14
Moldova	N/A	-25	-75	-32	N/A
Mongolia	-17	46	-3	7	N/A
Montserrat	120	75	N/A	N/A	N/A
Morocco	91	52	71	27	N/A
Mozambique	115	131	7	6	N/A
Namibia	40	131	71	31	N/A
Nauru	17	11	37	30	N/A
Nepal	463	84	-47	-51	N/A
Netherlands	21	7	35	28	-29
Netherlands Antilles	19	-4	N/A	N/A	N/A
New Caledonia	89	77	N/A	N/A	N/A
New Zealand	29	10	206	125	N/A
Nicaragua	122	48	27	18	N/A
Niger	18	14	62	13	N/A
Nigeria	-11	-20	19	11	N/A
Niue	10	8	-119	-120	N/A
Norway	30	8	3	-1	N/A
Oman	323	194	124	59	N/A

Country	CO2, 1990 - 2010	CO2, 1997 - 2010	GHG, 1990 - 2010	GHG, 1997 - 2010	Realized 2010 v. BAU 2010 CO2
Pakistan	112	48	94	52	N/A
Palestinian Territories	N/A	403	N/A	N/A	N/A
Panama	48	37	14	4	N/A
Papua New Guinea	33	23	9	0	N/A
Paraguay	102	50	5	2	N/A
Peru	108	65	58	48	N/A
Philippines	89	19	96	24	N/A
Poland	-9	-9	-18	-12	N/A
Portugal	23	3	40	12	N/A
Qatar	263	109	378	200	N/A
Reunion	139	56	N/A	N/A	N/A
Romania	-57	-37	-55	-32	N/A
Russia	N/A	18	-28	7	N/A
Rwanda	8	9	-35	-45	N/A
Saint Helena	52	50	N/A	N/A	N/A
Saint Kitts and Nevis	308	158	N/A	N/A	N/A
Saint Lucia	146	101	60	23	N/A
Saint Pierre and Miquelon	-66	47	N/A	N/A	N/A
Saint Vincent/Grenadines	150	46	N/A	N/A	N/A
Samoa	30	23	182	183	N/A
Sao Tome and Principe	95	70	N/A	N/A	N/A
Saudi Arabia	125	84	191	107	N/A
Senegal	132	66	3	25	N/A
Serbia	N/A	N/A	-42	-43	N/A
Seychelles	117	74	442	99	N/A
Sierra Leone	31	62	9	15	N/A
Singapore	296	128	666	285	N/A
Slovakia	N/A	-14	-55	-17	N/A
Slovenia	N/A	-4	8	8	N/A

Country	CO2, 1990 - 2010	CO2, 1997 - 2010	GHG, 1990 - 2010	GHG, 1997 - 2010	Realized 2010 v. BAU 2010 CO2
Solomon Islands	22	24	10	7	N/A
Somalia	-19	40	N/A	N/A	N/A
South Africa	59	23	52	33	N/A
Spain	39	18	52	29	N/A
Sri Lanka	125	32	28	12	N/A
Sudan	377	353	33	13	N/A
Suriname	33	32	62	55	N/A
Swaziland	31	0	60	2	N/A
Sweden	4	-10	11	10	N/A
Switzerland	-3	-4	-4	-1	N/A
Syria	77	47	79	40	N/A
Taiwan	142	37	N/A	N/A	N/A
Tajikistan	N/A	-44	-42	31	N/A
Tanzania	129	163	6	9	N/A
Thailand	225	54	118	42	N/A
Togo	142	115	-3	4	N/A
Tonga	113	41	58	35	N/A
Trinidad and Tobago	188	103	N/A	N/A	N/A
Tunisia	47	11	33	8	N/A
Turkey	108	48	60	30	N/A
Turkmenistan	N/A	168	36	77	N/A
Uganda	302	223	33	28	N/A
Ukraine	N/A	-18	-58	-18	N/A
United Arab Emirates	171	91	254	150	N/A
United Kingdom	-12	-7	-17	-7	-23
United States	12	1	15	5	-16
Uruguay	88	62	289	80	N/A
Uzbekistan	N/A	3	16	11	N/A
Vanuatu	-4	92	40	20	N/A

Country	CO2, 1990 - 2010	CO2, 1997 - 2010	GHG, 1990 - 2010	GHG, 1997 - 2010	Realized 2010 v. BAU 2010 CO2
Venezuela	59	29	25	12	N/A
Vietnam	620	220	1608	285	N/A
Wake Island	4	-1	N/A	N/A	N/A
Western Sahara	25	17	N/A	N/A	N/A
Yemen	83	94	135	74	N/A
Zambia	-19	-8	-13	4	N/A
Zimbabwe	-40	-35	-12	-8	N/A

Sources: U.S. Energy Information Administration (2000, n.d.); World Resources Institute (n.d.).

Appendix Table 2: Emission Intensities by Market Exchange Rate (MER) and Purchasing Power Parity (PPP) GDP, 2010

Country	CO2/GDP-MER TCO2/2012US$1000	GHG/GDP-MER TCO2e/2012US$1000	CO2/GDP-PPP TCO2/2012US$1000	GHG/GDP-PPP TCO2e/2012US$1000
Afghanistan	0.53	1.87	0.18	0.58
Albania	0.32	0.49	0.15	0.22
Algeria	0.83	1.13	0.36	0.50
American Samoa	0.50	N/A	0.45	N/A
Angola	0.44	3.88	0.24	2.03
Antigua and Barbuda	0.67	N/A	0.40	N/A
Argentina	0.60	N/A	0.20	0.61
Armenia	1.55	1.84	0.60	0.74
Aruba	0.43	N/A	0.43	N/A
Australia	0.43	0.71	0.47	0.76
Austria	0.18	0.19	0.21	0.22
Azerbaijan	0.91	1.74	0.31	0.63
Bahamas, The	0.45	0.39	0.40	0.31
Bahrain	1.49	1.50	1.17	1.02
Bangladesh	0.64	1.23	0.11	0.46
Barbados	0.32	N/A	0.21	N/A
Belarus	1.31	1.55	0.47	0.57
Belgium	0.30	0.30	0.33	0.34
Belize	0.33	10.78	0.14	6.73
Benin	0.84	4.09	0.32	1.74
Bermuda	0.12	N/A	0.19	N/A
Bhutan	0.28	-1.68	0.09	-0.61
Bolivia	0.96	9.52	0.27	2.69
Bosnia and Herzegovina	1.28	N/A	0.68	N/A
Botswana	0.36	3.88	0.21	1.88
Brazil	0.36	1.50	0.21	0.85
Brunei	0.74	1.76	0.95	0.98
Bulgaria	1.27	1.20	0.49	0.47

Country	CO2/GDP-MER TCO2/2012US$1000	GHG/GDP-MER TCO2e/2012US$1000	CO2/GDP-PPP TCO2/2012US$1000	GHG/GDP-PPP TCO2e/2012US$1000
Burkina Faso	0.22	3.44	0.06	1.34
Burma (Myanmar)	0.59	N/A	0.04	N/A
Burundi	0.18	20.82	0.04	6.75
Cambodia	0.41	4.20	0.08	1.34
Cameroon	0.37	8.00	0.12	3.89
Canada	0.39	0.46	0.38	0.48
Cape Verde	0.24	0.40	0.09	0.32
Cayman Islands	0.19	N/A	0.39	N/A
Central African Republic	0.17	51.13	0.05	26.14
Chad	0.03	7.00	0.01	2.82
Chile	0.49	0.48	0.29	0.29
China	1.81	2.02	0.75	0.87
Colombia	0.31	0.91	0.18	0.43
Comoros	0.27	0.82	0.09	0.48
Congo, Rep.	0.98	2.13	0.42	1.11
Congo, Dem. Rep.	0.29	25.77	0.12	11.91
Costa Rica	0.25	0.23	0.11	0.12
Cote d'Ivoire	0.32	N/A	0.13	N/A
Croatia	0.36	0.42	0.24	0.28
Cuba	0.38	0.61	1.04	N/A
Cyprus	0.41	0.39	0.37	0.37
Czech Republic	0.58	0.60	0.35	0.37
Denmark	0.15	0.17	0.22	0.25
Djibouti	1.12	N/A	0.41	N/A
Dominica	0.33	0.34	0.16	0.20
Dominican Republic	0.34	0.49	0.20	0.29
Ecuador	0.64	2.19	0.29	0.95
Egypt	1.31	1.82	0.36	0.50
El Salvador	0.28	0.57	0.13	0.29

Country	CO2/GDP-MER TCO2/2012US$1000	GHG/GDP-MER TCO2e/2012US$1000	CO2/GDP-PPP TCO2/2012US$1000	GHG/GDP-PPP TCO2e/2012US$1000
Equatorial Guinea	0.42	2.05	0.16	1.14
Eritrea	0.42	4.84	0.11	2.03
Estonia	1.21	1.33	0.75	0.85
Ethiopia	0.28	5.04	0.04	1.34
Fiji	0.39	0.40	0.32	0.35
Finland	0.23	0.26	0.28	0.33
France	0.15	0.19	0.17	0.22
French Guiana	0.24	N/A	0.32	N/A
Gabon	0.48	0.52	0.29	0.26
Gambia, The	0.67	6.84	0.13	1.85
Georgia	0.67	1.38	0.26	0.57
Germany	0.23	0.24	0.26	0.27
Ghana	0.54	3.05	0.15	1.28
Greece	0.32	0.37	0.28	0.33
Grenada	0.45	2.23	0.24	1.54
Guam	0.19	N/A	0.17	N/A
Guatemala	0.30	1.20	0.15	0.65
Guinea	0.35	7.62	0.04	2.61
Guinea-Bissau	1.02	4.56	0.31	1.92
Guyana	1.39	3.24	0.33	1.44
Haiti	0.43	1.41	0.08	0.63
Honduras	0.57	3.13	0.21	1.38
Hong Kong	0.37	N/A	0.27	N/A
Hungary	0.41	0.47	0.26	0.31
Iceland	0.17	0.20	0.26	0.32
India	1.11	1.42	0.37	0.48
Indonesia	0.95	2.38	0.39	0.99
Iran	2.10	N/A	0.63	N/A
Iraq	1.19	3.78	0.42	1.72

Country	CO2/GDP-MER TCO2/2012US$1000	GHG/GDP-MER TCO2e/2012US$1000	CO2/GDP-PPP TCO2/2012US$1000	GHG/GDP-PPP TCO2e/2012US$1000
Ireland	0.17	0.23	0.21	0.29
Israel	0.37	0.42	0.31	0.35
Italy	0.21	0.22	0.23	0.24
Jamaica	0.72	N/A	0.36	0.55
Japan	0.22	0.21	0.26	0.26
Jordan	1.05	1.16	0.59	0.64
Kazakhstan	2.01	2.45	0.87	1.09
Kenya	0.45	1.70	0.13	0.68
Kiribati	0.49	0.82	0.10	0.43
Korea, North	2.22	N/A	1.00	N/A
Korea, South	0.49	0.51	0.47	0.40
Kuwait	0.79	1.75	0.54	1.31
Kyrgyzstan	2.14	1.83	0.59	0.52
Laos	0.30	7.81	0.07	2.24
Latvia	0.44	0.44	0.23	0.24
Lebanon	0.56	0.58	0.31	0.33
Lesotho	0.31	1.17	0.10	0.66
Liberia	0.61	13.19	0.52	6.65
Libya	0.89	N/A	0.57	N/A
Lithuania	0.45	0.59	0.24	0.32
Luxembourg	0.25	0.25	0.30	0.30
Macau	0.06	N/A	0.04	N/A
Macedonia	0.95	1.11	0.37	0.42
Madagascar	0.31	10.00	0.10	3.32
Malawi	0.21	4.50	0.05	1.53
Malaysia	0.96	1.46	0.43	0.68
Maldives	0.70	0.56	0.44	0.37
Mali	0.09	3.58	0.02	1.67
Malta	1.04	0.99	0.74	0.71

Country	CO2/GDP-MER TCO2/2012US$1000	GHG/GDP-MER TCO2e/2012US$1000	CO2/GDP-PPP TCO2/2012US$1000	GHG/GDP-PPP TCO2e/2012US$1000
Martinique	0.25	N/A	0.25	N/A
Mauritania	0.74	2.61	0.22	0.99
Mauritius	0.51	0.61	0.15	0.31
Mexico	0.41	0.59	0.26	0.39
Moldova	1.64	2.10	0.57	0.75
Mongolia	2.17	8.78	0.72	3.11
Montenegro	0.63	10.94	0.34	4.89
Morocco	0.50	0.44	0.17	0.24
Mozambique	0.24	5.01	0.12	2.42
Namibia	0.33	2.04	0.17	1.40
Nepal	0.30	2.79	0.10	0.89
Netherlands	0.32	0.32	0.36	0.37
Netherlands Antilles	2.84	N/A	2.49	N/A
New Zealand	0.27	0.53	0.28	0.59
Nicaragua	0.69	4.87	0.33	1.92
Niger	0.26	4.30	0.06	1.89
Nigeria	0.40	2.43	0.20	1.14
Norway	0.12	0.11	0.17	0.15
Oman	1.10	1.66	0.57	1.02
Pakistan	0.92	1.91	0.22	0.63
Palestinian Territories	0.30	N/A	0.21	N/A
Panama	0.66	0.94	0.37	0.50
Papua New Guinea	0.44	6.18	0.20	2.72
Paraguay	0.40	8.10	0.12	2.69
Peru	0.32	1.02	0.15	0.47
Philippines	0.52	0.77	0.20	0.31
Poland	0.69	0.74	0.41	0.43
Portugal	0.24	0.31	0.21	0.27
Puerto Rico	0.37	N/A	0.32	N/A

Country	CO2/GDP-MER TCO2/2012US$1000	GHG/GDP-MER TCO2e/2012US$1000	CO2/GDP-PPP TCO2/2012US$1000	GHG/GDP-PPP TCO2e/2012US$1000
Qatar	0.58	0.62	0.43	0.48
Reunion	0.15	N/A	0.34	N/A
Romania	0.59	0.80	0.28	0.40
Russia	1.57	1.96	0.71	0.90
Rwanda	0.17	0.30	0.03	0.10
Saint Kitts and Nevis	0.53	N/A	0.37	N/A
Saint Lucia	0.37	0.82	0.21	0.50
Saint Vincent/Grenadines	0.28	N/A	0.14	N/A
Samoa	0.35	0.73	0.16	0.44
Sao Tome and Principe	1.33	N/A	0.30	N/A
Saudi Arabia	1.13	0.96	0.72	0.63
Senegal	0.50	2.03	0.18	0.99
Serbia	1.72	1.46	0.78	0.59
Seychelles	0.73	0.63	0.39	0.40
Sierra Leone	0.60	4.12	0.08	1.57
Singapore	1.16	1.06	0.77	0.69
Slovakia	0.51	0.44	0.28	0.31
Slovenia	0.36	0.37	0.27	0.29
Solomon Islands	0.33	3.10	0.12	1.35
Somalia	0.44	N/A	0.18	N/A
South Africa	1.42	1.49	0.87	0.93
Spain	0.23	0.26	0.23	0.25
Sri Lanka	0.31	0.94	0.07	0.34
Sudan	0.41	N/A	0.18	N/A
Suriname	0.79	2.40	0.51	1.44
Swaziland	0.30	0.56	0.09	0.30
Sweden	0.13	0.14	0.16	0.18
Switzerland	0.09	0.09	0.12	0.13
Syria	1.57	2.08	0.59	0.80

Country	CO2/GDP-MER TCO2/2012US$1000	GHG/GDP-MER TCO2e/2012US$1000	CO2/GDP-PPP TCO2/2012US$1000	GHG/GDP-PPP TCO2e/2012US$1000
Taiwan	0.56	N/A	0.33	N/A
Tajikistan	0.72	2.52	0.16	0.62
Tanzania	0.28	6.30	0.14	2.26
Thailand	1.13	1.39	0.45	0.56
Timor-Leste	0.31	N/A	0.13	N/A
Togo	0.51	5.15	0.19	2.40
Tonga	0.61	1.16	0.26	0.74
Trinidad and Tobago	2.43	N/A	1.26	N/A
Tunisia	0.41	0.49	0.19	0.23
Turkey	0.41	0.48	0.28	0.30
Turkmenistan	1.65	5.59	2.32	2.05
Uganda	0.20	2.25	0.05	0.80
Ukraine	2.69	3.25	0.89	1.09
United Arab Emirates	0.88	0.96	0.88	0.65
United Kingdom	0.20	0.20	0.21	0.24
United States	0.37	0.40	0.37	0.41
Uruguay	0.31	0.51	0.17	0.28
Uzbekistan	4.52	7.87	1.21	2.20
Vanuatu	0.21	0.94	0.10	0.51
Venezuela	0.86	1.71	0.47	0.96
Vietnam	1.42	2.26	0.42	0.69
Yemen	0.75	1.07	0.27	0.40
Zambia	0.20	7.66	0.11	4.24
Zimbabwe	1.96	8.64	0.30	N/A

Sources: U.S. Energy Information Administration (2000, n.d.); World Resources Institute (n.d.).

Appendix Table 3. Percentage Changes in Emission Intensity, 1995-2010

Country	CO2/GDP-PPP	GHG/GDP-PPP	CO2/GDP-LCU	GHG/GDP-LCU
Afghanistan	41	N/A	N/A	N/A
Albania	-24	-47	-25	-49
Algeria	-25	-15	-24	-8
American Samoa	-46	N/A	N/A	N/A
Angola	-43	-56	-44	-66
Antigua and Barbuda	10	N/A	-9	N/A
Argentina	-16	-14	N/A	N/A
Armenia	-48	-25	-48	-30
Aruba	6	N/A	N/A	N/A
Australia	-12	-7	-12	-17
Austria	-14	-29	-14	-18
Azerbaijan	-88	-78	-88	-76
Bahamas, The	-16	38	N/A	N/A
Bahrain	-12	-4	-12	6
Bangladesh	12	-31	11	-25
Barbados	-18	N/A	N/A	N/A
Belarus	-62	-68	-63	-55
Belgium	-26	-24	-26	-16
Belize	-27	32	-28	-57
Benin	183	43	183	-62
Bermuda	-9	N/A	-6	N/A
Bhutan	-49	-158	-55	-116
Bolivia	0	72	0	-72
Bosnia and Herzegovina	-48	N/A	-51	N/A
Botswana	-35	97	-34	-86
Brazil	-1	55	-1	-64
Brunei	96	2	96	0
Bulgaria	-42	-60	-42	-46
Burkina Faso	17	1	2	-64

Country	CO2/GDP-PPP	GHG/GDP-PPP	CO2/GDP-LCU	GHG/GDP-LCU
Burma (Myanmar)	-48	N/A	N/A	N/A
Burundi	-62	1404	-57	478
Cambodia	-3	-15	-5	-79
Cameroon	-35	15	-35	-74
Canada	-27	-31	-27	-24
Cape Verde	25	6	25	-197
Cayman Islands	27	N/A	N/A	N/A
Central African Republic	-33	-27	-1	-38
Chad	-41	-24	-46	-65
Chile	12	-25	10	30
China	-28	-48	-28	-38
Colombia	-22	-17	-23	-42
Comoros	20	39	19	-48
Congo, Rep.	N/A	-1	N/A	N/A
Congo, Dem. Rep.	N/A	1	N/A	N/A
Costa Rica	-23	-67	-24	-54
Croatia	-30	-34	-30	-17
Cuba	-54	N/A	-56	-9
Cyprus	-17	-14	-18	-4
Czech Republic	-42	-55	-44	-50
Denmark	-46	-43	-46	-36
Djibouti	-57	N/A	-55	32
Dominica	22	-25	15	-31
Dominican Republic	-28	-43	-28	-37
Ecuador	8	115	8	-72
Egypt	-7	-12	-7	-3
El Salvador	-9	-11	-9	-24
Equatorial Guinea	-77	1	-70	-82
Eritrea	-59	-17	-63	-33
Estonia	-35	-48	-33	-34

Country	CO2/GDP-PPP	GHG/GDP-PPP	CO2/GDP-LCU	GHG/GDP-LCU
Ethiopia	-5	-42	-3	-47
Fiji	0	-35	-1	47
Finland	-28	-42	-27	-29
France	-18	-27	-18	-14
French Guiana	-33	N/A	N/A	N/A
Gabon	-32	-35	-33	-29
Gambia, The	7	-29	N/A	N/A
Georgia	-52	-60	-52	-59
Germany	-26	-35	-26	-28
Ghana	7	35	5	-79
Greece	-28	-29	-25	-19
Grenada	19	-33	11	-26
Guam	-72	N/A	N/A	N/A
Guatemala	11	55	11	-37
Guinea	-26	14	-26	-56
Guinea-Bissau	14	88	13	-40
Guyana	15	-34	28	-27
Haiti	101	24	98	30
Honduras	26	92	26	-80
Hong Kong	15	N/A	N/A	N/A
Hungary	-38	-44	-37	-34
Iceland	N/A	-15	-16	-4
India	-34	-43	-34	-36
Indonesia	12	13	12	-68
Iran	15	N/A	N/A	N/A
Iraq	-62	N/A	N/A	N/A
Ireland	-36	N/A	N/A	N/A
Israel	-14	-25	-17	-16
Italy	-14	-23	-15	-9
Jamaica	-14	-5	-13	2

Country	CO2/GDP-PPP	GHG/GDP-PPP	CO2/GDP-LCU	GHG/GDP-LCU
Japan	-6	-20	-6	-12
Jordan	-28	-52	-28	-47
Kazakhstan	-49	-62	-49	-58
Kenya	3	-15	3	-30
Kiribati	75	105	101	65
Korea, North	-29	N/A	N/A	N/A
Korea, South	-18	N/A	N/A	N/A
Kuwait	13	-17	17	-14
Kyrgyzstan	-31	-58	N/A	N/A
Laos	48	-7	47	-77
Latvia	-54	-67	-55	-42
Lebanon	-12	-32	-14	-25
Lesotho	91	-29	76	-19
Liberia	-71	61	-85	-99
Libya	0	N/A	N/A	N/A
Lithuania	-57	-54	-58	-39
Luxembourg	-25	-28	-22	-20
Macau	-60	N/A	N/A	N/A
Macedonia	-44	N/A	-45	N/A
Madagascar	-4	54	-5	-44
Malawi	-37	9	-30	-40
Malaysia	7	-4	8	-29
Maldives	21	N/A	N/A	N/A
Mali	-38	-22	-42	-51
Malta	117	109	113	130
Martinique	-8	N/A	N/A	N/A
Mauritania	-64	-41	-67	-46
Mauritius	-1	4	-4	14
Mexico	-12	-11	-13	-12
Moldova	-49	-66	-50	-56

Country	CO2/GDP-PPP	GHG/GDP-PPP	CO2/GDP-LCU	GHG/GDP-LCU
Mongolia	-59	-27	-58	-72
Morocco	-21	-35	-21	-27
Mozambique	-37	-11	-31	-84
Namibia	43	44	37	-46
Nepal	39	-36	37	-73
Netherlands	-18	-18	-18	-9
Netherlands Antilles	-6	N/A	N/A	N/A
New Zealand	-20	-19	-17	67
Nicaragua	-6	168	-7	-73
Niger	-41	27	-27	-24
Nigeria	-73	-18	-66	-67
Norway	-10	-36	-14	-8
Oman	104	-16	99	-6
Pakistan	-12	-11	-12	-16
Panama	-48	20	-48	-62
Papua New Guinea	-18	185	-13	-85
Paraguay	-9	96	-7	-76
Peru	-14	25	-14	-59
Philippines	-29	-43	-29	-16
Poland	-48	-59	-48	-52
Portugal	-19	-22	-19	-12
Puerto Rico	6	N/A	8	N/A
Qatar	-63	N/A	N/A	N/A
Reunion	-10	N/A	N/A	N/A
Romania	-57	-61	-56	-52
Russia	-41	N/A	-41	N/A
Rwanda	-69	-89	-69	-44
Saint Kitts and Nevis	98	N/A	87	N/A
Saint Lucia	45	-29	46	-15
Saint Vincent/Grenadines	-3	N/A	N/A	N/A

Country	CO2/GDP-PPP	GHG/GDP-PPP	CO2/GDP-LCU	GHG/GDP-LCU
Samoa	-13	-32	-23	-152
Sao Tome and Principe	-12	N/A	N/A	N/A
Saudi Arabia	27	-9	27	22
Senegal	-17	-2	-15	-43
Serbia	N/A	-63	N/A	N/A
Seychelles	14	101	11	144
Sierra Leone	17	17	-13	-71
Singapore	21	71	20	88
Slovakia	-56	-60	N/A	N/A
Slovenia	-36	-42	-35	-23
Solomon Islands	0	328	1	-78
Somalia	-4	N/A	N/A	N/A
South Africa	-16	-24	-16	-16
Spain	-14	-24	-14	-5
Sri Lanka	-21	-44	-22	-47
Sudan	75	N/A	N/A	N/A
Suriname	-30	-23	-23	-51
Swaziland	-26	-32	-25	44
Sweden	-37	-36	-37	-28
Switzerland	-27	-31	-28	-18
Syria	-16	-28	-9	-19
Taiwan	-17	N/A	N/A	N/A
Tajikistan	-66	-48	-67	-43
Tanzania	8	0	8	-80
Thailand	20	-6	20	0
Togo	57	30	48	-67
Tonga	31	1	27	11
Trinidad and Tobago	-7	N/A	5	N/A
Tunisia	-34	-51	-35	-40
Turkey	-2	-29	-1	-10

Country	CO2/GDP-PPP	GHG/GDP-PPP	CO2/GDP-LCU	GHG/GDP-LCU
Turkmenistan	11	-40	7	-34
Uganda	23	-31	20	-67
Ukraine	-52	-56	-52	-49
United Arab Emirates	7	29	7	39
United Kingdom	-33	-43	-34	-37
United States	-26	-32	-26	-23
Uruguay	20	-68	18	213
Uzbekistan	-57	-56	-57	-51
Vanuatu	23	-30	21	-22
Venezuela	-1	21	-1	-44
Vietnam	43	-31	44	126
Yemen	-13	-12	1	-3
Zambia	-40	-36	-42	-66
Zimbabwe	-11	N/A	-9	-53

Sources: U.S. Energy Information Administration (2000, n.d.); World Resources Institute (n.d.); World Bank (n.d.).

Appendix Table 4. Energy Prices and Taxes, Levels (2010) and Percentage Changes (1997-2010 for all energy; 1998-2010 for gasoline)

Country	Average Energy Price 2012US$/MMBTU	Energy Price Percentage Change	Average Energy Tax 2012US$/MMBTU	Energy Tax Percentage Change	Gasoline Price 2012US$/gallon	Gasoline Price Percentage Change
Afghanistan	N/A	N/A	N/A	N/A	4.53	N/A
Albania	N/A	N/A	N/A	N/A	5.75	31
Algeria	N/A	N/A	N/A	N/A	1.26	-20
Andorra	N/A	N/A	N/A	N/A	5.86	N/A
Angola	N/A	N/A	N/A	N/A	2.56	32
Antigua and Barbuda	N/A	N/A	N/A	N/A	3.90	N/A
Argentina	N/A	N/A	N/A	N/A	3.78	-21
Armenia	N/A	N/A	N/A	N/A	4.25	70
Australia	37.77	67	2.40	9	5.00	113
Austria	53.27	27	7.44	10	6.41	21
Azerbaijan	N/A	N/A	N/A	N/A	2.95	26
Bahrain	N/A	N/A	N/A	N/A	0.83	-38
Bangladesh	N/A	N/A	N/A	N/A	4.29	79
Barbados	N/A	N/A	N/A	N/A	4.92	34
Belarus	N/A	N/A	N/A	N/A	4.25	145
Belgium	63.90	37	6.29	-26	7.36	29
Belize	N/A	N/A	N/A	N/A	4.45	N/A
Benin	N/A	N/A	N/A	N/A	4.09	106
Bhutan	N/A	N/A	N/A	N/A	4.25	41
Bolivia	N/A	N/A	N/A	N/A	2.75	2
Bosnia and Herzegovina	N/A	N/A	N/A	N/A	5.59	66
Botswana	N/A	N/A	N/A	N/A	3.66	131
Brazil	N/A	N/A	N/A	N/A	6.22	52
Brunei	N/A	N/A	N/A	N/A	1.53	-12
Bulgaria	N/A	N/A	N/A	N/A	5.94	76
Burkina Faso	N/A	N/A	N/A	N/A	5.67	63
Burma (Myanmar)	N/A	N/A	N/A	N/A	3.15	375
Burundi	N/A	N/A	N/A	N/A	5.63	53

Country	Average Energy Price 2012US$/MMBTU	Energy Price Percentage Change	Average Energy Tax 2012US$/MMBTU	Energy Tax Percentage Change	Gasoline Price 2012US$/gallon	Gasoline Price Percentage Change
Cambodia	N/A	N/A	N/A	N/A	4.53	89
Cameroon	N/A	N/A	N/A	N/A	4.72	45
Canada	33.62	77	2.68	86	4.76	128
Cape Verde	N/A	N/A	N/A	N/A	7.24	75
Central African Republic	N/A	N/A	N/A	N/A	6.73	63
Chad	N/A	N/A	N/A	N/A	5.19	45
Chile	39.58	68	2.85	N/A	5.43	117
China	N/A	N/A	N/A	N/A	7.56	429
Colombia	N/A	N/A	N/A	N/A	5.55	353
Congo, Rep.	N/A	N/A	N/A	N/A	5.00	36
Congo, Dem. Rep.	N/A	N/A	N/A	N/A	5.04	97
Costa Rica	N/A	N/A	N/A	N/A	4.49	N/A
Croatia	N/A	N/A	N/A	N/A	6.26	83
Cuba	N/A	N/A	N/A	N/A	6.77	165
Cyprus	N/A	N/A	N/A	N/A	5.78	45
Czech Republic	56.13	84	7.89	171	6.89	87
Denmark	60.46	45	8.94	23	7.87	47
Djibouti	N/A	N/A	N/A	N/A	6.41	38
Dominican Republic	N/A	N/A	N/A	N/A	4.84	137
Ecuador	N/A	N/A	N/A	N/A	2.09	8
Egypt	N/A	N/A	N/A	N/A	1.89	28
El Salvador	N/A	N/A	N/A	N/A	3.62	31
Eritrea	N/A	N/A	N/A	N/A	10.00	429
Estonia	46.17	N/A	2.11	N/A	6.06	164
Ethiopia	N/A	N/A	N/A	N/A	3.58	95
Finland	60.09	36	6.17	13	7.63	28
France	58.35	28	5.91	-34	7.79	38
Georgia	N/A	N/A	N/A	N/A	4.45	89
Germany	59.70	51	9.17	29	7.48	53

Country	Average Energy Price 2012US$/MMBTU	Energy Price Percentage Change	Average Energy Tax 2012US$/MMBTU	Energy Tax Percentage Change	Gasoline Price 2012US$/gallon	Gasoline Price Percentage Change
Ghana	N/A	N/A	N/A	N/A	3.23	98
Greece	60.61	82	6.09	63	8.07	143
Grenada	N/A	N/A	N/A	N/A	4.01	46
Guatemala	N/A	N/A	N/A	N/A	3.74	79
Guinea	N/A	N/A	N/A	N/A	3.74	8
Guyana	N/A	N/A	N/A	N/A	3.66	139
Honduras	N/A	N/A	N/A	N/A	4.09	60
Hong Kong	N/A	N/A	N/A	N/A	4.37	-37
Hungary	54.09	61	2.55	-54	6.57	79
Iceland	0.00	N/A	0.00	N/A	6.73	18
India	N/A	N/A	N/A	N/A	4.53	58
Indonesia	N/A	N/A	N/A	N/A	2.01	146
Iran	N/A	N/A	N/A	N/A	0.38	-7
Iraq	N/A	N/A	N/A	N/A	3.07	5914
Ireland	54.04	33	2.66	-59	7.00	35
Israel	55.37	41	2.61	N/A	7.28	66
Italy	59.59	25	2.89	-50	7.36	21
Jamaica	N/A	N/A	N/A	N/A	3.86	104
Japan	47.52	34	1.85	12	6.30	21
Jordan	N/A	N/A	N/A	N/A	4.09	91
Kazakhstan	N/A	N/A	N/A	N/A	2.79	82
Kenya	N/A	N/A	N/A	N/A	5.23	47
Korea, South	N/A	N/A	N/A	N/A	5.98	26
Kuwait	N/A	N/A	N/A	N/A	0.91	4
Kyrgyzstan	N/A	N/A	N/A	N/A	3.34	39
Laos	N/A	N/A	N/A	N/A	4.96	213
Latvia	N/A	N/A	N/A	N/A	5.82	107
Lebanon	N/A	N/A	N/A	N/A	4.45	149
Lesotho	N/A	N/A	N/A	N/A	3.82	92

Country	Average Energy Price 2012US$/MMBTU	Energy Price Percentage Change	Average Energy Tax 2012US$/MMBTU	Energy Tax Percentage Change	Gasoline Price 2012US$/gallon	Gasoline Price Percentage Change
Liberia	N/A	N/A	N/A	N/A	3.86	N/A
Libya	N/A	N/A	N/A	N/A	0.67	-40
Liechtenstein	N/A	N/A	N/A	N/A	6.53	51
Lithuania	N/A	N/A	N/A	N/A	6.26	140
Luxembourg	48.84	51	4.25	-37	6.10	53
Macedonia	N/A	N/A	N/A	N/A	5.98	67
Madagascar	N/A	N/A	N/A	N/A	5.98	149
Malawi	N/A	N/A	N/A	N/A	6.73	159
Malaysia	N/A	N/A	N/A	N/A	2.32	62
Mali	N/A	N/A	N/A	N/A	5.59	42
Malta	N/A	N/A	N/A	N/A	6.41	63
Mauritania	N/A	N/A	N/A	N/A	4.56	52
Mexico	23.98	33	0.55	-56	3.19	73
Moldova	N/A	N/A	N/A	N/A	4.76	107
Monaco	N/A	N/A	N/A	N/A	7.56	N/A
Mongolia	N/A	N/A	N/A	N/A	4.37	272
Montenegro	N/A	N/A	N/A	N/A	6.37	105
Morocco	N/A	N/A	N/A	N/A	4.84	20
Mozambique	N/A	N/A	N/A	N/A	4.37	56
Namibia	N/A	N/A	N/A	N/A	4.17	115
Nepal	N/A	N/A	N/A	N/A	4.64	54
Netherlands	65.16	38	3.50	-38	8.38	44
New Zealand	42.76	57	3.16	50	5.78	77
Nicaragua	N/A	N/A	N/A	N/A	4.29	79
Niger	N/A	N/A	N/A	N/A	4.21	9
Nigeria	N/A	N/A	N/A	N/A	1.73	161
Norway	67.71	28	10.33	8	8.34	35
Oman	N/A	N/A	N/A	N/A	1.22	-23
Pakistan	N/A	N/A	N/A	N/A	3.38	44

Country	Average Energy Price 2012US$/MMBTU	Energy Price Percentage Change	Average Energy Tax 2012US$/MMBTU	Energy Tax Percentage Change	Gasoline Price 2012US$/gallon	Gasoline Price Percentage Change
Panama	N/A	N/A	N/A	N/A	3.34	60
Paraguay	N/A	N/A	N/A	N/A	5.04	110
Peru	N/A	N/A	N/A	N/A	5.55	98
Philippines	N/A	N/A	N/A	N/A	4.13	138
Poland	52.00	125	4.63	46	6.18	124
Portugal	61.91	52	8.93	25	7.28	40
Qatar	N/A	N/A	N/A	N/A	0.75	-8
Romania	N/A	N/A	N/A	N/A	5.75	112
Russia	N/A	N/A	N/A	N/A	3.31	131
Rwanda	N/A	N/A	N/A	N/A	6.41	75
Samoa	N/A	N/A	N/A	N/A	4.05	N/A
Saudi Arabia	N/A	N/A	N/A	N/A	0.63	-23
Senegal	N/A	N/A	N/A	N/A	6.18	71
Sierra Leone	N/A	N/A	N/A	N/A	3.70	19
Singapore	N/A	N/A	N/A	N/A	5.59	52
Slovakia	53.54	88	2.55	3	6.69	115
Slovenia	54.35	N/A	5.17	N/A	6.57	95
South Africa	N/A	N/A	N/A	N/A	2.44	11
Spain	48.30	45	2.10	-43	6.14	43
Sri Lanka	N/A	N/A	N/A	N/A	4.68	9
Sudan	N/A	N/A	N/A	N/A	5.90	250
Swaziland	N/A	N/A	N/A	N/A	4.21	123
Sweden	57.47	26	5.90	-30	7.36	32
Switzerland	52.49	39	4.52	-28	6.53	49
Syria	N/A	N/A	N/A	N/A	3.78	64
Taiwan	N/A	N/A	N/A	N/A	3.94	35
Tajikistan	N/A	N/A	N/A	N/A	4.01	202
Tanzania	N/A	N/A	N/A	N/A	4.80	49
Thailand	N/A	N/A	N/A	N/A	5.55	262

Country	Average Energy Price 2012US$/MMBTU	Energy Price Percentage Change	Average Energy Tax 2012US$/MMBTU	Energy Tax Percentage Change	Gasoline Price 2012US$/gallon	Gasoline Price Percentage Change
Togo	N/A	N/A	N/A	N/A	4.64	117
Trinidad and Tobago	N/A	N/A	N/A	N/A	4.49	125
Tunisia	N/A	N/A	N/A	N/A	3.70	21
Turkey	76.88	142	7.10	91	9.92	149
Turkmenistan	N/A	N/A	N/A	N/A	0.87	88
Uganda	N/A	N/A	N/A	N/A	5.59	27
Ukraine	N/A	N/A	N/A	N/A	3.97	59
United Arab Emirates	N/A	N/A	N/A	N/A	1.85	58
United Kingdom	61.49	29	6.39	-30	7.56	33
United States	24.05	72	1.02	-2	2.99	83
Uruguay	N/A	N/A	N/A	N/A	5.86	28
Uzbekistan	N/A	N/A	N/A	N/A	3.62	545
Venezuela	N/A	N/A	N/A	N/A	0.09	-87
Vietnam	N/A	N/A	N/A	N/A	3.46	94
Yemen	N/A	N/A	N/A	N/A	1.38	4
Yugoslavia	N/A	N/A	N/A	N/A	5.90	90
Zambia	N/A	N/A	N/A	N/A	6.53	142
Zimbabwe	N/A	N/A	N/A	N/A	5.08	283

Sources: International Energy Agency (n.d.); GIZ (2013).