

Session Number: Parallel Session 6A
Time: Thursday, August 27, PM

*Paper Prepared for the 31st General Conference of
The International Association for Research in Income and Wealth*

St. Gallen, Switzerland, August 22-28, 2010

**Mitigation Potential of Removing Fossil Fuel Subsidies: A General
Equilibrium Assessment**

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Mitigation potential of removing fossil fuel subsidies: a general equilibrium assessment

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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 Gases (GHG) emissions by 10% in 2050 (OECD,2009). Indeed, these subsidies are huge. According with IEA estimates, total fossil fuel subsidies in 2008 amounted to USD 557 billions (IEA,OPEC,OECD, World Bank, 2010). This represents almost six times the yearly aid flows to developing countries defined as 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 450ppm, 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, this is not true for all countries/regions. The paper also provides some discussion about the robustness of these results.

JEL codes: H23, O41, Q56

Keywords: fossil-fuel subsidies, general equilibrium models, GHGs emissions

¹ The authors would like to express gratitude to T. Morgan from the International Energy Agency who has extensively worked on some of the fossil fuel subsidies databases used in this paper. The authors would also like to thank Jan Corfee-Morlot, Rob Dellink, Ron Steenblik, Helen Mountford, Cuauhtemoc Rebolledo-Gomez and Romain Duval from the Organisation for Economic Co-operation and Development for their input, suggestions and comments.

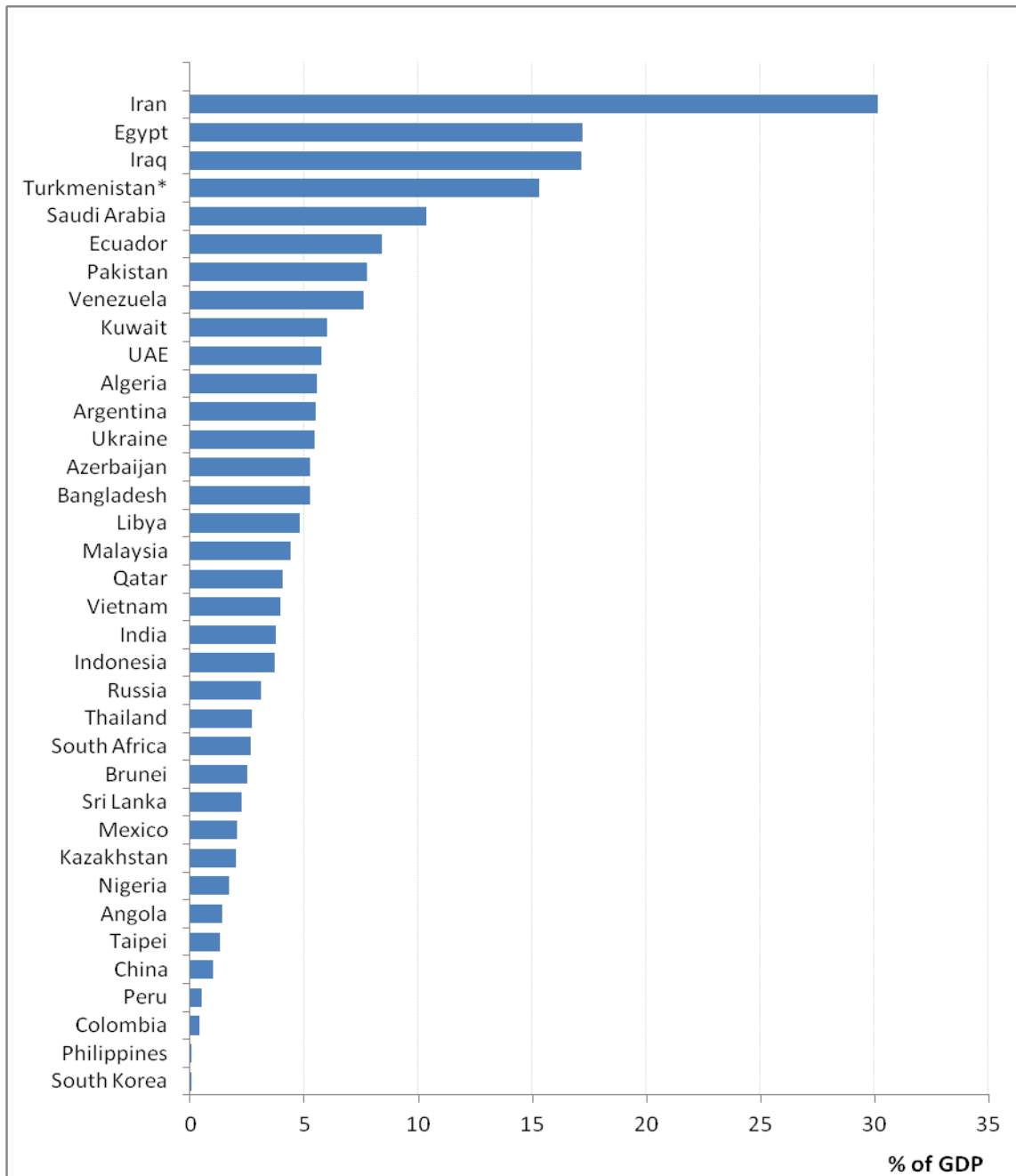
² The views of the authors do not necessarily represent the views of the OECD or of its member countries.

1. Introduction

1. In the September 2009 G20 Leaders 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 made by the OECD and the IEA showing that removing fossil fuel subsidies in a number of non-OECD countries could reduce world Greenhouse Gases (GHG) emissions by 10% in 2050 compared with their level in the absence such a reform (OECD, 2009). Indeed, these subsidies are huge. According with IEA estimates, total fossil fuel subsidies in 2008 amounted to USD 557 billions (IEA,OPEC,OECD, World Bank, 2010), almost six times the yearly aid flows to developing countries defined as the Official Development Assistance (ODA). As indicated in Figure 1, fossil fuel consumption subsidies³ are quite substantial in some countries, especially in several oil-exporting countries where they amount to 10% or more of the 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.

³ 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 2008 GDP[#]



[#]Note that IEA database is covering 37 countries 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.

2. From a theoretical perspective, in a 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 these subsidies. These gains correspond to the increase of consumer welfare and from a more efficient reallocation of resources. Hence, this policy qualifies for being a “win-win” option as it brings both environmental and economic benefits. In a global world economy,

characterized with other departures from the first-best world and where economies are interrelated through international trade, there is no guarantee that all countries would report welfare positive impacts, although the welfare at the world level should increase.

3. However, governments are reluctant to remove these subsidies as they claim they are justified on equity grounds, i.e. to protect the access of the poor households to fossil fuels and electricity. This argument could be reversed as the budgetary savings obtained from subsidy removal would give room to manoeuvre for implementing social support that could be more narrowly targeted to poor households. For example access to fossil fuels and electricity can be guaranteed by directly supporting the purchasing power of the poor without subsidizing indirectly all households, but mainly the richer ones.

4. 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 based on partial or General Equilibrium (GE) approaches.⁴ Although these analyses differ in the scope, method and years of reference, they agree on some broad conclusions. A majority of these 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, CO₂ 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. These 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.

5. Compared with previous studies, this analysis uses the most recent and comprehensive in country coverage subsidy data estimated by the IEA for 2008. The aim of this paper is to provide, thanks to 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 impacts of climate change.

6. The remainder of this paper proceeds as follows. Section 2 discusses the nature of these subsidies, their scope, the existing data collected by the IEA 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 checks the robustness of the results first regarding to the uncertainty in fossil-fuel subsidies data, next to uncertainty in the policy context in which subsidy removal is implemented and then regarding to fossil-fuel supply behaviour. Section 6 concludes.

2. Nature and scope of fossil fuel subsidies

7. Governments support consumption and production of fossil fuel in numerous ways: by intervening in markets in such a way as 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

⁴ 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).

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).

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

The IEA price-gaps approach

9. 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 consumptions (including subsidies to fossil-fuel inputs to electric power generation).

10. The “price-gaps” methodology is described in the Box 1⁵. 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-distorted instruments.

⁵ 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.

BOX 1. Quantification of Global 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 aggregated 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 consumptions, 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.

Source : based on IEA (2006)

11. This analysis covers 37 countries, including 2 OECD countries (South Korea and Mexico). All together, this amounts to roughly 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 both 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

Country	Energy	% deviation of domestic relative to world prices	
		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

¹Energy subsidies are approximated by the difference in the domestic energy price and world prices.

² See Table A2 in the Annex I for the details about these regions

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

12. 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.⁶ By

⁶ Although, in the later case, this partly reflects the use of the international prices of refined oil products as reference prices.

contrast, the subsidy rates estimated by the IEA for China are more moderate. These lower subsidies rate in China are partly the consequence of a reform engaged in 2008.

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

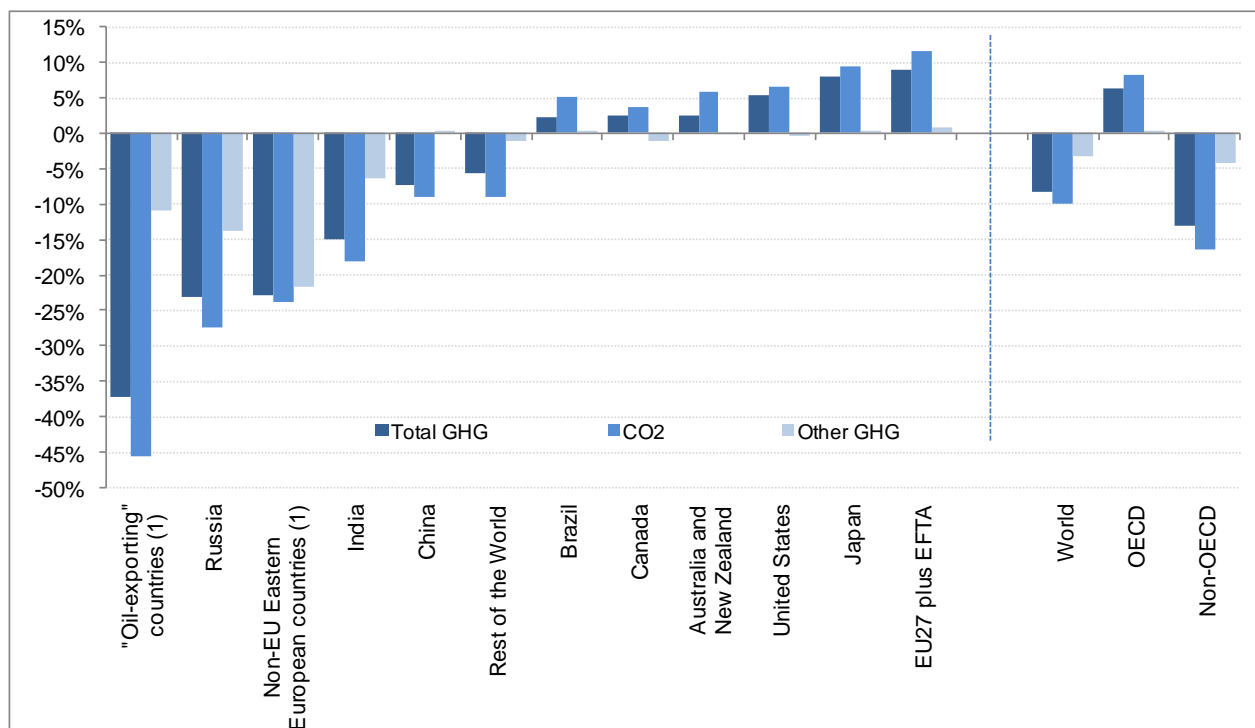
13. The impact of the subsidy reform is quantified by using the ENV-Linkages model developed by the Environment Directorate of the OECD. This model is a world General Equilibrium disaggregated by sectors and countries/regions and running up to 2050 using a recursive dynamics (see Burniaux and Chateau, 2010 or the Annex I 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 policy 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 Maisonnette (2010). The price gaps estimated by the IEA for 2008 are introduced by calibration in the initial year of the model, 2005, and they are supposed to remain constant in percentage up to 2050. In simulations of generic subsidy reforms, these price gaps are gradually phased-out over the period 2013 to 2020.

14. The **central scenario** considered in this paper assumes that all the 37 countries covered by the IEA(2010) fossil-fuel subsidies database (see Fig. 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 the central scenario build here, emissions in OECD countries are not capped as they are in the joint report (scenario studied in section 5.b). This number is also somewhat lower than the 10% reported in OECD(2009), as price gaps have tended to be reduced from 2007 to 2008 in line with some 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 Annex 2 decomposes the link between this current scenario and the one discussed in OECD(2009).

15. This 10% reduction in GHGs emissions represents a seventh of the mitigation effort needed in 2050 to put world emissions on a pathway that is compatible with stabilising concentration below 450 ppm of CO₂eq. The resulting drop of emissions of CO₂ is quite substantial in some countries/regions, amounting to more than 25% in Russia and 45% in the oil-exporting countries. While CO₂ emissions fall by 16% in non-Annex I countries in 2050, they remain almost unchanged in Annex I countries. This is because reductions in Russia and non-EU Eastern European countries are offset by emission increases in those Annex I countries that do not subsidize their energy demand, reflecting leakages induced by falling world energy prices. This leakage is particularly pronounced in the EU and EFTA countries where CO₂ emissions increase by 12% in 2050 relative to the baseline. Of the 6.1 GtCO₂ 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).

16. Figure 2 also illustrates an additional environmental benefit from subsidy reform, namely the reduction of non-CO₂ gases, although by a lesser extent than CO₂ emissions (3% in 2050 relative to baseline compared with 10% for CO₂ 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 GHGs emissions (% change from the baseline)



¹ See Table A2 in the Annex I for the details about these regions

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

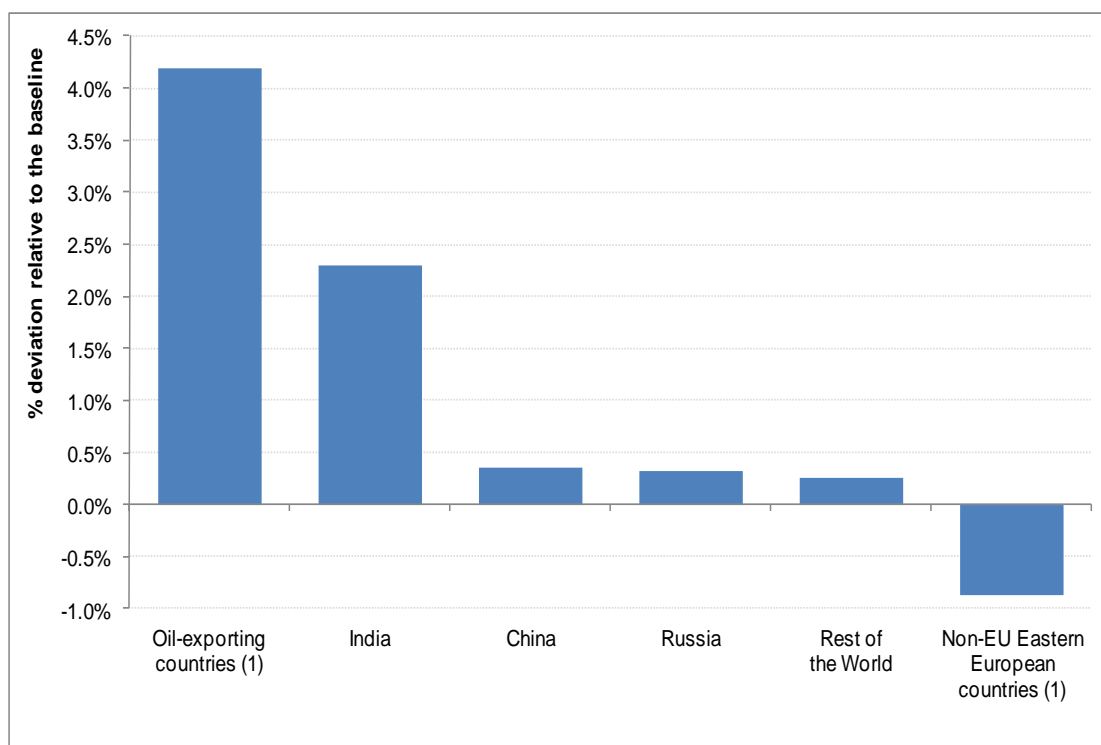
4. Economic implications of phasing-out fossil-fuel subsidies in non-OECD countries

17. 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 case, 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 all reform simulations, 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 A2 in Annex I), 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)



¹ See Table A2 in the Annex I for the details about these regions

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

18. A different outcome would prevail in the central scenario, where there is a multilateral removal of energy subsidies in all 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 the welfare gains they faced in scenarios where 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 sharp fall in world energy prices and demands that a multilateral removal of subsidies would induce.⁹

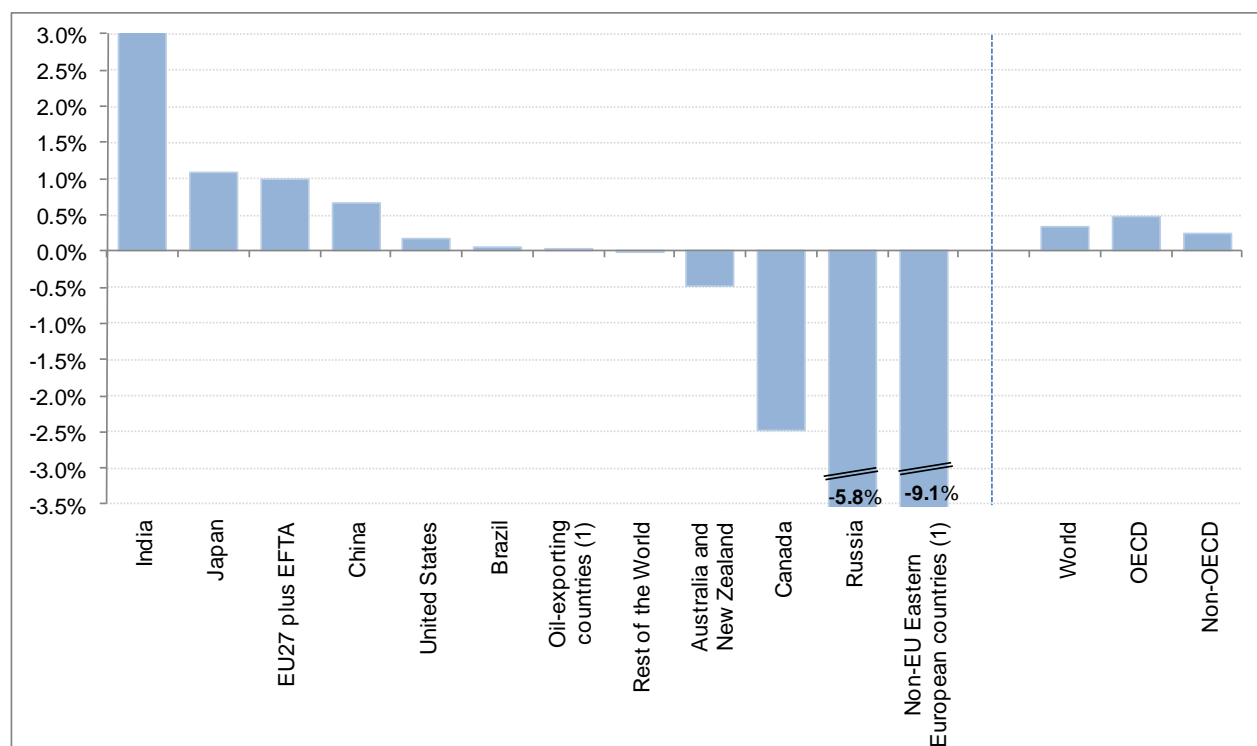
19. Indeed, a multilateral removal of fossil fuel subsidies in non-OECD countries is simulated to induce a drop of the international fossil fuel prices. Reflecting assumptions about supplies responses, the international prices for crude oil and natural gas would fall in the central scenario by 8 and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

20. 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)

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.

21. Energy-importing countries, not least the EU and Japan, would enjoy significant trade and welfare gains. Overall, the OECD area as a whole would gain more (0.5% in 2050) than the non-OECD area and the real income gain at the world level would be small, amounting to just 0.3% relative to the baseline in 2050. This primarily reflects the fact that demand for energy goods is not sensitive to price, so that the distortive impact of energy subsidies and the gain from their removal are limited.

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



¹ See Table A2 in the Annex I for the details about these regions

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

5. Uncertainties and robustness to alternative assumptions

22. 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.

a. Reference years, country coverage and methodological assumptions

23. Price gaps are often 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 impact of subsidy reform depending 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.¹⁰ 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.¹¹ Figure 5 illustrates that the total reductions of GHG emissions at the world level obtained by removing these price gaps are quite similar whatever the year used as a reference for estimating these price gaps and, ranging from 9.3% in 2050 using the 2005 gaps to 8.2% using the 2008 gaps, relative to their baselines¹².

24. 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 following reforms in pricing policies that have reduced their subsidies. Finally, the amount of carbon leakage occurring in countries that do not remove their 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.¹³

25. The choice of an appropriate reference price for estimating the electricity price gaps is not so easy compared to fossil fuels, as electricity is almost not traded internationally. Given this uncertainty¹⁴, if we exclude subsidies to electricity from the subsidy reform, then the emission reductions is somewhat lower: 7.6% in 2050 compared with 8.2% in the central scenario (Table 2). In this case the impacts of the reform are limited as well as positive impacts on welfare.

b. Context of implementation

26. 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 is not likely to be realistic. Indeed, after COP15 in Copenhagen, 75 countries, including all OECD countries, declared that they would restrict their emissions in 2020.

Example 1: OECD capped baseline emissions

27. Therefore, if the impact of subsidy reform has to be quantified in such context, emissions in countries that do not remove fossil fuel subsidies (OECD countries and Brazil) should be capped in order to prevent emissions in these countries from exceeding a given level, as would be the case if these countries implemented their declared targets. 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 (Table 2.).

¹⁰ 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.

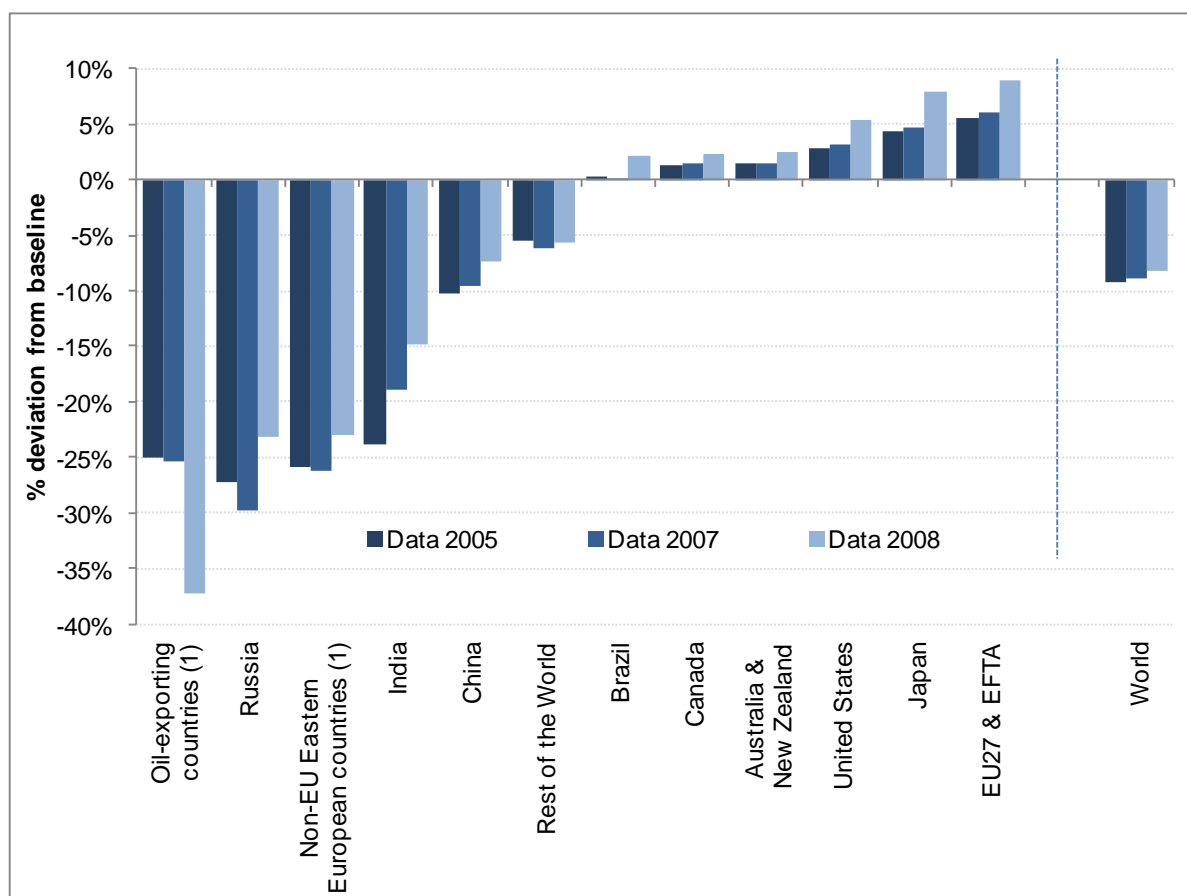
¹¹ In addition to a smaller country coverage, the methodology used by the IEA for estimating 2005 and 2007 price gaps for electricity is slightly different than for 2008.

¹² Since energy price-gaps are introduced in the starting year of the model, changing these wedge would alter the baseline. Then there is a baseline for each dataset of price gaps used.

¹³ Given that the supply of crude oil is relatively less elastic.

¹⁴ 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 CO₂, although in practice these subsidies are small in the countries covered by the IEA database.

Figure 5. Central scenario: Impact on 2050 GHGs emissions as estimated by calculating prices gaps in 2005, 2007 and 2008 (percentage change from baselines)



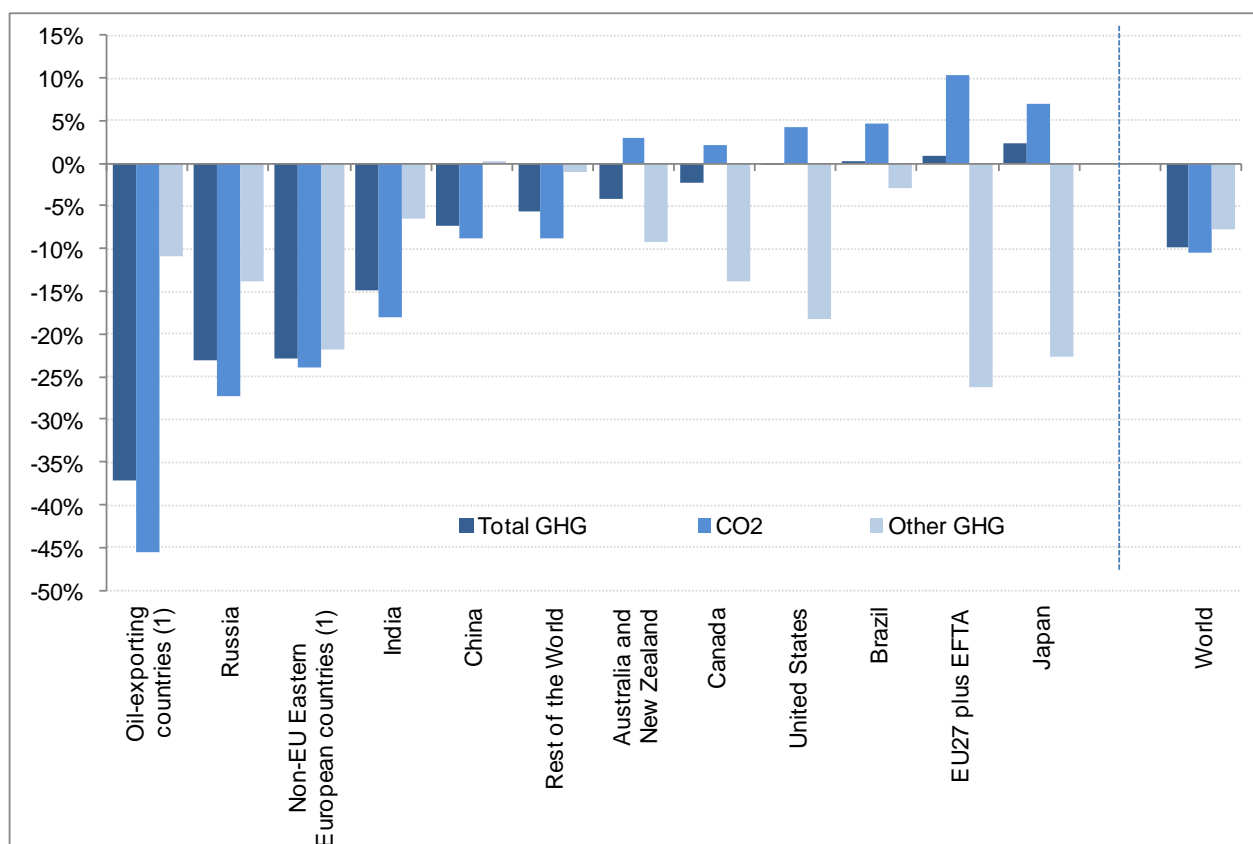
¹ See Table A2 in the Annex I for the details about these regions

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

28. Interestingly, the additional reduction exclusively concerns non-CO₂ gases that are reduced by 8% in 2050 compared with 3% in the no-cap case while the CO₂ 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. Total GHG emissions in OECD countries are capped to their baseline levels – such as to prevent leakages – but the cap is applied globally at the whole OECD level and including all gases, allowing for trading emissions across member countries and gases.¹⁵ Therefore, the cap implies a small carbon price, common for all OECD countries and gases, which, as far as CO₂ is concerned, is largely offset by the fall of international fossil fuel prices resulting from the subsidy reform, hence inducing CO₂ emission to increase above their baseline level, as illustrated by Figure 6. As a result, the cap is met by cutting down non-CO₂ emissions, sometimes substantially as in the EU (- 26%) and in Japan (- 23%). In addition, 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.

¹⁵ GHG emissions in Brazil are also capped, but in isolation from OECD, therefore also implying emission trading across gases only.

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



¹ See Table A2 in the Annex I for the details about these regions

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

Example 2: declared targets level

29. If countries achieve their declared targets in 2020, while at the same time, non-OECD countries phase out their fossil fuel subsidies over the period 2013-2020, the total resulting emission reductions would be more substantial. Under a **minimum-action scenario**, with targets¹⁶ that countries have been committing to after COP15, one could expect a reduction of world emissions by 10% relative to the baseline in 2020 (see lower part of table 2).

30. Countries have also announced maximum targets, like for instance, for the EU a reduction by 30% in 2020 relative to 1990 levels in case of multilateral action instead of 20% in case of unilateral action. This **ambitious-action scenario** would amount to a total emission reduction by 14% in 2020. The emission reduction expected from fossil fuel subsidy reform therefore amounts to 24% and 17% respectively of these declared targets. The Table 2 illustrates also that implementing these targets together

¹⁶ Two scenarios about declared targets are considered here following OECD (2010). The **minimum action scenario** is characterized by unilateral commitments and targets, 20% offsets and no linking between annex I carbon markets. In this scenario, Annex I pledges amount to -13% from 1990 while non Annex pledges amount I pledges amount to -4% from BAU. The **ambitious action scenario** with more ambitious targets; 20% offsets and a global carbon market for Annex I countries. Annex I pledges amount to -17% from 1990 while non Annex pledges amount I pledges amount to -7% from BAU.

with a subsidy reform in non-OECD countries would yield higher emission reductions (12% and 16%, respectively) at a lower economic costs.

Table 2. 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%
Declared targets and actions scenarios				
Minimum-action scenario	-10.4%	n.a.	-0.5%	n.a.
Minimum-action scenario with fossil-fuel subsidies phasing-out	-12.3%	n.a.	-0.4%	n.a.
Ambitious-action scenario	-14.4%	n.a.	-0.6%	n.a.
Ambitious-action scenario with fossil-fuel subsidies phasing-out	-15.8%	n.a.	-0.5%	n.a.

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

c. Values of fossil fuel supply elasticities

31. One of the largest uncertainty sources 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 the 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 environmental benefit of the subsidy removal becomes negligible, with the total emission reduction not exceeding 2% only.¹⁷

¹⁷ This residual reduction is induced through interfuel substitutions, i.e. as most of the subsidies concerns refined oil products, the international oil price falls more than the coal and gas prices, hence inducing a reduction of emissions.

32. 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.¹⁸ Therefore, higher supply elasticities imply that more fossil fuel are left in the ground as a result of a subsidy removal, hence implying GDP losses in fossil-fuel exporting countries that partly offset the welfare gains from the subsidy reform.¹⁹ 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).

6. Concluding remarks

33. 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 should bring both environmental and economic benefits. The latter however are likely to be unevenly distributed as most “oil-exporting countries” are likely to face real income reductions. However, the real income losses incurred by OPEC countries 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.

34. These results are reasonably robust for a number of alternative assumptions. However, the values of the supply elasticities of the various fossil fuels is critical in determining the trade-off between environmental and economics 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.

¹⁸ 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.

¹⁹ Although, in an intertemporal framework with finite fossil fuel reserves, these fossil-fuel resources left into 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 and A2), 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. 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 A2. 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.

CO₂ 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-CO₂ 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: 1) GHG taxes, global or specific by sectors, gases or emission sources; 2) tradable emission permits (with flexibility between regions and sectors); 3) offsets (including a stylised version of the Clean Development Mechanism); and 4) 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 (cf. 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 Maisonnette (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).²⁰ It thus provides a benchmark against which policy scenarios aimed at achieving emission cuts can be assessed.

²⁰ 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 A3 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 panel of Table A3 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).²¹ 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 by 26%, 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.

²¹ 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 A3 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.

ANNEX 3. COMPARISON WITH PREVIOUS ESTIMATES FROM OECD (2009)

OECD(2009) discussed a scenario of fossil fuel subsidy reform based on price gaps estimated by the IEA for 2007 using a sample of 20. This scenario was based on a baseline that did not incorporate the financial crisis and the subsidy reform was applied without caps on emissions in OECD countries. The following Table A4 decomposes the impacts in terms of global emissions reduction of the various differences between the current central case scenario and the one presented in OECD(2009).

Table A4. Comparison with previous OECD estimates of the impact of fossil fuel subsidy removal

Decomposition of the changes introduced since OECD(2009)

Project	% reduction of total GHGs with respect to the baseline in 2050	Baseline modeling	Year of reference for price gaps	Database coverage	Other policies considered
Book on Economics of Climate Change (OECD,2009)	-10.2%	without financial crisis	2007	20 countries	None
- change in baseline	-8.9%	with financial crisis	2007	20 countries	None
- change in reference year for price gaps	-7.5%	with financial crisis	2008	20 countries	None
- change in country coverage	-8.2%	with financial crisis	2008	37 countries	None
G20 central case	-9.8%	with financial crisis	2008	37 countries	Cap in OECD
Other scenarios with OECD caps					
- change in reference year for price gaps	-8.6%	with financial crisis	2008	20 countries	Cap in OECD
- change in baseline	-9.9%	with financial crisis	2007	20 countries	Cap in OECD

Source: OECD ENV-Linkages model based on IEA data.

Including the financial and economic crisis in the baseline projection implies a slightly smaller emissions reduction from the subsidy reform (9% instead of 10% in 2050). Using the most recent IEA data for 2008 instead of 2007 as was done in OECD(2009) further reduces the world emissions reduction (from 9% in 2050 to 8%). An intermediate scenario with the most recent 2008 gaps for the same 20 countries than in the 2007 IEA data base shows a further drop of the world emission reduction in 2050 (from 9 to 7.5%) reflecting changes in policy pricing of fossil fuel in a number of non-OECD countries. This is partly offset by the extended coverage of the IEA price gaps estimates which increases the reduction from 7.5% to 8%. Finally, these changes are almost entirely offset by the introduction of a cap in OECD countries, raising the world emissions reduction from 8% back to close the reduction reported in OECD(2009). Therefore, the impact of the cap in OECD countries is higher with the 2008 price gaps than with the 2007 ones, reflecting an underlying higher amount of carbon leakages.²²

²² As the extension of the country coverage in the IEA database mainly involves subsidies to oil products consumption the removal of which generates higher carbon leakages given the assumption that the supply of crude oil is less elastic.