THE GLOBAL SUBSIDIES INITIATIVE

UNTOLD BILLIONS:

FOSSIL-FUEL SUBSIDIES, THEIR IMPACTS AND THE PATH TO REFORM

The Effects of Fossil-Fuel Subsidy Reform: A review of modelling and empirical studies

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The Effects of Fossil-Fuel Subsidy Reform: A review of modelling and empirical studies

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BY:
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For the Global Subsidies Initiative (GSI) of the International Institute for Sustainable Development (IISD) Geneva, Switzerland

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EXECUTIVE SUMMARY

Reforming subsidies to fossil fuels is a challenging prospect for many governments. To help policy-makers better appreciate the trade-offs between economic, environmental and social impacts, various organizations have analyzed fossil-fuel subsidies and their effects, often with the aid of complex economic models. Measuring the impacts of subsidy reform is a critical step in determining under what conditions the net effect of subsidy removal is positive and what supporting measures need to be undertaken to ensure that negative effects are minimized.

This study reviews the literature on fossil-fuel subsidy reform, focusing in particular on six major studies that have been undertaken since the early 1990s:

1. *The effects of existing distortions in energy markets on the costs of policies to reduce CO_2 emissions: evidence from GREEN* (Burniaux et al., 1992);
2. *World fossil-fuel subsidies and global carbon emissions* (Larsen and Shah, 1992);
3. *World Energy Outlook 1999: Looking at Energy Subsidies – Getting the Prices Right* (IEA, 1999);
4. *Environmental Effects of Liberalizing Fossil-Fuels Trade: Results from the OECD GREEN Model* (OECD, 2000);
5. *Removing energy subsidies in developing and transition economies* (Saunders and Schneider, 2000); and
6. *The economics of climate change mitigation: How to build the necessary global action in a cost-effective manner* (Burniaux et al., 2009).

Each of these studies assessed the economic, environmental and, in a few cases, the social impacts of fossil-fuel subsidy reform at a global level. The intent of this paper is to determine if there are any common conclusions that can be drawn from these studies and to identify areas in need of further research. In so doing, it highlights the critical assumptions and elements of the analyses, in order to better understand how these affect the results. The paper also reviews the broader literature on energy-subsidy reform, including selected country- and sector-specific studies.

Largely because of differences in the scope, method and years analyzed, the studies reviewed here are not directly comparable. Nevertheless, some broad conclusions can still be drawn.

From an economic perspective, all six studies found that fossil-fuel subsidy reform would result in aggregate increases in gross domestic product (GDP) in both OECD and non-OECD countries. The expected increases among the studies ranged from 0.1 per cent in total by 2010 to 0.7 per cent per year to 2050.

With respect to environmental impacts, all six studies focused on reductions in emissions of either greenhouse gases (GHGs) or carbon-dioxide (CO_2). Very little work has been done to assess the effects of subsidy reform on other environmental impacts such as local air or water pollution, or on the demand for water or land. All six studies concluded that the reform of fossil-fuel subsidies would reduce CO_2 emissions. However, their results ranged from a 1.1 per cent reduction in CO_2 emissions by 2010 to an 18 per cent reduction by 2050. The study by Burniaux et al. (2009), the most recent of those reviewed, concluded that, overall, world CO_2 emissions would be reduced by 13 per cent and GHG emissions would be reduced by 10 per cent by 2050 if consumer subsidies for fossil fuels and electricity in 20 non-OECD countries were phased out.

The price-gap measures utilized in all six studies provide a lower bound estimate of subsidies to fossil fuels (Koplow, 2009). Accordingly, it is quite possible that all six studies underestimated the reductions in GHG emissions achievable through fossil-fuel subsidy reform. Extending the reform analysis to other countries and other fossil-fuel subsidies (most notably producer subsidies) would very likely show even larger positive environmental effects from subsidy reform.

The six studies analyzed concluded very little from a social-impact perspective. However, a considerable body of work on the social impacts of fossil-fuel subsidy reform has been advanced by the World Bank and others. The general conclusions are that there would be social impacts associated with fossil-fuel subsidy reform, but that these impacts could potentially be offset by re-targeting some of the saved subsidy expenditure towards social programs. More research on how to better target subsidies would be beneficial.

New research to improve future assessments of the impacts of subsidy reform could include further analysis of producer subsidies, demand and supply elasticities for fossil fuels, and methods for more effectively incorporating social-impact analysis and environmental policies into general-equilibrium models. Efforts to facilitate comparisons of results among studies of fossil-fuel subsidy reform should also be considered. This could be done through achieving consistency in defining global regions for analysis, and in the model outputs required to assess social impacts (for example, the social welfare effects for each quintile). Having modellers convert their price-gap data into estimates of subsidies in dollars per year or percentages of GDP would also help.

Despite the fact that further research can and should be undertaken, the analysis in this paper strongly supports the conclusion that there are significant environmental and economic benefits that would result from the reform of fossil-fuel subsidies. Fossil-fuel subsidy reform should be considered as a key element of a larger overall package for global climate-change mitigation. On this basis, there is a mounting body of evidence that policy-makers should not wait to begin the reform process.

THE EFFECTS OF FOSSIL-FUEL SUBSIDY REFORM: A REVIEW OF MODELLING AND EMPIRICAL STUDIES

By Jennifer Ellis, PhD

1. OVERVIEW, PURPOSE AND DEFINITIONS

1.1 Overview

In developed and developing countries, subsidies to the production and consumption of fossil fuels exist in a wide variety of forms including direct budgetary transfers, tax exemptions and price controls. Subsidies can be justified in theory if they promote an overall increase in social welfare. However, the consensus of expert opinion is that fossil-fuel subsidies have a net negative effect, both in individual countries and on a global scale (Von Moltke et al., 2004). Fossil-fuel subsidies alter fossil-fuel prices, leading to market distortions with consequences that go well beyond the specific policy objective that the subsidy is intended to achieve. These distortions have wide environmental, economic and social impacts, in many cases increasing energy consumption and GHG emissions, straining government budgets, diverting funding that could otherwise be spent on social priorities such as healthcare or education, and reducing the profitability of alternative energy sources (Koplow and Dernbach, 2001). For a full list of economic, environmental and social impacts of fossil-fuel subsidies, see Annex I.

Removing fossil-fuel subsidies is considered by many to be a win-win policy measure that would benefit both the global economy and the environment and therefore a "no regret" option for climate-change mitigation (Burniaux et al., 2009). In theory, eliminating fossil-fuel subsidies would result in higher fossil-fuel prices in countries that currently subsidize consumer prices, which would reduce consumption and thereby GHG emissions. At the same time, removing subsidies would remove a costly drain on the government budget. Consequently, eliminating subsidies to fossil fuels may be one of the most cost-effective and least distortionary options available to governments for reducing their GHG emissions.

However, governments contemplating fossil-fuel subsidy reform should carefully evaluate the environmental and economic benefits of doing so. It is possible that reforms could provoke some unintended negative environmental effects. In some poorer countries, for example, the sudden removal of subsidies for cooking fuels could lead to a reliance on biomass for cooking and heat in some areas, increasing pressure on forests and negatively affecting indoor air quality (Von Moltke et al., 2004). And at a global level, subsidy removal could result in downward pressure on international prices of fossil fuels, resulting in increases in consumption in regions not subject to a cap on GHG emissions.

In addition, there is concern that subsidy removal could have adverse social impacts, or that the social benefits may not be fairly distributed. Pearce and von Finckenstein (2000) observe that, by their very nature, subsidies redirect economic rents to certain stakeholders. Thus subsidy removal could, in the short-term, create some economic losers. The International Energy Agency (IEA, 1999) notes that even if there are some losers from subsidy reform, solutions that increase overall net economic and environmental well-being should still be implemented, and measures to compensate the losers considered. The money saved from subsidies could, in theory, be redirected to transfers or social programs that are better targeted for the poor. The timing and speed of reform is also critical. Many countries that have eliminated food or fuel subsidies in recent years have experienced large-scale civil unrest (Coady et al., 2006). For example, when the Government of Indonesia dramatically raised fuel prices twice in 2005—thereby escalating the prices of food and commodities—demonstrators took to the streets throughout the country, with mobs burning tires and effigies, and throwing stones in protest.

Fossil-fuel subsidy reform is likely to prove challenging for many countries, given the numerous economic, environmental and social changes reform could precipitate. Estimating the nature and scale of these changes is therefore critical to assessing the costs and benefits of subsidy reforms and to identifying what flanking measures may be needed to ensure that negative impacts are minimized.

1.2 Purpose of this paper

This paper considers some of the analytical approaches that have been used to date to estimate the economic, environmental and social impacts of fossil-fuel subsidy removal. It reviews the strengths and weaknesses of methods employed in studies to evaluate these impacts, and provides some assessment of the findings of these studies with the goal of answering the question: what do we know about the economic, environmental and social impacts of fossil-fuel subsidies and their reform? The focus is primarily on the effects of fossil-fuel subsidy reform at a macroeconomic level, looking at global and regional impacts. Micro-level impacts, such as distributional effects on the poor, are a critical element of fossil-fuel subsidy reform, but were not addressed in the global-level studies examined for this paper, and thus do not fall within the scope of this study.

The initial literature review established that the most useful work was found within multi-country, multi-fuel studies. The global-level studies have all been carried out with the aid of partial- and general-equilibrium models. This paper relies primarily on the published literature, supplemented in some cases by information obtained through direct communication with the model analysts. While considerable effort has been made to ensure that what is reported in this paper is accurate, it is possible that there are some errors due to insufficient documentation on the assumptions used by the modellers.

Some studies which used general-equilibrium models to examine single countries or partial-equilibrium models to examine single sectors are also examined, as are some empirical studies of fossil-fuel subsidy reform in individual countries, though the coverage is not comprehensive. Empirical assessments of the economic, environmental and social impacts of fossil-fuel subsidy reform in countries where subsidies have been removed are limited in number (Hope and Singh, 1995; Bacon and Kojima, 2006; World Bank, 2008). Empirical studies have the advantage of providing actual data, as opposed to modelled results, but the data are challenging to interpret as the impacts of fossil-fuel subsidy reform cannot easily be isolated from the wide range of other factors that affect national economies.

1.3 Types of fossil-fuel subsidies

The Organisation for Economic Co-operation and Development (OECD, 2005) defines a subsidy as "a result of a government action that confers an advantage on consumers or producers, in order to supplement their income or lower their costs." Energy subsidies come in two main forms: those designed to reduce the cost of consuming fossil fuels; and those aimed at supporting domestic fossil-fuel production (Burniaux et al., 2009). Some producer subsidies can have the effect of lowering fossil-fuel prices, thereby serving indirectly as consumer subsidies at the same time.

Subsidies aimed at consumers are generally intended to keep fossil-fuel prices low, in order to stimulate certain sectors of the economy or alleviate poverty, by expanding the population's access to energy (Saunders and Schneider, 2000; Morgan, 2007). These types of subsidies are more common in non-OECD, former eastern bloc countries and developing countries. These subsidies usually take the form of price controls (IEA, 2007) and can involve large price gaps. For example, in Iran, petroleum product prices were kept at 10 per cent of world market prices in 2002 (Jensen and Tarr, 2002). They are generally directed at electricity, household heating and cooking fuels, although some countries also subsidize transport fuels (IEA, 2007).

Subsidies aimed at producers generally keep costs of production lower or increase revenues, and their effect is to keep marginal producers in business (Saunders and Schneider, 2000). These subsidies can also be motivated by the desire to reduce import dependency (European Environment Agency [EEA], 2004). Production subsidies are more common in developed countries than in developing countries.

Subsidies include a wide variety of support measures. They can include cash transfers directly to producers or consumers, as well as less obvious support mechanisms, including tax exemptions and rebates. Price controls, market access limits and trade restrictions are also often a key element of fossil-fuel subsidies. The OECD (Varangu and Morgan, 2002) and the United Nations Environment Programme (UNEP, 2008) identify the following mechanisms as typical of those used by governments to support the production or consumption of fossil-fuels:

- *Direct financial transfers:* grants to consumers, grants to producers, low-interest or preferential loans and government loan guarantees;
- *Preferential tax treatment:* tax credits, tax rebates, exemptions on royalties, duties or tariffs, reduced tax rates, deferred tax liabilities and accelerated depreciation on energy-supply equipment;
- *Trade restrictions:* tariffs, tariff-rate import quotas and non-tariff trade barriers;
- *Energy-related services provided directly by government at less than full cost:* government-provided energy infrastructure, public research and development on fossil fuels; and
- *Regulation of the energy sector:* demand guarantees, mandated deployment rates, price controls, environmental regulations and market-access restrictions.

Subsidies provided through direct financial transfers (including tax rebates) are sometimes referred to as “direct transfers,” while those provided through other mechanisms are often referred to as indirect transfers. Most of the model-based studies that have analyzed the effects of eliminating fossil-fuel subsidies have used data derived from the measurement of price gaps rather than from detailed aggregations of individual subsidy programs.

1.4 Subsidies, offsets and market distortions

Some studies consider subsidies to complements and externalities as a form of subsidy (Koplow and Dernbach, 2001). *Subsidies to complements* include government support for goods and services, such as transportation infrastructure, that encourage greater use of fossil fuels (Koplow and Dernbach, 2001). *Externalities* are costs associated with fossil-fuel consumption and production that are shifted to the general population without any compensation paid by the consumers or producers (i.e., environmental damage, emissions, congestion, health implications, energy security measures) (Koplow and Dernbach, 2001; Riedy, 2003; EEA, 2004). Whereas subsidies arise due to some sort of government action, externalities arise from lack of government or private action to incorporate the externalities into the economic system (Riedy, 2003).

Taxes are also often applied to fuels, usually at different stages in the supply chain than where the subsidies are applied. Some studies take these taxes into account and refer to them as *offsets*. Subsidy offsets could include anything that should be subtracted from the net subsidy value, including local, state and federal fuel and energy taxes (Koplow and Dernbach, 2001). In some studies, these are just rolled into the definition of subsidy and given a positive or negative value. In others, they are not included and subsidies are calculated excluding tax (“ex-tax”) (OECD, 2000). Regulatory burdens are also considered in some studies as a subsidy offset, with a high degree of uncertainty.

Subsidies to complements, externalities and subsidy offsets are worth noting as a component of the overall distortion in fossil-fuel markets. Most studies referred to in this paper use a price-gap method of calculating subsidies and a model that removes all distortions (including both taxes and subsidies). As a result, some of the market distortions discussed in this section, such as offsets, are captured to some degree in the studies reviewed, and are therefore partially addressed in this paper. However, further work needs to be undertaken in this regard, particularly with respect to the evaluation of externalities.

1.5 Measuring fossil-fuel subsidies

Assessing the magnitude of fossil-fuel subsidies is a task challenged by poor data quality, limited data availability and lack of data comparability, as there is no harmonized or consistent reporting structure for fossil-fuel subsidies (Riedy, 2003; EEA, 2004). Direct financial transfers are generally the easiest to quantify, as they are usually included in government budgets. In addition, some market transfers to consumers through lowered prices and tax credits are also straightforward to estimate.

Most studies are based on the price-gap method, which calculates the combined effect of various government interventions (which may include subsidies) that have an impact on the market price, to create a wedge between domestic and international prices. (For more information on the price-gap approach, see Koplow, 2009). Determining values for subsidies to complements and externalities is subject to an extremely high degree of uncertainty and as a result is generally not attempted (Koplow and Dernbach, 2001).

Many of the studies that have attempted to quantify fossil-fuel subsidies on an international or country-by-country basis are not very comparable. For the most part, they focus on different time periods, providing snapshot assessments, using different assumptions and methods for calculating the subsidies. Some studies look at energy subsidies as a whole, including subsidies to renewable energy and nuclear energy, while others focus just on fossil-fuel subsidies. Since there are no consistently updated data sets, most of these studies are not easily replicable.

The two main approaches to measuring fossil-fuel subsidies—price-gap assessments, and producer and consumer subsidy equivalents—differ mainly in their coverage.

1.5.1 Producer support estimates (PSE) and consumer support estimates (CSE)

The PSE and CSE approach attempts to capture both net budgetary and net market transfers. These were known as producer subsidy equivalents and consumer subsidy equivalents until 1999 (OECD, 2000). Use of this approach has been limited in the energy sector to date (a notable exception is Steenblik and Wigley, 1990), although it is used extensively to measure support for agricultural commodities, and a similar metric (not including market price support) has been used to estimate support to the fishing industry (Cox and Schmidt, 2002). This approach requires the collection of large amounts of data on specific programs, as well as on production levels and prices that are often difficult to obtain. PSEs have only been calculated by the IEA for a small number of coal producers (OECD, 2000) and have not been updated recently. It remains a useful potential organizing framework that is likely to be applied more extensively for fossil fuels in the future.

1.5.2 Price-gap assessments

The price-gap approach assesses the wedge between the actual and supposed reference or "free-market" price for an energy commodity (net market transfers). It is, essentially, the market price support (for production) and the market transfer (for consumption) components of the PSE and CSE. The reference price for goods that are traded (like oil) is usually the international or border price adjusted for market exchange rates, transport and distribution costs, and country-specific taxes (Burniaux et al., 2009). In the case of goods that are not traded, like electricity, some attempt is usually made to determine what the cost would be in the absence of subsidies. The difference between the actual and reference price is calculated as a "price wedge" (percentage or per unit cost) that captures as many subsidies as possible as a single number. This method requires less data and is useful for multi-country assessments. However, it does not capture subsidies that do not affect prices but do affect the structure of supply, and it is sensitive to assumptions regarding the reference price.

Despite the limitations, the price-gap approach is the approach that has been used most often to measure subsidies in the fossil-fuel sector, and may be the only practical means of quantifying consumer subsidies over a large number of countries given the difficulty of data limitations in non-OECD countries and limited analytical resources (Burniaux, et al., 2009).

1.6 Magnitude of global fossil-fuel subsidies

This section provides some examples of past global estimates of fossil-fuel subsidies. Some of the estimates pertain to all energy forms (which would include renewable energy, nuclear power and biofuels) while others just count subsidies to fossil fuels.

Many OECD countries have eliminated or reduced direct and indirect subsidies for fossil fuels over the last two decades (Varangu and Morgan, 2002). Thus non-OECD countries are believed to make up the bulk of global consumer subsidies on a dollar basis (Riedy, 2003).

In 2005, the IEA assessed subsidies in 20 non-OECD countries. They estimated that the total value of subsidies in these countries was $220 billion per year (all dollar amounts are in U.S. dollar) and that if the other non-OECD countries were included, total subsidies could be $250 billion per year (IEA, 2007). By 2007, these subsidies had increased to $310 billion per year in the same 20 non-OECD countries (IEA, 2008). The majority of these are consumption subsidies aimed at lowering prices for end-users (Morgan, 2007).

For the 20 countries, oil products were the most heavily subsidized of fossil fuels at $152 billion per year in 2007. This figure includes subsidies for industrial and residential fuels, kerosene and liquefied petroleum gas (LPG), as well as transport fuels (Morgan, 2007). Natural gas subsidies were estimated at $70 billion in 2006, while consumer subsidies for coal were smaller and considered to be around $10 billion (Morgan, 2007). In 2007 Iran was the largest fossil-fuel subsidizer in the group at $56 billion per year, and Russia was the second largest at $51 billion per year. China, Saudi Arabia, India, Venezuela, Indonesia, Egypt and Ukraine are the other large subsidizers, with annual subsidies in excess of $10 billion per year (IEA, 2008).

In many countries, particularly developing countries with low GDP per capita, consumption-related fossil-fuel subsidies have exceeded 2 per cent of GDP for many years. Notable examples include: Turkmenistan (15.2 per cent of GDP in 2008); Ecuador (8.7 per cent); Egypt (8.4 per cent); Ukraine (3.3 per cent); and Bangladesh (3.0 per cent) (Coady et al., 2006; World Bank, 2008). In many of these countries, expenditures relating to the subsidization of fossil fuels were as large as or larger than health or public-education budgets, or both in some cases.

In the OECD, consumer subsidies are considered to be significantly smaller, and the main subsidies flow to producers. The size of these subsidies are, however, highly uncertain. In 1999, the IEA estimated energy producers in OECD countries are subsidized by $20–30 billion per year. Two years later, de Moor (2001) estimated OECD fossil-fuel subsidies to be closer to $57 billion per year in the years 1995 to 1998. Koplow (2007) estimated federal fiscal subsidies to energy in the United States in 2006 to be $74 billion, of which $49 billion were to fossil fuels. Most of these subsidies were related to production.

2. QUANTIFYING THE IMPACTS OF SUBSIDY REFORM - METHODOLOGICAL APPROACHES

At their core, fossil-fuel subsidies have an economic impact by distorting prices and therefore affecting production and consumption decisions. Increases in coal, oil and natural gas prices would ripple throughout other sectors of the economy, affecting the costs of production, and therefore the prices of other goods, particularly energy-intensive ones. In turn, this may affect the competitiveness of goods from certain sectors and countries in the global economy, and could result in changes in trade flows. All of these changes have effects on global emissions from fossil-fuel combustion. Many of the environmental and social impacts of fossil-fuel subsidies stem from this economic distortion—both through increased consumption in countries where fossil-fuel prices are kept artificially low, and through the continued operation of less-efficient, and often less-clean fuel producers in countries where prices are kept artificially high to support domestic producers (OECD, 2000; Morgan, 2007). Subsidies also affect government budgets by imposing fiscal burdens, which in turn reduce the amount of money available to spend on social programs (Saunders and Schneider, 2000).

It should not be assumed that removing all fossil-fuel subsidies would necessarily have positive economic, environmental and social effects across the board. The results of removing fossil-fuel subsidies are highly complex and some groups within certain countries would be negatively affected. Removing fossil-fuel subsidies could also have negative terms of trade effects for some countries.

The impacts of subsidies and subsidy reform can be quantified in two ways: 1) empirical approaches that examine countries in which fossil-fuel subsidy reform has been undertaken; and 2) economic modelling approaches, that examine what might happen if fossil-fuel subsidies were removed.

Empirical studies are of value because they provide actual data and can account for unexpected economic interactions. However, since they can only examine a single country at a time, they provide limited insight into the inter-country economic interactions on a global scale. This paper focuses on the economic modelling approaches to quantifying the impacts of fossil-fuel subsidy reform. Lessons learned from actual fossil-fuel subsidy reform in Ghana, Senegal and France are the subject of the paper "Strategies for reforming fossil-fuel subsidies: Practical lessons from three countries" in *Untold Billions: fossil-fuel subsidies, their impacts and the path to reform,* the present series of papers. Nevertheless, empirical findings from subsidy reform in some countries are profiled in the results section to provide perspective with respect to the modelled results.

2.1 Economic modelling approaches

Partial-equilibrium as well as general-equilibrium models have been used to study the impacts of fossil-fuel subsidy reform. These models compare factors such as projected emissions and economic activity if subsidies were removed to "business as usual" emissions and economic activity (Koplow and Dernbach, 2001).

2.1.1 Partial-equilibrium models

Partial-equilibrium models consider *only the product market in which subsidy reform is occurring* (in this case, the energy market), and estimate price, demand and production changes in fossil fuels as a result of subsidy removal based on simple supply-and-demand curves and economic assumptions (Von Moltke et al., 2004).

On a basic level, if a subsidy that is keeping fossil-fuel prices artificially low is removed, the prices will rise. If producers were also receiving a subsidy, they will suffer a loss of their surplus and may raise prices. If prices rise, demand will likely fall, resulting in a loss of consumer welfare and a decrease in consumption. If consumption declines, emissions will also decline. If demand and producer surplus fall (in a closed economy), production may fall, resulting in a loss of employment and a decrease in welfare. However, government expenditures on the subsidy will also fall, creating a net government surplus, which could then benefit society through reductions in government deficits and debts, or through improvements in government social programs. The magnitudes of these changes will be determined by the price elasticities of supply and demand (Von Moltke et al., 2004).

Partial-equilibrium models can provide some useful insights into the impacts of subsidy reform. However, they cannot address questions relating to economic sectors that use energy as a significant input. Raising energy prices will result in higher production costs in other sectors and therefore higher resulting prices of many goods in addition to energy. Partial-equilibrium models also do not address macroeconomic questions relating to international competitiveness effects. To answer these kinds of questions, general-equilibrium models are required.

2.1.2 General-equilibrium models

Computable general-equilibrium (CGE) models simulate markets for production factors and goods using sets of equations that specify supply-and-demand behaviour across a multitude of markets (Von Moltke et al., 2004). In theory, general-equilibrium analysis is supposed to look at the economy as a whole and therefore take account of linkages between all markets, including labour markets and markets for all goods that require energy as an input. Numerous CGE models are currently in use, each containing a set of complex non-linear equations that must be solved for, based on assumptions regarding economic behaviour, including price elasticities of supply and demand. The models are first run using values with the subsidy in place, and then again with the subsidy removed to estimate the overall net benefits and costs associated with subsidy removal.

The data requirements for general equilibrium modelling are massive. Although CGE models provide a wider scope of numerical results than partial-equilibrium models, the accuracy of the results is dependent on the accuracy of the assumptions and data. Energy is a fairly ubiquitous input to the production of most goods in the market, changes in energy prices will affect almost all goods. Some key industries, particularly energy-intensive ones, should be included in the model in a disaggregated manner. However, in practice, most of the CGE models that have been used to simulate fossil-fuel subsidy reform require the modeller to make choices as to what is modelled in detail and what is left in aggregated form, and the disaggregation of markets is not always undertaken.

General-equilibrium models can be static or dynamic. Static CGE models look at the economy at only one point in time, in response to some policy change. The results are usually reported as some percentage difference in each variable between the base case and the reform case for some set future year for example 2015 or 2020. The process by which that percentage difference was achieved is not reported. Dynamic CGE models trace what happens to each variable from the base year through the forecast year, usually at annual intervals.

Most general-equilibrium models forecast changes in various factors such as GDP, GHG emissions and real income over a set period of time, such as 20–50 years into the future. In order to provide comparable data, the baseline "business as usual" scenario must also be modelled out 20–50 years into the future. This creates additional uncertainty that must be addressed.

2.1.3 Critical economic modelling assumptions and sources of uncertainty

Variations among modelled results of the economic, environmental and social impacts of fossil-fuel subsidy reform are largely due to differences in the way that data are collected and aggregated, and disparities in the assumptions used. They also account for the main sources of uncertainty in the models.

Differences in the method of calculating subsidies. Most models use price-gap data and other inputs to calculate price wedges. However, there are a wide range of decisions associated with calculating price wedges such as whether to include or exclude taxes, which prices to use as the reference price, whether to incorporate positive as well as negative price distortions and whether to use market exchange rates or exchange rates adjusted for purchasing power parities (PPPs). Market exchange rates in the short-term can deviate substantially from their long-term equilibrium. PPP exchange rates eliminate the short-term rate fluctuations but are more difficult to calculate and interpret. Using exchange rates might overstate price wedges in some countries, but in larger groups, the overstated price wedges may average out across countries (OECD, 2000).

In addition, in non-OECD countries where domestic fossil-fuel prices are set administratively, the price wedges vary over time depending on the fluctuations of the international energy prices. Thus the results also depend on the years for which the wedges are estimated. There are also many non-OECD countries for which there are no data available, so assumptions regarding the level of subsidies for these countries have a significant impact on results.

There are significant challenges associated with estimating international reference prices for electricity and natural gas (Koplow, 2009). For coal, much of the international trade takes place under long-term contracts, yet most of the published price data relate to spot trades, which are of limited use in the calculation of price gaps. Price-gap subsidy estimates for coal are often small considering the critical role coal plays in electricity generation around the world and are often much lower than the estimate generated by the OECD's producer subsidy equivalent method (Koplow, 2009).

Differences among model results can also arise from the subsidy wedges in the baseline scenarios projected. In many non-OECD countries, domestic energy prices are set in order to achieve some domestic purchasing power goal and are not linked to international prices. As international oil prices increase over time, so would the subsidy wedges in the baseline scenario, subject to budgetary constraints. All studies to date have assumed that these wedges are constant over time in the baseline scenario, which is a conservative assumption. The extent to which these wedges should increase in case of an incomplete pass-through of an increase of the international energy prices on the domestic markets is unknown. However, an alternative scenario in which wedges are increasing in the baseline projection should be considered as a sensitivity analysis in future studies.

Demand elasticities. Two types of demand elasticity are important when analyzing energy markets: own-price elasticities of demand; and cross-price elasticities of demand.[1] Elasticities are critical for determining demand and supply responses to price changes. Demand for a product is inelastic if consumers will pay almost any price for the product. Demand is very elastic if consumers will only pay a narrow range of prices and will consume markedly less if the price rises.

Most CGE models require assumptions regarding the *own-price elasticity* of demand of each fossil fuel which indicates the degree to which consumers will reduce their consumption in response to price changes. Own-price elasticities of demand for fuels will be negative—demand for a particular fuel will be higher as the price of that fuel decreases. Fossil fuels are considered to be relatively price demand inelastic (IEA, 1999).

Where it is possible for consumers to switch fuels, assumptions regarding the *cross-elasticities of demand of different fossil fuels become critical. Cross-elasticities of demand relate to how much the demand for a specific good changes when the prices of other goods change. Normally, when prices for a given fuel rise, demand for competing fuels increase (IEA, 2007).*

Long- and short-run own and cross-elasticities are also relevant. In the short-run, changes in price often have little effect on fuel demand, as consumers do not expect the price change to persist or do not

1 In addition, income elasticities highlight the effects of income increases on oil demand.

have the capacity to switch fuels or change their energy-consuming equipment (IEA, 2007; Morgan and Emoto, 2007). Over the long-run, changes in behaviour occur and new investments are made in new energy-using equipment that employs different fuels or are more efficient. Fossil-fuel elasticities are therefore larger in absolute terms in the long-run than they are in the short-run (IEA, 2007). Elasticities also vary from sector to sector depending on the types of energy-using equipment available in that particular sector. In the transport sector, few viable alternatives are available for oil-consuming cars and trucks, and it takes time for consumers to change their vehicles or travelling habits. Thus transport fuels are more price-inelastic in the short-run than other types of fuels. Since only electricity can be used to operate electric devices, electricity demand is also relatively price-inelastic in the short-run (Morgan and Emoto, 2007).

Elasticities are a key component in models but their values are highly uncertain. This clearly adds uncertainty into the results the models generate. In the 1990s, long-run elasticities for energy demand were considered by the World Bank to be about -0.5 (Porter, 2002). More recently, the World Bank (2008) estimated the own-price elasticities of demand for a variety of fossil fuels, suggesting that the fuels might be becoming slightly more price-elastic (Table 1).

TABLE 1[2]: OWN-PRICE ELASTICITIES OF DEMAND (WORLD BANK, 2008)

Energy Type	Long-run Price Elasticity of Demand
Energy	-0.72
Industrial energy	-0.93
Electricity	-0.69
Electricity - industrial	-0.32
Electricity - residential	-0.56
Coal	-0.60
Diesel	-0.67
Gasoline	-0.61
Natural gas - industrial	-1.35
Natural gas - residential	-0.56

The World Bank (2008) elasticities are higher than those estimated by the IEA (2007). The IEA predicts that demand for oil will become more price-inelastic in the future as the share of the transport sector continues to rise given the lack of alternative technologies in transportation (Small and Van Dender, 2008). The IEA estimated the weighted average crude oil price elasticity of total oil demand across all regions to be -0.03 in the short-term and -0.15 in the long-term. It also provides the own-price elasticity for oil broken down by region, and income elasticities.

Cross-price elasticity estimates were rarely provided in the studies examined for this paper, although interfuel substitution is likely incorporated into the models. The OECD (2000) assumed cross-price elasticities to be 2.0. Empirical analysis of fossil-fuel subsidy reform by Hope and Singh (1995) suggests that significant interfuel substitution does occur and therefore is a critical component of general equilibrium models.

2 The data in this table are country- and time-period-specific. The table is for illustrative purposes only and is not applicable to all countries, particularly developing countries, for all periods.

Supply elasticities are also critical in determining the responses of world energy prices to subsidy reform and hence the potential GHG impacts. Currently, the data needed to estimate supply elasticities for coal, crude oil and natural gas are poor for many regions of the world.

World price effects. The reform of fossil-fuel subsidies in countries that currently subsidize consumption could lead to increases in fuel prices in those countries, likely dampening domestic demand. At the global level, however, international prices for fossil fuels could fall. World price effects from multilateral fossil-fuel subsidy reform would have implications for overall global fossil-fuel consumption and could result in an increase in consumption, and therefore GHG emissions, in countries that are already paying market prices, offsetting to some degree decreases in emissions in formerly subsidizing countries. The scale of this effect is dependent on both demand and supply elasticities for fossil fuels, data for which are of variable reliability. Changes in world prices would also affect the terms of trade of fossil-fuel importers and exporters. And some fossil-fuel prices might rise relative to others, resulting in fuel-substitution effects. Most general equilibrium models that have been employed to analyze fossil-fuel subsidy reform consider such world price effects.

Fuel and other energy substitution possibilities in the short- and long-term. Fuel and energy substitution possibilities must be considered on both a short- and long-run basis. In the short-term, the removal of subsidies in some places, causing prices to rise, may just result in the substitution of different, sometimes more polluting fuels, which would have an ambiguous effect on emissions. As a result, the cross-elasticities of fossil fuels are critical to the model (Porter, 2002). In the long-term, removing subsidies would likely have an even larger impact on long-run emissions because power-plant investment decisions are strongly affected by fuel prices (Porter, 2002). For example, because of government intervention to force electric utilities to consume high-priced domestic coal, the removal of support to coal in Europe reduced coal consumption as old coal-fired plants, which were kept operating in the presence of subsidies, were decommissioned and replaced by other energy technologies.

Incorporation of non-energy sectors and interfactor substitutions. Non-energy production sectors that utilize energy will be affected by changes in fossil-fuel prices. Energy-intensive sectors will be particularly affected. While non-energy sectors should be incorporated into general-equilibrium analyses of fossil-fuel subsidy reform in a disaggregated way, not all multi-region, multi-fuel studies do so. Changes in fuel prices also result in a multitude of interfactor substitutions, whereby materials, capital, land and labour can all be substituted for energy. For example, the long-term potential for less energy-intensive material substitutions in industries has implications for the environment and economy and should be accounted for in a general-equilibrium analysis of fossil-fuel subsidy reform (Von Moltke et al., 2004). Interfactor substitution of labour for energy was observed frequently in Indonesia during fossil-fuel subsidy reforms (Hope and Singh, 1995). Interfactor substitution depends in part on the energy cost shares of industries in various countries (the percentage that energy cost constitutes in terms of total production inputs). If energy cost shares are low in a particular country or industry, there may be less interfactor substitution.

Rate of technological change. Assumptions regarding the rate of technological change allowing for less energy-intensive production processes are critical in both the base case and subsidy-removal case. A key reason for low energy efficiency in many subsidizing countries is the large distortions in price that result from subsidies. Thus higher prices may force a more rapid rate of technological change, resulting in greater energy efficiency and lower demand. Energy efficiency tends to be lowest in non-OECD countries where subsidies are also the highest. As a result, subsidy removal may have a significant effect on technological change in these countries. The very long-term effects of subsidy removal are usually greater than the medium-term effects. Technological and production plant investment decisions as well as technological change could have significant impacts over 50-year time horizons (Porter, 2002).

Most of the models analyzed attempt to account for a large number of these assumptions. In addition, there are numerous other assumptions that should be and often are incorporated into general-equilibrium models. Assumptions regarding the types of subsidy being removed can be important. For example, removing purchase obligations may result in greater substitution effects than would occur with just price changes in a market without purchase obligations (Porter, 2002). Environmental policies, such as environmental taxes or emissions restrictions, will affect the model results by imposing costs on the use of certain fuels and therefore could affect energy choices, in both the base case and subsidy-removal case (Von Moltke et al., 2004).

2.1.4 Environmental modelling add-ons

The environmental impacts of fossil-fuel subsidy reform are generally analyzed through an environmental add-on to an economic model. Changes in fuel consumption are utilized to calculate potential changes in GHG emission levels. All that is required is the projected consumption and carbon-emission factors for each fuel (Von Moltke et al., 2004). As a result, most economic models of subsidy reform include estimates of changes in CO_2 or GHG emission levels.

If other environmental impacts are to be considered, such as local air pollution levels, other models are required in addition to the partial- or general-equilibrium analysis. Local air pollution assessments generally need to account for the geographic generation and dispersion of pollutants. A gridded emissions inventory is required to provide input into the dispersion model (Von Moltke et al., 2004). The results of the dispersion model are then used to provide information on the impacts of local air pollution on human health, ecosystems and buildings. Sometimes a monetary value is placed on these impacts, estimated by various approaches: valuing productivity loses; valuing expenditures on preventing damage; people's willingness to pay for less damage; or people's willingness to accept compensation for damage.

In analyzing the effects of energy subsidy removal at a global level, dispersion models are generally not possible, due to the requirements for localized emissions data. As a result, a simpler approach that focuses on fixed damage-cost co-efficients for various pollutants is typically used, and the results are expressed in terms of dollars of damage (to some combination of ecosystems, health and buildings) per tonne of pollutant (Von Moltke et al., 2004). These co-efficients are often derived from geographic dispersion models. The effects of eliminating fossil-fuel subsidies are calculated by multiplying the co-efficient by the expected decrease in emissions. The value of the results depends very strongly on the assumptions used to develop the co-efficients.

There are also approaches to modelling long-term fossil-fuel resource depletion and the stock of natural capital available to future generations. Burniaux et al. (1992) discussed the impact of subsidy removal on the oil-production path in the oil-producing countries. This model has a resource depletion submodule. The removal of the subsidies allows oil-producing countries to export more oil in the long-term compared with the baseline.

Nevertheless, while local air pollution and resource depletion impacts provide interesting information about the overall environmental impact of fossil-fuel subsidies, generally changes in CO_2 or GHG emissions are the only environmental impacts considered in studies of fossil-fuel subsidy reform (Porter, 2002).

2.1.5 Social modelling add-ons

Although many fossil-fuel subsidies are regressive, reform could have negative impacts on the poor. The ripple-through effects of higher fossil-fuel prices throughout the economy, for example in terms of higher production costs, might increase the prices of other goods and decrease incomes (Clements et al., 2003). Moreover, while the poor may benefit from fossil-fuel subsidy reform in aggregate, there may be certain sectors of the population that suffer the negative impacts. Nevertheless, if redistribution of the budgetary surplus from subsidy removal is well-targeted to these affected groups, they could gain.

As indicated above, most studies of the social impacts of fossil-fuel subsidy reform start with a partial- or general-equilibrium economic analysis to determine the price, supply and demand impacts of fossil-fuel subsidy reforms. Social impact analyses, focusing on the distributional effects of subsidy reform, access to energy by the poor as a result of subsidy reform and the re-targeting of money saved by governments through subsidy reform, are then added-on. Studies often focus in particular on impacts in developing countries, as these are the countries that are considered to have the most vulnerable populations. Some of the approaches to social impact analysis, where they exist, are outlined below.

Distributional effects. Considering changes in GDP only masks the fact that different groups will benefit more or less from fossil-fuel subsidy reforms. Distributional changes in employment, consumption patterns and real incomes among different income groups in society can also be assessed using general-equilibrium models. Modellers typically construct a matrix of the distribution of gains and losses. These gains and losses can then be weighted to reflect the fact that income changes affect the poor disproportionately more than the rich (Von Moltke et al., 2004). Changes in real income can then be converted into changes in welfare.

Both the *direct* and *indirect* effects of higher fossil-fuel prices on household budgets should be considered (Coady et al., 2006). Direct effects result from the higher prices for fossil fuels. Indirect effects result from the higher prices of other goods and services that utilize fossil-fuel inputs. Calculating direct effects requires information on household consumption of different fossil fuels across national income distributions, generally obtained through household surveys. For each household, fuel expenditures are divided by total household consumption (Coady et al., 2006).

Assumptions regarding elasticity of demand are very critical in social models. Assuming zero elasticity of demand means that households will continue consuming the same amount of fossil fuels, despite increases in price. The increase in price means that they will have to apportion a greater part of their income to energy expenditures and therefore their welfare will be decreased. This overestimates the real income effect on households since, in reality, most households would reduce their consumption or switch away from the fuel. An elasticity of demand that is not zero will have different effects, resulting in both a reduced consumption of energy but also less of a household budget impact. Nevertheless, the reduced consumption of energy can also be considered to have welfare effects.

Households are allocated into quintiles and deciles based on per capita consumption as a proxy for household welfare, and then effects are analyzed for each quintile and decile (Coady et al., 2006).

In addition, reduced demand for energy, higher energy prices, and higher prices of other goods and services that depend on energy inputs, can all have employment effects that should be accounted for. Indirect effects can be calculated using an input-output model of the economy that provides information on the effects of higher fossil-fuel prices on the costs of other goods and services. Input-output analysis gives an upper bound because it does not consider substitution and the co-efficients are fixed.

Access to energy. Changes in fossil-fuel prices affect household decisions to utilize certain fuels. If fossil fuels become more expensive, many households in the least developed countries may switch to using non-commercial fuels such as wood or other biomass. Increasing demand for wood and biomass can have adverse environmental effects including deforestation and soil erosion. Their use in simple hearths can also increase indoor air pollution effects (Von Moltke et al., 2004). If households cannot turn to other forms of energy they may simply consume less, which can result in health impacts (from lower indoor temperatures), reductions in quality of life, increased drudgery for women, and reduced ability to complete homework and other educational activities. None of the studies of fossil-fuel subsidy reform examined proposed methodologies for assessing these impacts.

Re-targeting of budget money. There are no guarantees that governments will re-target subsidy money to social programs. This does and can happen. In Indonesia, for example, expenditures on social safety nets were increased to accompany subsidy reform to protect the poor from the adverse effects of higher petroleum prices (Clements et al., 2003). However to describe this as a definite quantified benefit of subsidy reform might be misleading. Nevertheless, the net present value of some potential social programs, such as rural electrification, could be presented (Von Moltke et al., 2004).

2.2 Existing modelling studies

Modelling the global economy to generate answers regarding the economic, environmental and social impacts of fossil-fuel subsidy reform is highly complex. As outlined above, there are a huge number of assumptions that go into modelling the global economy as well as very substantial data requirements. As a result, few studies to date have effectively integrated the assessment of all economic, environmental and social impacts. Nevertheless, they do provide useful insights into the effects of fossil-fuel subsidy reform, and the art of what is possible in subsidy reform analysis.

A wide variety of models have been used to quantify the impacts of subsidy reform. Most models assess economic and environmental impacts, while only some include social impacts. Some models look at subsidy reform for all fossil fuels on a global level (IEA, 1999; OECD, 2000; Saunders and Schneider, 2000), while others look at subsidy reform for all fossil fuels within a single country. Yet others examine subsidy reform at the global level for just a single fossil fuel.

This section outlines the specific methodological approaches of some of the studies that have been employed to analyze fossil-fuel subsidy reform and, to the extent possible based on the information provided within the study, an overview of the models utilized, the assumptions and the types of results generated. This paper does not provide an exhaustive survey of studies that have been undertaken of fossil-fuel subsidy reform in single countries or for single fuels.

2.2.1 Multi-region, multi-fuel modelling

There have been six multi-region, multi-fuel studies that have assessed fossil-fuel subsidies and reform scenarios to date: Larsen and Shah, 1992; Burniaux et al., 1992; IEA, 1999; OECD, 2000; Saunders and Schneider, 2000; and Burniaux et al., 2009. These studies all took different approaches, and used different assumptions.

The main methodological features of these studies are summarized in Table 2 with respect to: the time period analyzed; the approach to calculating current fossil-fuel subsidies; the countries and regions considered; key assumptions regarding interfuel substitution and other economic sectors; and the economic and environmental results generated.

More detailed descriptions of each of these studies are provided in Annex II. However, in several instances, the methodological approaches and assumptions used were not provided in significant detail in the studies. All of the relevant assumptions provided in the studies are included in this paper.

The assumptions regarding the size and nature of the fossil-fuel subsidies being removed have relevance for the outcomes of the models. Except for Larsen and Shah (1992), who provided overall dollar values for the subsidies, these numbers were only provided in terms of the size of the price gaps as a percentage of the reference price. No additional numbers, in terms of the percentage of the GDP or total dollar values of the subsidies, were given in the studies. It might be possible to derive these numbers, if necessary. However, even with these derivations, given the different years of the studies, the different choices of countries to incorporate in each study, the different approaches to aggregating and disaggregating these countries, and the different approaches to aggregating the subsidy numbers, the comparability of the results of the studies in terms of the size of subsidies being removed is very limited.

TABLE 2: COMPARISON OF MULTI-COUNTRY, MULTI-FUEL STUDY METHODOLOGIES (CONTINUED ON NEXT 2 PAGES)

Study	Type and name of model	Subsidy calculation	1. Base data year 2. Model years	Countries or regions	1. Interfuel substitution 2. Other economic sectors	Special features or assumptions	Economic impact results (relative to base case)	Environmental impact results (relative to base case)
Burniaux et al., 2009	OECD "ENV-Linkages"	Price-Gap	1. 2007 2. 2013–2050	Four non-OECD countries (China, India, Brazil, Russia); two non-OECD regions (Oil-producing countries and non-EU Eastern European countries); and the rest of the world	1. Yes	1) Gradual Price-Gap removal, 2013–2020 2) Includes all GHGs not just CO_2 3) Modelling to determine the impact of subsidy removal in non-OECD countries on Annex I country mitigation costs 4) Includes electricity	1) % change in GDP for non-OECD and OECD countries and regions by 2020 and 2050 with unilateral and multilateral removal of subsidies 2) % change in real income for each non-OECD and OECD country and region by 2020 and 2050 with unilateral and multilateral removal of subsidies 3) % change in global GDP and real income in the case of multilateral removal of subsidies 4) % change in GDP and real income in all countries and regions as a result of 20% mitigation, 50% mitigation and a global carbon tax with subsidy removal and without	1) Net % change in global CO_2 and GHG emissions by 2020 and 2050 2) Net % change in non-OECD and OECD country and region CO_2 and GHG emissions by 2020 and 2050
OECD, 2000	Dynamic General-Equilibrium "GREEN"	Price-Gap and support data (consumer and producer subsidies, positive and negative wedges ex-tax)	1. 1996 2. 1996–2010	Twelve regions: Four OECD (U.S., Japan, EU-15, other OECD); and eight non-OECD (the Former Soviet Union, Eastern Europe, China, India, Brazil, Energy Exporters, Dynamic Asian, rest of the world)	1. Yes 2. Only modelled industry and power generation sectors	1) Transportation sector excluded; 2) Sensitivity analyses on coal supply and interfuel substitution	1) % change in real global income by 2010 2) % change in terms of trade by 2010	1) Net % change in CO_2 emissions by 2010

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Study	Type and name of model	Subsidy calculation	1. Base data year 2. Model years	Countries or regions	1. Interfuel substitution 2. Other economic sectors	Special features or assumptions	Economic impact results (relative to base case)	Environmental impact results (relative to base case)
Saunders and Schneider, 2000	Multi-Sector Dynamic General-Equilibrium/ "GTEM"	Price-Gap (consumer subsidies only, broken down by three classes of user: power sector, industry and households)	1. 1995 2. 1995–2010	Seventeen regions: Five OECD (Australia, Canada, U.S., Japan, European Union) and 12 non-OECD (Former Soviet Union, Eastern Europe, China, Indonesia, Korea, Thailand, India, South Africa, Middle East, Mexico, Argentina, rest of the world).	1. Yes 2. Yes, 15 of the most energy-intensive industries	1) Examines impacts on prices of consumer goods and inputs into production, trade and investment flows, and regional income and expenditure levels 2) Includes all GHGs not just CO_2	1) % increase in prices of some fossil fuels for some non-OECD countries in 2010 2) % decreases in consumption of fossil fuels for some non-OECD countries in 2010 3) % change in the production of select energy-intensive products in non-OECD and OECD countries in 2010 4) % average aggregated changes in fossil-fuel exports from non-OECD countries in 2010 5) % change in world fossil-fuel prices in 2010 6) % increase in fossil-fuel consumption in OECD countries in 2010	1) % change in global GHG emissions in 2010 2) % change in some OECD and non-OECD GHG emissions in 2010
IEA, 1999	Static Partial-Equilibrium	Price-Gap (consumer subsides only including tax)	1. 1997 and 1998 2. Results that year	Eight non-OECD countries (China, Russian Federation, India, Indonesia, Iran, South Africa, Venezuela, Kazakhstan)	1. No 2. No	1) No inter-country trade interactions 2) No impact on world fossil-fuel prices considered	1) % annual change in GDP for each country 2) % change in global GDP per annum* 3) Net present value of annual changes in GDP 4) Total economic efficiency cost	1) Net % change in global CO_2 emissions 2) Net % change in non-OECD emissions

Study	Type and name of model	Subsidy calculation	1. Base data year 2. Model years	Countries or regions	1. Interfuel substitution 2. Other economic sectors	Special features or assumptions	Economic impact results (relative to base case)	Environmental impact results (relative to base case)
Burniaux et al., 1992	Dynamic General-Equilibrium "GREEN"	Price-Gap (consumer subsidies only but removed both positive and negative wedges)	1. 1985 2. 1990–2050	Twelve regions: Four OECD (U.S., Japan, EU-15, other OECD) and eight non-OECD (the Former Soviet Union, Eastern Europe, China, India, Brazil, Energy Exporters, Dynamic Asian, rest of the world)	1. Yes 2. No	1) Incremental Price-Gap removal 1990–2000	1) % change in global real income per annum, 2) Some regional differences in real income and terms of trade per annum	1) Net % change in CO_2 emissions by 2050
Larsen and Shah, 1992	Dynamic General-Equilibrium	Price-Gap (consumer subsidies only)	1. 1987 2. 1990–2020	Thirteen non-OECD regions: (Former Soviet Union, China, Poland, India, South Africa, Czechoslovakia, Mexico, Brazil, Argentina, Venezuela, Indonesia, Saudi Arabia, Egypt)	1. No 2. No		1) % change in global income per annum 2) Total economic efficiency cost	1) Net % change in CO_2 emissions by 2020

* Note that GDP change from partial-equilibrium models are incomplete in that they use the direct budgetary cost of the subsidy as a proxy for change to GDP. In general- equilibrium models, feedbacks into the wider economy are also included.

2.2.2 Multi-region, single-fuel modelling

There are many multi-region, single-fuel studies of fossil-fuel subsidy reform, most of which focus on coal. It is possible that some methodological insights can be gained from some of these studies.

Anderson and McKibben, 1997. Anderson and McKibben used C-Cubed, a dynamic general-equilibrium model of the global economy, to examine the economic and environmental impacts of coal subsidy removal. The C-Cubed model can take into account possibilities for substitution in production and consumption between products both within and across countries when domestic prices are changed in some or all regions. It assumes the gradual reduction of coal subsidies by 2005 and includes a tax on the environmental damage from coal mining. It considered what would happen if just Western Europe and Japan removed their coal subsidies, if non-OECD countries removed their subsidies and if both OECD and non-OECD countries removed their coal subsidies. It considered terms of trade and international capital movement in its results.

2.2.3 Single-country, multi-fuel modelling

Clements et al., 2003. Clements et al., examined the economic impacts of the reform of fossil-fuel producer subsidies in Indonesia using a multi-sectoral computable general-equilibrium model. The model looked at the short-term implications of reform on economic activity and the poor. It did not consider GHG emissions.

The analysts assumed a mark-up pricing rule which assumes that when producers have to pay higher petroleum costs, they mark up their prices and pass the costs on to consumers. They assumed that the level of petroleum production is unaffected—that a decline in domestic demand is compensated for by an increase in exports. Government consumption and investment and income tax are assumed to be constant. Two versions were run: a Keynesian model, in which labour was assumed to be mobile but capital was not; and a non-Keynesian model in which capital was assumed to be mobile.

Jensen and Tarr, 2002. Jensen and Tarr looked at the impacts of subsidy reform in Iran on the poor, but did not consider GHG emission impacts. They used a "small open economy" general-equilibrium model designed for trade policy analysis for a large number of sectors. In a small open economy formulation, prices of imports and exports are fixed and there are no terms of trade effects. A constant return to scale effect was assumed for oil. Thus, production output was assumed to change proportionally to changes to inputs. The model incorporates 20 household types, 10 urban and 10 rural, grouped according to income. Shares of each group's expenditure on commodities are based on a household expenditure survey. When government subsidies are reduced, the model assumes that government revenues are increased and distributed back to all households in equal shares. They assumed a price elasticity of demand for different energy goods of -0.4.

3. QUANTIFYING THE IMPACTS OF SUBSIDY REFORM – RESULTS

This section compares the results of the studies that have been undertaken with regard to the impacts of fossil-fuel subsidies, although it should be noted that most of the studies referred to in this paper include the removal of all distortions (including taxes and subsidies). Where relevant empirical results from countries that have engaged in fossil-fuel subsidy reform are available, they are presented.

It is critical to note, however, that the transparency of many of the modelling studies is limited. There is no standard approach to assessing the impacts of fossil-fuel subsidies, nor is there a standard set of assumptions or data. Moreover, many of the studies fail to clearly state all of their assumptions and approaches, or do so in a manner that does not allow for easy comparisons with other studies. Finally, the studies were undertaken over a 17-year time period and thus the price wedges utilized for analysis may have varied significantly depending on the reference year.

3.1 Economic impacts

Results from a wide variety of global and single-country economic modelling studies of subsidy reform suggest that on an aggregate level, changes to GDP are likely to be positive (Von Moltke et al., 2004), due to the incentives resulting from price changes leading to more efficient resource allocation.

As resources are deployed more productively across countries, this will have terms of trade effects. Terms of trade is the ratio of the price a country receives for its exports to the price it pays for its imports expressed as a percentage. Whether, and how, terms of trade effects are modelled is important for understanding regional impacts. An improvement in a country's terms of trade is generally understood to improve a country's social welfare. In oil-importing countries, removing taxes implies a terms of trade loss that partly offsets the welfare gain from the tax reform; removing subsidies implies a terms of trade gain that comes in addition to the gain from the subsidy reform. Oil-producing countries record terms of trade gains from removing taxes in OECD countries and large terms of trade losses from removing subsidies. In addition, Burniaux et al., (1992) note interesting but temporary terms of trade losses in oil-producing countries from delaying the depletion of reserves.

Eliminating subsidies also reduces government expenditure—it is assumed by some studies that these government savings will then be translated into improved social programs. However it is not entirely clear whether or how this is accounted for in the modelling. It is also often assumed that the economic gains from subsidy reform will be higher in non-OECD countries because subsidies there are larger (Von Moltke et al., 2004).

Economic results are provided first for the multi-region, multi-fuel modelling exercises. Results are presented from other models (single-fuel or single-region studies) where insights can be gained in terms of reinforcing the findings of the six main studies or providing counter information. Finally, some empirical results are considered.

3.1.1 Multi-region, multi-fuel modelling

The results of the multi-region, multi-fuel studies are difficult to summarize in a table because they are reported out in a different manner: some as net increases in GDP or real income by the end date of the model run (which are all different years); and others as per annum increases in GDP or income over the course of the model run. Some report out on a global level, while others provide results for individual countries.

Table 3 attempts to provide some degree of synthesis to the numbers with details provided for each study in the text below. It would be helpful to assess these results in relation to the size of the subsidies that were reformed in each study. However given the different regions examined, the subsidy size numbers are challenging to compare. This could however, be a useful analysis to undertake in the future.

TABLE 3: SUMMARY OF ECONOMIC EFFECTS OF FOSSIL-FUEL SUBSIDY REFORM

Study	Income or GDP increases (Global)	Income or GDP increases (OECD)	Income or GDP increases (non-OECD)	Total economic efficiency cost
Burniaux et al., 2009	0.2% higher in 2050	0.2% higher in 2050 (Annex I countries)	0.1% higher in 2050 (non-Annex I countries)	NA
OECD, 2000	0.1% by 2010	NA	NA	NA
Saunders and Schneider, 2000	NA	0.1% higher in 2010	0.45% higher in 2010	
IEA, 1999	NA	NA	0.73%	$17.2 billion
Burniaux et al., 1992	0.7% per year to 2050	0.1% per year to 2050	1.6% per year to 2050	NA
Larsen and Shah, 1992	NA	NA	1.8% per year to 2020	$33 billion

Full details and analysis of the results from the six multi-region, multi-fuel studies are included in Annex II.

3.1.2 Multi-region, single-fuel modelling

Anderson and McKibben, 1997. Anderson and McKibben found that removing subsidies also results in changes in terms of trade and international capital movement. Western European countries as net importers of coal have their terms of trade negatively affected, while Australia and other coal exporting countries such as Eastern Europe, the former Soviet Union and China see their terms of trade improve. Net importing developing countries are negatively affected if just Western Europe and Japan reform. However, overall, all countries are better off when coal markets are reformed in developing countries.

3.1.3 Single-country, multi-fuel modelling

Jensen and Tarr, 2002. In their study of subsidy reform in Iran, Jensen and Tarr found that due to price increases in fossil fuels, demand declines and exports increase. The output of energy-intensive sectors (steel, chemicals, aluminum, etc.) decline by 25 to 65 per cent. Activity in farming, food production and other service sectors increases. Worker retraining might be required or the energy-intensive sectors might recover by becoming more efficient. However this is not modelled.

Clements et al., 2003. In their computable general-equilibrium study of fossil-fuel producer subsidy reform in Indonesia, Clements et al. found that a reduction in the subsidy increases production costs, which increases prices in other sectors, particularly in energy-intensive sectors such as utilities, construction, mining and quarrying, which in turn reduces overall consumer product demand. In turn, production is decreased, which leads to a lower demand for labour and capital inputs, which reduces household incomes, thereby reducing consumer demand. Since most kerosene is used for cooling, lighting and heating in private homes, it will not affect production inputs. However it will compress household consumption for non-petroleum products, which will in turn have second-order effects on other sectors. They ran both a Keynesian and a non-Keynesian model. In the Keynesian model, real output is reduced in the short-term. In the non-Keynesian model, the decline in government deficits and public debt (resulting from the decline in subsidies) results in lower interest rates, which increases private sector investment in production. As a result, real output experiences no decrease.

In both models, the aggregate price level increases by 1.1 per cent as a result of a 25 per cent increase in petroleum prices. Electricity prices increase the most sharply and agricultural goods the least. In the Keynesian model, the reduction in subsidies reduces real output by 2 per cent (a fiscal multiplier of two on the 1 per cent of GDP that subsidies represent), due to second-order effects on production and income. In the non-Keynesian model, there are no effects on real output as higher private investment is triggered by the lower deficits, offsetting the impacts of increased oil prices.

3.1.4 Empirical case studies

Hope and Singh, 1995. Hope and Singh conducted a study of energy price reform in six developing countries (Columbia, Ghana, Indonesia, Malaysia, Turkey and Zimbabwe). Their primary goal was to estimate the impacts of energy prices on spending using survey data on household spending patterns. However, some macroeconomic impacts were assessed. Although some modelling was undertaken, this study was based on empirical results from actual subsidy reform in the 1980s in these countries, and therefore would bear a more detailed examination than is provided here. The size of the fuel price increases varied from country to country but were in the range of 20 to 35 per cent for Indonesia, Columbia, Turkey and Zimbabwe, while they were only 3 to 4 per cent for Ghana, and 70 to 80 per cent for Malaysia.

In Malaysia, GDP continued to increase, except for one year, after subsidy removal in 1984–85. GDP grew in Malaysia by 7.8 per cent in 1984, decreased by -1.0 in 1985, and grew by 1.2 per cent in 1986 and 4.7 per cent in 1987. However, it is challenging to determine whether GDP was affected by subsidy removal or not, or by the wide range of other external and internal factors that affect GDP. Hope and Singh note that this was a period of adjustment and change in government revenues as a result of many fiscal policies. Nevertheless, government deficits were reduced, and government revenues increased by 2 per cent at least in part as a result of subsidy reform.

In Indonesia, energy prices were increased between 1982 and 1985 by between 20 and 50 per cent a year depending on the fuel. According to Hope and Singh, the Consumer Price Index was stable during the first three years and GDP decreased by 0.4 per cent in 1982 but then increased by 3.25 per cent in 1983 and 6.1 per cent in 1984. It was calculated that a shortfall of 18.5 per cent in government revenues was avoided as a result of the price reforms.

In all six countries studied by Hope and Singh, there were no large changes in the Consumer Price Index during the period of energy price increases. In three of the countries (Columbia, Indonesia and Ghana) GDP growth rates were higher during the time of energy price increases, compared to the preceding two years. For the other three countries (Malaysia, Turkey and Zimbabwe) a fall in GDP growth rates was experienced during the period of subsidy reform but recovered quickly in the year following the reforms. Nevertheless, the authors stressed that it is challenging to isolate the effects of energy price increases from the effects of other policy changes.

3.2 Environmental impacts

Fossil-fuel production and consumption can have a wide range of environmental impacts on water bodies, landscapes and the atmosphere. However, the majority of models that examine the impacts of fossil-fuel subsidy reform consider only the impacts on GHG emissions and, in most cases, only CO_2 emissions. One OECD (1997) study did find that fossil-fuel subsidy removal can result in greater proportional acid emission reductions than GHG emission reductions in some locations. However there are few other studies of this nature.

Predicting the overall GHG impacts of subsidy reform is challenging. In theory, if a subsidy (either to the consumer or producer) that keeps prices artificially low is removed, the fuel price will rise, resulting in a decrease in demand and therefore a decrease in GHG emissions. However there is also the question of interfuel substitution. Different fossil fuels are more or less polluting. Thus if subsidy removal results in the substitution of a more polluting fuel in place of a less polluting one, then overall GHG emissions might not be reduced.

Study estimates of the reduction in CO_2 emissions from full global subsidy removal range from 1.1 per cent in 2010 (Saunders and Schneider, 2000) to 18 per cent in 2050 (Burniaux et al., 1992) compared to base case scenarios.

3.2.1 Multi-region, multi-fuel modelling

The six main studies discussed in this report provide reasonably comparable numbers with regard to reductions in CO_2 or GHG emissions. The results of these six studies are summarized in Table 4.

TABLE 4: SUMMARY OF ENVIRONMENTAL EFFECTS OF FOSSIL-FUEL SUBSIDY REFORM

Study	Changes in CO_2 emissions (Global)	Changes in CO_2 emissions (OECD)	Changes in CO_2 emissions (non-OECD)
Burniaux et al., 2009	13.0% below base case by 2050	0.4% above base case by 2050 (Annex I countries)	20% below base case by 2050 (non-Annex I countries)
OECD, 2000	6.2% below base case in 2010	0.1% above base case in 2010	6.3% below base case in 2010
Saunders and Schneider, 2000	1.1% below base case by 2010	NA	NA
IEA, 1999	4.6% decrease	NA	16% decrease
Burniaux et al., 1992	6% below base case in 2000 18% below base case in 2050	NA	NA
Larsen and Shah, 1992	5% below base case in 2020	NA	NA

Full details and analysis of the results from the six multi-region, multi-fuel studies are included in Annex II.

3.2.2 Multi-region, single-fuel modelling

Most single-fuel studies focus on coal. Coal in particular is critical since it accounts for 30 per cent of the world's energy supply and 40 per cent of global carbon emissions from energy use (Anderson and McKibben, 1997).

Steenblik and Coroyannakis, 1995. For illustrative simplicity, the authors looked at what would happen if there were a one-for-one substitution of imported coal for domestically produced coal (therefore no change in price or demand) and still found reductions in emissions due to the differences in the types of coal mines (deeper versus shallower) and coal quality (low versus high sulphur). But they also suggested that emissions could be reduced more in the long-run through fuel substitution as many coal-fired plants are replaced.

Anderson and McKibben, 1997. Anderson and McKibben found that if OECD as well as non-OECD countries removed coal subsidies, production of coal in subsidizing countries would fall, or there would be an increase in imports. Global prices would rise, resulting in lower global demand and an overall reduction in CO_2 emissions by 8 per cent below projected levels for 2005. If just Western Europe and Japan were to remove their coal subsidies gradually by 2005, they would lower OECD CO_2 emissions by 13 per cent and global CO_2 emissions by 5 per cent. Porter (2002) indicates that this reduction also includes assumptions regarding a tax on the environmental damage from coal mining. If non-OECD countries raised their price levels to those of international markets, they would reduce CO_2 emissions by 4 per cent (Anderson and McKibben, 1997).

3.2.3 Empirical case studies

Most empirical assessments of fossil-fuel subsidy reform focus on macroeconomic and social impacts. Nevertheless, the World Bank (2008) offers some numbers with respect to countries that have undertaken fossil-fuel subsidy reform in the last two decades. The World Bank noted that transitional economies in Eastern Europe and the former Soviet Union who have reduced or eliminated subsidies have also undergone a sharp reduction in emissions intensity. For example, in Ukraine, energy tariffs on electricity, gas and coal were raised by 25 to 50 per cent between 2002 and 2007. Around the same time, CO_2 emissions per GDP dropped from 5.6 tons per dollar in 1998 to 3.9 in 2005.

It is difficult to disentangle the effects of subsidy reform in these countries from the massive structural changes that were also ongoing in these economies. Nevertheless, it is suggestive that pricing reforms will have positive environmental impacts.

3.3 Social impacts

There has been limited quantitative assessment of access to energy and the health impacts are beyond the scope of this paper. As a result, distributional effects are the only ones discussed. For some insights into the health effects of fossil-fuel subsidy reform, see Garbaccio and Jorgenson (2000).[3]

3.3.1 Multi-region, multi-fuel modelling

The six primary multi-region, multi-fuel studies discussed in this report do not consider social impacts, such as distributional effects, in a quantitative manner, although some provide qualitative commentary. For example, the OECD (2000) acknowledges that pockets of areas could be negatively affected as they have to pay more for fuel or are no longer able to continue production.

3.3.2 Single-country, multi-fuel modelling

The bulk of the distributional impacts research is based on studies that consider only one or a few countries (without considering any inter-country interactions), and look primarily at the distributional effects of fossil-fuel subsidy reform, rather than the larger GDP and GHG emission effects. Based on a survey of these studies, de Moor (2001) argued that the maximum income loss for fossil-fuel subsidy reforms is slightly over 3 per cent and it is usually low-income urban households who depend on commercial fuels that are most affected. According to de Moor (2001), the poorest of the poor in rural areas would be little affected by fossil-fuel subsidy reform as they utilize non-commercial traditional biomass or wood fuel. Some key studies are described below:

3 Garbaccio and Jorgenson (2000) found that reducing CO_2 emissions by 5 per cent a year would reduce premature deaths by 4 per cent and hospital visits and days lost from sickness. This can be converted to a gain in GDP of 0.2 per cent. Similarly an IEA (1995) study found that eliminating fossil-fuel subsidies would reduce nitrous oxide emissions by 40 per cent over 20 years and sulfur dioxide emissions by 65 per cent (Von Moltke et al., 2004).

Freund and Wallich, 2000. Freund and Wallich conducted a study of energy subsidy reform in Poland, which results in an 80 per cent increase in prices. For one case, they assumed a zero elasticity of demand and found that welfare declines would be greater for the richest quintile (8.2 per cent) than for the poorest quintile (5.9 per cent). Using varying elasticities of demand, the impacts were found to range from 4.6 per cent to 7.6 per cent of households' total budgets. The more elastic the demand, the lower the welfare loss because households simply stopped using as much fuel.

Jensen and Tarr, 2002. Jensen and Tarr modelled the effects of fossil-fuel subsidy reform on the poor in Iran. They found that since fossil-fuel subsidies were so high at 18 per cent of GDP to keep fossil-fuel prices on average at 10 per cent of world market prices, subsidy reform would increase household gains in the poorest of rural households by 200 per cent and the poorest of urban households by 100 per cent if the money were transferred back to the poor in equal amounts. Even without these transfers, the analysts found that the elimination of energy subsidies results in a 33 per cent increase in welfare. Domestic demand for fossil-fuel products declines, and exports increase dramatically by 76 per cent (because oil production is assumed constant).

Clements et al., 2003. In this study of fossil-fuel producer subsidy reform in Indonesia using a Keynesian model, the authors found a decrease in real consumption by household group of 2.1 to 2.7 per cent. In their non-Keynesian model, the declines in real consumption are much smaller at 0.9 per cent. Urban poor and non-poor groups are both affected. High-income urban and rural groups are affected due to their relatively higher consumption of petroleum products. The poverty index increases modestly by 0.6 per cent (Keynesian) and 0.3 per cent (non-Keynesian).

Overall in the short-term, eliminating petroleum subsidies will increase price levels and reduce household consumption. The impact is higher in the Keynesian scenario. Both high- and low-income groups are affected. The impacts on low-income groups could be offset through the use of social safety nets through the fiscal savings generated by subsidy reform. However by contributing to macroeconomic stability, subsidy reduction should, over the long-run, be beneficial to the poor.

Coady et al., 2006. The authors of this study simulated both the direct and indirect effects of fossil-fuel subsidy reform in Bolivia, Ghana, Jordan, Mali and Sri Lanka. They found that the direct effects of increased fossil-fuel prices on aggregate real income ranged from 0.9 per cent in Mali to 2.0 per cent in Jordan, but that the size of the fossil-fuel price increases (i.e., the size of the subsidy being removed) played a key role in determining the size of the effects. In many countries, the direct effects were distributionally neutral, affecting the highest and lowest income quintiles similarly. However in Ghana, Jordan and Sri Lanka they were regressive, affecting the lowest income quintile more than the highest. Indirect effects resulting from increases in the prices of other goods and services were higher, ranging from 1.1 per cent to 6.7 per cent but tended to be equally distributed across income quintiles. This reflects the higher proportion of their budgets that lower income quintiles must devote to energy as opposed to other goods and services. The total effect (combined direct and indirect effects) ranged from 2 per cent for Mali, to 8.5 per cent for Ghana. In all countries, this total effect is slightly regressive affecting the lowest quintile the most.

Overall, examining the effects based on the size of the subsidy removed, Coady et al. (2006) suggest that a 50 per cent average increase in fuel prices leads to an average 4.6 per cent decrease in real incomes. However the authors note that any reasonably well-targeted direct transfer program could alleviate these affects in a far more targeted and efficient manner than fossil-fuel subsidies. The authors assumed a unitary elasticity of demand function (the price elasticity of demand is 1) in their calculations, maintaining that long-run elasticities are likely higher than short-run ones and that using an elasticity of 1 would likely set the upper boundary of the income effects of fossil-fuel subsidy reform.

3.3.3 Empirical case studies

The main empirical assessments with respect to the distributional effects of fossil-fuel subsidy reform can be found in Hope and Singh (1995).

Hope and Singh, 1995. Hope and Singh's study of energy price reform in six developing countries (Columbia, Ghana, Indonesia, Malaysia, Turkey and Zimbabwe) estimated the impacts of energy prices on spending using survey data on household spending patterns. Although some modelling was undertaken, this study was based on empirical results from actual subsidy reform in the 1980s.

In all six countries, the loss of income resulting from subsidy reform ranged from 1 per cent to 3 per cent with urban poor being the worst affected. Details are provided for each of the six countries examined. In Malaysia, for example, kerosene consumption between 1983 and 1985 fell by nearly 35 per cent due to a 33 per cent increase in prices suggesting an elasticity of -0.81. Welfare losses were considered to be 1.5 per cent in Malaysia.

4. CONCLUSIONS

This paper reviewed studies to assess the economic, environmental and social impacts of fossil-fuel subsidy reform. There are a few empirical assessments of fossil-fuel subsidy reform (Hope and Singh, 1995). The majority of the studies that have been undertaken to date are based on partial- and general-equilibrium models. Of these, only six (Burniaux et al., 1992; Larsen and Shah, 1992; IEA, 1999; OECD, 2000; Saunders and Schneider, 2000; Burniaux et al., 2009) have considered fossil-fuel subsidy reform on a multi-country and multi-fuel basis. All six studies are reasonably comprehensive in terms of considering multiple global economic factors and all utilize the price-gap approach to calculating subsidies. They therefore focus on the impacts of removing subsidies to consumers, which are largely provided in developing countries. The removal of producer subsidies, which are provided in almost all countries, are thus not included in the analyses. The models differ in their assumptions and approaches.

Each of the six main studies has strengths and weaknesses. For example, the IEA (1999) study did not account for world price or trade effects, and OECD (2000) excluded the transportation sector. Burniaux et al.'s (1992) results placed significant emphasis on the development and use of a higher emitting synthetic fuel, which may or may not occur. Only Saunders and Schneider (2000) presented results of the impacts of fossil-fuel subsidy reform on non-energy sectors in a disaggregated way. Likewise, only the OECD (2000) considered producer subsidies, and provided information on the fuel cross-price elasticity assumptions utilized in the model. Burniaux et al. (2009) was the only study to examine the interplay of fossil-fuel subsidy removal with other climate-change mitigation measures.

Nevertheless, despite different methodologies, all six studies reached somewhat similar conclusions with regard to the economic, environmental and social impacts of fossil-fuel subsidy reform.

4.1 Economic impacts

All six of the multi-region, multi-fuel studies found overall increases in real income or GDP in both OECD and non-OECD countries. Global increases in GDP ranged from 0.1 per cent in total by 2010 (Saunders and Schneider, 2000) to 0.7 per cent per year to 2050 (Burniaux et al., 1992).

Of the studies that broke their results into OECD and non-OECD results, two found GDP increases would be higher in non-OECD countries (Burniaux et al., 1992; Saunders and Schneider, 2000), and one found that the GDP increases would be higher in OECD (Annex I) countries (Burniaux et al., 2009). The differences in GDP increases between OECD and non-OECD countries were slight (less than one per cent) in all three studies. However, the aggregation of countries into OECD and non-OECD masks some significant GDP or real income declines in some non-OECD countries found by Burniaux et al. (2009).

These results are generally supported by the single-country modelled and empirical results. However, in some single-country analyses, GDP or economic output in that particular country declines slightly with fossil-fuel subsidy reform, but generally increases shortly thereafter.

4.2 Environmental impacts

With respect to environmental impacts, all six studies focused on either GHG or CO_2 emissions reductions. All six studies concluded that fossil-fuel subsidy reform would have a CO_2 emission reduction impact. However, the CO_2 reduction results ranged among the studies from 1.1 per cent by 2010 (Saunders and Schneider, 2000) to 18 per cent by 2050 (Burniaux et al., 1992). The widely differing end dates make these numbers challenging to compare. Because it is based on the most up-to-date data and methodological approaches, and is generally supported in magnitude by the other studies, the paper by Burniaux et al. (2009) may provide the most useful guidance with regard to emissions reductions. Burniaux et al. concluded that, overall, world CO_2 emissions would be reduced by 13 per cent and GHG emissions would be reduced by 10 per cent by 2050. This is considered a conservative estimate. The price-gap measures utilized in all six studies provide a lower bound estimate of subsidies (Koplow, 2009). As a result, it is possible that all six studies underestimate the GHG emissions reduction benefits of subsidy reform. By extending the reform analysis to other countries and other fossil-fuel subsidies (most notably to producers), the positive environmental effects of subsidy reform could significantly increase.

It should be noted that the two studies that broke CO_2 emission results down by OECD and non-OECD countries found that even though global CO_2 emissions are expected to drop, there might be a slight increase in CO_2 emissions in OECD countries as a result of fossil-fuel subsidy reform (ranging from 0.1 per cent to 0.4 per cent above base case). However, given global fairness concerns regarding CO_2 emissions reduction, policy reforms that could result in increased emissions in OECD countries should be considered carefully.

Single-fuel studies, mostly focused on coal, support the notion that CO_2 emissions will be reduced by fossil-fuel subsidy reform, as do some empirical assessments (World Bank, 2008). However, in a meta-analysis of other studies, Morgan (2007) drew the conclusion that removal of coal subsidies in OECD countries would not lead to significant increases in coal prices and therefore significantly lower fossil-fuel consumption or emissions, given that in most subsidizing countries consumers are free to choose suppliers. However, since most empirical assessments focused on the social distributional effects of fossil-fuel subsidy reform, there are few empirical results with respect to emissions reductions.

4.3 Social impacts

The six main studies assessed in this report did not consider the social or distributional effects of fossil-fuel subsidy reform within countries quantitatively. Qualitatively it was acknowledged that some groups would suffer, but it was generally suggested that impacts on the poorest of the poor would likely be neutral or positive. Burniaux et al. (2009) did however find that some non-OECD countries would experience significant GDP or real income declines even if the overall global and non-OECD aggregate GDP and real income effect was positive.

Studies that focused on single countries or single fuels generally supported the overall positive impacts of fossil-fuel subsidy reform. Nevertheless, most of the single-country studies did suggest that there would be negative social impacts associated with fossil-fuel subsidy reforms. For example, Coady et al. (2006) suggested that there would be an average 4.6 per cent decrease in real incomes from a 50 per cent average increase in fuel prices, although this could be alleviated by targeting some of the subsidies saved. This is supported by the empirical evidence in which 1 to 3 per cent income losses were found from real instances of subsidy reform in six developing countries (Hope and Singh, 1995). In most cases, it was found that welfare declines would be either distributionally neutral or higher in the richest quintile than the poorest quintile (Freund and Wallich, 2000). However this was not always the case, with the urban poor found to be most affected in some studies (Hope and Singh, 1995).

There are options for targeting saved subsidy expenditures towards social programs that more effectively reach the poor. Any broad fossil-fuel subsidy reform process should explicitly incorporate a commitment to re-target the subsidy savings. There can be significant challenges in establishing the necessary administrative mechanisms for delivering assistance to the poor, and governments should start setting up the mechanisms as soon as possible as it can take years to implement these social programs. For example, the State of Andra Pradesh, India, had difficulty identifying groups that needed targeted assistance as the number of Below Poverty Line ration cards, issued by the Food and Civil Supplies Department to the poor, exceeded the entire population of the State. The programs to re-target subsidy money may not have to be perfect to increase the welfare of the poor more effectively than fossil-fuel subsidies. Jensen and Tarr (2002) modelled the implications of redistributing subsidy money equally among all households and found that the welfare of poor households would still increase by 200 per cent. Developing countries can and should seek the assistance of multilateral lending institutions and international organizations in implementing subsidy reform. In addition, more analysis should be completed with respect to how this kind of re-targeting has been successfully undertaken in countries that have undergone fossil-fuel subsidy reform.

The social impacts of fossil-fuel subsidy reform require further study with respect to how they can be examined through global-equilibrium approaches. The World Bank has developed a considerable body of work on the social impacts of fossil-fuel subsidy reform; and research from the Global Subsidies Initiative draws lessons and best practice from case studies of subsidy reform efforts in Ghana, Senegal, France, Brazil, Indonesia, India and Poland.

4.4 Recommendations for further work

Overall, it appears that the broad global effects of fossil-fuel subsidy reform would be positive from economic, environmental and social perspectives. However, due to the significant data challenges and methodological uncertainties associated with assessing fossil-fuel subsidy reform, all of the results of the studies evaluated should be viewed with some caution. Some of the key methodological challenges that could be addressed in future analyses of fossil-fuel subsidy reform to improve results, include:

- ensuring that both producer and consumer subsidies are incorporated;
- determining appropriate own-price and cross-price demand-and-supply elasticities for fossil fuels;
- identifying methods for incorporating greater social impact analysis; and
- incorporating existing and expected environmental policies.

Efforts to improve the comparability of results among general equilibrium studies of fossil-fuel subsidy reform should also be considered. This could be done through the establishment of:

- consistent sets of global regions for analysis;
- required model outputs for social impacts, such as social welfare effects for each quintile; and
- requirements to convert price-gap data into estimates of subsidies in dollar per year or percentage of GDP.

Despite the fact that further research can and should be undertaken, the analysis in this paper of the six key global studies on fossil-fuel subsidy reform provides strong support to the conclusion that there are significant environmental and economic benefits that would result from eliminating subsidies. The phase-out of fossil-fuel subsidies should be considered as a key element of a larger overall package for global climate-change mitigation. On this basis, there is a mounting body of evidence that policy-makers should proceed with action.

REFERENCES

Anderson, K. and McKibben, W.J. (1997). "Reducing Coal Subsidies and Trade Barriers: Their Contribution to Greenhouse Gas Abatement." Seminar Paper 97-07. Centre for International Economic Studies, University of Adelaide: Adelaide, Australia.

Bacon, R. and Kojima, M. (2006). *Coping with Higher Oil Prices*. Energy Sector Management Assistance Program, World Bank: Washington, DC.

Birol, F., Aleagha, A.V. and Ferrouki, R. (1995). "The economic impact of subsidy phase out in oil exporting developing countries: a case study of Algeria, Iran and Nigeria." *Energy Policy*. 23(3):209-215.

Burniaux, J.-M., Martin, J.P. and Oliveira-Martins, J. (1992). "The effects of existing distortions in energy markets on the costs of policies to reduce CO_2 emissions: evidence from GREEN." *OECD Economic Studies*.19 (Winter), 141-165.

Burniaux, J.-M., Chanteau, J., Dellink, R., Duval, R. and Jamet, S. (2009). "The economics of climate change mitigation: How to build the necessary global action in a cost-effective manner." Economics Department Working Papers No. 701.

Clarke, R. and Edwards, T.H. (1997). "The Welfare Effects of Removing the West German Hard Coal Subsidy." University of Birmingham, Department of Economics Discussion Paper 97-23.

Clements, B., Jung, H.-S. and Gupta, S. (2007). "Real and Distributive Effects of Petroleum Price Liberalization: The Case of Indonesia." *Developing Economies*. 45(2):220-237.

Coady, D., El-Said, M., Gillingham, R., Kpodar, K., Medas, P. and Newhouse, D. (2006). "The Magnitude and Distribution of Fuel Subsidies: Evidence from Bolivia, Ghana, Jordan, Mali and Sri Lanka." IMF Working Paper.

Committee on Pricing and Taxation of Petroleum Products. (2006). *Report of the Committee on Pricing and Taxation of Petroleum Products*. India.

Cox, A. and Schmidt, C.-C. (2002). "Subsidies in the OECD Fisheries Sector: A review of recent analysis and future directions." FAO Expert Consultation on Identifying, Assessing and Reporting on Subsidies in the Fishing Industry. December 3-6, Rome.

de Moor, A. (2001). "Towards a Grand Deal on subsidies and climate change." *Natural Resources Forum*, 25(2):167-176.

European Environment Agency (EEA). (2004). *Energy Subsidies in the European Union: A Brief Overview.* Copenhagen: EEA.

Freund, C. and Wallich, C. (2000). "Raising Household Energy Prices in Poland: Who Gains? Who Loses?" World Bank Discussion Paper.

Garbaccio, R.F. and Jorgenson, D.W. (2000). "The Health Benefits of controlling Carbon Emissions in China." Expert Workshop on Assessing the Ancillary Benefits and Costs of Greenhouse Gas Mitigation Policies. March 27- 29, Washington D.C.

Hope, E. and Singh, B. (1995). "Energy price increases in developing countries." Policy Research Paper 1442. The World Bank: Washington D.C.

International Energy Agency (IEA). (1999). *World Energy Outlook 1999: Looking at Energy Subsidies – Getting the Prices Right*. International Energy Agency: Paris.

International Energy Agency (IEA). (2007). *World Energy Outlook 2006*. International Energy Agency: Paris.

International Energy Agency (IEA). (2008). *World Energy Outlook 2008*. International Energy Agency: Paris.

Jensen, J. and Tarr, D. 2002. "Trade, Foreign Exchange, and Energy Policies in the Islamic Republic of Iran: Reform Agenda, Economic Implications, and Impact on the Poor." Research Working papers, 1-37.

Koplow, D. and Dernbach, J. (2001). "Federal Fossil-fuel Subsidies and Greenhouse Gas Emissions: A Case Study of Increasing Transparency for Fiscal Policy." *Annual Review of Energy and Environment.*

Koplow, D. (2007). "Subsidies in the US Energy Sector: Magnitude, Causes, and Options for Reform." *Subsidies and Sustainable Development: Political Economy Aspects*. OECD. Paris.

Koplow, D. (2009). *Measuring Energy Subsidies Using the Price-Gap Approach: What does it leave out?* International Institute for Sustainable Development: Winnipeg.

Larsen, B. and Shah, A. (1992). "World fossil-fuel subsidies and global carbon emissions." World Bank Policy Research Paper, WPS 1002.

Morgan, T. (2007). *Energy Subsidies: Their Magnitude, How they Affect Energy Investment and Greenhouse Gas Emissions, and Prospect for Reform*. Menecon Consulting.

Morgan, T. and Emoto, H. (2007). *The Impacts of Higher Energy Prices on Demand, Energy Prices & Taxes, 1st Quarter*. International Energy Agency.

Organisation for Economic Co-operation and Development (OECD). (2000). *Environmental Effects of Liberalizing Fossil Fuels Trade: Results from the OECD GREEN Model*. Joint Working Party on Trade and Environment. OECD: Paris.

Organisation for Economic Co-operation and Development (OECD). (2005). *Environmentally Harmful Subsidies: Challenges for Reform*. OECD: Paris.

Pearce, D. and von Fincklestein, F. (2000). "Advancing Subsidy Reform: Towards a Viable Policy Package." *Finance for Sustainable Development: Testing New Policy Approaches*, Background Paper 15, UN CSD 8th Session (24 April – 5 May 2000).

Porter, G. (2002). "OECD Workshop on Environmentally Harmful Subsidies." OECD. Paper presented at the OECD Workshop on Environmentally Harmful Subsidies, November 7, Paris.

Riedy, C. (2003). "Subsidies that Encourage Fossil Fuel Use in Australia." Working Paper. Institute for Sustainable Futures, University of Technology: Sydney.

Saunders, M. and Schneider, K. (2000). "Removing energy subsidies in developing and transition economies." ABARE Conference Paper, 23rd Annual IAEE International Conference, International Association of Energy Economics, June 7-10, Sydney.

Small, K.A. and Van Dender, K. (2007). "Fuel Efficiency and Motor Vehicle Travel: The Declining Rebound Effect." *Energy Journal* 28(1):25-51.

Steenblik, R. and Coroyannakis, P. (1995). "Reform of Coal Policies in Western and Central Europe." *Energy Policy.* 23:537-553.

Steenblik, R. and Wigley, K. (1990). "Coal policies and trade barriers." *Energy Policy* 18 (5) 351-367.

United Nations Environment Programme (UNEP). (2008). *Reforming Energy Subsidies: Opportunities to Contribute to the Climate Change Agenda*.

Varangu, K. and Morgan, T. (2002). *Defining and Measuring Environmentally-Harmful Subsidies in the Energy Sector*. OECD.

Von Moltke, A., McKee, C. and Morgan, T. (2004). *Energy Subsidies: Lessons Learned in Assessing their Impact and Designing Policy Reforms*. Sheffield: Greenleaf Publishing.

World Bank. (2007). *Spending for Development: Making the Most of Indonesia's New Opportunities. Indonesia's Public Expenditure Review*. World Bank: Washington, DC.

World Bank. (2008). *Climate Change and the World Bank Group: Phase I: An Evaluation of World Bank Win-Win Energy Policy Reforms*. World Bank: Washington, DC.

ANNEX I: OUTLINE OF THE ECONOMIC, ENVIRONMENTAL AND SOCIAL IMPACTS OF FOSSIL-FUEL SUBSIDIES

Economic Impacts

Subsidies distort prices, fail to reflect the true costs of supply and therefore affect resource allocation decisions, production and consumption (IEA, 1999; Saunders and Schneider, 2000; Morgan, 2007). The IEA estimated in 1999 that the net present value of the loss of economic growth due to energy subsidies in the eight largest non-OECD countries to be $257 million per year. The precise economic impacts of fossil-fuel subsidies are in part related to whether they take the form of: a) producer supports that lower prices for consumers by lowering production costs for producers; b) consumer supports that lower prices for consumers but also reduce returns for producers; or c) price support, which increases revenues for producers but increases prices for consumers.

For example, subsidies that lower the cost of fossil fuels generally increase the consumption of fossil fuels and sometimes demand (if the fuels are not available to consume), which in turn generates a whole range of additional economic impacts. The level of subsidies for each type of fossil fuel also distorts interfuel substitution decisions. For example, in the 1990s, subsidies for coal fostered excessive production in many developed countries, and excessive consumption of coal in many developing countries (Anderson and McKibben, 1997).

The main economic impacts of fossil-fuel subsidies are:

- *Subsidies can increase energy consumption and reduce incentives for energy efficiency.* Subsidies that reduce prices for consumers promote higher consumption of energy, and reduce incentives to use energy efficiently. Subsidies that reduce production costs for producers reduce producer incentives to minimize costs and increase efficiency (Morgan, 2007).
- *Subsidies can decrease foreign exchange revenues.* Subsidies that encourage greater consumption reduce export opportunities for fossil-fuel-producing nations and revenues from those lost exports (Birol et al., 1995; de Moor, 2001).
- *Subsidies are a drain on government finances* through direct financial transfers from government budgets, government expenditures on infrastructure or research and development or reduced government income from taxation. This can lead to fiscal deficits and debt accumulation. In Indonesia, fossil-fuel subsidies were as high as 5.5 per cent of GDP in 2000 (Clements et al., 2003). They dropped to 1.5 per cent in 2003 but rose again to 3.5 per cent by 2005 (World Bank, 2007). In 2002, subsidies to petroleum products in Iran totaled 18 per cent of GDP (Jensen and Tarr, 2002).
- *Subsidies can increase countries' dependence on imports.* Subsidies that increase fossil-fuel consumption in non-fossil-fuel-producing countries increase those countries' dependence on imports.
- *Subsidies undermine investment in alternative energy sources and alternative energy technologies*. By increasing consumer demand for fossil fuels, or decreasing production costs for producers, subsidies distort the market and reduce investment in alternative energy sources or alternative energy technologies that are potentially more efficient or less environmentally harmful (Varangu and Morgan, 2002).
- *Subsidies encourage energy-intensive production at the expense of labour.* Subsidies that lower prices for consumers can result in a concentration of economic activity on energy-intensive production, perhaps at the expense of labour-intensive production (Birol et al., 1995).
- *Subsidized fuels are used for purposes for which they were not intended.* By lowering prices for certain fuels, subsidies can result in misuse of those fuels for purposes that were not intended. For example, in India and Indonesia subsidized kerosene intended for household cooking has been used illegally or as a cheap addition to transport fuel (Committee on Pricing and Taxation of Petroleum Products, 2006).
- *Subsidies can lead to shortages or costly rationing systems.* Subsidies that lower prices for consumers

but also lower returns to producers can lead producers to produce less or export more, resulting in shortages or the requirement for rationing systems. Likewise, merely by lowering prices and increasing consumer demand, shortages and rationing can also result (Morgan, 2007).

- *Subsidies can reduce producers' ability to invest in cleaner or more efficient technology.* Subsidies that lower prices for consumers but also lower returns to producers can limit producers' ability to invest in cleaner or more efficient technology, resulting in greater costs of production and greater environmental impacts.
- *Subsidies can promote smuggling and corruption.* Subsidies that lower prices for consumers but also lower returns to producers can encourage smuggling of the fuels to countries where prices are higher. This has occurred in Africa and Indonesia and benefits those selling the fuels while having negative economic impacts for the country as a whole (Clements et al., 2003). Corruption is another common consequence when fuels are subsidized and scarce as attempts are made to control distribution channels, in the case of LPG and kerosene.

Environmental Impacts

Although the impacts of subsidies are complex, and there are cases where subsidies have positive environmental impacts such as reducing pressure on forests by reducing biomass fuel use, there is little doubt that overall, fossil-fuel subsidies result in greater fossil-fuel consumption (Morgan, 2007). Fossil-fuel production and consumption have a wide range of environmental impacts. The main impacts include:

- *Greenhouse gas emissions.* Fossil-fuel consumption is a key contributor to global GHG emissions. Fossil-fuel production and consumption (but primarily consumption) is estimated to contribute 97 per cent of all man-made CO_2 emissions in the OECD (Varangu and Morgan, 2002). Coal was responsible for 42 per cent of global emissions from fuel combustion in 2007 (IEA Online Energy Statistics, 2009).
- *Local air pollution.* Fossil-fuel combustion produces pollutants including sulfur dioxide, nitrogen oxides and particulates, which are released into the atmosphere and can cause long- and short-term health impacts as well as damage to structures, agriculture and natural environments (Saunders and Schneider, 2000; OECD, 2000).
- *Water pollution.* Fossil-fuel production and consumption can lead to water pollution through many avenues, including tanker accidents and oil spills (OECD, 2000), water pollution from runoff and leaching from tailings and coal washeries, and water contamination from flooding of closed mines that eventually contaminates groundwater (Anderson and McKibben, 1997).
- *Landscape destruction.* Fossil-fuel extraction often contributes to landscape destruction, particularly in the case of coal mining (Anderson and McKibben, 1997).
- *Depletion of non-renewable fossil-fuel stocks.* Subsidies that accelerate fossil-fuel consumption accelerate this depletion of non-renewable resources (de Moor, 2001).

Social Impacts

Subsidies to fossil fuels, particularly those that keep down the price of liquid fuels, natural gas or electricity, are often justified in non-OECD countries on the basis that they benefit the poor and reduce the cost of living (IEA, 1999). There is an argument to be made for subsidies of this kind, particularly with respect to electricity, which is considered key for reducing poverty and indoor air pollution (Varangu and Morgan, 2002). However subsidies do not always accomplish this, and may not be the most efficient mechanism for poverty alleviation. Subsidies may be regressive, benefiting middle- and upper-income groups more than lower-income groups. Direct transfers to target groups rather than general subsidies may be more effective in reducing poverty.

The main potential social impacts of fossil-fuel subsidies are considered to be:

- *Subsidies may benefit the rich more than the poor,* who spend more money on energy and have greater access to energy than the poor (Clements et al., 2003; UNEP, 2008). A study by the World Bank (2008) found that the bottom 40 per cent of the income distribution receive only 15 to 20 per cent of fossil-fuel subsidies. Even when the rate of energy consumption by the poorest quintiles increases as a result of subsidies, the wealthy derive larger absolute benefits from lower energy prices (World Bank, 2008).
- *Subsidies may reduce energy available to the poor* because in an artificially low-price environment, producers may have little incentive to produce or supply more, and a higher percentage of what is produced may be consumed by the rich (UNEP, 2008).
- *Subsidies often do not target types of energy that would be more beneficial to the poor.* Subsidies may favour larger capital-intensive projects, such as dams or power plants, at the expense of local labour-intensive means of providing energy services (IEA, 1999). Power plant and dam construction can displace or create negative environmental impacts that primarily affect poor communities, while not improving their access to energy.
- *Subsidies may divert government money that could be more effectively directed to social programs* such as healthcare, free education, food coupons or targeted cash transfers.
- *Fossil-fuel consumption and production produce local emissions that cause many health effects* that impact the poor in particular, due to their more limited choices regarding where they live (Von Moltke et al., 2004).

ANNEX II: METHODOLOGICAL APPROACHES AND RESULTS OF SIX MULTI-REGION, MULTI-FUEL MODELLING STUDIES

1. Burniaux et al., 1992

Methodological approach

Burniaux et al. conducted a multi-region dynamic general-equilibrium study of all consumer subsidies in OECD and non-OECD countries from 1990 to 2050 using the OECD in-house GREEN model. The study focused primarily on consumer subsidies measured through a price-gap analysis and not on producer supports or budgetary support to production or consumption (Varangu and Morgan, 2002). However, in the *no-price distortion* case, the modeller re-set prices that exceeded world prices to world prices. Using 1985 price-gap data, the analysts studied the impact of gradually removing price distortions over the 1990–2000 period against a base case scenario. Burniaux et al. looked at 12 regions: four OECD regions (U.S., Japan, EU-15 and other OECD); and eight non-OECD regions (the Former Soviet Union, Eastern Europe, China, India, Brazil, energy-exporting lesser-developed countries, Dynamic Asian Economies, and the rest of the world).

Burniaux et al.'s base case scenario was based on guidelines laid down in the Energy Modelling Forum No. 12 (EMF12). It assumed that, as alternative back-stop technologies, renewable energy sources world start to become available in 2010. These included a carbon-based synthetic fuel, a carbon-free synthetic fuel and a carbon-free electric source. The base case assumed the depletion of crude oil reserves from 2030 on, resulting in rising oil prices. It assumes that oil will be partially replaced by a carbon-based synthetic fuel, which emits more CO_2 than oil, whereby emissions in OECD countries will start to rise.

Results

The model found that removing subsidies would place downward pressure on world fossil-fuel prices. The analysts assumed that the supply elasticity of coal is 5.0, which is higher than that for oil and gas. Upward elasticity for oil and gas becomes zero in 2050 due to the bounding effects of depletion. Due to that and other factors, coal prices remain stable compared with oil and gas. The price of oil rises over the course of the simulation of subsidy reform but remains 20 per cent below the price of oil in the base case. Natural gas prices are even lower at 28 per cent below the base case. The lower prices of oil and gas in the subsidy reform case result in lower demand for the higher emitting carbon-based synthetic fuel. By 2050, energy demand increases by 21 per cent in the OECD, and decreases by 28 per cent in non-OECD countries. Global energy demand decreases by 16 per cent.

The authors found that real income increases per annum resulting from the removal of all consumer subsidies would be 0.7 per cent for the world over the 1990 to 2050 period, 0.1 per cent for OECD countries and 1.6 per cent for non-OECD countries. Real income in the Former Soviet Union was estimated to increase by 27 per cent, although this may have been based only on the data available at the time as Burniaux et al. (2009) found that real income decreases for Russia. China, however, would experience worsening terms of trade and a real income loss of 0.7 per cent per year. Energy-exporting countries would also experience a loss in income of about 5 per cent annually.

Terms of trade impacts shift over the course of the period examined. OECD countries initially experience small welfare terms of trade gains, but this shifts in 2030 when they become more reliant on oil imports, rather than synthetic alternatives. In many oil-producing countries, even those forecast to experience an initial loss in income as a result of subsidy reform, the elimination of domestic subsidies results in a reduction in the rate of exhaustion of their oil supply and a re-allocation of those resources for the future, therefore improving their terms of trade from 2030 onwards. However, China does not experience a shift in its real income losses, due to the shift from reliance on coal to greater reliance on imported oil (Burniaux et al., 1992).

The authors estimated that CO_2 emissions in 2050 would be 18 per cent below base case scenarios if fossil-fuel price distortions were removed, due to a 16 per cent decrease in fossil-fuel consumption. However a key element of this study is the assumption that there will be new renewable energy sources introduced in 2010, including a higher-emitting carbon-based synthetic fuel. Emissions are reduced versus the base case in part because the subsidy reform case results in lower global oil prices, making oil more competitive with the higher emitting synthetic fuel, whereas in the base case the higher-emitting synthetic fuel becomes more competitive. The short-term emissions effect of subsidy removal in 2000 before the introduction of the synthetic fuel is only 6 per cent. Given the uncertainty regarding the introduction and emissions rates of new fuels, the 6 per cent estimate might be more realistic.

While this study was state-of-the-art at the time, conclusions regarding CO_2 emissions reductions and GDP improvements based on assumptions regarding a higher-emitting synthetic fuel, should be taken with caution, and limits the comparability of this study with the other studies.

2. Larsen and Shah, 1992

Methodological approach

Larsen and Shah combined price-gap information with supply and demand elasticities to estimate the social and environmental impacts of energy subsidies using a multi-region dynamic general-equilibrium study of consumer subsidies in non-OECD countries from 1990 to 2020. The countries they included were the Former Soviet Union, China, Poland, India, South Africa, Czechoslovakia, Mexico, Brazil, Argentina, Venezuela, Indonesia, Saudi Arabia and Egypt. Their emissions base year was 1987.

The authors' assumptions regarding the own-price elasticities of demand varied depending on the size of the subsidies in each country. They argued that many existing estimates of long-run price elasticities were valid only for marginal price changes, which would not be the case in countries where subsidies are high. Thus smaller elasticity estimates must be employed. The *own-price elasticities of demand* utilized in their study in most countries ranged from -0.15 to -0.25. In countries where subsidies were relatively lower, own-price elasticities of -0.6 were applied.

The authors chose to ignore interfuel substitution. They note that for countries such as the Former Soviet Union, where subsidies were high for all fuels, this is an unproblematic assumption. However in countries where greater differences exist in the subsidies for each fuel, the potential for interfuel substitution does exist. Thus the authors noted that their estimates of CO_2 emission reductions may have been too high.

Larsen and Shah ran two simulations, one with a world price effect, and one without. In the first scenario, they assume that world prices do not decrease in response to the decline in demand in subsidizing countries that occurs when subsidies are removed. In the second scenario, they do account for a world price effect, whereby reduced demand in subsidy removing countries lowers world prices, which, in turn, increases fuel consumption in non-subsidizing countries, thereby moderating the overall reductions in emissions. However, they do not consider the implications of fossil-fuel prices on the prices of other goods and services.

Results

Larsen and Shah found income increases of 1.8 per cent per annum up to the year 2020 in a sample of non-OECD countries resulting from the removal of all consumer subsidies.

The authors also found that the net reductions in global CO_2 emissions would be 5 per cent in 2020. They noted that the bulk of reductions in global emissions would come from countries that consume a large amount of subsidized coal. However, overall global fuel prices would fall and consumption in countries that do not subsidize energy would rise.

3. IEA, 1999

Methodological approach

The IEA study, based on a static partial-equilibrium analysis, used a price-gap approach that only accounted for subsidies that lower the consumer price for fossil fuels and included taxes on reference as well as end-use prices. It did not attempt to incorporate subsidies to producers that raise consumer prices. The estimates of the total subsidies in the IEA study were higher than the World Bank subsidy assumptions used by Saunders and Schneider (2000). Since producer subsidies that increase prices to consumers may have the effect of lowering consumption and therefore GHG emissions, the IEA study may have overestimated GHG benefits from complete subsidy reform because removing some consumer subsidies could increase fossil-fuel consumption. Nevertheless, the IEA claims that overall, due to the inability to account for the dynamic effect of removing energy subsidies on factors like energy efficiency and greater competition, that their study likely underestimates the positive effects of removing fossil-fuel subsidies.

The IEA did not examine inter-country trade interactions, nor effects on production sectors other than energy sectors. Its analysis was on a country-by-country basis. The results were then totalled and averaged (the methodology does not specify how). Total primary energy supply numbers were used and electricity was incorporated, no matter how it was generated. Prices for crude oil were not considered because subsidies to producers were considered too challenging to identify (IEA, 1999). The countries considered included China, the Russian Federation, India, Indonesia, Iran, South Africa, Venezuela and Kazakhstan. Subsidies in OECD countries were assumed to be zero and thus no change in emissions from OECD countries occurred in the model because the impact of subsidy removal in non-OECD countries on global fuel prices was not taken into account.

Price-gap numbers were calculated for the countries considered using 1997 data for some countries and 1998 data for other countries as a simple subtraction of the consumer price from a reference price. The change in consumption for each fuel was calculated based on a constant-elasticity inverse demand function based on IEA assumptions for the *own-price elasticities of demand* for each fuel. Three own-price elasticities of demand were developed using an in-house Delphi method. Own-price elasticities of demand were assumed to be -0.25 for all mobility-related fuel, -0.5 for fuels employed in stationary uses in households and industry, and -0.5 for electricity.

The reductions in GHG emissions were calculated based on the change in fuel consumption for each type of fuel, multiplied by a CO_2 emission factor. An overall percentage reduction for each country was calculated and then totalled and averaged (in some weighted manner) to produce the total sample reduction. Reductions in energy consumption were expressed as a percentage of total primary energy supply.

Efficiency losses due to lower than optimal fuel prices were calculated as the difference between total transfers (calculated using the quantity consumed before the subsidy removal multiplied by the change in consumption and the energy price) and consumer and producer surplus. Welfare losses were calculated as the change in price multiplied by the change in quantity divided by two. Annual economic efficiency gains were reported for each country as an annual percentage of GDP, although it is not clear how they were calculated. The net present value of these annual differences in GDP was calculated with a 7 per cent discount rate. A total global economic efficiency cost was calculated, although it is not stated how.

Changes in trade were commented on qualitatively with some quantitative estimates of changes. For example, it was suggested that importers such as India, Indonesia and South Africa could decrease their imports (by an estimated 10 per cent for automotive diesel fuel in Indonesia, and 10 per cent for kerosene in South Africa). India's imports could decrease even more substantially while exporters would have more fuels for export. However, these estimates were included for the purpose of showing a few examples rather than providing a comprehensive picture of trade changes. The IEA (1999) notes that these increased exports may dynamically contribute to lower long-run prices, which could be reinforced by energy-efficiency effects.

The IEA study did not account for interfuel substitution based on cross-elasticities between the prices of different fuels, nor did it consider the impact of reduced demand in non-OECD countries on global fossil-fuel prices. It did not account for the longer run savings from the more rapid development of energy efficient technologies. It also only looked at CO_2 and did not include other GHGs.

Results

The IEA study estimated that the removal of consumer subsidies in eight non-OECD countries would increase annual GDP on average in those countries by 0.73 per cent. Individual country results ranged from an increase in GDP by 2.22 per cent in Iran to 0.10 per cent in South Africa.

The IEA study suggested that the removal of subsidies in eight non-OECD countries would lower their CO_2 emissions by 16 per cent due to a decrease in energy use by 13 per cent. Globally this would amount to a decrease of CO_2 emissions of 4.6 per cent.

4. OECD, 2000

Methodological approach

GREEN was the OECD's in-house general-equilibrium model, which only assesses CO_2 emissions, and its analysis only covers the industry and power generation sectors, not the transportation sector. It used price-gap data and other available fossil-fuel support data from 1996 to calculate price wedges for fossil-fuel subsidies. The OECD calculated both positive and negative price wedges—this attempted to capture subsidies that lower prices to consumers, and subsidies that raise prices for consumers, but provide support to producers. The OECD excluded taxes to both reference and end-use prices.

The price wedge calculation required many assumptions. For example, the OECD included a 2 per cent oil price wedge for the United States, which was just assumed because the U.S. price is used as the world reference price. Market exchange rates were used to calculate the price wedges, rather than purchasing power parities. Producer subsidies were incorporated to some extent, however the study acknowledges that it did not capture all of the producer supports for expenses such as exploration, extraction and refining.

The version of GREEN used in 2000 divided the world into 12 regions—four OECD regions (U.S., Japan, EU-15 and other OECD) and eight non-OECD regions (the Former Soviet Union, Eastern Europe, China, India, Brazil, energy-exporting lesser-developed countries, Dynamic Asian Economies and the rest of the world). These groupings of countries eliminated some country-specific detail. For example, Canada was included as a member of "other OECD" and is a major trading partner with the U.S., but those effects were not captured. Also price variations within countries could not be captured.

To simulate the effects of a hypothetical reform of fossil-fuel subsidies, the GREEN model was run up to 2010 with a base case that included the price wedges, and then with a reform case that eliminated the price wedges. It examined three subsidy reform scenarios: a) OECD countries only eliminate price wedges; b) non-OECD countries only eliminate price wedges; and c) all countries eliminate price wedges.

Sensitivity analyses were conducted on elasticity assumptions of coal supply and interfuel substitution. Coal supply elasticities were assumed to be infinite. Sensitivity analyses that lowered this elasticity to 3.0 yielded little difference, while lowering it to 1.0 reduced positive impacts on CO_2 emissions as domestic producers continued to produce coal. *Interfuel substitution cross-elasticities* were assumed to be 2.0 in the original model. Sensitivity analyses were run on an interfuel substitution elasticity of 5.0 yielding very little difference in outcomes at the global level. However regional and national trade shifts were significant due to greater fuel switching, as coal demand was reduced in most regions of the world. Nevertheless, coal demand rose in some parts of the world.

Porter (2002) criticized the analysis for: a) underestimating the CO_2 emission reduction benefits of subsidy reform, due to poor data on producer price wedges; b) excluding transportation and agricultural related fossil-fuel use (which, on average, accounts for 40 per cent of fossil-fuel use); c) failing to model producer price wedges for crude oil; and d) failing to account for induced technological change.

Nevertheless, the OECD itself observed that the drop in demand in non-OECD countries might have been overestimated because, due to low producer prices, supply may always have been rationed in these countries. With price increases and supply increases, demand might not drop as much as predicted (OECD, 2000).

Results

On a global level, the OECD found that reduced fossil-fuel demand reduces global prices, so exporters experience a reduced terms of trade and importers experience an improved terms of trade. Real income effects were less than plus or minus 1 per cent in all scenarios with a total global effect of a 0.1 per cent increase in real income from the reforms, by 2010, relative to the base case. This suggests that reforms will result in no severe economic hardships and that many regions will be better off. Decreased demand in places with large positive price-gaps frees up supply for export. Imports rise in most OECD countries and fall in non-OECD countries due to drops in demand. Increased demand in Japan, Europe and Brazil with large negative price-gaps is generally met through increased imports. Overall, fossil-fuel trade flows rise by 4.4 per cent in 2010.

The oil-exporting nations will feel larger negative impacts than other countries in the scenario where all countries remove subsidies, and in the scenario where the non-OECD countries remove subsidies. The oil-exporting nations would benefit only if the OECD countries remove their subsidies as well.

The OECD found that in the scenario where all countries remove fossil-fuel subsidies, CO_2 emissions would fall by 6.2 per cent in 2010. These reductions in CO_2 largely result from reductions in consumption in non-OECD countries, which offset the increased demand in OECD countries. In the scenario where the OECD countries only remove subsidies, CO_2 emissions would increase by 0.1 per cent by 2010 due to drops in prices and increases in demand (and imports) in Japan and Europe, due to the large negative price-gaps that exist in these countries. However, most other OECD countries experience a reduction in CO_2 emissions due to reductions in demand or substitution by less carbon-intensive fuels. In the scenario in which only non-OECD countries remove subsidies, CO_2 emissions are reduced by 6.3 per cent in 2010.

5. Saunders and Schneider, 2000

Methodological approach

This study used the Australian Bureau of Agricultural and Resource Economics (ABARE) Global Trade and Environment Model (GTEM), a multi-region, multi-sector dynamic general-equilibrium model for their analysis. The GTEM takes into account the interactions among different sectors of the economy, different economies and the impacts of policies on key economic variables (price of consumer goods and inputs into production, sectoral and regional output, trade and investment flows and regional income and expenditure levels) inter-temporally (over time).

The GTEM allows for aggregation and disaggregation of regions and commodities. At its most disaggregated level, it could at the time track 45 regions and 50 industries or sectors, aggregated to 17 regions (Australia, Canada, U.S., Japan, European Union, Former Soviet Union, Eastern Europe, China, Indonesia, Korea, Thailand, India, South Africa, Middle East, Mexico, Argentina and the rest of the world) and 15 industries (the most energy-intensive commodities likely to be affected by subsidy changes). The GTEM also models emissions of three GHGs—CO_2, methane and nitrous oxide.

Saunders and Schneider used 1995–96 World Bank estimates of energy *consumption* subsidies because they were reasonably comprehensive for developing and transition economies. The base year for the analysis is 1995–96. Data from the World Bank included subsidies for 10 non-OECD regions: the Former Soviet Union and Eastern Europe (aggregated), China, Indonesia, Korea, Thailand, India, South Africa, Middle East, Mexico and Argentina on petroleum products, gas, and coal, broken down by three classes of user (the power sector, industry and households). The authors' estimates of subsidies were lower than those of the IEA (1999) (considerably in some cases, for example, with coal subsidies in China).

The authors ran the GTEM from 1995 to 2010 for a reference case and a subsidy reform model case. In the reference case, GDP growth was projected from a convergence procedure: the per worker GDP of all economies are assumed to converge to that of the U.S. in the very long-term. Global energy consumption was projected to grow annually by 2 per cent from 1995 to 2010. Shares of nuclear energy, hydropower and renewable energy were projected to fall. The greatest growth in energy demand occurs in developing countries. Emissions grow with demand. The study does not consider any implementation of the Kyoto Protocol.

In the reference scenarios, it is assumed that fossil-fuel consumer subsidies are removed over a five-year period from 2001 to 2005. The model accounts for interfuel substitution and changes in trade patterns among countries. However the estimates of the own- and cross-elasticities of the fuels included in the model are not provided.

Results

Saunders and Schneider found that in economies where subsidies are removed, prices rise relative to the percentage of subsidy. Thus in the former Soviet Union with large subsidies, prices rise 55 per cent. But prices fall right away in some places (for example gas in Eastern Europe because Russian gas is immediately diverted there). Consumption falls in the economies where prices rise.

In energy-producing countries, energy exports increase because there is limited downward pressure on production. This results in downward pressure on global prices (i.e., the world coal price is 4 per cent lower, and the world petroleum products price is 2 per cent lower). Energy consumption in OECD countries rises due to lower prices, but does not completely offset declines in non-OECD countries.

Overall, according to Saunders and Schneider, global fossil-fuel consumption declines by 0.1 per cent. Some energy-intensive industry production falls in some developing countries and rises in others (for example iron and steel fall in China and India, but chemical, rubber and plastic production increase in the Former Soviet Union.) Energy-intensive goods in OECD countries become more competitive and production rises due to lower global prices. Saunders and Schneider reported GDP increases of 0.45 per cent for non-OECD countries in 2010 and 0.1 per cent for OECD countries.

Saunders and Schneider found that although GHG emissions fall in economies where prices rise, they are offset by rises in emissions in other countries. Thus the total global decrease in GHG emissions is 1.1 per cent by 2010.

6. Burniaux et al., 2009

Methodological approach

This study used the OECD ENV-Linkages model to evaluate the impacts of the gradual removal of energy subsidies from 2013 to 2020. Price-gap data from the IEA for 2007 were used for four non-OECD countries (China, India, Brazil and Russia), two non-OECD regions (oil-producing countries and non-EU Eastern European countries) and the rest of the world.

The IEA price gaps estimated for 20 non-OECD countries account for 40 per cent of the world energy demand. In re-aggregating these countries to fit with the ENV-Linkages countries and regions the analysts assumed zero-wedges in the countries where no data were available. This is a conservative assumption, as it is likely that there are subsidies in some of these countries. The results, in terms of percentage decreases in CO_2 and other GHG emissions, relative to the base case for each country considered, are modelled out to 2050.

All OECD models include assumptions regarding interfuel substitution, but values for the elasticities of demand were not provided. It is assumed that there is a world price effect in which world energy prices fall in the case of multilateral subsidy removal, resulting in terms of trade losses by non-OECD countries and terms of trade gains by energy importing OECD countries.

Results

Burniaux et al. examined both unilateral and multilateral energy subsidy removal. They found that most non-OECD countries and regions experience economic efficiency gains measured in GDP and real income percentage increases by both 2020 and 2050, if these countries and regions remove their energy subsidies unilaterally. Changes were small in most countries, ranging from 0.1 per cent to over 2 per cent. India experienced the greatest increases, reaching a high of a 2.2 per cent increase in both GDP and real income by 2050. Only the oil-producing countries experienced a slight decrease in GDP (0.1 per cent) and real income (1.1 per cent) by 2020. However this reverses itself by 2050. The non-EU Eastern European countries experience a slight decrease by 2050 (1.4 per cent for GDP and 1.8 per cent for real income) as a result of falling world fossil-fuel prices.

In the case of multilateral energy subsidy removal, the GDP and real income increases of some non-OECD countries, such as India, China and Brazil, increase in 2020 and 2050, but decrease for some countries including Russia, the oil-producing countries and the non-EU Eastern European countries (sometimes significantly—up to 15.2 per cent in the case of the non-EU Eastern European countries in 2050). This is because of the terms of trade losses resulting from a fall in world energy prices resulting from multilateral subsidy removal. Most OECD countries, with the exception of Australia and Canada, experience slight GDP and real income increases due to decreased world energy prices and improved terms of trade.

In the absence of any other climate-change mitigation measures, Burniaux et al. found that CO_2 emissions and GHG emissions would drop substantially in some non-OECD countries if energy subsidies were removed multilaterally (up to 40 per cent in some countries and regions), amounting to a total of 20 per cent in non-Annex I countries in 2050. However, due to declines in world energy prices, emissions in Annex I countries that do not subsidize energy increase over the same period. Thus overall, world CO_2 emissions are reduced by 3.9 per cent in 2020 and 13 per cent in 2050; and GHG emissions are reduced by 3.1 per cent in 2020 and 10.2 per cent in 2050.

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Jennifer has a PhD in Geography from the University of Waterloo and has been an environmental consultant for 10 years. As a consultant, she has focused on conflict resolution, research and project management with regard to sustainability, with a particular focus on energy. She has prepared reports and managed projects for local, provincial and national governments in Canada and internationally with regard to fisheries management, energy efficiency, transportation demand management, environmental monitoring and reporting, cradle-to-cradle sustainability solutions, climate change and growth management. Recently, she has undertaken research contracts with regard to cycling conversion factors, clean energy solutions in developing countries, energy service companies in developing countries, fossil-fuel subsidies and local food sustainability. She also works for the City of Rossland, British Columbia, as the project manager of the Sustainability Commission and is responsible for the implementation of a multitude of city research, planning and action projects, including a climate change adaptation project and an indicators and sustainability monitoring process.

THE GLOBAL SUBSIDIES INITIATIVE (GSI) OF THE INTERNATIONAL INSTITUTE FOR SUSTAINABLE DEVELOPMENT (IISD)

The International Institute for Sustainable Development (IISD) launched the Global Subsidies Initiative (GSI) in December 2005 to put a spotlight on subsidies—transfers of public money to private interests—and how they undermine efforts to put the world economy on a path toward sustainable development.

Subsidies are powerful instruments. They can play a legitimate role in securing public goods that would otherwise remain beyond reach. But they can also be easily subverted. The interests of lobbyists and the electoral ambitions of officeholders can hijack public policy. Therefore, the GSI starts from the premise that full transparency and public accountability for the stated aims of public expenditure must be the cornerstones of any subsidy program.

But the case for scrutiny goes further. Even when subsidies are legitimate instruments of public policy, their efficacy—their fitness for purpose—must still be demonstrated. All too often, the unintended and unforeseen consequences of poorly designed subsidies overwhelm the benefits claimed for these programs. Meanwhile, the citizens who foot the bills remain in the dark.

When subsidies are the principal cause of the perpetuation of a fundamentally unfair trading system, and lie at the root of serious environmental degradation, the questions have to be asked: Is this how taxpayers want their money spent? And should they, through their taxes, support such counterproductive outcomes?

Eliminating harmful subsidies would free up scarce funds to support more worthy causes. The GSI's challenge to those who advocate creating or maintaining particular subsidies is that they should be able to demonstrate that the subsidies are environmentally, socially and economically sustainable—and that they do not undermine the development chances of some of the poorest producers in the world.

To encourage this, the GSI, in cooperation with a growing international network of research and media partners, seeks to lay bare just what good or harm public subsidies are doing; to encourage public debate and awareness of the options that are available; and to help provide policy-makers with the tools they need to secure sustainable outcomes for our societies and our planet.

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The GSI is an initiative of the International Institute for Sustainable Development (IISD). Established in 1990, the IISD is a Canadian-based not-for-profit organization with a diverse team of more than 150 people located in more than 30 countries. The GSI is headquartered in Geneva, Switzerland and works with partners located around the world. Its principal funders have included the governments of Denmark, the Netherlands, New Zealand, Norway, Sweden and the United Kingdom. The William and Flora Hewlett Foundation has also contributed to funding GSI research and communications activities.

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