Mitigation potential and Trade Effects of removing fossil fuel subsidies

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Abstract

Quoting a joint analysis made by the OECD and the IEA, G20 Leaders committed in September 2009 to "rationalize and phase out over the medium term inefficient fossil fuel subsidies that encourage wasteful consumption". This analysis was based on the OECD ENV-Linkages General Equilibrium model and shows that removing fossil fuel subsidies in a number of non-OECD countries could reduce world Greenhouse Gas (GHG) emissions by 10% in 2050 (OECD, 2009). Indeed, these subsidies are huge. IEA estimates indicate that total subsidies to fossil fuel consumption in 37 non-OECD countries in 2008 amounted to USD 557 billions (IEA, OPEC, OECD, World Bank, 2010). This represents almost five times the yearly bilateral aid flows to developing countries as defined by the Official Development Assistance (ODA). This paper discusses the assumptions, data and both environmental and economic implications of removing these subsidies. It shows that, though removing these subsidies would amount to roughly a seventh of the effort needed to stabilize GHG concentration at a level of 450ppm or below 2°C, the full environmental benefit of this policy option can only be achieved if, in parallel, emissions are also capped in OECD countries. Finally, though removing these subsidies qualifies as being a "win-win" option at the global level in terms of environmental and economic benefits, this is not true for all countries/regions. The removal of fossil-fuel subsidies in non-OECD countries would have almost no impact on the total trade volumes at the world level although it would generate compositional changes both across traded goods and services and trading areas. Trade in fossil fuels, especially coal and natural gas, would be reduced, but these fuels account for a relatively small segment of total world trade and would be compensated, at least in the medium term, by an expansion of trade in energy-intensive goods. As for effects among different trading areas, the reform of fossil-fuel subsidies would increase the contribution of OECD countries in total world trade at the expense of a reduction of oil-exporting countries' imports and exports. This evolution results from the loss of competitiveness incurred by producers of energy-intensive goods in oil-exporting countries that remove their subsidies and, at least in the medium term, by the corresponding gain of competitiveness reported by energy-intensive industries in OECD countries due to the fall of international fossil-fuel prices.The paper also provides some discussion about the robustness of these results.

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[2] The views of the authors do not necessarily represent the views of the OECD or of its member countries. This paper is a synthetic version of two working paper from the authors, Burniaux and Chateau (2010b, 2011)

1. Introduction

At their September 2009 Summit, G20 Leaders committed to “rationalize and phase out over the medium term inefficient fossil fuel subsidies that encourage wasteful consumption”. This decision came after a joint analysis by the OECD and the IEA showed that removing fossil fuel subsidies in a number of non-OECD countries could reduce world Greenhouse Gas (GHG) emissions by 10% in 2050 compared with their level in the absence of such a reform (OECD, 2009). Indeed, these subsidies are huge. According to IEA estimates, total subsidies to fossil fuel consumption in 37 non-OECD countries amounted in 2008 to USD 557 billions (IEA, OPEC, OECD, World Bank, 2010), almost five times the yearly bilateral aid flows to developing countries in the form of Official Development Assistance (ODA).[3] As indicated in Figure 1, fossil fuel consumption subsidies[4] are quite substantial in some countries, especially in several oil-exporting countries where they amount to 10% or more of GDP (see Annex 2 for subsidies expressed in USD and over time). Even in oil-importing countries like India, subsidies in terms of GDP are not negligible, amounting to almost 5% of 2008 GDP.

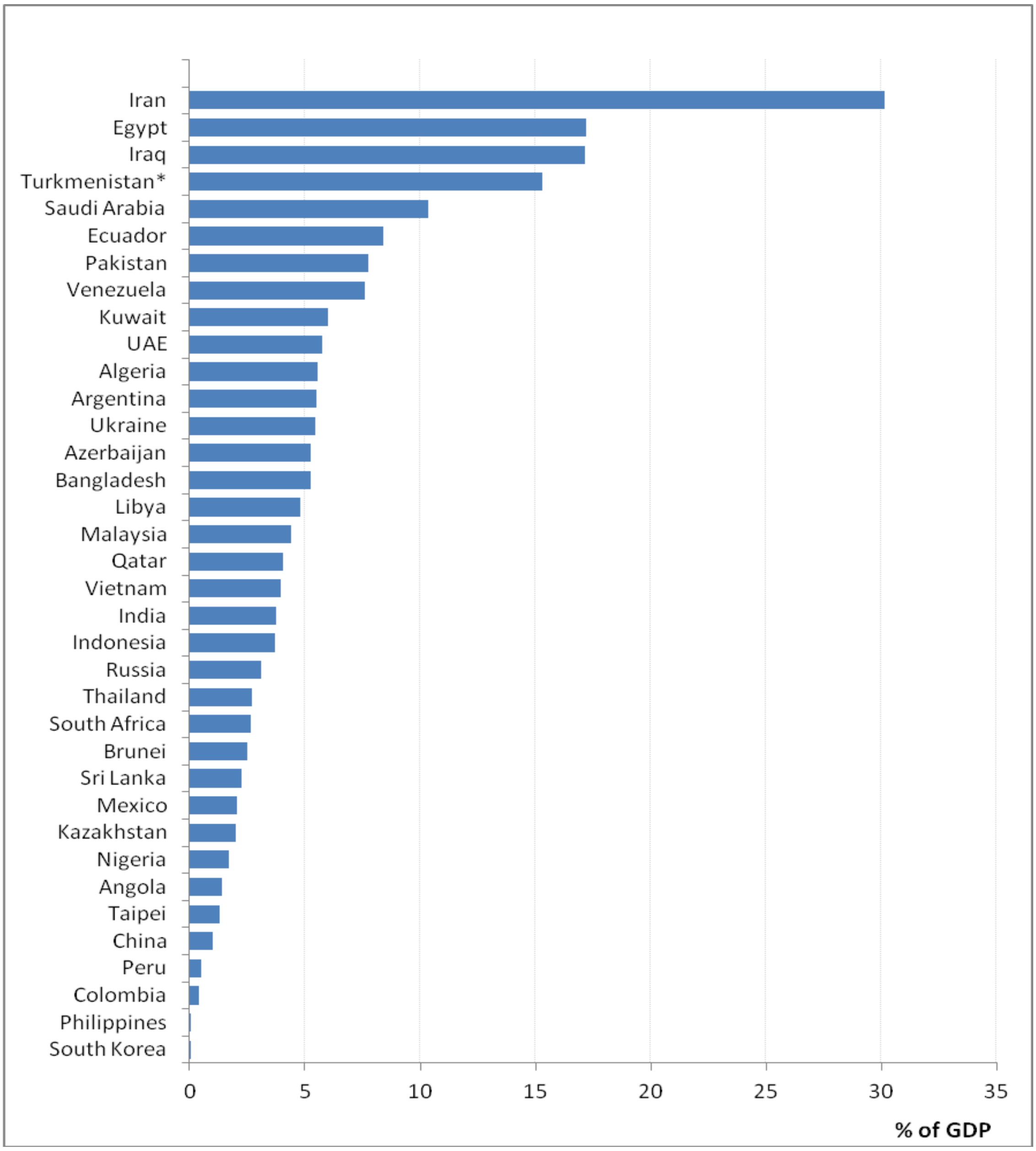
From a theoretical perspective, in an autarkic economy where subsidies are the only existing price distortions, removing these subsidies should reduce energy related GHGs emissions, while bringing real income gains to the country that removes the subsidies. These gains originate from an increase of consumer welfare and from a more efficient reallocation of resources. Hence, this policy reform is a “win-win” option as it brings both environmental and economic benefits. In a global world economy, characterized other departures from the first-best world and where economies are interrelated through international trade, there is no guarantee that all countries would report positive welfare impacts from subsidy removal, although the welfare at the world level should increase.

However, governments are reluctant to remove these subsidies as they claim they are justified on equity grounds, *i.e.* to protect the access of poor households to fossil fuels and electricity. This argument could be reversed as the budgetary savings obtained from subsidy removal would give room for manoeuvre to implement social support that could be better targeted to poor households. For example access to fossil fuels and electricity can be guaranteed by directly supporting the purchasing power of the poor unlike across-the-board subsidized fossil fuels and electricity consumption that subsidizes all households.

3. Latest IEA estimates for 2009 amount to USD 312 billion.

4. This analysis covers subsidies to coal, refined petroleum products, natural gas and electricity consumptions. The electricity subsidy may in principle cover subsidies to nuclear-based, hydroelectric and renewable electricity sources, hence including subsidies that do not increase the consumption of fossil fuel. However, these subsidies are negligible in the countries covered by the IEA database.

Figure 1. Fossil-fuel subsidies as a percentage of GDP, 2008



[#]Note that IEA database is covering 37countries while the figure reports only 36 countries, excluding Uzbekistan, because reconciliation of IEA and IMF numbers for this country has appeared to be cumbersome.

Source: Author's calculation based on IEA (2010) fossil fuel subsidies data and IMF, IEA(2009) GDP data.

A recent publication by the Global Subsidies Initiative (GSI) provides a comprehensive survey of the analysis undertaken in the past in order to quantify the economic and environmental consequences of fossil fuel subsidies at the world level (Ellis, 2010). These surveyed studies are all at the world level, with multiple sectors and countries or regions and generally based on partial or General Equilibrium (GE) approaches.[5] Although these analyses differ in scope, method and years of reference, they share some broad conclusions. A majority of the studies conclude that a worldwide reform of subsidies to fossil fuel consumption should reduce world GHG emissions in the longer term although the magnitude of this reduction is subject to uncertainty as it differs across studies. For instance, global CO_2 emission reductions range from 5% in IEA (1999) and Larsen and Shah (1992) to 13-18% in Burniaux *et al.* (1992 and 2009). In addition, these studies agree that subsidy reforms increase GDP in OECD countries and even more in non-OECD countries although the resulting world GDP gain should be rather modest and below 1% in the longer term. The studies say little about the social impacts of subsidy reform, such as the impact on poor households. So far, these aspects have only been dealt with using single country models.

Compared with previous studies, the subsidy dataset used for this analysis is estimated by the IEA for 2008 and is the most comprehensive in country coverage. The aim of this paper is to provide, based on simulations using the OECD General Equilibrium ENV-Linkages model, quantified estimates of the emission reduction and the 'real income' gains that can be achieved by removing fossil-fuel subsidies. Throughout this paper, the concept used to assess changes in real income is the Hicksian equivalent variation in income relative to the baseline scenario. This utility-based measure does not incorporate the benefits of avoiding climate change.

The remainder of this paper proceeds as follows. Section 2 discusses the nature of these subsidies, their scope, the existing data and the methodology used to assess these subsidies. Section 3 discusses the environmental impact of removing these subsidies. Section 4 presents the real income implications of the subsidies removal. Section 5 presents trade impacts. Section 6. checks the robustness of the results first with regard to the uncertainty in fossil-fuel subsidies data, next the uncertainty in the policy context in which subsidy removal is implemented and finally regarding fossil-fuel supply behaviour. Section 7 concludes.

2. Nature and scope of fossil fuel subsidies

Governments support consumption and production of fossil fuels in numerous ways: by intervening in markets to affect costs or prices, by transferring funds to recipients directly, by assuming part of their risk, by selectively reducing the taxes they would otherwise have to pay, and by undercharging for the use of government-supplied goods or assets. Often, more than one transfer mechanism is used. For example, on the consumption side, a government may provide tax breaks to purchasers of motor vehicles and at the same time regulate the price of transport fuels below the international market price or even below the cost of producing the fuels. The effects of subsidies depend not only on how governments subsidize but also on what economic variables they subsidize — *i.e.* consumer or producer prices, consumption or production levels, enterprise revenues, intermediate inputs, or production factors (IEA, OPEC, OECD, World Bank, 2010).

This analysis only concerns consumer subsidies that are mostly present in non-OECD countries. Each form of consumer subsidies should ideally be modelled explicitly in order to quantify their impact, but such an approach was not feasible in this analysis due to lack of data. Instead, the approach followed here in estimating subsidies data is a simplified one usually referred to as the "price-gaps approach".

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5. The six studies surveyed in Ellis (2010) include one partial equilibrium model (IEA, 1999) and five general equilibrium models (Burniaux *et al.*, 1992a and b; Larsen and Shah, 1992; OECD, 2000; Saunders and Schneider, 2000 and Burniaux *et al.*, 2009).

2.1 The IEA price-gaps approach

Most of the data on energy consumption subsidies that have been published for multiple non-OECD countries in recent years relate to oil products, natural gas and coal (IEA, 2006 and 2008) or petroleum products only (Coady *et al.*, 2010), and have relied on the measurement of price gaps. These price gaps comprise subsidies to fossil fuels used in final and intermediary consumption (including subsidies to fossil-fuel inputs to electric power generation).

The "price-gap" methodology is described in Box 1.[6] It aims at summarizing various forms of consumer price regulations using one single indicator that is the observed price deviation between the domestic consumer price and a reference price considered as undistorted (usually the corresponding international price). Although it is by far the most common approach used in the literature to evaluate transfers supporting consumption through price instruments, some authors have pointed out a number of weaknesses when this approach is applied to energy goods. Koplow (2009) indicated that this methodology incorporates a number of underlying assumptions that should be kept in mind: for instance, the identification of an appropriate reference price is not always obvious for non-traded goods such as electricity; international energy prices could in turn be distorted during some periods and, finally, the price-gap estimates do not capture all producer subsidies. Regarding this last point, OECD (2003) suggested that the price-gap methodology tends to underestimate the level of subsidies in countries that use this kind of market-distorting instruments.

Box 1. Quantification of Energy Subsidies by the IEA

Energy subsidies are estimated using a price-gap approach, which compares end-user consumer prices with reference prices corresponding to the full cost of supply or, where available, the international market price, adjusted for the costs of transportation and distribution. This approach captures all subsidies that reduce consumer prices below those that would prevail in a competitive market. Such subsidies can take the form of direct financial interventions by government, such as grants, tax rebates or deductions and soft loans, and indirect interventions, such as price ceilings and free provision of energy infrastructure and services.

Simple as the approach may be conceptually, calculating the size of subsidies in practice requires a considerable effort in compiling price data for different fuels and consumer categories and computing reference prices. For traded forms of energy, such as refined petroleum products, the reference price corresponds to the export or import border price (depending on whether the country is an exporter or importer) plus internal distribution margins. For non-traded energy, such as electricity, the reference price is the estimated long-run marginal cost of supply. VAT is added to the reference price where the tax is levied on final energy sales. Other taxes, including excise duties, are not included in the reference price. So, even if the pre-tax pump price of gasoline in a given country is set by the government below the reference level, there would be no net subsidy if an excise duty large enough to make up the difference is levied. The aggregate results are based on net subsidies only for each country, fuel and sector. Negative subsidies, *i.e.* where the final price exceeds the reference price, were not taken into account. In practice, part of the subsidy in one sector or for one fuel might be offset by net taxes in another. Subsidies were calculated only for end-user consumption, to avoid the risk of double counting: any subsidies on fuels used in power generation would normally be reflected at least partly in the final price of electricity. All the calculations for each country were carried out using local prices, and the results were converted to US dollars at market exchange rates.

For incorporating these price gaps into the OECD Env-Linkages model, the GTAP data base was adjusted taking into account both VAT rates and the price gaps calculated by the IEA.

Source : based on IEA (2006, 2010).

6. IEA (1999) provided a more detailed discussion of the price-gap approach and practical issues relating to its use in calculating subsidies and their effects.

This analysis covers 37 countries, including two OECD countries (South Korea and Mexico). According to the IEA, these estimates cover approximately 95% of global subsidized fossil-fuel consumption. The price wedges estimated for 2008 by energy sources and by countries/regions are significant in a number of cases (Table 1). The first column of the Table shows the average wedges for all demands that are *effectively* subsidized in each country/region, thereby illustrating the magnitude of the wedges. The second column reports the average wedge across *all* demands (including demands that are not subsidized), so that the difference between the two columns reflects the coverage of the subsidies across demands. Countries not covered in the IEA database are included in regional aggregates (for instance, the Rest of the World region) by assuming zero wedges.

Table 1. Price Gaps in 2008 as estimated by the IEA[1]

		% deviation of domestic relative to world prices	
Country	**Energy**	Average subsidy rate over the demands that are effectively subsidised for each type of fuel	Average subsidy rate over the total demand for each type of fuel
China	Coal	-6.6	-1.2
	Gas	-21.4	-7.1
	Refined oil	-19.7	-1.7
	Electricity	-12.8	-1.7
India	Coal	0.0	0.0
	Gas	-60.4	-32.2
	Refined oil	-41.8	-20.4
	Electricity	-20.3	-1.7
Brazil	Coal	0.0	0.0
	Gas	0.0	0.0
	Refined oil	0.0	0.0
	Electricity	0.0	0.0
Russia	Coal	0.0	0.0
	Gas	-78.8	-21.4
	Refined oil	0.0	0.0
	Electricity	-37.6	-24.8
Oil-exporting countries[2]	Coal	0.0	0.0
	Gas	-37.7	-11.4
	Refined oil	-45.5	-34.3
	Electricity	-47.2	-43.5
Non-EU Eastern European countries[2]	Coal	0.0	0.0
	Gas	-30.3	-15.8
	Refined oil	-5.7	-0.6
	Electricity	-19.4	-10.9
Rest of the world	Coal	-7.4	-0.9
	Gas	-29.5	-8.2
	Refined oil	-5.7	-4.1
	Electricity	-9.1	-5.8

1. Energy subsidies are approximated by the difference in the domestic energy price and world prices.
2. See Table A1.2 in Annex 1 for the details about these regions

Source: Author's calculation based on IEA fossil fuel subsidies data for 2008 (IEA, 2010).

The energy wedges differ across energy sources and countries/regions. Energy tends to be subsidised more heavily in Russia (especially for natural gas), India and the oil-exporting countries. By contrast, the subsidy rates estimated by the IEA for China are more moderate. The lower subsidy rates in China are partly the consequence of a pricing reform engaged in 2008.

3. Environmental impact of removing fossil fuel subsidies in non-OECD countries

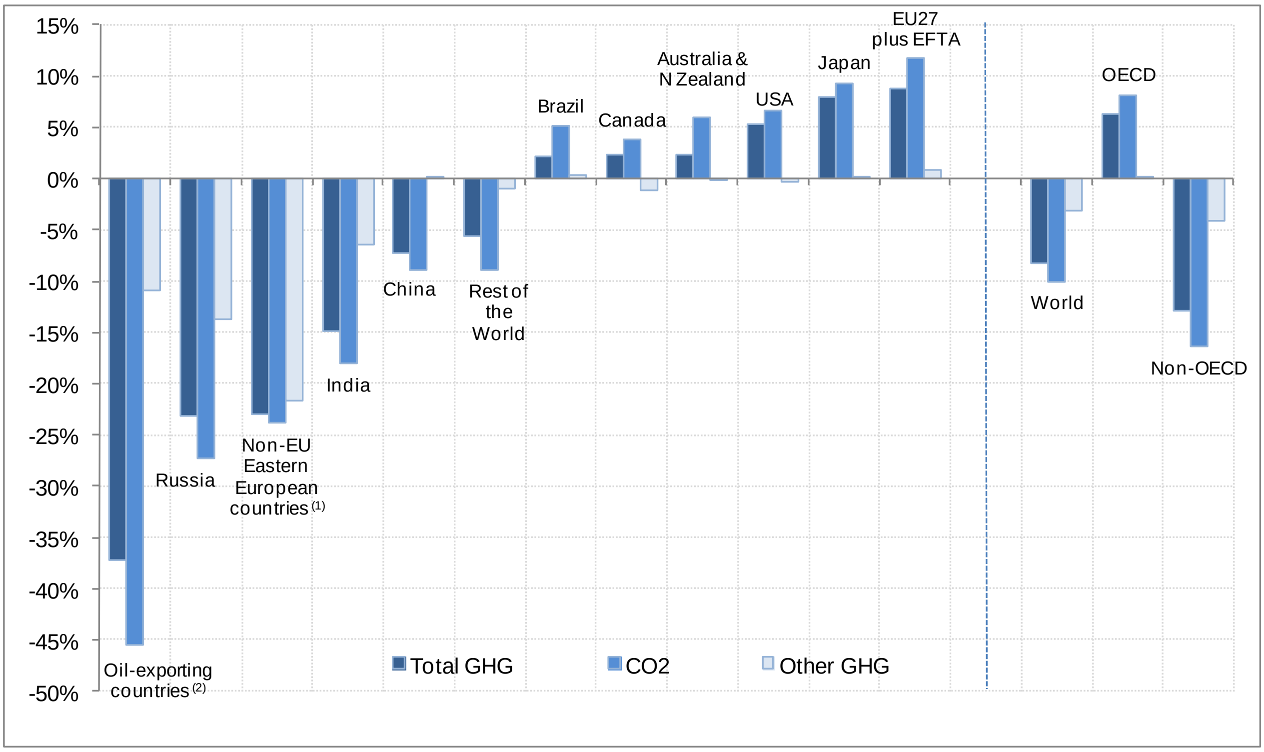
The impact of subsidy reform is quantified by using the ENV-Linkages model developed by the Environment Directorate of the OECD. This is a world General Equilibrium model disaggregated by sectors and countries/regions and running to the year 2050 using recursive dynamics (see Burniaux and Chateau, 2010a) or Annex 1 for a more detailed description of the model structure). All scenarios in this paper are shown relative to a baseline projection simulating the evolution of the world economy up to 2050 under the assumption of no climate change policies beyond those that are already in place. This projection is based on an underlying long-term economic growth scenario described in Duval and de la Maisonneuve (2010). In this baseline projection, the price gaps estimated by the IEA for 2008 are introduced by calibration in the initial year of the model, 2005, and they remain constant in percentage terms up to 2050. In simulations of generic subsidy reforms, these price gaps are gradually phased-out over the period 2013 to 2020.

The **central scenario** considered in this paper assumes that all the 37 countries covered by the IEA fossil-fuel subsidies database (see Figure 1) will remove their subsidies gradually from 2013 to 2020. If they do so, world GHG emissions could be reduced by 8% in 2050 relative to the baseline (Figure 2). This number is lower than the 10% reported in the joint report for the G20 initiative (IEA,OPEC,OECD, World Bank, 2010). The main reason is that, in this scenario, emissions in OECD countries are not capped as they are in the joint report. This number is also somewhat lower than the 10% reported in OECD (2009), as price gaps have tended to decline from 2007, which was the base year for OECD (2009), to 2008 in line with changes in pricing policies in some non-OECD countries and also because the baseline projection has been updated since OECD (2009) in order to take into account the world financial and economic crisis.

The resulting drop of emissions of CO_2 is quite substantial in some countries/regions, amounting to more than 25% in Russia and 45% in the oil-exporting countries. While CO_2 emissions fall by 16% in non-Annex 1 countries in 2050, they remain almost unchanged in Annex 1 countries. This is because reductions in Russia and non-EU Eastern European countries are offset by emission increases in other Annex 1 countries. As consumption of fossil fuels in non-OECD countries fall as a result of the subsidy removal, international fossil fuel prices drop inducing an increase of the fossil fuel consumption in countries that do not subsidize their energy demand or do not remove their existing fossil fuel subsidies, a phenomenon usually referred to as a carbon leakage. This leakage is particularly pronounced in the EU and EFTA countries where CO_2 emissions increase by 12% in 2050 relative to the baseline. Of the 6.1 $GtCO_2$ emission reduction achieved by removing energy subsidies in non-OECD countries in 2050 (corresponding to a reduction of their emissions by 16%), around 17% is offset by an increase of emissions in OECD countries. With binding emission caps in OECD countries, carbon leakages would be contained, and the environmental benefits from subsidy removal would be larger (see Section 5).

Figure 2 also illustrates an additional environmental benefit from subsidy reform, namely the reduction of non-CO_2 gases, although by a lesser extent than CO_2 emissions (3% in 2050 relative to baseline compared with 10% for CO_2 emissions, see Figure 2). This illustrates the complementarities across gases. The last section will discuss how these complementarities are enhanced if emissions are capped in OECD countries.

Figure 2. Central scenario: Impact on 2050 GHG emissions (percentage change from the baseline)



Notes: See Table A1.2 in Annex 1 for the details about these regions.

Source: OECD ENV-Linkages using IEA fossil fuel subsidies data (IEA (2010)).

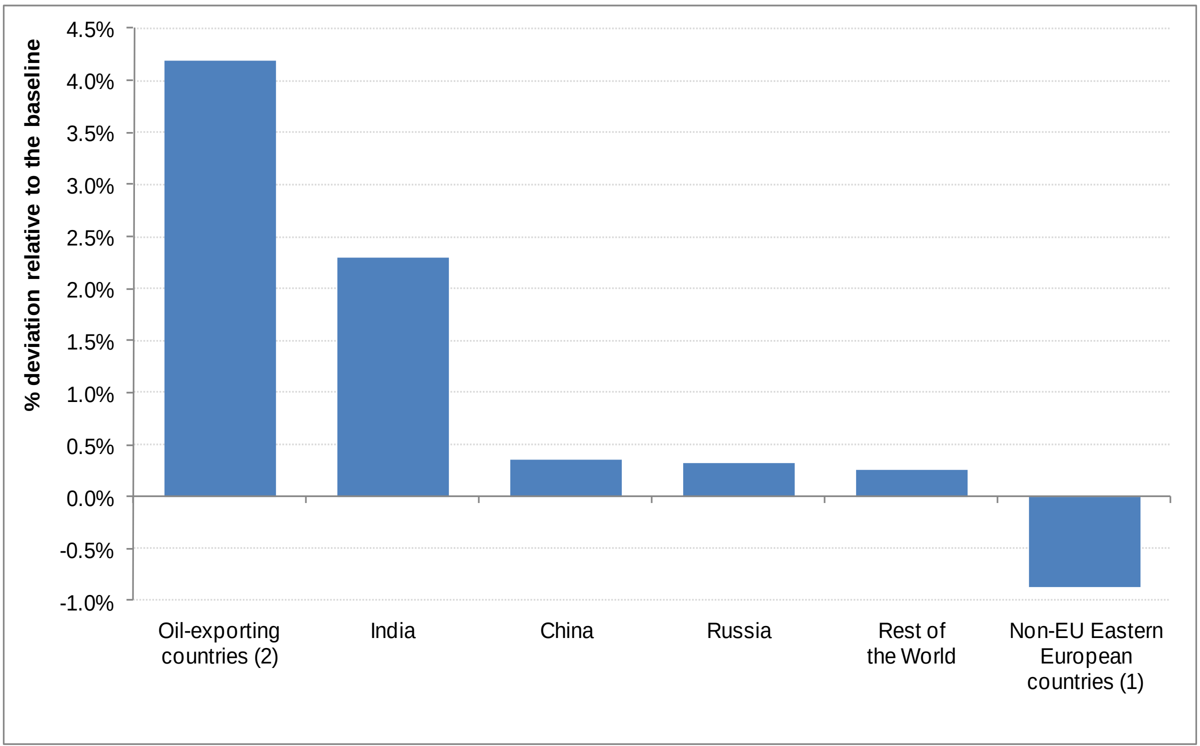
4. Economic implications of phasing-out fossil-fuel subsidies in non-OECD countries

If each non-OECD country were to remove its fossil-fuel subsidies unilaterally, it would generally record welfare gains, in line with what is suggested by the theory (Figure 3).[7] Most countries or regions report welfare gains ranging from 0.3% in the "rest of the world" regional aggregate to more than 4% in the oil-exporting countries in 2050. These gains correspond to the welfare improvement associated with the subsidy removal together with, in most cases, a more efficient allocation of resources across sectors.[8] Therefore, from this perspective, the removal of fossil fuel subsidies brings in both environmental and economic benefits.

7. In the reform simulations modelled here, the budgetary saving obtained from the subsidy removal is entirely refunded to households in a lump-sum manner. In other words, subsidies to the consumption of fossil fuel are then replaced by a direct transfer to households. Alternatively, this transfer could be used to reduce other distorting taxes, which would increase the real income gain from subsidy removal, or to reduce poverty in a more targeted and efficient way than through a uniform subsidy to fossil fuel consumption.

8. With the noticeable exception of the "non-EU Eastern European countries". This regional aggregate consists of very heterogeneous economies (see Table A1.2 in Annex 1), where the removal of the subsidies induces a dramatic shift in the economic structure towards low-productivity sectors. The resulting overall productivity loss more than offsets the welfare gains from the subsidy removal.

Figure 3. Unilateral removal of fossil fuel subsidies scenarios: Impacts on 2050 equivalent variations in income (% change from the baseline)



Notes: See Table A1.2 in Annex 1 for the details about these regions.

Source: OECD ENV-Linkages using IEA fossil fuel subsidies data (IEA (2010)).

A different outcome prevails in the central scenario, where there is a multilateral removal of energy subsidies in all non-OECD countries together (Figure 4). India would still benefit from welfare increases by 3% in 2050 relative to the baseline. But, in this scenario, some of the non-OECD countries that remove their subsidies, including Russia and the oil-exporting countries would no longer enjoy welfare gains. This is because the efficiency gains from improved resource allocation domestically would be more than offset by the terms-of-trade losses associated with the sharp fall in world energy prices and demands that a multilateral removal of subsidies would induce.[9]

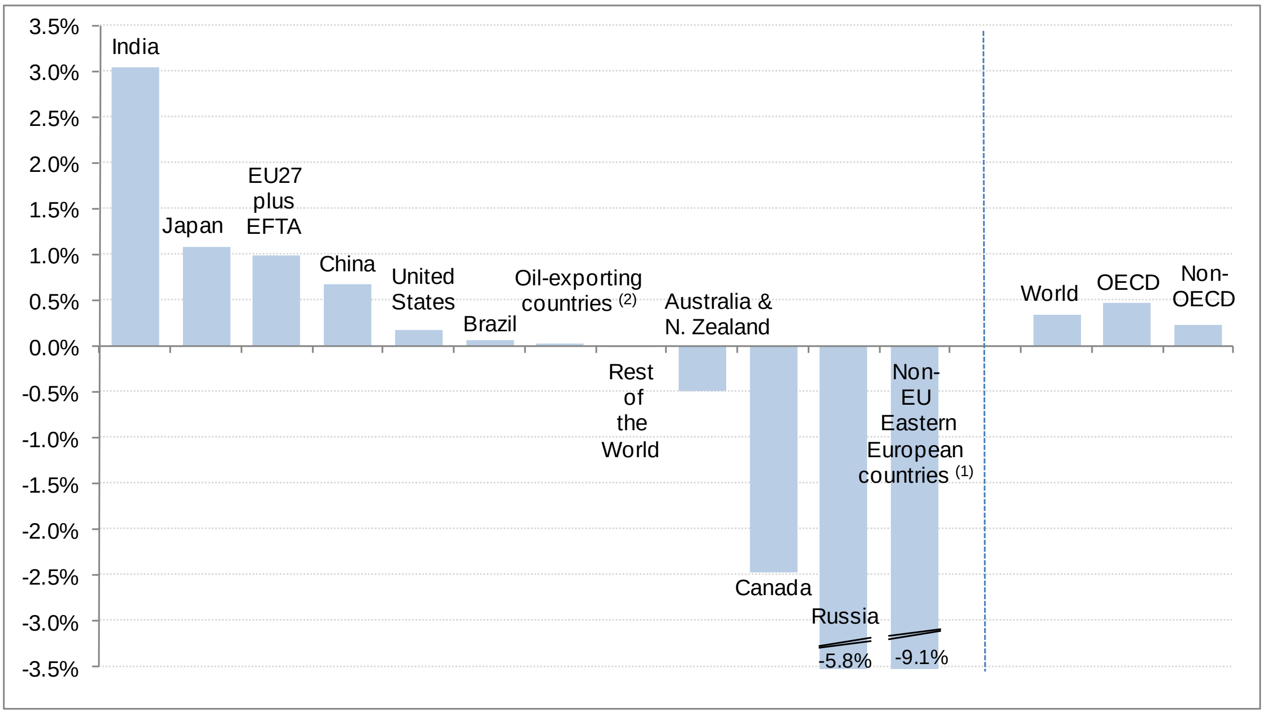
Indeed, a multilateral removal of fossil fuel subsidies in non-OECD countries is simulated to induce a drop of the international fossil fuel prices. Reflecting assumptions about supply responses, the international prices for crude oil and natural gas would fall in the central scenario by 8 and 13% respectively in 2050 relative to the baseline, while the international coal price only drops by 1%.

Interestingly, the "oil-exporting countries" as a whole do not incur any real income loss as the GDP loss resulting from reduced oil extraction is compensated by the relatively large welfare gains from the subsidy removal (as reported in Figure 3). Energy-importing countries, not least the EU and Japan, would enjoy terms-of-trade trade and welfare gains. Overall, the OECD area as a whole report an increase of real

9. An additional explanation is that the fall in world fossil fuel prices induces producers to reduce their supply, leaving more of their reserves in the ground. This leads to a GDP loss, ceteris paribus, although it would correspond to a delayed income as the fossil fuel reserves saved would generate additional revenues later on.

income by 0.5% in 2050 (Figure 4) while the real income gain at the world level would amount to 0.3% relative to the baseline in 2050.

Figure 4. Central scenario: Impact on 2050 equivalent variation in income
(Percentage change from the baseline)



Notes: See Table A1.2 in Annex 1 for the details about these regions.

Source: OECD ENV-Linkages using IEA fossil fuel subsidies data (IEA (2010)).

5. Trade Impacts of phasing-out fossil-fuel subsidies in non-OECD countries

Scenarios of unilateral removal

Trade adjustments in countries that remove their subsidies are driven by the assumption that international capital flows in a given year are exogenous and always equal to their baseline. In other words, the model depicts an equilibrium situation in which any transitory trade imbalances have been compensated through the adjustment of the real exchange rates such as to restore the same current-account levels as in the baseline projection.

In energy-importing countries (e.g., India), the removal of fossil-fuel subsidies drastically reduces imports of fossil fuels. In fossil-fuel exporting countries, the drop in domestic consumption of fossil fuels resulting from the subsidy removal also reduces imports of fossil fuels and is partly compensated by redirecting domestic production towards exports.[10] In both cases, this generates a transitory current account surplus that is absorbed by an appreciation of the real exchange rates and of the country's terms-of-trade. In turn, this appreciation results in an increase in non-energy imports and a decline in exports — especially exports of energy-intensive industries (EIIs) that face both an increase of the cost of their fossil-fuel inputs and a loss of competitiveness due to the appreciation of the real exchange rate. Table 2 confirms that countries unilaterally removing domestic subsidies to fossil-fuel consumption, according to the simulations, report a fall in their total import volume and real exchange rates and terms-of-trade appreciations, translating into a reduction of their exports.

Table 2. Trade impacts of unilateral removal of fossil-fuel consumption subsidies

(% deviation relative to the baseline in 2020)

	Real Exchange rate	Terms of Trade	Exports (vol)	Import (vol)
China	0.5%	0.1%	-0.1%	0.1%
India	3.2%	2.2%	-5.8%	0.5%
Russia	-2.6%	1.5%	-1.6%	-0.2%
Oil-Exporting countries	-1.4%	2.1%	-1.4%	0.3%
Non-EU eastern European countries	-0.4%	0.3%	-0.5%	-0.2%
Rest of the world	0.3%	0.1%	-0.3%	0.0%

Source: OECD ENV-Linkages Model based on fossil fuel subsidies data estimated by IEA

Scenario of multi-lateral subsidy removal

A different outcome would prevail in the central scenario with a multilateral removal of fossil-fuel subsidies in all countries simultaneously and a cap on emissions in the remaining countries (OECD countries and Brazil). In this scenario, world GHG emissions are reduced by 3% in 2020 and 10% in 2050 relative to the baseline projection (IEA, OPEC, OECD, World Bank, 2010; Burniaux and Chateau, 2010). Real income at the world level would increase slightly but these gains would be unevenly distributed across countries and regions. India would benefit from an increase in welfare of 3% in 2050 relative to the baseline. But, under this scenario, some of the non-OECD countries that remove their subsidies, including Russia and the oil-exporting countries, would no longer enjoy the welfare gains they faced in scenarios in which they act alone. This is because the efficiency gains from improved resource allocation would be more than offset by the terms-of-trade losses associated with the fall in world energy prices and consumption that a multilateral removal of subsidies would induce. By contrast, fossil-fuel importing OECD countries would record real income gains associated with the improvement of their terms-of-trade due to falling world energy prices (Table 3).

Table 3 confirms the terms-of-trade depreciations that would be experienced by oil-exporting countries in 2020 following a fall in international energy prices, ranging from 1.2% for coal to 6.7% and 6.4% for crude oil and natural gas respectively.[11] By contrast, real exchange rates and terms of trade appreciate in fossil-fuel importing non-OECD countries that remove their subsidies (in particular, India) and in fossil-fuel importing OECD countries (such as in Japan).

11 The magnitudes of these energy-price falls reflect the assumption that the world supply of coal is more elastic than for crude oil and natural gas.

Table 3. Real exchange rates and terms-of-trade impacts of a multilateral removal of fossil-fuel subsidies (% deviation relative to the baseline in 2020)

Country or world region	Real Exchange rate	Terms of Trade
Australia and new Zealand	-0.3	-0.6
Japan	0.5	2.7
Canada	-0.5	-1.1
US	0.2	0.8
EU & EFTA	0.1	0.2
Brazil	0.2	0.3
China	0.8	0.2
India	4.0	3.9
Russia	-4.0	-1.7
Oil-Exporting countries	-2.0	-3.9
Rest of the world	0.6	0.1
Non-EU eastern European countries	-2.4	-2.8

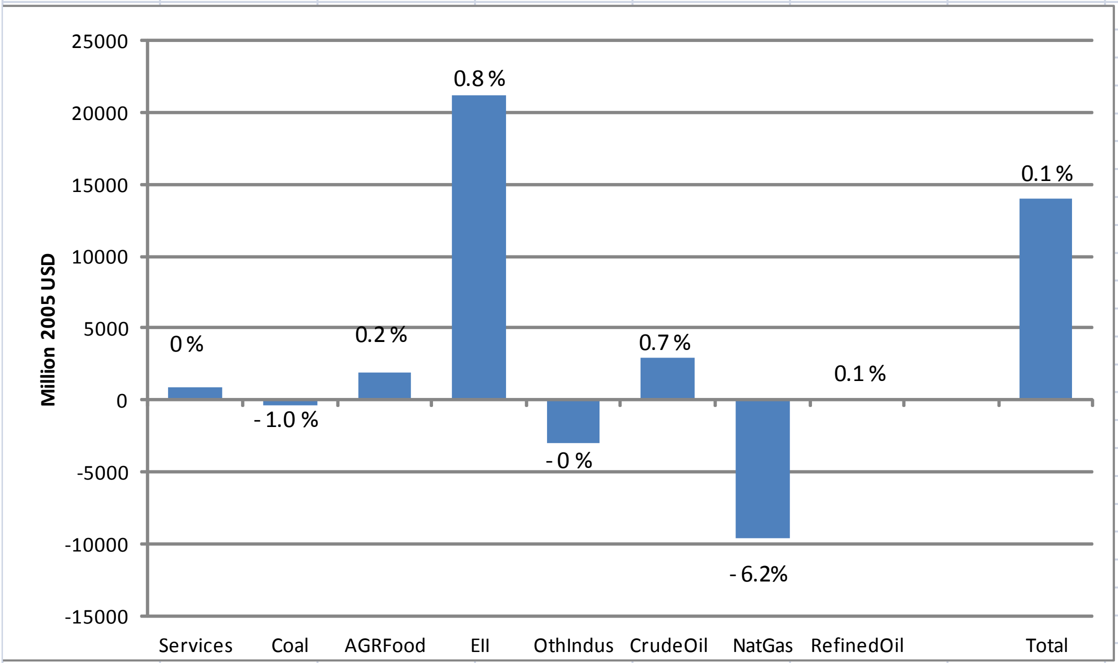
Source: OECD ENV-Linkages Model based on fossil fuel subsidies data estimated by IEA

Figure 5 reports the changes in total world trade volumes by services, agricultural products, and energy commodities. Trade in fossil fuels responds differently to subsidy removal. World trade volumes for coal are reduced slightly (by 1%), reflecting the assumption of a relatively elastic coal supply. Trade in natural gas shrinks by 6% in 2020, mainly due to a fall by more than a third of natural gas trade among oil exporting countries. Despite the fall in international gas prices, trade reallocation is hindered by the fact that most international trade in natural gas takes place between countries within the same region.[12] By contrast, there is no reduction in world trade volumes of refined oil products and a slight increase (by 0.7%) of trade in crude oil. This increase corresponds to a fall in international oil prices, together with a reallocation of crude-oil production in oil-exporting countries towards exports to OECD countries that increase by almost 8% compared with the baseline levels.

Altogether, world trade volumes increase slightly (by 0.1%), which mainly reflects the expansion of trade volumes in products of energy-intensive industries (by almost 1% relative to the baseline). As discussed below, this increase corresponds to the competitiveness gains recorded by these industries in OECD countries, despite the existence of a cap on their GHG emissions.

12 In the baseline projection, 50% of the total trade in natural gas takes place among OECD countries and another 20%, among oil exporting countries.

Figure5 Impact on world trade volumes in 2020 from a multilateral removal of fossil-fuel subsidies, by major categories of goods and services



Percebtages correspond to deviations relative to the baseline in 2020.
Source: OECD ENV-Linkages model based on fossil fuel subsidies data for 2008 estimated by the IEA (2010).

Panel A of Figure 6 reports the bilateral changes in trade reallocation across main trading areas resulting from the removal of subsidies to fossil-fuel consumption. These changes are estimated in 2020 and expressed in volume levels relative to the baseline. The left-hand four bars report an increase in total export volumes from OECD countries by a little more than 30 billion U.S. dollars of 2005 (USD2005), mainly as a result of increasing intra-OECD trade and exports to non-oil-exporting, non-OECD countries. In the meantime, total OECD imports in volume also increase, by around 30 billion USD2005 (right-hand bars), including 14 billion USD2005 in additional imports from oil-exporting countries, mainly of cheaper oil products. Total trade volumes increase in 2020 by almost 15 billion USD2005 (the right-hand bars), as in Figure 1. This results from a combination of expanding OECD trade (both imports and exports) and a shrinking contribution (of both imports and exports) of trade by oil-exporting countries. In the remaining non-OECD countries, the trade adjustments are driven by the real exchange-rate appreciation resulting from the removal of fossil-fuel subsidies and a resulting drop in exports (mainly services and other industries) and an increase in imports, mainly energy-intensive goods from OECD countries (see Figure 2).

Panel B of Figure 6 reports these changes expressed in terms of percentage deviations relative to the baseline. From this perspective, the major change is the reduction of the contribution to world trade of oil-exporting countries, with their total imports reduced by more than 2% in 2020. Intra-oil-exporting trade falls by almost 12% in 2020, reflecting not only the evolution of oil-product trade but also the loss of competitiveness of energy-intensive industries based in oil-exporting countries, as explained below. This trade reduction in oil-exporting countries is partly compensated by a reallocation of their exports of oil products towards OECD countries (with an increase by around 3% in 2020). Overall, the other bilateral trade adjustments, when expressed in terms relative to the baseline, remain marginal.

Apart from adjustments in fossil-fuel trade flows that are important but restricted to relatively small segments of international trade, a major source of trade reallocation concerns trade in products of energy-intensive industries (EIIs). For instance, the export surplus recorded by OECD countries (by around 30 billion USD2005 in 2020) results primarily from additional exports of products of EIIs (by an amount of 48 billion USD2005). Thus, while OECD countries gain market shares in exports from EIIs, they import more crude oil and refined oil products from oil-exporting countries by an amount of 13 billion USD2005. This accounts for almost half of the total increase in imports by OECD countries of around 30 billion USD2005 in 2020. The reallocation of EII trade is also a major component in the adjustment faced by oil-exporting countries with a drop of their EII exports by 32 billion USD2005 (20% of their baseline levels) in 2020. At the same time, imports of EII products by oil-exporting countries increase by 25 billion USD2005 (11% of their baseline levels), highlighting the loss of competiveness of domestic EIIs in oil-exporting countries.

Therefore, the removal of fossil-fuel subsidies in oil-exporting countries and the resulting decline in international oil prices induce a reallocation of EIIs trade in favour of OECD countries. Rather surprisingly, this occurs despite the existence of caps on OECD countries' GHG emissions, consistent with the assumptions that these countries restrict their emissions to the targets they declared after COP15. The explanation relates to the way the emissions cap is implemented in OECD countries. Total GHG emissions in OECD countries are capped to their baseline levels — so as to prevent leakage — but in the model the cap is applied globally at the whole OECD level and includes all gases, allowing for trading emissions across member countries and gases. Therefore, the cap implies a low carbon price, common for all OECD countries and gases, which, as far as CO_2 is concerned, is largely offset by the fall of international fossil-fuel prices resulting from the subsidy reform. This allows CO_2 emissions to increase above their baseline levels and EIIs to expand, reflecting the shift in international competitiveness and the corresponding trade reallocation. As a result, the OECD cap is met by reducing non-CO_2 emissions, sometimes substantially as in the EU (- 26%) and in Japan (- 23%).

Long-term effects

While the subsidy reform is simulated to be completed in 2020, its long-term effects are important, reflecting the adjustment dynamics embodied in the model.[13] World GHG emissions fall further, from 3% in 2020 to 10% in 2050. International prices for oil and gas also keep falling after 2020, although at a lower pace for oil, due to the delayed adjustment of the industrial structure in countries that have removed their subsidies after 2020. The one-off real income gain reported in oil-exporting countries that have removed subsidies is gradually offset by the adverse longer-term impact on their economic growth as the subsidy removal increases the cost of investment and reduces the rate of capital accumulation in these countries. As a result, the contribution of oil-exporting countries in total world trade volumes keeps shrinking after 2020. As Figure 3 shows, exports from oil-exporting countries in 2050 are more than 6% below their baseline level (compared with 1% below the baseline level in 2020), in part because exports to OECD countries fall by 4% relative to the baseline (instead of increasing as in 2020) reflecting mainly the loss of competitiveness of oil-exporting countries' energy-intensive industries on international markets. In the meantime, total import volumes of oil-exporting countries fall by almost 4% in 2050 (compared with around 2% in 2020), resulting in a fall of 2% relative to the baseline of OECD exports to oil-exporting countries (compared with a 1% reduction in 2020).

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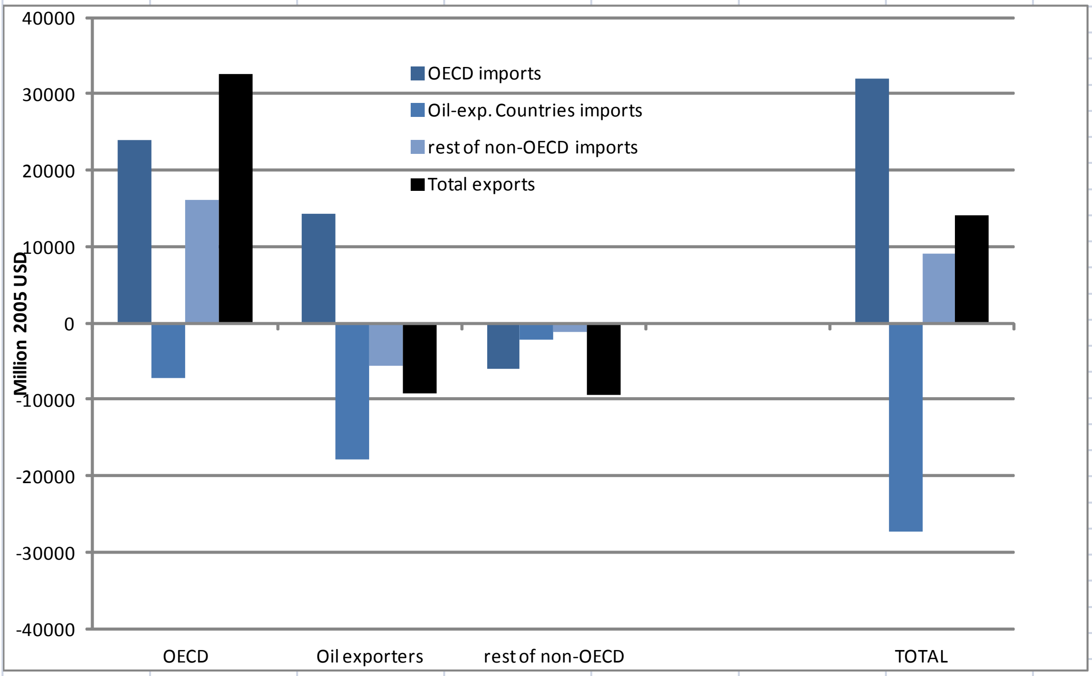
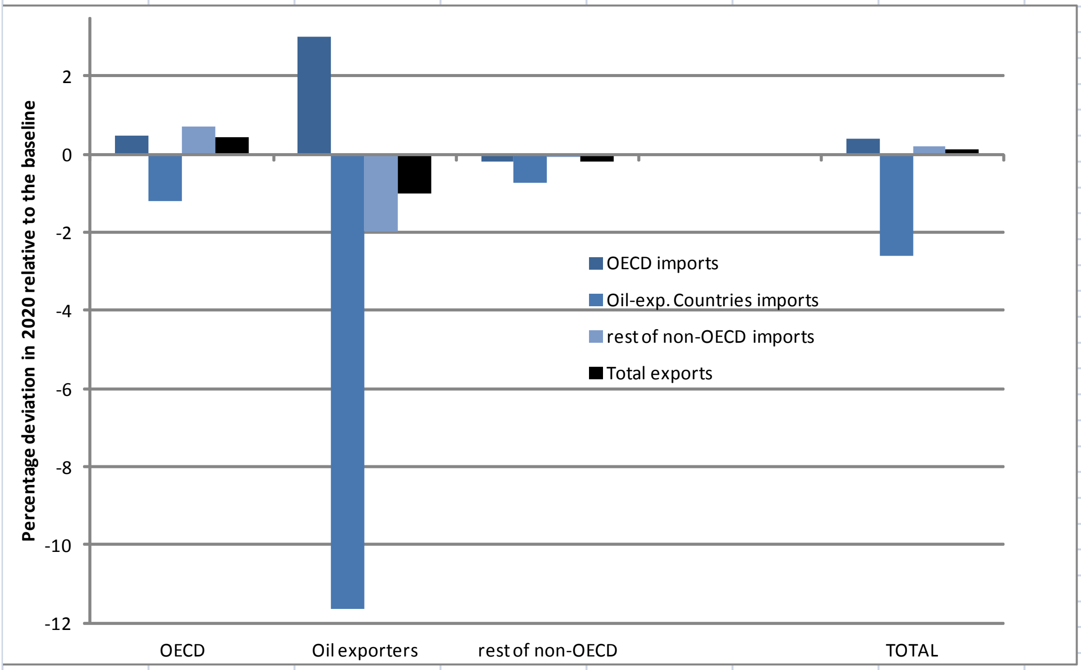
[13] In particular, due to the existence of two different capital vintages for each sector with a putty-clay structure of production.

Figure 6 - Panel A. Trade reallocation across regional trading area from a multilateral removal of fossil-fuel subsidies, changes in volumes in 2020 relative to the baseline



Source: OECD ENV-Linkages model based on fossil fuel subsidies data for 2008 estimated by the IEA (2010).

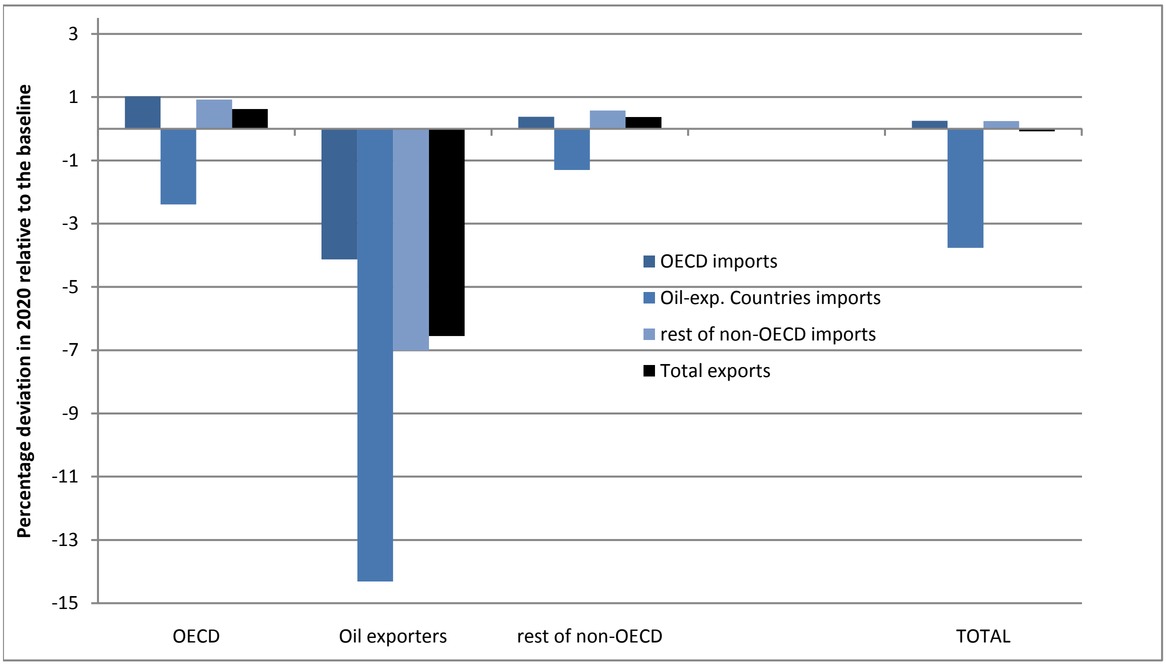
Figure 2, Panel B. Trade reallocation across regional trading area from a multilateral removal of fossil-fuel subsidies, percentage deviations in 2020 relative to the baseline



Source: OECD ENV-Linkages model based on fossil fuel subsidies data for 2008 estimated by the IEA (2010).

In summary, the adverse impact of the subsidy reform on the long-term growth of oil-exporting countries implies a further reduction of trade from and to oil-exporting countries after 2020. This is no longer offset by a corresponding increase of trade volumes from and to OECD countries — first, because the international oil price keeps falling after 2020 but at a lower pace than during the period where subsidies were removed; second, because the expansion of OECD exports beyond 2020, in particular for goods of energy-intensive industries, is hindered in the long term by the reduction of import demand by oil-exporting countries. Despite these restrictions, the share of OECD countries in world trade increases relative to the baseline in 2050, although by a relatively small extent (Figure 7): total OECD export volumes increase by 0.6% (an increase of 122 billion USD2005, of which 90% correspond to energy-intensive goods) and total OECD import volumes increase by 0.3% (an increase of 53 billion USD2005, entirely accounted for by additional imports of fossil fuels[14]).

Figure 7. Trade reallocation across regional trading area from a multilateral removal of fossil-fuel subsidies, percentage deviations in 2050 relative to the baseline



Source: OECD ENV-Linkages model based on fossil fuel subsidies data for 2008 estimated by the IEA (2010).

14 The compositional change of OECD imports from oil-exporting countries in 2050 is therefore characterized by an increase in fossil-fuel import volumes that is more than compensated by a rather sharp drop by more of 20% of imports of energy-intensive commodities originating from these countries.

6. Uncertainties and robustness to alternative assumptions

The above analysis relies on many assumptions that potentially affect the results. This section will address three sources of uncertainties: *i*) the country coverage and methodology used in estimating the price gaps; *ii*) the policy context in which subsidy removal is implemented; and, *iii*) the values of some key parameters, such as the supply elasticities of fossil fuels, that are critical in determining the environmental effectiveness of subsidy reform.

6.1. Reference years, country coverage and methodological assumptions

Price gaps, including the ones used for the subsidy estimates in this exercise, are usually calculated by using the corresponding world market price as a reference price. To the extent that world market prices are relatively volatile and that countries tend to isolate their domestic market from world market price fluctuations, for instance, by setting domestic prices administratively, price gaps are likely to change over time and the estimated impact of subsidy reform will depend on the year for which the price gaps are estimated. From this perspective, 2008 might not be considered as a representative year as it was characterized by a peak in international oil prices.[15] In the past, the IEA has also estimated price gaps in 2005 and 2007 for 20 non-OECD countries amounting to roughly 40% of the world energy consumption.[16] Figure 8 illustrates that the total reductions of GHG emissions at the world level obtained by removing price gaps are quite similar regardless of the year used as a reference for estimating the price gaps, ranging from 9.3% in 2050 using the 2005 gaps to 8.2% using the 2008 gaps, relative to their baselines.[17]

However, the pattern of reductions across countries/regions is different depending on the reference year for estimating the price gaps. The emission reductions achieved in the oil-exporting countries is much higher when using 2008 gaps, reflecting the fact that the extended country coverage in the 2008 IEA database mostly concerns oil-exporting countries. By contrast, the reductions obtained in India and China using the 2008 price gaps are lower, as these gaps have been reduced compared with previous years to reflect reforms in pricing policies to reduce their subsidies. Finally, the amount of carbon leakage occurring towards countries that do not remove fossil fuel subsidies is also larger with the 2008 gaps due to the relatively larger proportion of subsidies to the consumption of refined oil products resulting from the larger country coverage and the fact that, in the model, the oil price reacts relatively strongly to a decline in demand for oil.[18]

The choice of an appropriate reference price for estimating the electricity price gaps is not so easy compared to fossil fuels, as electricity is generally not traded internationally. Given this uncertainty,[19] if subsidies to electricity are excluded from the subsidy reform, the total emission reduction is somewhat lower: 7.6% in 2050 compared with 8.2% in the central scenario (Table 2).

15. As this possible drawback is compensated by the benefit from the extended country coverage, 2008 is still used as the reference year for the central scenario.

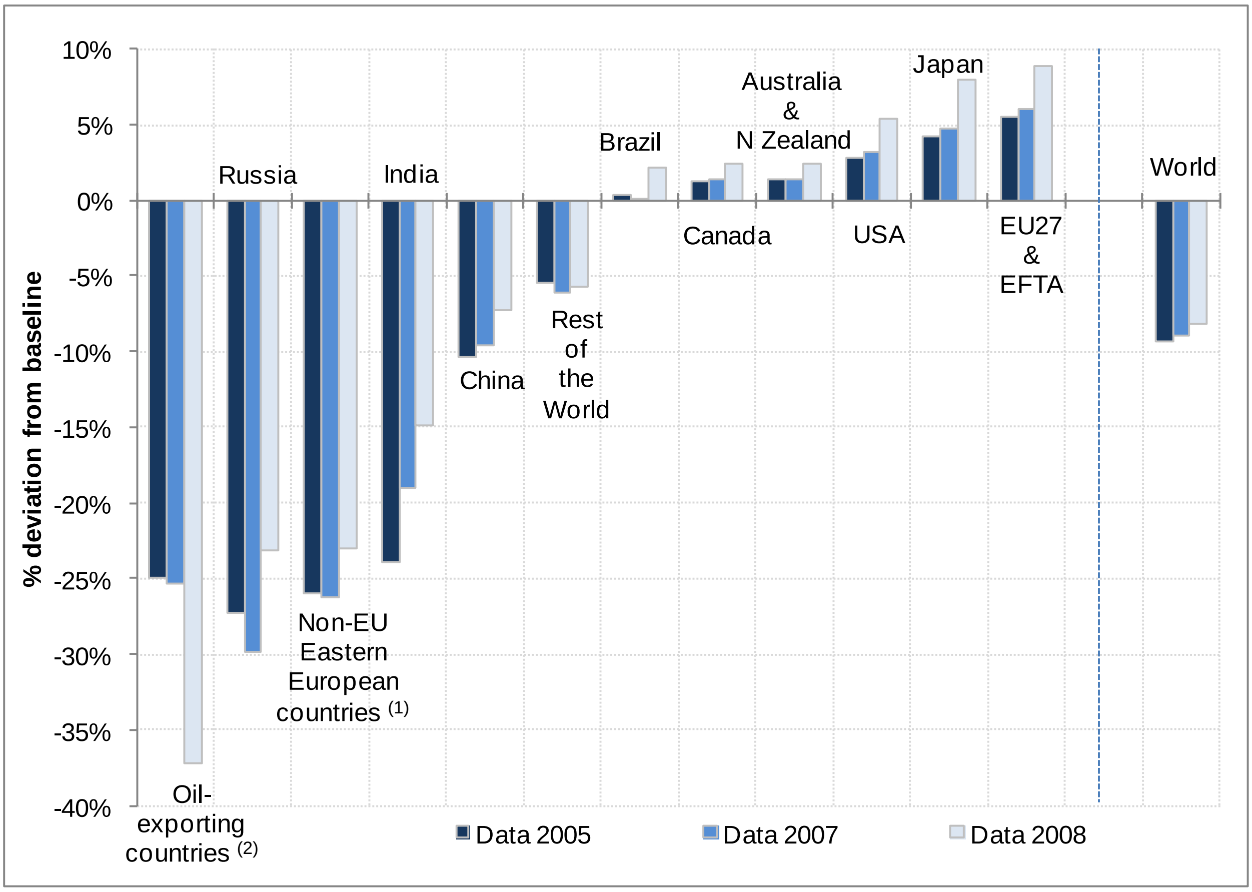
16. In addition to a smaller country coverage, the methodology used by the IEA for estimating 2005 and 2007 price gaps for electricity is slightly different than for 2008.

17. Since energy price-gaps are introduced in the starting year of the model, changing these wedges would alter the baseline. Thus, there is a specific baseline projection for each dataset of price gaps used.

18. Given that the supply of crude oil is relatively less elastic.

19. In addition to the fact that this includes in principle subsidies to electricity sources that are not based on fossil fuels (nuclear, renewable, solar, wind and hydroelectric) and do not emit CO_2, although in practice these subsidies are small in the countries covered by the IEA database.

Figure 8. Central scenario: Impact on 2050 GHG emissions as estimated by calculating price gaps in 2005, 2007 and 2008 (percentage change from baselines)



Notes: See Table A1.2 in Annex 1 for the details about these regions.

Source: OECD ENV-Linkages using IEA fossil fuel subsidies data (IEA (2010,2009, 2008)).

6.2. Context of implementation

The central scenario describes a situation where emissions in OECD countries are not subject to any constraint while fossil fuel subsidies in a lot of non-OECD countries are removed. This situation may not be realistic. Indeed, after COP15 in Copenhagen, 75 countries declared that they would restrict their emissions in 2020.

Therefore, it is relevant to quantify the impact of subsidy reform in a context where emissions in countries that do not remove fossil fuel subsidies (OECD countries and Brazil) cannot exceed a given level, as would be the case if these countries restrict their emissions according with their COP15 declared targets. This is simulated by capping emissions in these countries to their baseline levels, hence preventing the carbon leakages simulated in the above central scenario. In such a case, the total GHG emission reduction achieved at the world level is higher – 10% in 2050 instead of 8% with no cap (Figure 8, Table 3).

Interestingly, the additional reduction exclusively concerns non-CO_2 gases that are reduced by 8% in 2050 compared with 3% in the no-cap case while the CO_2 reduction remains the same (10-11% in 2050 relatively to the baseline). The explanation relates to the way the emission cap is implemented in OECD countries and Brazil. As the international fossil fuel prices – mainly oil – fall in response to the subsidy reform, the emission caps in these countries are mostly met by cutting down non-CO2 emissions, sometimes substantially as in the EU (-26%) or in Japan (-23%), while CO2 emissions levels remain above baseline levels.[20]

Table 3. World GHG reductions and equivalent variation in income from phasing out fossil fuel subsidies under different assumptions (percentage change from the baseline)

Simulations	Total GHG emissions		Welfare	
	2020	2050	2020	2050
Central scenario	-2.5%	-8.2%	0.2%	0.3%
Central scenario with emission cap in remaining countries	-3.3%	-9.8%	0.2%	0.3%
Central scenario but without phasing-out electricity subsidies	-1.7%	-7.6%	0.1%	0.1%
Central scenario with higher fossil fuel supply elasticities	-3.5%	-11.3%	0.1%	0.2%
Central scenario with lower fossil fuel supply elasticities	-2.9%	-7.9%	0.3%	0.5%
Central scenario with inelastic fossil fuel supply	-1.6%	-1.8%	0.5%	0.8%

Source: OECD ENV-Linkages using IEA fossil fuel subsidies data (IEA (2010)).

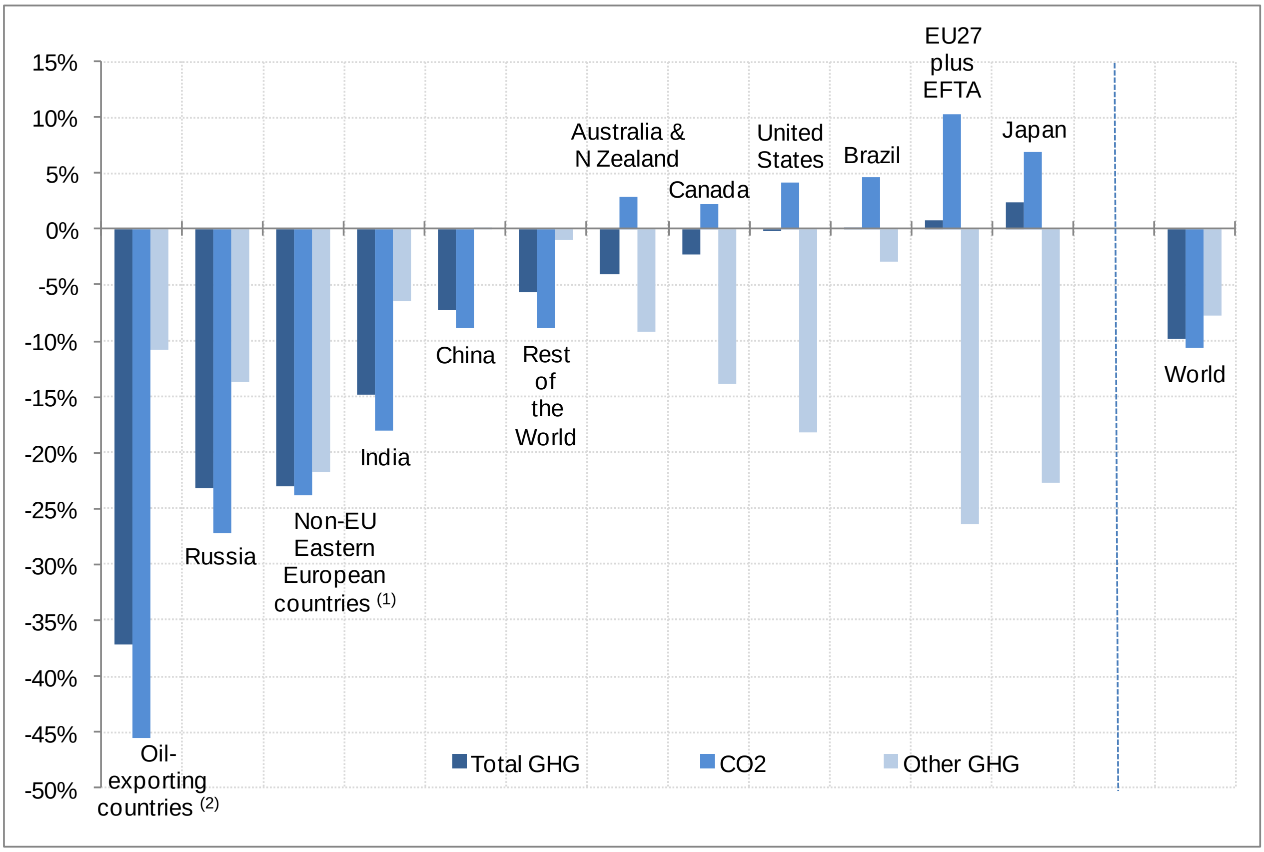
6.3. Values of fossil fuel supply elasticities

One of the largest sources of uncertainty is related to the assumed values of the price-elasticity of fossil fuel supply. The central scenario is based on the assumption that the supply of coal is much more elastic (with an elasticity equal to 10) than for crude oil and natural gas (with elasticities respectively equal to 1 and 0.8). As illustrated in Table 2, lower supply elasticities yield lower emission reductions because a larger proportion of the emission reduction achieved in non-OECD countries is offset by emission increases in OECD countries. In the extreme case of completely inelastic fossil fuel supplies, the

20. In this scenario, total GHG emissions in OECD countries are capped to their baseline levels –so as to prevent leakage – but the cap is applied globally at the whole OECD level and including all gases. Therefore, there is a small amount of emission trading across OECD countries with the EU and Japan buying emissions from the other OECD countries, as expected from their higher marginal abatement costs. GHG emissions in Brazil are also capped, but in isolation from OECD countries, therefore implying emission trading across gases only.

environmental benefit of the subsidy removal becomes negligible, with the total emission reduction under 2%.[21]

Figure 6. Removal of fossil-fuel subsidies when emissions in OECD countries are capped: Impact on 2050 GHG emissions (percentage change from the baselines)



Notes: See Table A1.2 in Annex 1 for the details about these regions.

Source: OECD ENV-Linkages using IEA fossil fuel subsidies data (IEA (2010)).

The sensitivity to the values of the fossil fuel supply elasticities also reveals a trade-off between environmental and economic benefits, hence modifying the balance between the two sides of the "win-win options". In the ENV-Linkages model, the fossil-fuel extracting sectors (coal mining, crude oil and natural gas) are modelled assuming a quasi-Leontief input structure and a specific factor corresponding to the use of the corresponding resource, the supply of which is more or less elastic.[22] Therefore, higher supply elasticities imply that more fossil fuel is left in the ground as a result of a subsidy removal, hence implying

21. This residual reduction reflects the complementarities between emissions from different sources implying a drop of non-C02 emissions as a result of the fossil-fuel subsidy reform (see last paragraph of section 3).

22. This specification implies that the production of coal, for instance, is proportionate to the amount of coal extracted or, in other words, that no more coal can be produced by substituting capital or labour to the extraction of the resource.

GDP losses in fossil-fuel exporting countries that partly offset the welfare gains from the subsidy reform.[23] Vice versa, if the supply of fossil fuel is completely inelastic at the world level, these negative supply impacts are suppressed yielding estimates of the welfare gains that are closer to what would be obtained in a standard static neo-classical framework (a gain of 0.8% of world welfare in 2050 but with very few environmental gains).

7. Concluding remarks

The consumption of fossil fuel is heavily subsidized in many non-OECD countries. To the extent, that these subsidies amount to a negative carbon price, their removal is an obvious first step in the process of pricing carbon worldwide (OECD, 2009). Based on a world general equilibrium model, this analysis has shown that removing these subsidies would bring both environmental and economic benefits. The latter however are likely to be unevenly distributed. While "oil-exporting countries" are likely to face real income reductions, although these losses are relatively small as the losses from their terms-of-trade deterioration are mostly compensated by the welfare gains from the reform of their subsidies.

These results are reasonably robust to a number of alternative assumptions. However, the values of the supply elasticities of the various fossil fuels are critical in determining the trade-off between environmental and economic benefits. This raises the risk that overestimating these elasticities, in particular with respect to coal, may tend to overestimate the resulting reduction of GHG emissions. This highlights the importance of collecting more empirical evidence about the supply elasticity of fossil fuels, especially for coal.

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23. Although, in an intertemporal framework with finite fossil fuel reserves, these fossil-fuel resources left in the ground can be extracted later on, leading to GDP increase relative to the baseline projections. These GDP gains are not taken into account in this analysis as the version of the ENV-Linkages model used here does not incorporate fossil-fuel reserve depletion dynamics.

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ANNEX 1. AN OVERVIEW OF THE OECD ENV-LINKAGES MODEL

The OECD ENV-Linkages model is a recursive dynamic neo-classical general equilibrium model. It is the successor to the OECD GREEN model for environmental studies (Burniaux, *et al.* 1992; Burniaux, 2000). The model is documented in Burniaux and Chateau (2008, 2010). Previous works using ENV-Linkages extensively include two books: OECD (2008) and OECD (2009).

ENV-Linkages is a global economic model built primarily on a database of national economies. In the version of the model used here, the world economy is divided in 12 countries/regions, each with 25 economic sectors (Tables A1.1 and A1.2), including five different technologies to produce electricity. The core of the static equilibrium is formed by the set of Social Account Matrices (SAMs) that described how economic sectors are linked; these are based on the GTAP database (currently using version 6.2). A fuller description of the database can be found at Dimaranan (2006). Many key parameters are set on the basis of information drawn from various empirical studies and data sources.

Table A1.1 ENV-Linkages model sectors

1) Rice	14) Food Products
2) Other crops	15) Other Mining
3) Livestock	16) Non-ferrous metals
4) Forestry	17) Iron & steel
5) Fisheries	18) Chemicals
6) Crude Oil	19) Fabricated Metal Products
7) Gas extraction and distribution	20) Paper & Paper Products
8) Fossil Fuel Based Electricity	21) Non-Metallic Minerals
9) Hydro and Geothermal electricity	22) Other Manufacturing
10) Nuclear Power	23) Transport services
11) Solar& Wind electricity	24) Services
12) Renewable combustibles and waste electricity	25) Construction & Dwellings
13) Petroleum & coal products	26) Coal

All production in ENV-Linkages is assumed to operate under cost minimisation with an assumption of perfect markets and constant returns to scale technology. The production technology is specified as nested Constant Elasticity of Substitution (CES) production functions in a branching hierarchy. Each sector uses intermediate inputs – including energy inputs - and primary factors (labour, capital, land and natural resources). For each good or service, output is produced by different production streams which are differentiated by capital vintage (old and new). The substitution possibilities among production factors are assumed to be higher with the *new* than with the *old* capital vintages — technology has a putty/semi-putty specification. Capital accumulation is modelled according to the traditional Solow/Swan neo-classical growth model.

The energy bundle is of particular interest for analysis of climate change issues. Energy is a composite of fossil fuels and electricity. In turn, fossil fuel is a composite of coal and a bundle of the “other fossil fuels”. At the lowest nest, the composite “other fossil fuels” commodity consists of crude oil, refined oil products and natural gas. The value of the substitution elasticities are chosen as to imply a higher degree of substitution among the other fuels than with electricity and coal.

Table A1.2 ENV-Linkages model regions

ENV-Linkages regions	GTAP countries/regions
1) Australia & New Zealand	Australia, New Zealand
2) Japan	Japan
3) Canada	Canada
4) United States	United States
5) European Union 27 & EFTA	Austria, Belgium, Denmark, Finland, Greece, Ireland, Luxembourg, Netherlands, Portugal, Sweden, France, Germany, United Kingdom, Italy, Spain, Switzerland, Rest of EFTA, Czech Republic, Slovakia, Hungary, Poland, Romania, Bulgaria, Cyprus, Malta, Slovenia, Estonia, Latvia, Lithuania
6) Brazil	Brazil
7) China	China, Hong Kong
8) India	India
9) Russia	Russian Federation
10) Oil-exporting countries	Indonesia, Venezuela, Rest of Middle East (*e.g.* Bahrain, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Palestinian Territory, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, United Arab Emirates, Yemen),, Islamic Republic of Iran, Rest of North Africa(*e.g.* Algeria, Egypt, Libya), Nigeria
11) Non-EU Eastern European countries	Croatia and Rest of Former Soviet Union (*e.g.* Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Tajikistan, Turkmenistan, Ukraine, Uzbekistan))
12) Rest of the world	Korea, Taiwan, Malaysia, Philippines, Singapore, Thailand, Viet Nam, Rest of East Asia, Rest of Southeast Asia, Cambodia, Rest of Oceania, Bangladesh, Sri Lanka, Rest of South Asia, Pakistan, Mexico, Rest of North America, Central America, Rest of Free Trade Area of Americas, Rest of the Caribbean, Colombia, Peru, Bolivia, Ecuador, Argentina, Chile, Uruguay, Rest of South America, Paraguay, Turkey, Rest of Europe, Albania, Morocco, Tunisia, Egypt, Botswana, Rest of South African Customs Union, Malawi, Mozambique, Tanzania, Zambia, Zimbabwe, Rest of Southern African Development Community, Mauritius, Madagascar, Uganda, Rest of Sub-Saharan Africa, Senegal, South Africa.

World trade is based on a set of regional bilateral flows. Allocation of trade between partners responds to changes in relative prices between regions. The basic assumption is that imports originating from different regions are imperfect substitutes (Armington specification). Each region runs a fixed current-account surplus (or deficit).

The ENV-Linkages model has a simple recursive-dynamic structure, where households base their decisions on static expectations concerning prices and quantities. Household consumption demand and savings are implemented through an “Extended Linear Expenditure System”. Since consumers are not represented with forward-looking behavior, some care needs to be exercised in studying policies that consumers may reasonably be expected to anticipate – either the policy itself or its consequences. In each period, investment net-of-economic depreciation is equal to the sum of government savings, consumer savings and net capital flows from abroad.

The government in each region collects various kinds of taxes in order to finance government expenditures. Aggregate government expenditures are linked to real GDP. Assuming fixed public savings (or deficits), the government budget is balanced through the adjustment of the income tax on consumer income.

CO_2 emissions from combustion of energy are directly linked to the use of different fuels in production. Other GHG emissions are linked to output in a way similar to Hyman *et al.* (2002). The following non-CO_2 emission sources are considered: *i)* methane from rice cultivation, livestock production (enteric fermentation and manure management), coal mining, crude oil extraction, natural gas and services (landfills); *ii)* nitrous oxide from crops (nitrogenous fertilizers), livestock (manure management), chemicals (non-combustion industrial processes) and services (landfills); *iii)* industrial gases (SF6, PFC's and HFC's) from chemicals industry (foams, adipic acid, solvents), aluminum, magnesium and semi-conductors production.

For studying the impacts of climate change policy, four types of instruments have been developed: *i)* GHG taxes, global or specific by sectors, gases or emission sources; *ii)* tradable emission permits (with flexibility between regions and sectors); *iii)* offsets (including a stylised version of the Clean Development Mechanism); and *iv)* regulatory policy. Taxes and tradable permits are applied directly to GHG emissions. Offsets are driven by an exogenous limit on demand for offset credits and competition between potential suppliers. Regulatory policy has been introduced in the model through quantity constraints (Burniaux, *et al.* 2008).

Market goods equilibria imply that, on the one side, the total production of any good or service is equal to the demand addressed to domestic producers plus exports; and, on the other side, the total demand is allocated between the demands (both final and intermediary) addressed to domestic producers and the import demand. The general equilibrium framework ensures that a unique set of relative prices emerges such that demand equals supply in all markets simultaneously (*i.e.* across all regions, commodities, and factors of production). All prices are expressed relatively to the numéraire of the price system that is chosen as the index of OECD manufacturing exports prices. Implementation of a policy in the model leads to a new equilibration process and thus a new set of equilibrium prices and quantities to compare with the original equilibrium.

The process of calibration of the ENV-Linkages model is broken down into three stages (Burniaux and Chateau, 2008). First, a number of parameters are calibrated, given some elasticity values, on base-year (2001) values of variables. Second, the 2001 database is updated to 2005 by simulating the model dynamically to match historical trends over the period 2001-2005; thus all variables are expressed in 2005 real USD. Third, the baseline projection until 2050 is based on convergence assumptions about labour productivity and other socio-economic drivers (demographic trends, future trends in energy prices and energy efficiency gains), as further described in Duval and De la Maisonneuve (2010). The baseline has been adjusted to incorporate the effects of the economic crisis of 2008-2009. In addition, the baseline assumes no new climate policies, but does include other government policies for instance on energy policy as included in the energy projections of the IEA (2009).[24] It thus provides a benchmark against which policy scenarios aimed at achieving emission cuts can be assessed.

24. The baseline simulation also contains the assumption that the EU Emission Trading System is implemented over the period 2006-2012, assuming a permits price that will rise gradually from 5 to 25 constant $US in 2012.

ANNEX 2. FOSSIL FUEL SUBSIDIES OVER TIME

The following Table A2.1 reports the total fossil fuel subsidies in billions of USD and as % of GDP for the 20 countries covered by the IEA database in 2005, 2007 and 2008. The bottom pannel of Table A2.1 shows the subsidies in the additional countries introduced in the IEA 2008 database. All together, fossil fuel subsidies amounted to USD 557 billions in 2008 with largest amounts of subsidies being concentrated in oil-exporting countries (Iran, Egypt, Saudi Arabia).[25] Over time and across the 20 countries sample, subsidies in values have increased by 36% from 2005 to 2007 and by a further 41% in 2008. The large increase in 2008 mostly reflects the rise of the international oil price while price gaps in some countries, like India and China, were reduced reflecting changes in pricing policies. The extension of the country coverage in the 2008 database accounts for an increase of the total subsidies amount by26%, with the largest subsidies being reported again in oil-exporting countries (Uzbekistan, Iraq, UAE) but also in Mexico (USD 22.5 billions). On average for the whole sample of countries in 2008, the share of fossil fuel subsidies in GDP averages 3% but there are large disparities across countries ranging from 54.5% in Uzbekistan to close to zero in Brazil, Philippines and South Korea.

25. This, of course, reflects the choice of the international oil price as a reference price as the marginal cost of extracting oil in these countries is very low.

Table A2.1 Fossil fuel subsidies by country in USD billions and as % share of GDP

Country	Fossil fuel subsidies					
	2005		2007		2008	
	Billions of USD	as % of GDP	Billions of USD	as % of GDP	Billions of USD	as % of GDP
Iran	41.9	22.28	56.3	19.69	101.1	30.16
Egypt	11.9	13.20	15.7	12.07	27.9	17.17
Saudi Arabia	16.4	5.18	25.2	6.55	48.5	10.34
Pakistan	4.4	4.04	8.3	5.79	12.7	7.74
Venezuela	14.8	10.28	17.9	7.85	24.2	7.58
Argentina	8.0	4.39	9.4	3.62	17.8	5.48
Ukraine	13.3	15.49	15.2	10.61	9.8	5.45
Malaysia	3.5	2.57	7.3	3.92	9.8	4.41
Vietnam	1.4	2.67	1.7	2.39	3.6	3.97
India	18.3	2.34	23.4	2.12	45.5	3.77
Indonesia	11.4	3.98	17.2	3.98	19.0	3.72
Russia	38.7	5.06	51.0	3.94	51.7	3.09
Thailand	3.1	1.76	3.0	1.22	7.4	2.70
South Africa	4.8	1.98	8.8	3.11	7.4	2.67
Kazakhstan	7.1	12.47	8.6	8.22	2.7	2.00
Nigeria	2.4	2.14	2.5	1.49	3.5	1.69
Chinese Taipei	0.6	0.16	1.7	0.44	5.0	1.29
China	27.8	1.24	38.5	1.14	43.7	1.01
Philippines	0.2	0.17	0.5	0.33	0.1	0.07
Brazil	1.0	0.12	1.2	0.09	n.a.	n.a.
Subtotal	**231.0**	**3.16**	**313.4**	**2.93**	**441.6**	**3.86**
Uzbekistan	n.a.	n.a.	n.a.	n.a.	15.2	54.50
Iraq	n.a.	n.a.	n.a.	n.a.	15.7	17.13
Turkmenistan	n.a.	n.a.	n.a.	n.a.	4.8	15.28
Ecuador	n.a.	n.a.	n.a.	n.a.	4.6	8.38
Kuwait	n.a.	n.a.	n.a.	n.a.	9.5	6.02
UAE	n.a.	n.a.	n.a.	n.a.	15.0	5.73
Algeria	n.a.	n.a.	n.a.	n.a.	8.8	5.53
Azerbaijan	n.a.	n.a.	n.a.	n.a.	2.4	5.25
Bangladesh	n.a.	n.a.	n.a.	n.a.	4.4	5.23
Libya	n.a.	n.a.	n.a.	n.a.	4.3	4.81
Qatar	n.a.	n.a.	n.a.	n.a.	4.2	4.06
Brunei	n.a.	n.a.	n.a.	n.a.	0.4	2.51
Sri Lanka	n.a.	n.a.	n.a.	n.a.	0.9	2.28
Mexico	n.a.	n.a.	n.a.	n.a.	22.5	2.07
Angola	n.a.	n.a.	n.a.	n.a.	1.2	1.38
Peru	n.a.	n.a.	n.a.	n.a.	0.6	0.48
Colombia	n.a.	n.a.	n.a.	n.a.	1.0	0.42
South Korea	n.a.	n.a.	n.a.	n.a.	0.2	0.02
Subtotal					**115.8**	**3.19**

n.a. Data not available

Source: Estimations based on IMF WEO (2009) GDP data, and IEA (2010) fossil fuel subsidies data.