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Low Oil Prices:
Long-term Economic Effects for the EU and Other Global Regions based on the Computable General Equilibrium PLACE Model

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Abstract

Oil prices on global markets have plunged from US$115 per barrel in mid-June of 2014 to US$48 at end-January 2015, while other fuel prices have continued the slow downward trend of recent years. The rapid decline in oil prices by about 60 percent was accompanied by U.S. dollar appreciation against the major global currencies (except the Swiss franc), partly offsetting the oil price decline measured in currencies other than the dollar. Oil prices that remain low over the long-term would give a positive boost to the global economy, but the effects will vary across countries. While net oil (fossil fuel) importers are expected to win (Europe, Japan, China, India), net oil exporters (OPEC countries, EFTA, Russia, Canada) are set to lose. However, in the EU, with carbon emission constraints in place, the possible benefits for oil users will be restricted because of climate regulations. This paper quantifies the economic effects of lower fossil fuel prices in the 2020 time horizon, modeled as a supply shock, and emphasizes their interaction with EU climate policy.

The impact assessment of the oil price shock was conducted using a multi-county, multi-sector computable general equilibrium (CGE) model, PLACE, maintained by the Center for Climate Policy Analysis (CCPA). The effects of a permanent 60 percent oil price shock are assessed against a baseline scenario through 2020 based on the IEA 2012 World Energy Outlook assuming a high oil price scenario of US$118 in 2015 and US$128 in 2020 (both in 2010 constant prices) and correlated price changes of coal (by 50 percent), and natural gas (by 30 percent). Although a static CGE model does not explicitly account for the time needed for the effects of the shocks to materialize, the five year time span between 2015 and 2020 seems a reasonably long period to match most of the modeling assumptions.

Model simulations show that, first, oil exporters will suffer substantial double-digit welfare losses through 2020 due to significant deterioration in their terms of trade. Second, the EU, as a large oil importer, will benefit significantly from lower oil prices, with the New Member States being relatively better off, as a consequence of their relatively high energy intensity. Third, if the assumed permanent oil price shock occurs at half the level of the headline 60 percent scenario (proxying for US dollar appreciation or reflecting a rebound in oil prices from their early 2015 levels through 2020), welfare effects will be smaller and less than proportional for most countries. Finally, in the EU, the existing emissions cap constrain the use of cheaper fossil fuels and limits the welfare increase by about 0.5 percentage points.

In general, EU countries are better off due to lower fossil fuel prices, but the economic adjustment costs of carbon mitigation policy increase. In particular, the significant decline in coal and gas prices contributes to this effect, creating a challenge for green technologies. From the welfare perspective, the combination of low oil prices and higher carbon prices is much better for the EU than a combination of high oil prices and low carbon prices, while the environmental effects, measured in emissions abatement, are the same in both cases. The interpretation of results from the CGE model has been supported by regression, attributing the diversity of the simulated welfare effects by region to certain characteristics of regional economies, such as refined oil products-to-GDP and net exports of crude oil-to-GDP ratios.

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Low Oil Prices: Long-Term Economic Effects for the EU and other Global Regions based on the Computable General Equilibrium PLACE Model

Jakub Boratyński[1] and Leszek Kąsek[2,3]

1. Introduction

Prices for Brent oil on global markets plunged from US$115 per barrel in mid-June 2014 to US$48 at end-January 2015. Over that same period, prices of other energy commodities remained stable or declined only slightly: coal prices stand more or less unchanged while gas prices rose somewhat but not enough to make up for substantial declines during the last three years. The abrupt 61 percent collapse in oil prices in US dollar terms was accompanied by an appreciating U.S. dollar (against the major global currencies except the Swiss Franc). Hence, the oil price change expressed in most currencies other than the U.S. dollar is significantly smaller. At the same time, the strengthening of the dollar is not being driven primarily by commodity flows nor by the expansion of oil production from unconventional sources in the U.S. Instead, the relative strength of the U.S. economy and the expected divergence in monetary policy between the U.S., Europe, and Japan (more specifically, differences in front-end yield curves) are generally seen as the main drivers of a rising dollar.

This oil supply shock is expected to boost the subdued growth of the global economy, and oil importers are expected to gain due to improved terms of trade while oil exporting countries will be among the losers. These patterns will strengthen if lower fuel prices become permanent. In addition to income effects, permanently lower fossil fuel prices would also provoke substitution effects and reallocation towards relatively less expensive production factors (including energy sources), especially in energy intensive sectors. A temporary price drop translates to temporary income effects only. Future oil prices are difficult to forecast since they are driven by a myriad of factors, including geopolitics, and in coming years fuel prices may move in either direction. Hence, a scenario analysis seems suitable to investigate the impact of changing oil prices.

The purpose of this paper is to quantify the long-term welfare effects of the oil price shock, defined with various magnitudes, and their interaction with European Union climate policy. Cheap oil and other fossil fuels create a challenge for alternative low-carbon technologies, which suddenly become less attractive. If fuel prices remain low, a further switch towards low- or zero-carbon technologies will depend largely on energy and climate policies and regulations, rather than market-driven prices of fossil fuels. In such a

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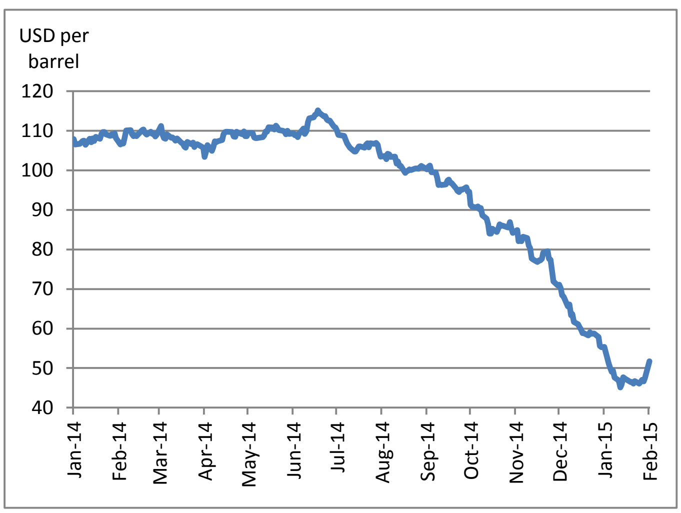
case, higher carbon prices need to compensate for the change in relative prices between "brown" and "green" technologies.

In the European Union, a carbon price has been in place since 2005 with the introduction of the Emissions Trading Scheme (EU ETS), which covers large carbon emitters from power and industry. The EU has the most ambitious climate policy targets for 2020 of any region of the world, and carbon emissions are controlled by the EU Emissions Trading Scheme and national non-ETS emission limits. The carbon price in the EU helps control emissions by raising the relative price of carbon-intensive fuels; as a result, improvements in EU terms of trade due to falling world oil prices provide less of a boost to welfare.

The paper is organized as follows. First, it discusses briefly the recent literature on oil price developments. Second, it presents the tool used for the quantification of economic effects: PLACE Model, which is a multi-region, multi-sector, static computable general equilibrium model based on the GTAP8 database. Third, scenarios of oil and other fossil fuel price shocks are defined. This section presents Reference 2013[4] as the baseline scenario, from which EU climate policy through 2020 is lifted. The final section discusses the results for 25 countries in the EU and 10 global regions in terms of welfare, output, emissions, and carbon prices in the EU, and concludes with results.

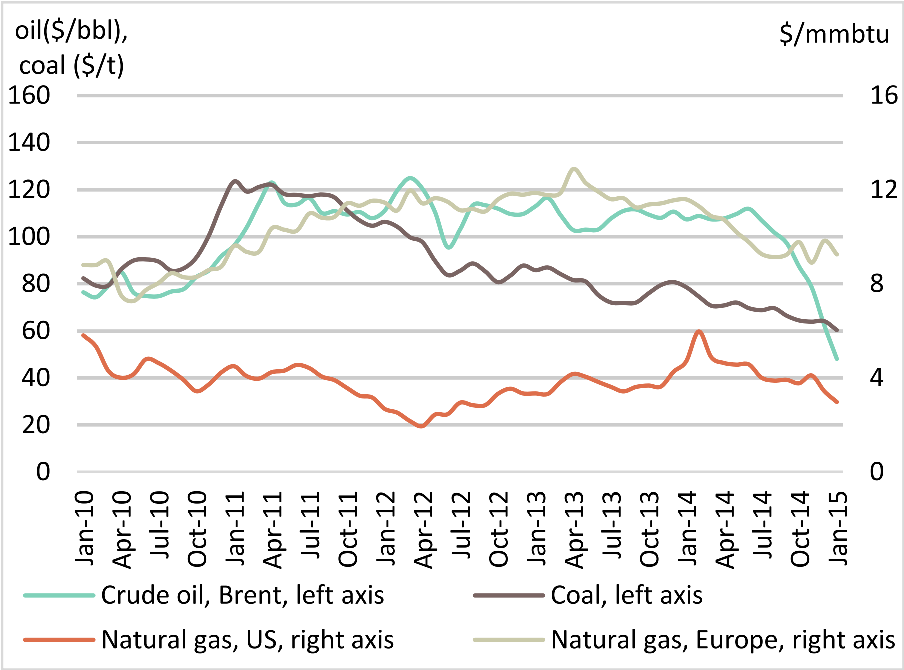
Figure 1
Brent Oil Spot Prices in January 2014-February 2015, in USD



Source: Authors' calculations based on data from Energy Information Agency

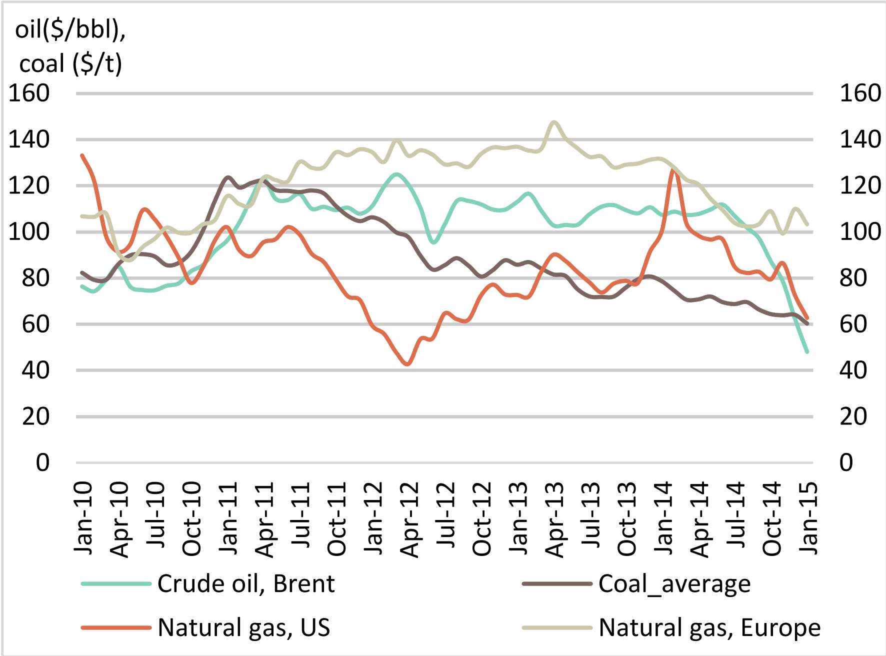
[4] European Commission (2013), EU energy, transport and GHG emissions. Trends to 2050. Reference *scenario 2013*, *manuscript*, Luxembourg.

Figure 2
Spot Monthly Prices of Oil, Coal, and Natural Gas in 2010-2015, in Nominal USD



Source: Authors' calculations based on data from the World Bank's Development Prospects Group

Figure 3
Real Indices for Spot Monthly Prices of Oil, Coal, and Natural Gas in 2010-2015, 2010 Average=100



Notes: Nominal changes deflated by CPI in the USA
Source: Authors' calculations based on data from the World Bank's Development Prospects Group

2. Recent selected literature on oil price developments

The most recent literature on oil price developments mainly addresses the causes for the surprisingly sudden decline in oil prices on global markets since mid-2014. Analysis of economic repercussions for consumers and producers across the major regions and countries primarily focus on short-term effects for 2015-2016. Naturally, the literature on oil price developments is very rich and goes back decades. However, there has been little long-term analysis of cheap oil in a multi-region, multi-country CGE, which is the aim of this paper, with an emphasis on inter-linkages with the existing EU energy and climate policy framework for 2020.

The drivers behind the sharp plunge in oil prices since mid-2014 includes a relatively long list of factors (see, for example, World Bank 2015 or Bank of Canada 2015). These drivers include both demand factors (lower-than-expected demand for oil in the rapidly growing emerging markets, in particular China, combined with persistently disappointing growth in in the EU and Japan in the aftermath of the financial crisis of 2007–08), and supply-side drivers (increased production of oil from unconventional sources mainly in the U.S. and Canada, and a November 2014 change in OPEC strategy towards maintaining the market share). According to the Bank of Canada, the “financialization” of commodities, which might have amplified price changes on global markets, was reverted in recent years by regulatory changes. Also, oil price declines have coincided with an approximate 10 percent nominal appreciation of the U.S. dollar against major currencies in trade-weighted terms, which remains the major transaction currency in global commodity markets. All in all, the recent developments may indicate that the “super-cycle” in world oil prices, and commodity prices in general, lasting over the past decade and a half, has come to an end. Explaining the developments in the second half of 2014, Arezki and Blanchard (2015) refer to surprise increases in oil production in Libya and Iraq and the decision of OPEC to maintain current production levels, as the major factors of the oil price decline.

The recent paper by Baumeister and Kilian (2015) argues that conjectures that the steep decline in the price of oil in the second half of 2014 was a result of a positive oil supply shock and the announcement by OPEC in late November are not supported by the data. The authors provide evidence that more than half of the oil price decline was predictable, using their four-variable VAR forecasting model,[5] based on public information available in June 2014, and reflecting a slowing global economy and positive oil supply shocks which occurred earlier. The authors argue that a shock to oil price expectations in July 2014 that lowered the demand for oil inventories and a demand shock due to unexpectedly weaker global economy in December 2014, especially in Europe and Asia, were responsible for the remaining oil price decline. The oil price decline of 2014 is not viewed as unusual by historical standards, because sharper and faster declines already occurred in early 1986 and mid-2008. Also, Baumeister and Kilian find no evidence of a systematic relationship between the U.S. dollar exchange rate and the price of oil. This is because: (a) stronger U.S. dollar also stimulates exports to the U.S., which in turn increases the demand for oil, (b) the declines in prices of other dollar-denominated commodities were modest in the second half of 2014, and (c) both oil prices and the dollar exchange rate are linked to the global economic developments. According to Kilian (2015), the recent decline in oil prices is to end in 2015 if the global

[5] The model contains the real price of crude oil by U.S. refiners, the percent change in global oil production, a proxy for changes in global crude oil inventories, and a measure of global real economic activity from Kilian (2009). According to its authors, the model proved its significant predictive power at horizons up to six months.

economy does not deteriorate further. Given that reductions in oil drilling activity are reported, oil production is predicted to fall with some lag. Arezki and Blanchard (2015) point out that a partial recovery of oil prices (to about US$70 in late 2019) was also suggested by futures markets of late 2014.

Regarding short- to medium-term economic effects, the fall in oil price is expected to provide a positive boost to the global economy as a whole, but the effects will vary across countries, depending on their terms of trade. While net oil (fossil fuel) importers are expected to win (Europe, Japan, China, India), net oil exporters (OPEC countries, Russia, Canada) are to lose. At the microeconomic level, lower oil prices hurt oil producers but benefit consumers. A lower oil price leaves consumers more disposable income, which they can spend on various goods and services. Also, it reduces production costs in energy-intensive sectors, which do not extract but use oil. However, in countries with slow economic growth and low inflation (Eurozone, Japan), there is a risk that lower oil prices could add to deflation.

The 2015 World Bank report refers to literature suggesting that a 30 percent oil price decline, driven by a supply shock would be associated with an increase in world GDP of about 0.5 percent in the medium-term. The same report mentions empirical estimates of the negative impact on output in some oil-exporting countries, including Russia and some countries in the Middle East and North Africa, ranging from 0.8–2.5 percentage points in the year following a 10 percent decline in the annual average oil price. The same shock would increase growth in oil-importing economies by some 0.1–0.5 percentage points, depending on the share of oil imports in GDP.

The economic effects of higher oil prices on GDP in the OECD are assessed in Brook, et al. (2004), but the initial level (around US$30 in 2000 prices) and the magnitude of the potential oil shock (a sustained US$10 increase) differ significantly from the much bigger shock analyzed in this paper. Simulations using OECD’s large-scale macroeconomic model suggest that oil price increases have moderate negative short-run (2-year) impact on output of -0.45 percent for the U.S. and the OECD as a whole, -0.50 percent for the Euro area and -0.60 percent for Japan, from the respective GDP baseline levels, if real interest rates were to be held constant. The moderate output effects can be attributed to a declining ratio of oil consumption per unit of output in the OECD in the last decades (as well as in developing countries from the 2000s), resulting from more efficient production processes, ongoing fuel-saving technical change, increasing utilization of alternative energy sources, and a shift of output from industry towards services.

Similarly, Blanchard and Gali (2008) attribute the significantly milder effects of oil price shocks on inflation and output in the industrialized economies in the 2000s compared to the 1970s to the smaller adverse shocks, the smaller share of oil in production and consumption, easier substitutions away from oil, more flexible labor markets, and the increased credibility of monetary policy. Using structural VAR techniques, the authors estimate that for the two episodes in the 1970s, cumulative GDP loss over the eight quarters following each episode’s benchmark date (relative to trend GDP estimated based on the eight preceding quarters) amounted to 8.9 percent for OECD countries. By contrast, for the two episodes in the 2000s, the OECD’s GDP gained 2.1 percent compared to the baseline.

According to Brook et al., the long-term effects capturing supply-side influences are higher than short run ones. In case of a sustained US$15 oil price increase, the output effects in the bigger OECD countries would be amplified and deviate about 1.5 percent from the baseline after three years from the shock if long-term supply-side channels were taken into account in reduced-form macroeconomic models. Also, the authors provide evidence of asymmetry between more significant effects on output resulting from oil

price increases than oil price decreases. This is because periods of elevated oil prices accelerate the development of more energy-efficient technology and a replacement of energy-inefficient capital with its more efficient vintages, yet if the oil price falls, these improvements are not undone. Thus, oil consumption does not rebound strongly. This indicates a possible non-linear relationship between the oil price shock and GDP, with price increases having a larger impact on activity than oil price declines.

Arezki and Blanchard (2015) run two simulations for the global economy: the first assumes that the supply shift accounts for 60 percent of the price decline reflected in the futures markets of late 2014, while the second assumes that the shift is gradually undone and reaches zero contribution to the price decline in 2019. These simulations capture only the supply side effects. The first simulation envisages an increase in global output of 0.7 percent in 2015 and 0.8 percent in 2016, and then a gradual moderation to around 0.6 percent through 2019, all relative to the baseline. In the second scenario, the effects on output are naturally smaller: 0.3 percent in 2015 and 0.4 percent in 2016 and a gradual fall to zero in 2019. The effects of lower oil prices affect net oil importers and net oil exporters asymmetrically, and significant differences also occur within each of the two groupings due to differences in oil/energy consumption in GDP, various energy taxation systems, and the proximity to large oil exporting countries that are negatively affected. The effects for China are larger than those for Japan, the U.S., and the Eurozone. As an example, in the first scenario, GDP in China increases by 0.7 percent in 2015 and 0.9 percent in 2016 compared to the baseline, while in the U.S., it expands by 0.5-0.6 percent. In the first scenario, real GDP in the oil exporting countries as a group goes down by approximately 0.3 percent and the loss gradually widens to 0.7 percent in 2019. Its magnitude depends on the share of oil in the country's exports and the share of energy taxation in budget revenues. The authors do not report, however, the point results for individual oil exporting countries.

Peersman and Robays (2009a, 2009b, 2009c) distinguish between the nature of oil price shocks and analyze the following: oil supply shocks, oil specific demand shocks, and demand shocks caused by global economic activity. An oil supply shock is an exogenous shift of the supply curve and moves oil prices and oil production in opposite directions. The shock on the demand side (driven by economic activity) results in a shift of oil prices and oil production in the same direction. Shifts in oil demand that are not driven by economic activity are labeled oil-specific demand shocks. These shocks concern uncertainty about the future supply of crude oil and uncertainty about future oil prices. To analyze the economic consequences of oil shocks across countries, Peersman and Robays used a structural vector auto-regression model (SVAR) for 1986Q1-2008Q1. If an exogenous oil supply shock occurs, net oil importers (U.S., Euro area, Japan, Switzerland) experience a permanent fall in economic activity. A median impulse response of GDP in the long-run (20 quarters) to a 10 percent oil price rise amounts to about -0.3 percent. In net oil exporting countries, output is expected to grow, e.g., by 0.12 percent in Canada and 0.26 percent in Norway. A global demand shock which causes a 10 percent rise in oil prices leads to a transitory increase of real GDP (ranging from 0.12 percent in the UK to 0.38 percent in Norway), but output declines in the long term, e.g. Japan (-1.0 percent), Canada (-0.5 percent) and the UK (-0.5 percent). An oil-specific demand shock leads to a 10 percent rise in oil prices and is followed by a temporary fall in real GDP within the first year, ranging from 0.22 percent in Switzerland to 1.1 percent in Japan.

Kilian (2009) used a structural monthly VAR model of the global crude oil market (using data for 1975 to 2007, including a composite monthly index of global real economic activity) to identify the underlying

demand and supply shocks. The author decomposes shocks affecting oil prices into: oil supply shocks; shocks to the global demand for all industrial commodities; and demand shocks that are specific to the global crude oil market, i.e., shifts of oil prices concerning the availability of future oil supplies. Different effects associated with the underlying nature of the oil price shocks explain the resilience of the U.S. economy to oil price increases in the 2000s as compared to the 1970s and early 1980s. For the large open U.S. economy, the causal relationship between (global) oil prices and (domestic) output may run in two directions. Some shocks may have a direct impact on the U.S. economy, while others may generate indirect effects reflected in the price of oil and other commodities on global markets.

3. Methodology: multi-region, multi-sector, static, general equilibrium model PLACE

A multi-region, multi-sector computable equilibrium model (CGE) is a well-suited tool to analyze the complex channels through which changes in oil prices affect global economies. Such a model captures changes in terms of trade for the oil importers and exporters. Changes in welfare by country will depend on the sectoral composition of output and energy (fuel) intensity across sectors. A CGE model provides an endogenous solution for the revenue losses accruing to oil exporters and extra unspent incomes to oil importers. Fossil fuels are inputs into many goods, and both consumers and producers are affected. The energy mix adjusts to relative prices of energy commodities. Finally, the production structure changes as capital and labor are reallocated across sectors, towards those in higher demand (i.e those experiencing lower costs due to the shock of a lower oil price). These channels can be analyzed in a global CGE model such as PLACE. Version 2.0 of the model is summarized in the February 2015 report of the Warsaw-based Center for Climate Policy Analysis (CCPA),[6] while the first version of the model is described in the April 2014 report of the CCPA.[7]

PLACE is a static multi-sector, multi-region CGE model, using the GTAP8 database, which comprises 2007 global input-output data. Its predecessor was a 4-region ROCA model, developed for the World Bank.[8] For the simulations in this paper, the model dimensions cover 20 sectors (aggregated from 57 in GTAP) and 35 regions (aggregated from 129 in GTAP): 10 regions outside the EU and 25 regions within the EU, where Luxemburg was aggregated with Belgium, Malta with Italy, and Cyprus with Greece. Among the 20 industries (sectors) in the model, a distinction is made between the sectors covered by the EU's cap & trade (EU ETS) and non-ETS sectors. In addition, a subset of EU ETS sectors, which are energy-intensive and trade-exposed (EITE), is explicitly taken into account. See Annex 1 for more details.

Each sector in PLACE produces one specific commodity using four primary factors (skilled and unskilled labor, capital, and natural resources), six main energy goods (coal, gas, crude oil, refined oil products, electricity, and heat) plus biofuels and biomass, and 12 other non-energy goods (specific sectors may only use a subset of the abovementioned factors). The production technology for each sector is represented by a combination of Leontief and nested constant elasticity of substitution (CES) production functions. At the top level, materials (non-energy) are combined with a composite of capital, labor and energy in fixed (Leontief) proportions (with the exception the electricity & heat sector). At the second level, a CES function describes substitution possibilities between the energy aggregate and the value-added composite of capital and labor (in the case of electricity and heat generation, the materials bundle is combined with

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[6] Center for Climate Policy Analysis 2015.
[7] Center for Climate Policy Analysis 2014.
[8] .Böhringer and Rutherford 2012.

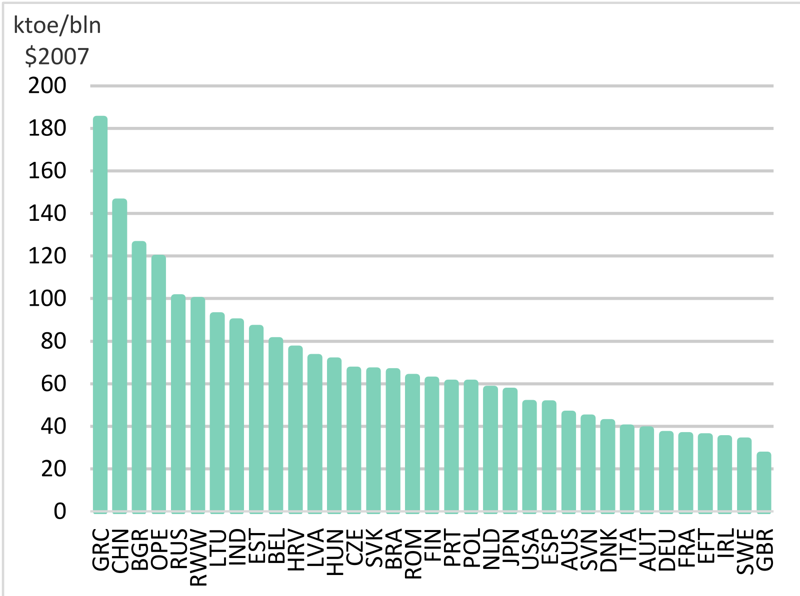
the labor and capital-energy composite according to the CES function). At the third level, capital-labor or capital-energy substitution possibilities within the value-added composite are represented by CES functions. Finally, energy is a (nested) CES composite of individual energy sources. In this paper, the simulation setting assumes that aggregate capital and labor are fixed within a given region, while they are mobile between sectors (except sector-specific capital representing natural resources in the fossil fuel extraction sectors). Therefore changes in welfare and other macroeconomic outcomes result from changes in allocation efficiency. In order to capture the long-run welfare effects in the static framework, it is assumed that (nominal) balance of payments is fixed for each region. Although it is not likely to be fulfilled in the short or medium term, especially for the net oil exporters, this assures no welfare gains or losses due to foreign borrowing or lending. In this way, changes in the terms of trade are internalized in the welfare measure.

International trade is based on product heterogeneity (the Armington assumption), which means that domestic and foreign goods are distinguished by origin. Each good used in the domestic market (as a component of intermediate or final demand) is a CES function composite combining the domestically produced good and the bundle of imported goods (the latter itself being a CES composite of goods imported from different regions). The current version of PLACE comprises energy-related CO_2 emissions from fuel combustion, CO_2 emissions from industrial processes, and non-CO_2 emissions (CH_4, N_2O, F-gases).

The economic effects of policies or shocks reflect the extent to which these policies or shocks affect the economy in the future as compared to the reference situation interpreted as permanent, long-run deviations from the baseline. The analysis based on the PLACE Model is comparative-static. Hence, the price shock simulations for 2020 are implemented within the model calibrated to the base year 2007 and re-calibrated to the hypothetical baseline situation in 2020, according to PRIMES/GAINS Reference 2013 projections (European Commission 2013) for EU regions, as well as OECD, IEA and EPA projections for non-EU regions. The external 2020 projections that are matched in the re-calibration procedure include GDP growth, energy use and emissions, international fossil fuel prices and EU ETS carbon price forecasts. The policy effects simulated in the PLACE Model should be interpreted as permanent, long-run deviations from the baseline caused by the sustained influence of the policy or shock.[9]

[9] In such a framework it is not presumed that the effects of the shocks materialize strictly by 2020. The 2020 is treated as a reference point for comparative-static analysis.

Figure 4
Oil Intensity (Oil use to GDP Ratio) in the PLACE Model countries and Regions, 2007



Note: The oil use is calculated as a sum of usage of (domestic and imported) crude oil and petroleum products by firms and consumers, deducting crude oil used as input in the sector petroleum products to avoid double counting
Source: Authors' calculations based on GTAP8 database

4. Definition of shocks and scenarios 2020 for the PLACE Model

4.1. Baseline scenario 2020

To explore possible oil price scenarios through 2020, a number of longer-term price shocks were simulated in the PLACE Model, and assessed against the baseline scenario. The PLACE Model was initially calibrated to the GTAP8 database with a base year 2007 and then re-calibrated for 2020. The baseline scenario 2020 adopted the fossil fuel projection path through 2020 from the IEA World Energy Outlook 2012 (Current Policies Scenario), while the GDP growth and energy demands were taken from the OECD and European Commission publications, in particular on the Reference scenario 2013 from the EC publication.

The baseline scenario finalized in late 2013 assumed a sharply rising trajectory of fossil fuel prices by 2020 compared to the 2011-2012 levels, with oil price projected to rise by about 70 percent, from $73 per barrel in 2007 to $125 in 2020 (in 2010 U.S. dollar prices). The baseline path could be interpreted as an estimate of the equilibrium long-term price.

Table 1
Projections of fossil fuel prices (in 2010 US$)

	Fuel prices					
	2010 US$			index (2007 = 1)		
	2007	2015	2020	2007	2015	2020
Crude oil (per barrel)	72.9	115.7	125.4	1.00	1.59	1.72
Natural gas (per MBtu)	7.4	10.9	11.9	1.00	1.48	1.61
Steam coal (per ton)	76.6	107.5	112.4	1.00	1.40	1.47

Source: Adapted from the IEA forecasts, WEO 2012

In the baseline scenario, major global economies were to grow in line with their potential growth rates, for the EU, it is estimated at around 1.5 percent through 2020 only due to the adverse effects of the global economic crisis. The non-EU countries were to grow in line with the long-term OECD projections from 2012, which are consistent with the IEA's projection of fossil fuel prices in WEO2012.

Table 2
Assumed Long-Term Annual GDP Projections for the EU and non-European Regions, in Percent

	2010-2015	2015-2020
EU	1.4	1.5
AUS	3.2	3.3
CHN	9.0	7.7
JPN	0.9	1.1
IND	7.0	7.0
USA	2.6	2.4
BRA	4.0	4.4
RUS	4.4	3.3
EFT	3.0	3.6
OPE	5.5	4.0
RWW	3.6	3.8

Source: Authors' compilation based on: European Commission (2012) for the EU and OECD (2012) for non-EU countries

4.2. Oil price shock scenarios 2020

Due to the uncertainty around the future oil prices, the headline policy scenario is constructed on the assumption that oil prices remain constant at the January 2015 level of about US$50 per barrel in the projection window to 2020. The percentage price fall for 2020 relative to the baseline is to be the same as for 2015. Average oil prices in January 2015 were by about 60 percent lower than prices projected for 2015 in the baseline scenario. Hence, the headline scenario **LowOil60** assumes a 60 percent drop in oil price in 2020 as compared to the baseline scenario. In this scenario, coal prices are assumed to be 50 percent and natural gas prices 30 percent lower than in the baseline. These two numbers do not reflect

sharp price plunges since mid-2014, but the downward price movement of coal and gas from average 2011-2012 levels through early 2015. The 30 percent decline for natural gas is a ‘compromise’ between an approximate 20 percent drop of gas price in Europe and an above 40 percent decrease of gas prices in the U.S., both relative to the baseline scenario.

The **LowOil30** scenario is to reflect a moderate fall in fossil fuel prices, half of the price changes defined in the LowOil60 scenario. This would reflect a situation in which fossil fuel prices rebound significantly (by about US$30) from their early 2015 levels. This scenario may also proxy the situation in which the recent oil price drop coincides with appreciation of the U.S. dollar, which means that the decline in price expressed in local currencies is significantly less than changes expressed in U.S. dollars.[10] In the second half of 2014, the dollar appreciated by 10 percent against major currencies in trade-weighted nominal terms.

In the third scenario **OnlyOil60**, only oil prices decline by 60 percent, while coal and gas prices remain the same as in the baseline scenario. This scenario may reflect a situation in which an increase in oil supply (thanks to new oil discoveries, technological progress, or other factors acting in the crude oil sector) is not accompanied by an additional supply of other fossil fuels. Actually, such a situation occurred between mid-June 2014 and early 2015. However, there is empirical evidence that over the long-term the prices of fossil fuels have been highly correlated, so this scenario needs to be interpreted with caution.

Finally, in the **NoCarbonCap** scenario, the EU ETS carbon price is forced to zero in the baseline setting instead of EUR 10 as in the Reference 2013 scenario, in which the EU ETS emissions target for 2020 is met. In the NoCarbonCap scenario, the EU ETS target for 2020 is not met, while fossil fuel prices are as low as in the LowOil60 scenario. The welfare difference between the NoCarbonCap scenario and the headline LowOil60 scenario can be roughly interpreted as an additional welfare cost of meeting the EU emission targets. The four scenarios discussed in the paper are summarized in Table 3.

The fossil fuel price changes are modeled as a supply shock. Technically, the variables representing available fossil fuel resources are scaled endogenously to reach a certain price target. The scarcity rent is effectively reduced when the supply increases, thus reducing the fuel price.

In the simulations, taxes imposed domestically on coal and natural gas are modeled as ad valorem taxes, while for refined oil products, indirect taxes apply per unit of quantity. These assumptions result from the fact that in the EU, the excise (per quantity) taxes on refined oil products typically constitute a higher share in the final price than VAT. Moreover, the excise tax rates are significantly higher for oil products than for coal and natural gas. As a result, the sharp decrease in the basic (producer) prices of petroleum products will translate into lower than proportional change in end-user prices as the fixed tax is paid per physical unit of fuel.

[10] The standard, real economy, CGE model such as PLACE does not have financial markets but works in the domain of real exchange rates, i.e. terms-of-trade (ToT) composed of export and import prices for heterogeneous goods treated bilaterally. "Appreciation" in that context would imply that ToT change in favor of some countries and against other countries—ToT changes in the model are driven by changes in export and import prices.

Table 3
Summary of Scenarios 2020 Simulated in the PLACE Model

Oil (and other fossil fuel) price shocks relative to the baseline 2020	**Baseline scenarios**	
	Reference 2013 (REF2013)	Hypothetical, removal of the EU ETS carbon cap for 2020
Sharp fall in fossil fuel prices: Oil: -60% Coal: -50% Gas: -30%	**LowOil60 [headline scenario]**	**NoCarbonCap**
Moderate fall in fossil fuel prices: Oil: -30% Coal: -25% Gas: -15%	**LowOil30**	Not discussed
Sharp fall in oil prices only: Oil: -60% Coal: 0% Gas: 0%	**OnlyOil60**	Not discussed

Source: Authors

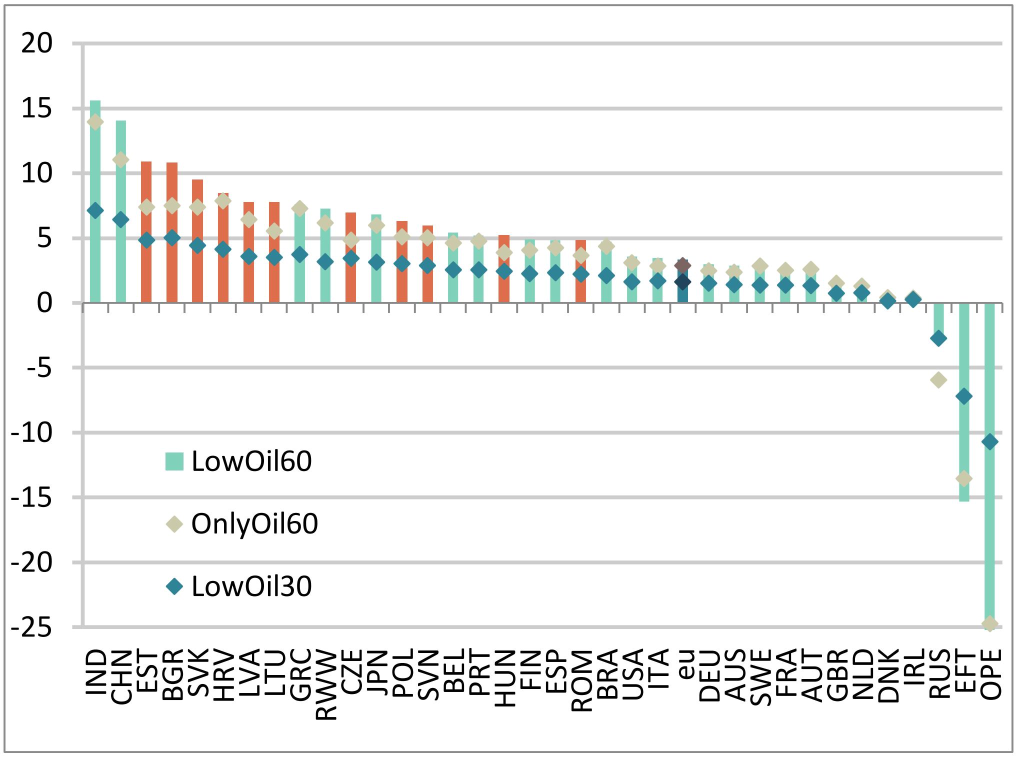
5. Results and conclusions

This final section discusses the results for 25 individual countries in the EU and 10 global regions in terms of welfare for all regions, and carbon prices, sectoral output, and EU ETS emissions for the EU countries. In this model setting (with fixed long-run labor supply and fixed government consumption), changes in welfare are equivalent to changes in private consumption, or they can be interpreted in terms of Hicksian equivalent variation. The headline scenario is LowOil60, in which oil prices fall by 60 percent, coal by 50 percent, and natural gas by 30 percent, all as compared to the baseline.

India and China are the biggest winners of low oil prices, gaining 16 percent and 14 percent in welfare compared to the baseline scenario, while OPEC and EFTA countries are the biggest losers, and their losses are double-digit. In the EU, countries which joined the EU in the mid-2000s plus Croatia (the New Member States) benefit most, in particular, Bulgaria, Estonia, and Slovakia. This is mainly because of their relatively high energy intensity and dependency on fossil fuel imports. The gains in the biggest OECD economies— the U.S., Germany, France, or UK—are substantial but below four percent. The distribution of gains and losses in the OnlyOil60 scenario is similar to the headline scenario, but the magnitudes are smaller as only oil prices fall while other fossil fuel prices remain constant compared to the baseline. The notable exception is Russia, where welfare falls by less than three percent in the headline scenario, while it decreases by almost six percent in the OnlyOil60 scenario. Domestic consumers and producers in Russia perform better if coal and gas prices fall jointly with oil, while cheap oil cannot be easily “absorbed” by domestic users and they do not offset the decline in export receipts. The comparison of OnlyOil60 and LowOil60 scenarios shows that nearly 80 percent of the world’s welfare gains can be attributed to the oil price decline, while the shocks in coal and gas prices play a smaller role. Halving the headline fuel price shock (LowOil30) translates into smaller magnitude of

private consumption effects, generally somewhat smaller than a half of the values in LowOil60 (Figure 5).

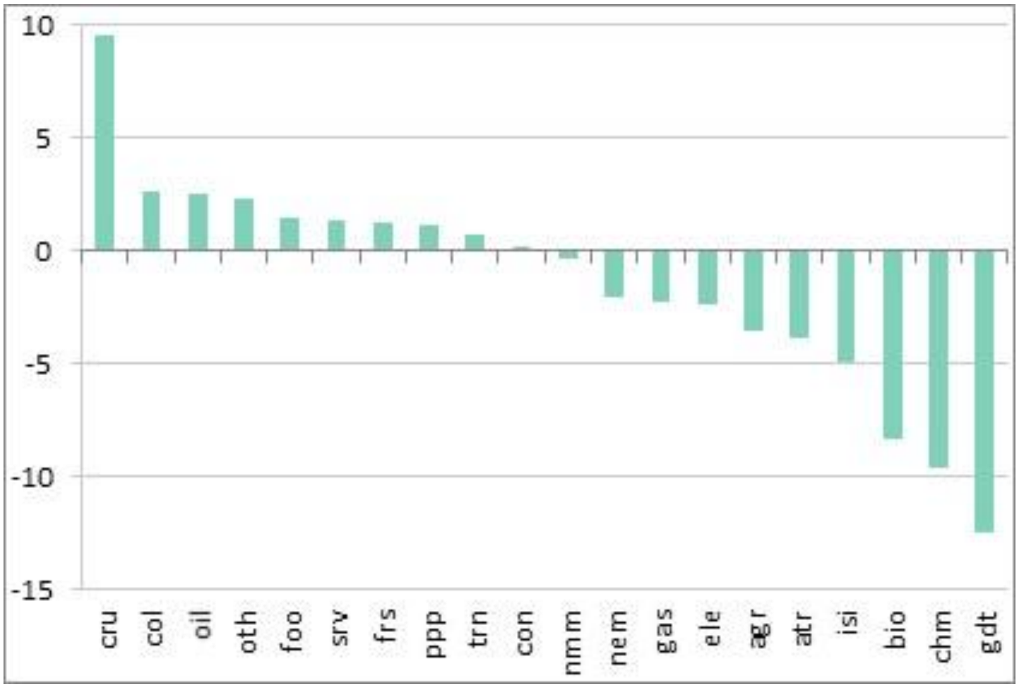
Figure 5
Welfare (Private Consumption) in LowOil60, LowOil30 and OnlyOil60 Scenarios, Deviation from the Baseline in %



Source: Simulations in the PLACE Model

For the EU as a whole improvement in welfare exceeds three percent in the LowOil60 scenario. Output in the EU expands mainly in sectors directly involved in oil extraction and refining (petroleum products and crude oil), and different modes of transport, which are large consumers of petroleum products (Figure 6). However, in energy intensive sectors (chemicals, iron and steel, non-ferrous metals, non-metallic minerals), output declines even though the fuel price shock triggered a decrease in production cost. This is due to a loss in competitiveness with the rest of the world, where production costs declined even more. The relatively large declines in gas distribution (along with some decline in gas extraction) and biofuels are a result of fuel substitution under the emissions cap. Without an emissions constraint, the production and use of all fuels generally increases, even though the energy mix changes in favor of cheaper oil products. The decline in natural gas output is generally driven by its *relative* price increase compared to other fossil fuels, in line with the assumptions in the headline LowOil60 scenario.

Figure 6
Output in the EU as a Whole by Sector in the LowOil60 Scenario, Deviation from the Baseline in %



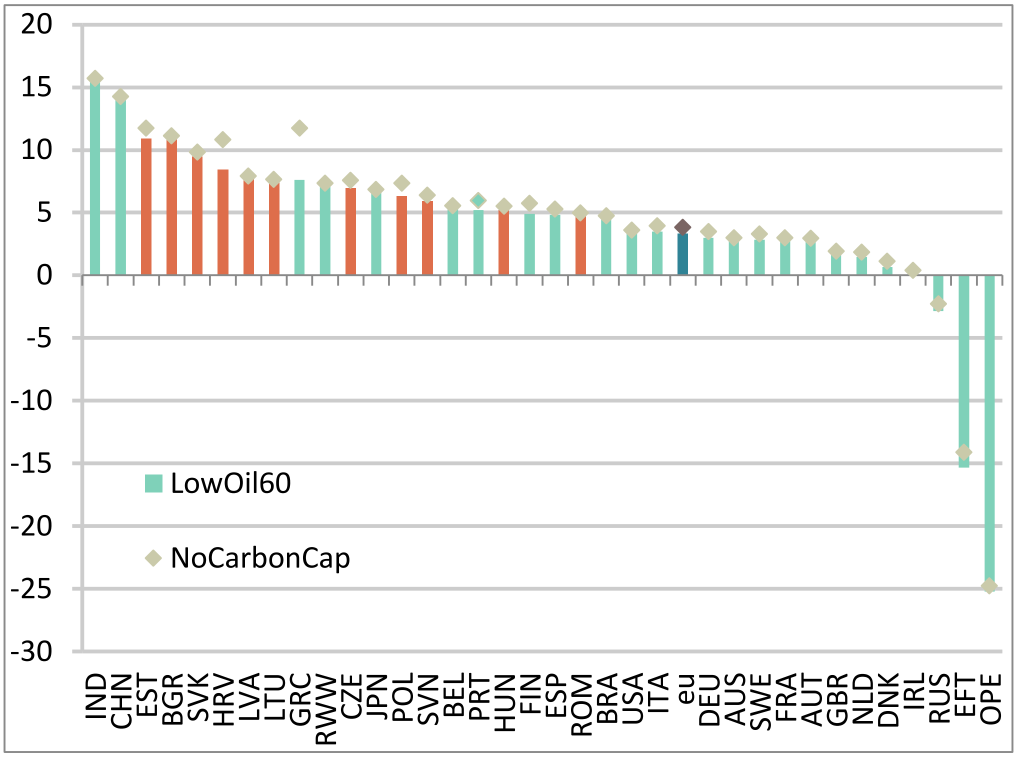
Source: Simulations in the PLACE Model

Removing carbon caps in the EU[11] (and thus forcing carbon prices in the EU ETS and non-ETS sectors to zero) in the NoCarbonCap scenario leads to an increase in welfare in the environment of low fuel prices but the increase is only 0.5 percentage points for the EU as a whole. Better than average EU results occur in Croatia, Poland, Portugal, Estonia, Finland, and Greece (an outlier with more than four percentage points increase), partly explained by relatively high oil or coal intensities of those economies. A relaxation of the carbon emissions cap in the EU leads to improved welfare in the key energy exporters to the EU: OPEC, EFTA, and Russia (Figure 7).

[11] The EU ETS covers EU Member States and the EFTA (excluding Switzerland), while non-ETS individual national targets apply to EU countries only.

Figure 7

Welfare (Private Consumption) in LowOil60 and NoCarbonCap Scenarios, Deviation from the Baseline in %



Source: Simulations in the PLACE Model

If fossil fuel prices remained as low as in LowOil60 scenario, the EU ETS carbon price in 2020 would need to more than double (EUR 24, compared to EUR10 in the baseline scenario (in which the carbon cap in the EU ETS is incorporated in line with the 20-20-20 energy and climate package). The carbon price would reach about EUR17 if the fuel price shock was half as intensive as the assumed headline shock. However, if only oil prices fell but coal and gas prices remained at baseline levels, the EU ETS price would be marginally lower than in the baseline scenario (Table 4). The latter result indicates that a lower oil price does not by itself put pressure on the EU ETS carbon price; rather it is lower prices of coal and gas that depress the ETS price. The explanation of this is twofold. First, oil is not a dominant fuel in the ETS sectors. Second, trade-exposed ETS sectors lose competitiveness on international markets and their "demand for emissions" falls.

Shadow carbon prices in non-ETS sectors, necessary to constrain the national emissions in non-ETS sectors to their baseline levels, would be high and range from EUR30 in Poland to extremely high EUR190 in Greece. We assume that a carbon tax is implemented through country specific rates equal to the shadow price so that national targets are met. The carbon tax in the non-ETS is added to prices of all fuels used in non-ETS sectors, including in transport, households, services, agriculture, and light industry.

However, the carbon tax does not bring the end-user price of oil back to the initial level before the shock but only dampens the price decline, typically by 20-40 percent. At the same time, prices of coal and natural gas, including the carbon price, will typically rise for non-ETS users. This difference is a result of high excise tax rates on refined oil products already in the baseline; thus, the weight of an additional

carbon tax in the purchaser price is relatively small. As a result, higher emissions from oil are compensated by a reduction of emissions from coal and natural gas and emissions not related to fuel combustion, including non-CO_2 gases in non-ETS sectors.[12] In the EU ETS sectors, increased carbon prices offset a large share of lower coal and oil prices. Therefore, the positive welfare effects from lower fuel prices are substantially diminished.

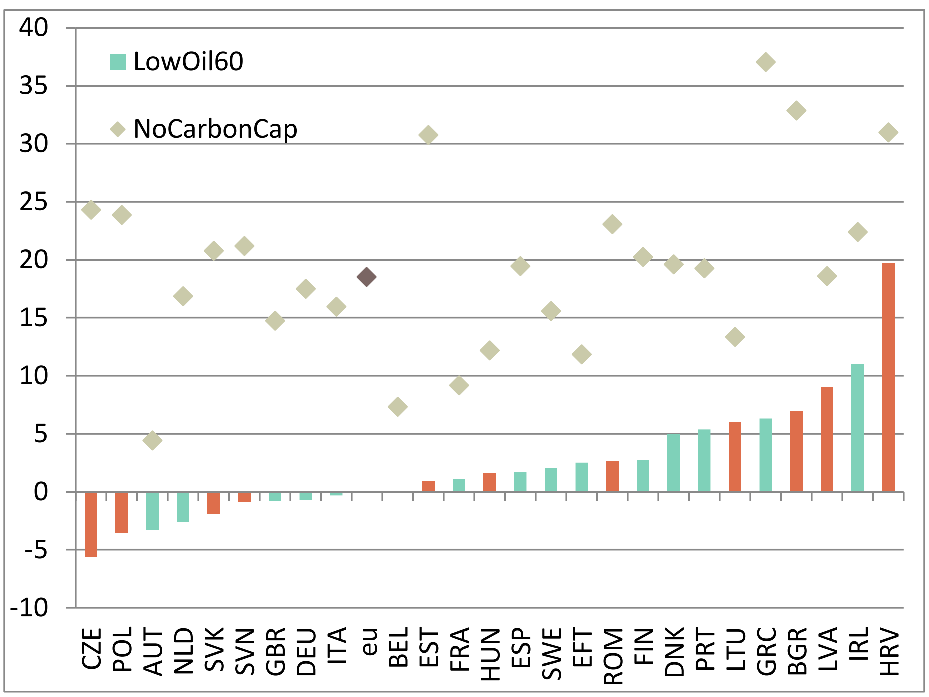
Table 4
EU ETS Carbon Price, in EURO 2010 Constant Prices

	LowOil60	LowOil30	OnlyOil60
EU ETS carbon price	23.6	16.9	9.7

Source: Simulations in the PLACE Model

If emissions were not controlled in the EU ETS (NoCarbonCap scenario), they would increase by about 18.5 percent in the EU as compared to the baseline. They would be higher in all EU countries, with the most substantial changes in Greece and New Member States. In the LowOil60 scenario, the EU ETS emissions are capped and cannot exceed the baseline level. As an endogenous solution in the PLACE Model, the emissions are mainly reduced in the countries characterized by relatively cheap abatement opportunities (Figure 8).

Figure 8
Emissions in EU ETS by country in the LowOil60 and NoCarbonCap scenarios, deviation from the baseline in %



Source: Simulations in the PLACE Model

[12] Marginal abatement costs in different sectors/regions, implicit in the PLACE model, are a joint "product" of benchmark cost shares of fuels, values of elasticities of substitution, and the forms of production functions.

To investigate the drivers in results by region, the simulation outcomes for welfare are explained in regressions of countries' or regions' characteristics, following the approach adopted by Dixon et al. (2007). The regional characteristics include:

- value share of refined oil products use (net of taxes) in GDP (OilShr),
- value share of coal use in GDP (ColShr),
- ratio of crude oil net exports to GDP (CruNetExp),
- ratio of refined oil products net exports to GDP (OilNetExp),
- dummy variable for the carbon cap and emission pricing: set to 1 if the cap applies, and set to 0 otherwise (Cap).

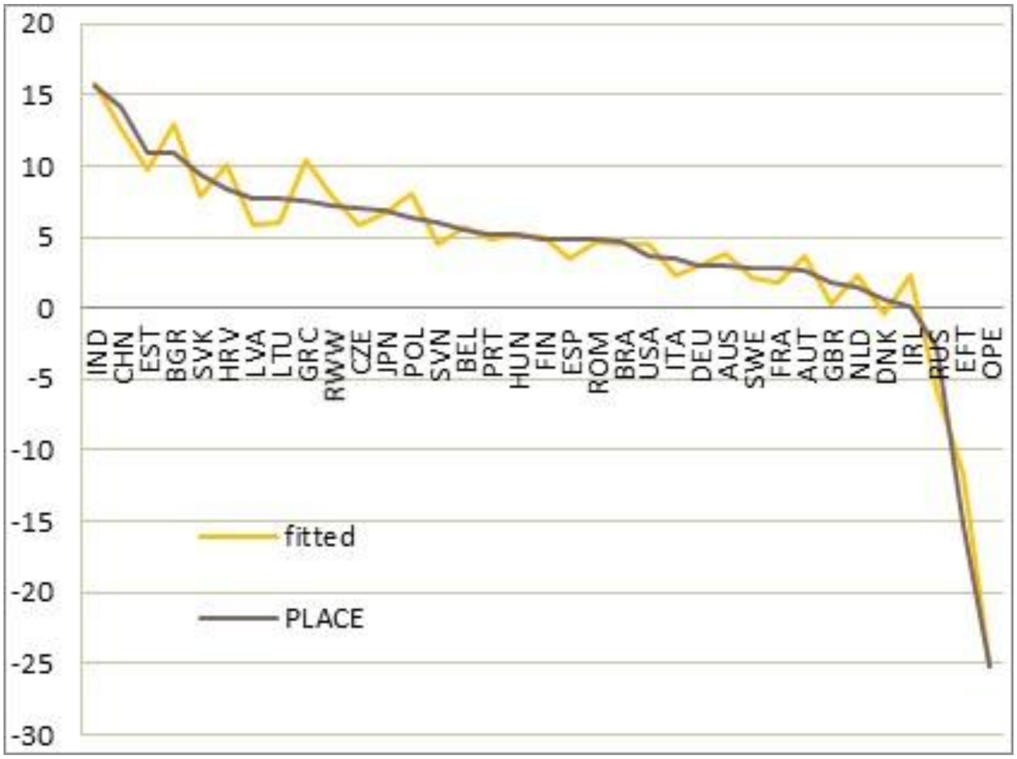
All the above shares and ratios are expressed in per cent and were derived from the baseline solution. They describe a future picture of the global economy, combining the data from the base year with external projections—most notably on energy prices and energy demand. The equation, estimated for the results of LowOil60 scenario is:

$$Welfare_r = 0.5 \cdot OilShr_r + 2.2 \cdot ColShr_r - 0.9 \cdot CruNetExp_r - 0.7 \cdot OilNetExp_r - 1.4 \cdot Cap_r$$
$$R^2 = 0.97$$

where $Welfare_r$ represents the percentage change in welfare in region r, resulting from simulations in the PLACE Model. The "sample" included 35 "observations" for individual PLACE regions. The final specification was chosen from competing specifications based on R^2 and significance of parameter estimates criteria.

The inter-regional differentiation of the explanatory variables explains 97 percent of the variability in welfare responses to the fuel price shocks. The fit of regression equations to the PLACE simulation outcomes is illustrated in Figure 9. The largest part of the differences in welfare effects between regions can be attributed to the OilShr and CruNetExp variables—the intensity of the use of refined oil products, and net exports of crude oil to GDP ratio. The regression with the two variables already explains 89 percent of the variability of the outcomes for welfare.

Figure 9
Percentage Changes of Welfare in the LowOil60 Scenario: PLACE Results and Fitted Values



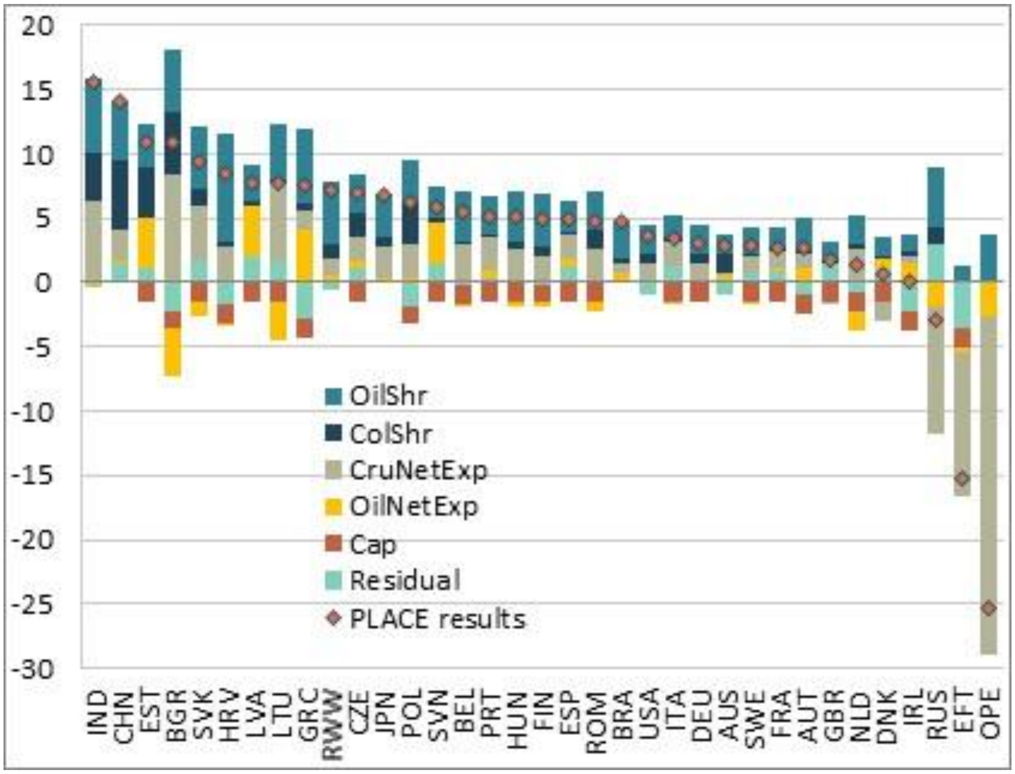
Source: Own calculations

The interpretation of the regression results is as follows. An increase in the value share of refined oil products use in the GDP by 1 percentage point (p.p.) raises the welfare gain from lower fuel prices on average by 0.5 p.p. Similarly, 1 p.p. increase in the share of coal raises the welfare gain by 2.2 p.p. These two effects can be referred to as cost effects. By contrast, the higher the ratio of crude or refined oil net exports to GDP, the worse for welfare—a 1 p.p. increase in one of these ratios diminishes the welfare effect by 0.9 p.p. and 0.7 p.p., respectively. These can be called terms-of-trade effects. Finally, the existence of emission caps and pricing constrains welfare gains by 1.4 p.p. The latter result differs to some extent from the conclusions based on comparison of LowOil60 and NoCarbonCap scenarios. Possibly, this is because the parameter estimate for the Cap variable may capture the effects of other EU specific factors, not controlled by the remaining regression variables.

As an addition to the approach of Dixon et al. (2007), Figure 10 presents a decomposition of welfare effects. The points indicate welfare effects of lower fuel prices for the LowOil60 scenario, while the bars show how different characteristics of the regions drive these effects. The dominant drivers are terms of trade, dependent on net exports of crude oil and with pronounced negative contributions for net oil exporters, and the production cost effect related to lower oil prices (variable OilShr). For some countries (the Baltic countries, Bulgaria, and Greece), a surplus or deficit in refined oil products trade explains welfare effects significantly. Finally, some countries (most notably China, India and the Eastern European economies) record relatively high benefits of low coal prices, due to their high reliance on coal. The residual part in each bar reflects the fact that the simple pattern captured by regression equation does not

comprise all the complex relationships inherent in the CGE model simulations. For example, the regression equation does not capture the relatively high competitiveness gains of the Russian chemical industry. Nonetheless, the results of this exercise support the conclusions resulting directly from the CGE model simulations.

Figure 10
Determinants of Welfare Responses to Fuel Price Shock



Source: Own calculations

Annex I: Dimensions of the PLACE Model: Sectors and Regions

Sectors

Abbreviation		Sectors	EU ETS	EITE
Energy Sectors				
1	COL	Coal (mining and agglomeration of hard coal, lignite and peat)	**X**	
2	CRU	Crude oil (extraction of crude petroleum, service activities excluding surveying)	**X**	
3	GAS	Primary gas production (extraction of natural gas, service activities excluding surveying)	**X**	
4	GDT	Gas manufacture and distribution (distribution of gaseous fuels through networks, production of town gas)	**X**	
5	OIL	Refined products (coke oven products, refined petroleum products, nuclear fuels)	**X**	**X**
6	ELE	Electricity and heating (production, collection, and distribution)	**X**	
Non-Energy Sectors				
7	FRS	Forestry (forestry, logging, and related services)		
8	BIO	Biofuels agriculture (paddy rice, wheat, other grains, oilseeds, sugar cane and beet, vegetable oils)		
9	AGR	Rest of agriculture and fishing (vegetables and fruits, plant fibers, other crops, cattle, other animal products, raw milk, wool, fishing)		
10	FOO	Food industry (beverages, tobacco, cattle meat, other meat, milk, processed rice, sugar, other food)		
11	CHM	Chemical industry (basic chemicals, rubber and plastics, other chemicals)	**X**	**X**
12	NMM	Non-metallic minerals (cement, lime, ceramic, glass, gypsum, plaster, gravel, concrete)	**X**	**X**
13	ISI	Iron and steel industry (basic production and casting)	**X**	**X**
14	NEM	Non-ferrous metals (production and casting of: copper, aluminum, zinc, lead, gold, silver)	**X**	**X**
15	PPP	Paper–pulp–print (including publishing, printing)	**X**	**X**
16	CON	Construction (building houses, factories, offices, roads)		
17	OTH	Other manufacturing (textiles, clothing, leather, lumber, fabricated metal products, motor vehicles, other transport equipment, electronic equipment, other machinery, recycling, other mining: metal ores, uranium, gems)		
18	SRV	Services (water distribution, trade, hotels and restaurants, communications, financial intermediation, insurance, real estate, recreational, cultural and sporting activities, public administration and defense, social security, health and social work, sewage and refuse disposal, sanitation, dwellings)		
19	ATR	Air transport	**X**	
20	TRN	Other transport (water and land transport, travel agencies)		

Regions

Abbreviation	Country	Abbreviation	Country	Abbreviation	Country
AUT	Austria	**FRA**	France	**NLD**	Netherlands
BEL	Belgium, Luxembourg	**GBR**	Great Britain	**POL**	Poland
BGR	Bulgaria	**GRC**	Greece, Cyprus	**PRT**	Portugal
CZE	Czech Republic	**HRV**	Croatia	**ROM**	Romania
DEU	Germany	**HUN**	Hungary	**SVK**	Slovakia
DNK	Denmark	**IRL**	Ireland	**SVN**	Slovenia
ESP	Spain	**ITA**	Italy, Malta	**SWE**	Sweden
EST	Estonia	**LTU**	Lithuania		
FIN	Finland	**LVA**	Latvia		

Abbreviation	**Countries included**
AUS	Australia, New Zealand
BRA	Brazil
CHN	China
EFT	**EFTA countries involved in EU ETS:** Norway, Liechtenstein, Iceland
IND	India
JPN	Japan
OPE	**OPEC countries**: Saudi Arabia, Ecuador, Venezuela, Nigeria, United Arab Emirates, Iran, Kuwait, Qatar, Algeria, Libyan Arab Jamahiriya, Angola, Western Sahara, Congo
RUS	Russia
USA	United States of America, Canada
RWW	**Rest of the World**: Indonesia, Switzerland, Ukraine, Belarus, Moldova, Georgia, Azerbaijan, Armenia, Turkey, Albania, Bosnia and Herzegovina, Montenegro, Serbia, Andorra, Faroe Islands, Gibraltar, Guernsey, Vatican, Jersey, Monaco, San Marino, Hong Kong, South Korea, Taiwan, Singapore, Bahrain, Israel, Oman, Other North America countries, Mongolia, Lao People's Democratic Republic, Malaysia, Philippines, Thailand, Vietnam, Mexico, Argentina, Bolivia, Chile, Colombia, Paraguay, Peru, Uruguay, Costa Rica, Guatemala, Honduras, Nicaragua, Panama, Salvador, Kazakhstan, Egypt, Morocco, Tunisia, Cameroon, Côte d'Ivoire, Ghana, Senegal, Mauritius, Zimbabwe, Botswana, Namibia, Republic of South Africa, Rest of Southern-Eastern Asia, Rest of former USSR, Rest of Southern America, Rest of Central America, Rest of Western Asia, Rest of Oceania, Caribbean, Cambodia, Bangladesh, Nepal, Pakistan, Sri Lanka, Kyrgyzstan, Ethiopia, Kenya, Madagascar, Malawi, Mozambique, Tanzania, Uganda, Zambia, Rest of Eastern Asia, Rest of Western Africa, Central Africa, Rest of South-African Customs Union, Rest of Southern Asia, Rest of Eastern Asia

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