UNITED NATIONS UNIVERSITY

UNU-WIDER

World Institute for Development Economics Research

Working Paper No. 2012/65

Implications of Alternative Mitigation Policies on World Prices for Fossil Fuels and Agricultural Products

Sergey Paltsev*

July 2012

Abstract

Emissions mitigation policies affect prices, including prices for fossil fuels and agricultural products. Consumer prices for coal and natural gas are expected to rise when climate policy is implemented, while oil prices may be reduced or remain the same in comparison to a no policy scenario. Impacts on agricultural prices are more controversial as reduced negative productivity impacts on yields are compensated by increased costs of energy inputs to agriculture, lower CO_2 fertilization effect, and a competition for land from biofuels. In most of the mitigation scenarios considered in the paper, mitigation policies increase agricultural prices in comparison to the no policy scenario.

Keywords: climate change mitigation, fuel prices, agricultural prices, biofuels, computable general equilibrium

JEL classification: Q54, Q47, Q18

*Massachusetts Institute of Technology, The MIT Joint Program on the Science and Policy of Global Change, email: paltsev@mit.edu

This study has been prepared within the UNU-WIDER project on Development under Climate Change, directed by Channing Arndt.

UNU-WIDER gratefully acknowledges the financial contributions to the project by the Finnish Ministry for Foreign Affairs and the Swedish International Development Cooperation Agency—Sida, and the financial contributions to the research programme by the governments of Denmark (Ministry of Foreign Affairs), and the United Kingdom (Department for International Development).

ISSN 1798-7237 ISBN 978-92-9230-528-4

Acknowledgements

The paper is prepared for the Development under Climate Change project by the World Institute for Development Economics Research at the United Nations University (UNU-WIDER). The author is thankful to Channing Arndt, Kenneth Strzepek, and James Thurlow for their valuable comments. The EPPA model used in the analysis is supported by a consortium of government, industry, and foundation sponsors of the MIT Joint Program on the Science and Policy of Global Change (the full list is available at: http://globalchange.mit.edu).

UNU World Institute for Development Economics Research (UNU-WIDER)
Katajanokanlaituri 6 B, 00160 Helsinki, Finland

Typescript prepared by Lisa Winkler at UNU-WIDER

1 Introduction

Climate change may pose substantial risks to natural and human systems (IPCC 2007). Policies that mitigate climate change involve a reduction in greenhouse gas (GHG) emissions. A major share of the total GHG emissions is related to fossil fuels and agriculture. Emission-reducing activities change prices of goods, and some goods may become more expensive, while some goods may become cheaper. The directions and magnitudes of changes depend not only on a situation in particular markets, but they are also greatly affected by inter-linkages with other markets. In this paper we focus on the impacts of mitigation policies on the prices for fossil fuels and agriculture. To capture inter-dependencies between different markets, regions, and agents, we employ a computable general equilibrium (CGE) approach that is well-suited to study economywide linkages and impacts.

We use the MIT emissions prediction and policy analysis (EPPA) model (Paltsev et al. 2005), augmented to consider land use and land use change as described in Gurgel et al. (2007). As pricing mechanisms of mitigation policies are directed toward a reduction in fossil fuels use, their prices to consumers are expected to increase to induce their lower use. An option to use biofuels to replace fossil fuels creates a strong link between fuel and agricultural prices as both biofuels and agricultural products compete for land. Climate affects productivity of land, therefore, different climate trajectories can directly affect agricultural prices.

There are numerous studies that explore how prices might be influenced by climate policies. For goods that contain carbon (like fossil fuels), carbon pricing creates a wedge between the producer prices and the costs to consumers, as consumers also face an additional charge associated with the carbon content of the good. Clarke et al. (2007) found that the prices that producers get for oil and coal are lower with tighter emissions control scenarios, but natural gas price trajectory is more complex with a possible increase due to substitution for coal and oil in the scenarios with less stringent emission-reducing targets, and natural gas producer price decrease at more stringent emissions targets when low- or zero-carbon technologies displace natural gas. Clarke et al. (ibid.) do not report consumer prices for fuels but based on the table they provide for a relationship between carbon price and energy price, consumer prices for fuels are generally increasing when climate stabilization policies are introduced. Based on calculations for the Kyoto Protocol targets, Radetzky (2002) argued that the producer prices for fossil fuels will stay the same as the producers will adjust production capacity to the changes in demand. The International Energy Agency (IEA 2010) assumed in the scenario when strong emissions reductions are introduced (450 Scenario) that import prices for fossil fuels (which are defined as consumer prices exclusive of fuel taxes) are going to be lower in comparison to the current policies scenario.

Impacts of climate-related policies on agricultural prices are even more controversial and complex. Most of the recent discussion in the literature is focused on a relationship between biofuel policies and food prices, a debate induced by the food price crisis of 2008. Based on a literature review, Gerber et al. (2008) argued that the 'non-biofuel' sources account for a larger share of the food price increase than biofuels. Birur et al. (2008), based on a CGE model, found that medium-run market prices for biofuel feedstock (grains, oilseeds, and sugarcane) increased by about 10 percent due to the biofuel policies in 2001–06. Abbott et al. (2009) provided a review of studies where biofuels are one of the drivers of food price increases, but other key drivers are crop supply, exchange rates and macroeconomic factors. Baier et al. (2009) found that although biofuels had a noticeable impact on individual crop prices, they had a much smaller impact on global food prices, where 90 percent of the rise comes from factors other than biofuels. Chakravorty et al. (2011) used the model to arrive at the conclusion that a third of the increase in food prices are due to the clean energy mandates of biofuels, while two-thirds of the increase can be attributed to changes in consumption patterns.

Studies that look at a more extended time horizon also showed different outcomes. Paltsev et al. (2009) constructed a climate mitigation policy scenario to 2100 where an increase in crops, food, and livestock prices of around 5 percent relative to no climate policy scenario is attributable to biofuels' competition for land. On the contrary, Nelson et al. (2010) constructed scenarios to 2050 where agricultural prices are lower in the scenarios with mitigation due to a reduction in negative productivity effects of climate change. Babcock (2009) argued that benefits to agriculture from providing carbon offsets to other sectors of the economy will be modest and that the farmers will be able to pass to consumers most of the costs associated with higher prices for energy-intensive inputs when climate policies are introduced. Gurgel et al. (2011) provided simulation results up to 2100 where they explored how responsive agriculture technology is to rising land prices. In the scenarios with both low and high elasticity, crop, livestock, and food prices showed considerable increases in emissions mitigation scenarios.

Most of the surveys indicate that it is difficult to reconcile the various calculations and provide a clear comparison as different studies are done with a different set of assumptions, for different scenarios, and for different projection horizons. The goal of this paper is to provide a consistent set of price impacts based on the same model and for a consistent set of long-term scenarios.

The paper is organized in the following way. In the next section we describe the model and scenarios. Section 3 discusses the impact on fossil fuel prices. In Section 4 we look at agricultural prices in different scenarios of climate change mitigation. Section 5 provides a sensitivity analysis with respect to cost of biofuels and Section 6 concludes.

2 Model and scenarios

In this study we use the MIT emissions prediction and policy analysis (EPPA) model.[1] It is a dynamic recursive general equilibrium model of the world economy, built on the global trade analysis project (GTAP) database (Narayanan and Walmsley 2008) and additional data about GHG and other pollutant emissions. The EPPA model considers a long-run simulation horizon (2005 to 2100) and the treatment of the main GHG gases (CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6). The model also allows the evaluation of economic impacts from mitigation policies, including welfare and equity measures.

The GTAP data in the EPPA model is aggregated in 16 regions and 21 sectors (Table°1). EPPA also disaggregates the GTAP data for transportation to include

1 Paltsev et al. (2005) presents a detailed description of the EPPA model.

household transport (i.e., personal automobile), the electricity sector to represent existing supply technologies (e.g., hydro, nuclear, fossil), and includes several alternative energy supply technologies, as for example second generation biomass or carbon capture and storage (CCS), not extensively used or available in the benchmark year of the model (2004), but that could potentially be demanded at larger scale in the future depending on energy prices and/or climate policy conditions. To represent such technologies, the model takes into account detailed bottom-up engineering parameters. The parameterization of these sectors is described in detail in Paltsev et al. (2005).

In each period, production functions for each sector and regions describe how capital, labor, land, energy, and other intermediate inputs are combined to obtain goods and services. The model represents a number of primary factors to be able to better characterize the supply and demand of energy and alternative technologies to fossil fuels. The EPPA model is formulated as a mixed complementarity problem in the General Algebraic Modeling System GAMS software and solved using the Mathematical Programming System for General Equilibrium modeling language (Rutherford 1995).

The model closure in each period considers a fixed endowment of primary factors in each region, which is free to move among sectors, except for the non-malleable fraction of the capital.[2] Land is used only in the agricultural sectors and to grow natural vegetation. One land use type can be converted to another if the full conversion costs are paid. Fossil fuel resources, as also nuclear and hydro resources, are specific to the energy sectors using them. The model does not consider unemployment and prices are flexible. From the demand side, the marginal propensity to save is constant and regionally specified, given the benchmark share of savings in the aggregate household expenditure. The international capital flows that compensate the trade imbalances are exogenously specified to smoothly decline through time. It means that an implicit real exchange rate will adjust in each period to accommodate changes in export and import flows. The government expenditure reacts to changes in relative prices, and the tax revenue is subject to the level of the economic activity.

The model also considers the land competition for alternative uses. Each land type area can be converted to another type or removed from agricultural production to a non-use category (secondary vegetation). Land is also subject to exogenous productivity improvements, reflecting assessment of this potential (Reilly and Fuglie 1998). Land use conversion is achieved by assuming that 1 hectare of land of one type is converted to 1 hectare of another type, assuring consistency between the physical land accounting and the economic accounting in the general equilibrium setting, and the marginal conversion cost of land from one type to another is equal to the difference in value of the types, with real inputs being added during the conversion process through a land transformation function, following Gurgel et al. (2007). Conversion of natural forest areas to agriculture produces timber and other forestry products.

---

[2] The non-malleable fraction of the capital is specific to the sector and used in fixed proportions to other inputs. It allows representing the short-run rigidity in technology and fixed investments, what is particularly important in the case of energy suppliers, as electricity power facilities, which can make very few changes in its capacity and inputs mix once its operation starts.

Table 1: Regions, sectors and primary factors in the EPPA model

Regions	Sector	Primary Factors
United States (USA)	*Non-energy*	Capital
Canada (CAN)	Crop (CROP)	Labor
European Union (EUR)	Livestock (LIVE)	Cropland
Japan (JPN)	Forestry (FORS)	Pasture
East Europe (ROE)	Food (FOOD)	Harvested forest*
Australia and New Zealand (ANZ)	Services (SERV)	Natural grass
Brazil (BRA)	Energy intensive (EINT)	Natural forest
	Other industry (OTHR)	Oil
Russia (RUS)	Industrial transportation (TRAN)	Shale oil
India (IND)	Household transportation (HTRN)	Coal
Africa (AFR)	*Energy*	Natural gas
China (CHN)	Coal (COAL)	Hydro
Middle East (MES)	Crude oil (OIL)	Nuclear
Rest of Asia (REA)	Refined oil (ROIL)	Solar and wind
Mexico (MEX)	Natural Gas (GAS)	
Latin America (LAM)	Liquid fuel from biomass (BOIL)	
Fast growing Asia (ASI)	Oil from Shale (SOIL)	
	Electricity: fossil (ELEC)	
	Electricity: hydro (H-ELE)	
	Electricity: nuclear (A-NUC)	
	Electricity: wind (W-ELE)	
	Electricity: solar (S-ELE)	
	Electricity: biomass (biELE)	
	Electricity: natural Gas Combined Cycle (NGCC)	
	Electricity: NGCC-with CCS	
	Electricity: integrated gasification combined cycle (IGCC) with CCS	

Notes: *Includes managed forest areas for forestry production as also secondary forests from previous wood extraction and agricultural abandonment (natural vegetation regrowth).

The base year of the EPPA5 is 2004. The model simulates the economy recursively at 5-year intervals from 2005 to 2100. Economic development in 2005 and 2010 is calibrated to the actual GDP growth data. Future scenarios are driven by economic growth that results from savings and investments and exogenously assumptions about the productivity improvement in labor, energy, and land. Growth in demand for goods produced from each sector including food and fuels occurs as GDP and income grow. The use of depletable resources decreases its stocks, driving production to higher cost grades. Sectors that use renewable resources such as land compete for the available flow of services from them, generating rents. These together with policies, such as constraints in the amount of greenhouse gases, change the relative economics of different technologies over time and across scenarios. The timing of entry of advanced technologies, such as cellulosic biofuels, is endogenous when they become cost competitive with existing technologies.

To provide an assessment of the impacts of mitigation policies we consider the following scenarios: no climate policy (Reference) scenario and three stabilization scenarios framed as departures from the Reference scenario achieved with specific policy instrument, notably a global cap-and-trade system with emissions trading among all regions beginning in 2015. The stabilization levels are chosen so that the associated CO_2 concentrations would be approaching roughly 650, 550, and 450 ppm by 2100. Lower stabilization levels allow for lower cumulative GHG emissions over the 21st century, so fossil fuel use is also lower at more stringent targets.

The climate implications of these scenarios are discussed in detail in Prinn et al. (2011), where by 2100 the global mean temperature increases by 5.8 ºC relative to 2000 in the No Policy scenario, while climate stabilization at 450 ppm leads to 1.8 ºC increase relative to 2000; 650 and 550 ppm scenarios lead to 3.1 and 2.5 ºC increases, correspondingly. Next we focus on examining the implications of alternative mitigation policies on world prices for fossil fuels and agricultural products using the EPPA model. In this paper we discuss the prices of fossil fuels (oil, coal, and natural gas) and agricultural products in the aggregate.

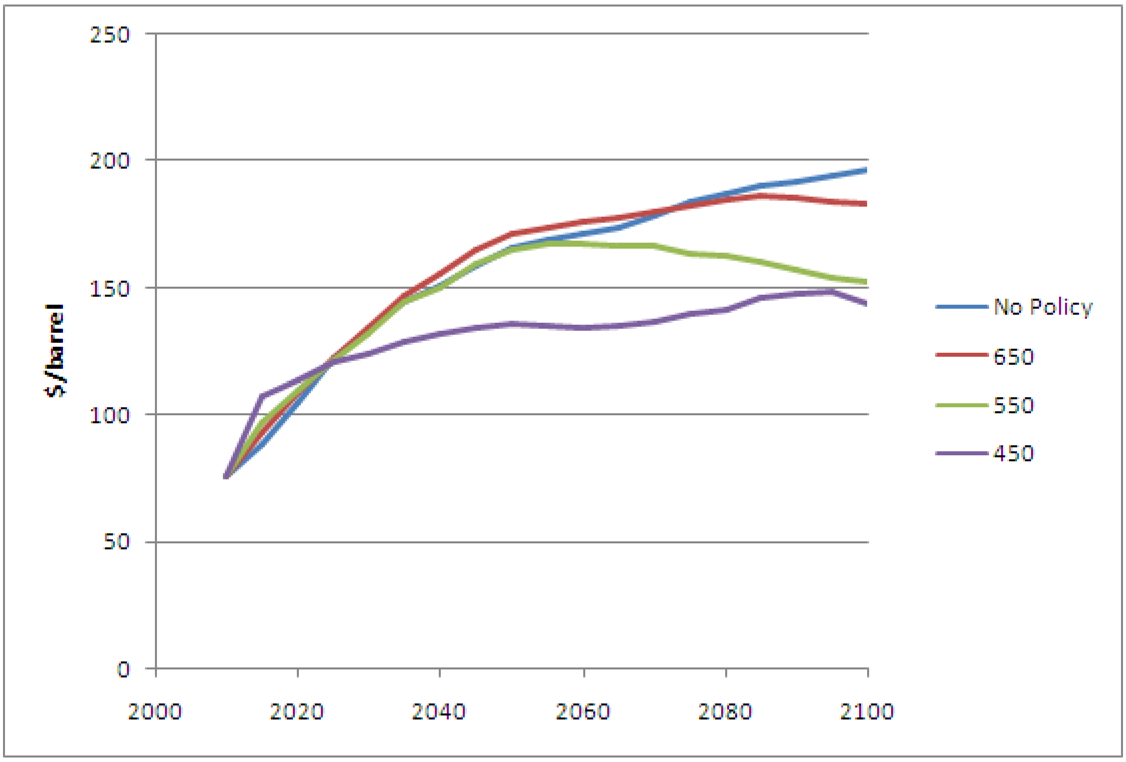
3 Fossil fuel prices

The prices of fossil fuels are determined by interaction of supply of fossil fuel and demand for it, considering interactions with alternative fuels that can substitute for fossil fuel. As fossil fuel resources deplete, cost of production for additional resources is rising. On the demand side, technological progress improves energy efficiency. In addition to consumer response to rising energy prices, they also lower their use of energy per unit of production or consumption due to non-price induced energy efficiency improvement. A detailed description of modeling these mechanisms in the EPPA model is provided in Paltsev et al. (2005). As mentioned, there are two sets of prices for fossil fuels—those that producers get net of carbon charge and those that consumers pay including carbon charge. We report all prices in real 2005 US dollars as they are determined by the EPPA model. We report global average prices. In reporting producer prices we have not netted any fuel taxes or other charges and levies except for carbon charge.

We start with consumer prices for oil in different scenarios, provided in Figure 1. In the Reference (No Policy) scenario oil prices continue to rise due to oil depletion. On the demand side, there is increased use driven by the Asian region, mostly by China and India in the first half of the century, and by Africa and the Middle East in the second part of the century due to population and income growth. The oil price reach $165/barrel in 2050 and rise to about $200/barrel in 2100 in the Reference scenario: 650 ppm policy does not substantially change the oil price profile up to 2080; 550 ppm policy see lower consumer price relative to the no policy situation by 2040–45 and after. In 450 ppm scenario, consumer price has a downward pressure starting in 2030. In 2050 consumer oil prices are around $165/barrel in all considered scenarios except for 450 scenario where oil price in 2050 is around $135/barrel. Consumer prices for oil in 2100 are $200, $180, $150, and $140 in No Policy, 650, 550, 450 scenarios, respectively. So for oil consumers, strong climate mitigation policies bring lower oil prices.

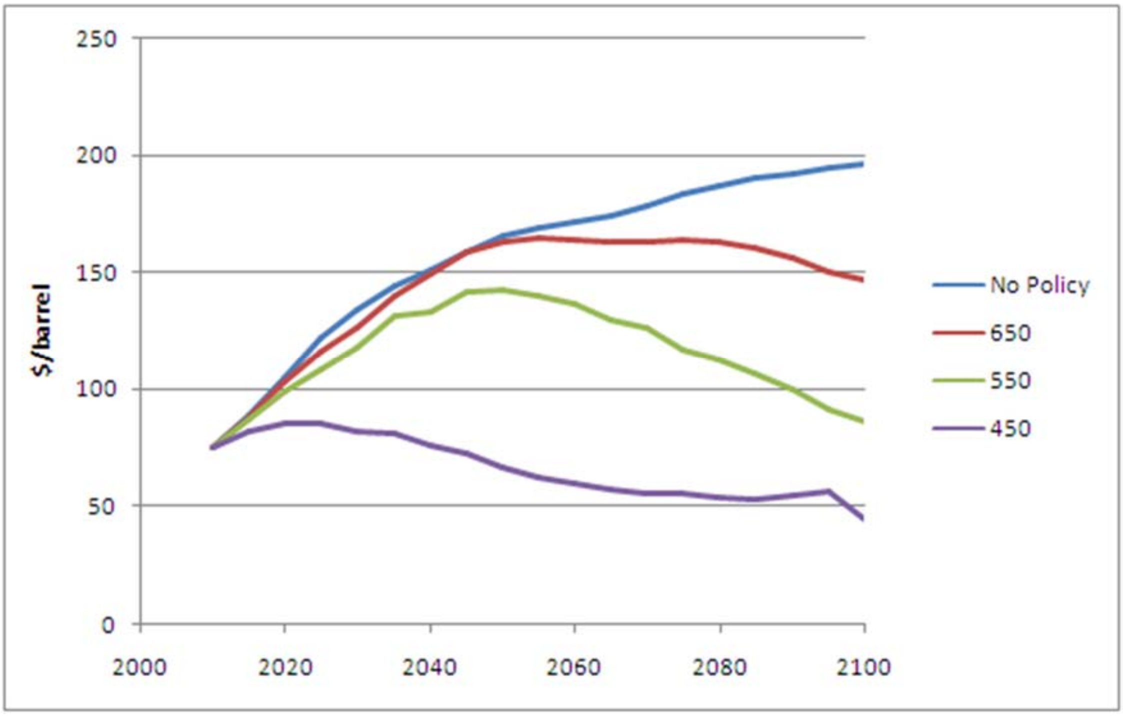
Figure 2 provides the prices net of carbon charge. These are the prices (gross of non-carbon taxes) that oil producers get in different scenarios. In the No Policy (Reference) scenario the prices are the same as those presented in Figure 1 because there is no carbon charge. As there is growing carbon charge in the policy scenarios, consumer and producer price profiles deviate more over time and with more stringent policy target. In 2050, 550 and 450 ppm scenarios give producer price of around $140/barrel and $70/barrel, respectively, in comparison to around $160/barrel in the No Policy and 650 ppm scenario. By 2100 the difference even is bigger, the net of carbon oil prices in the No Policy, 650, 550, and 450 scenarios are $200, $145, $85 and $45/barrel. Producers reduce prices responding to competition from second generation biofuels that do not pay carbon charges and a reduction in demand for oil. For oil producers, climate policies bring lower prices for their products. Because some oil producers have substantial margins between sale prices and cost of production, they are able to adjust their prices and reduce their margins to minimize a reduction in demand for oil.

Figure 1: Consumer (carbon inclusive) oil prices in alternative scenarios



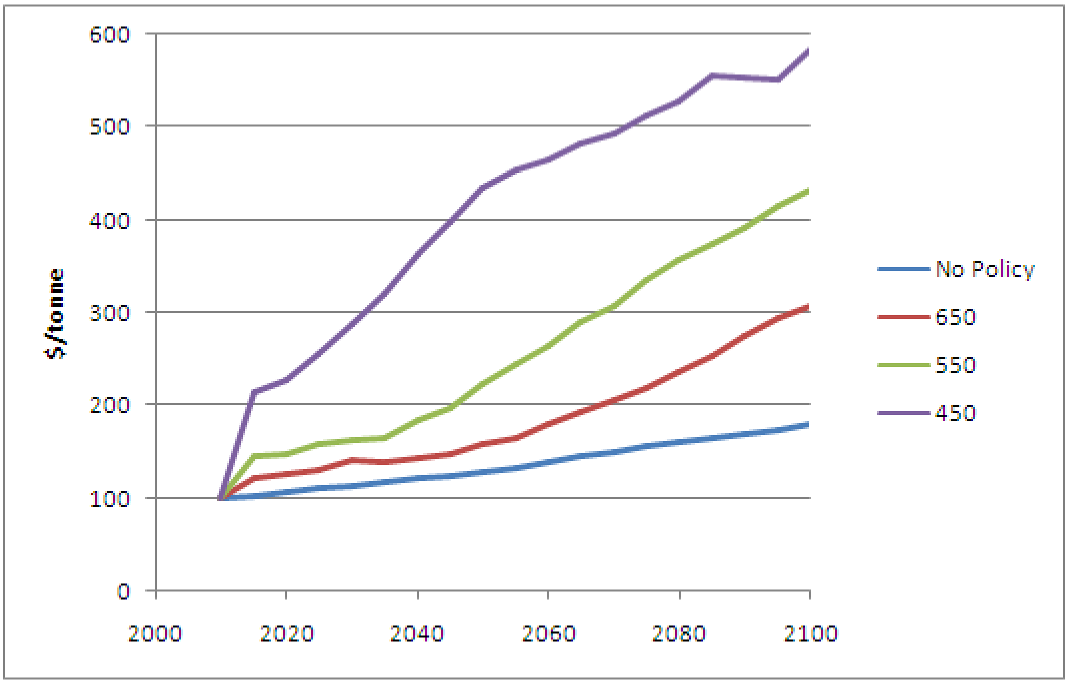
Source: EPPA model results.

Figure 2: Oil prices (net of carbon change) in alternative scenarios



Source: EPPA model results.

Figure 3: Carbon inclusive coal prices in alternative scenarios

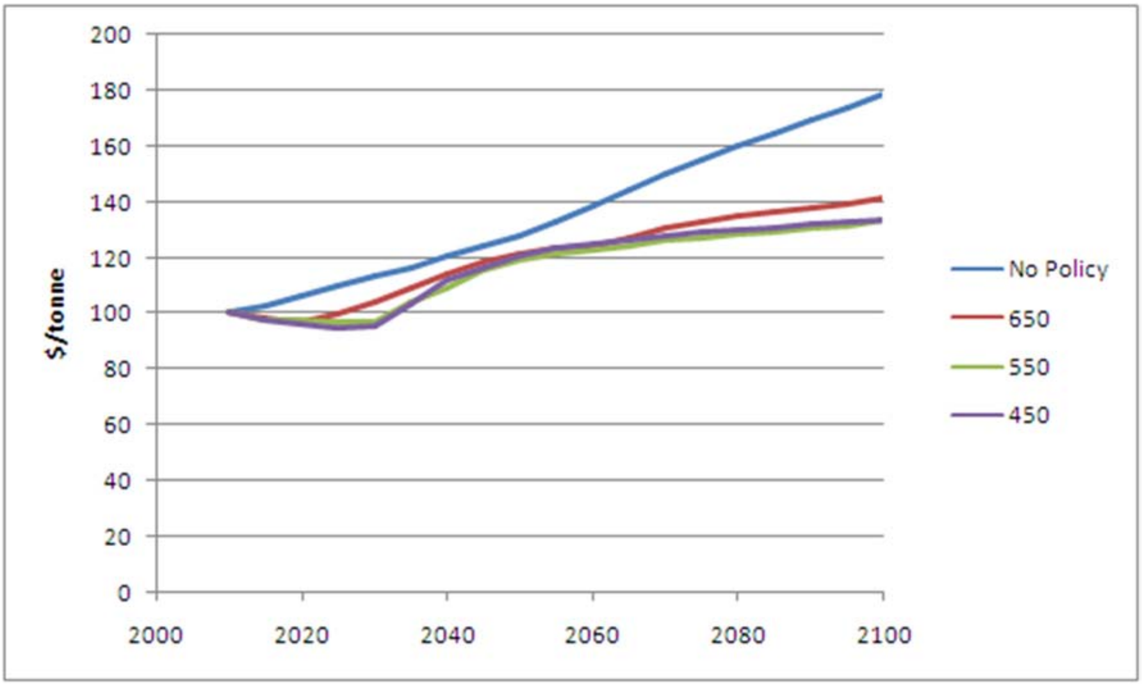


Source: EPPA model results.

Figure 3 shows the consumer coal prices in different scenarios. In the Reference scenario, coal prices grow from about $100/ton in 2010 to about $130/ton in 2050 to about $180/ton in 2100. Coal is the most carbon-intensive fuel out of coal, oil, and natural gas, so it is affected the most by carbon policies. Carbon charge makes coal substantially more expensive for consumers as its prices grow to a range of $300–600/ton by 2100 in different stabilization scenarios. These high prices drive virtually all unabated coal out of the global energy system in the most stringent scenarios, keeping only coal with CCS.

With coal demand drastically reduced coal producers get hit, but unlike the situation in oil markets, coal producers do not have high margins as they are producing at close to marginal cost. A reduction in demand and small coal rents lead to a relatively narrow range of the net of carbon charge prices that coal producers get in the stabilization scenarios. As represented in Figure 4, they range in $130–140/ton in 2100. There is a slight increase in producer prices around 2040 due to appearance of coal with CCS which become economic around that time. So for coal, mitigation policies bring substantially higher prices for coal consumers, while coal producers get lower prices for its products. Carbon charges have the largest impact on coal among the fuels as the fuel price per unit of energy is low and carbon emissions per unit of energy are high.

Figure 4: Coal prices (net of carbon change) in alternative scenarios

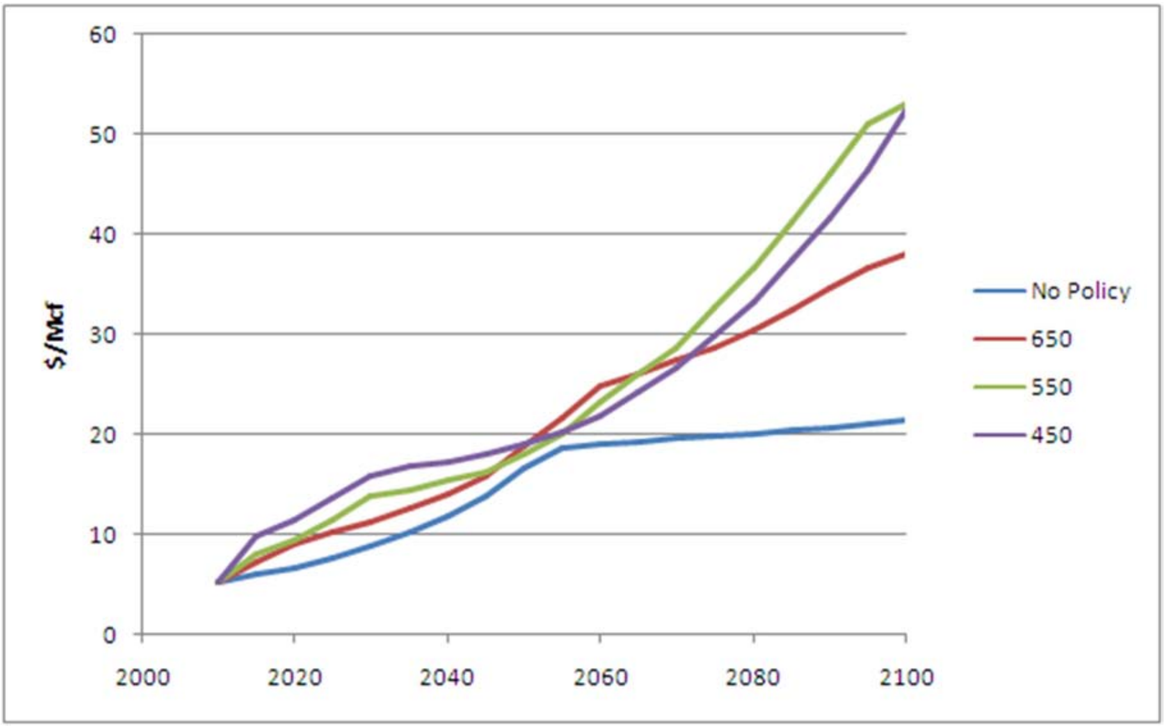


Source: EPPA model results.

The impact of mitigation scenarios on natural gas prices is more complex. Figure 5 presents consumer prices of natural gas in different scenarios. In the Reference scenario, natural gas prices grow from about $5/Mcf in 2010 to about $21/Mcf in 2100. In this scenario, in mid-century coal gasification technology becomes economic, which is reflected by a slower growth in prices in the second half of the century when a substitute technology is available. Basically, it tells that at prices around $20/Mcf coal gasification technology limits further increases in natural gas prices as consumers are not willing to pay higher prices when another option exists that provides the fuel with same qualities.

When mitigation policies are introduced, carbon pricing makes coal more expensive, as discussed above. It results in higher cost of coal gasification technology, which reduces its ability to compete with natural gas. Another effect is driven by a carbon content of natural gas which is lower than for coal and oil. Emissions can be reduced by substituting natural gas for coal and oil. As a result, in climate policy scenarios higher demand for natural gas drives the prices higher to a range of $38–53/Mcf by 2100 for carbon inclusive prices. The differences are visible even in earlier periods. For example, in 2030 natural gas prices in the No Policy, 650, 550, 450 scenarios are $9, $11, $14, $16/Mcf, correspondingly.

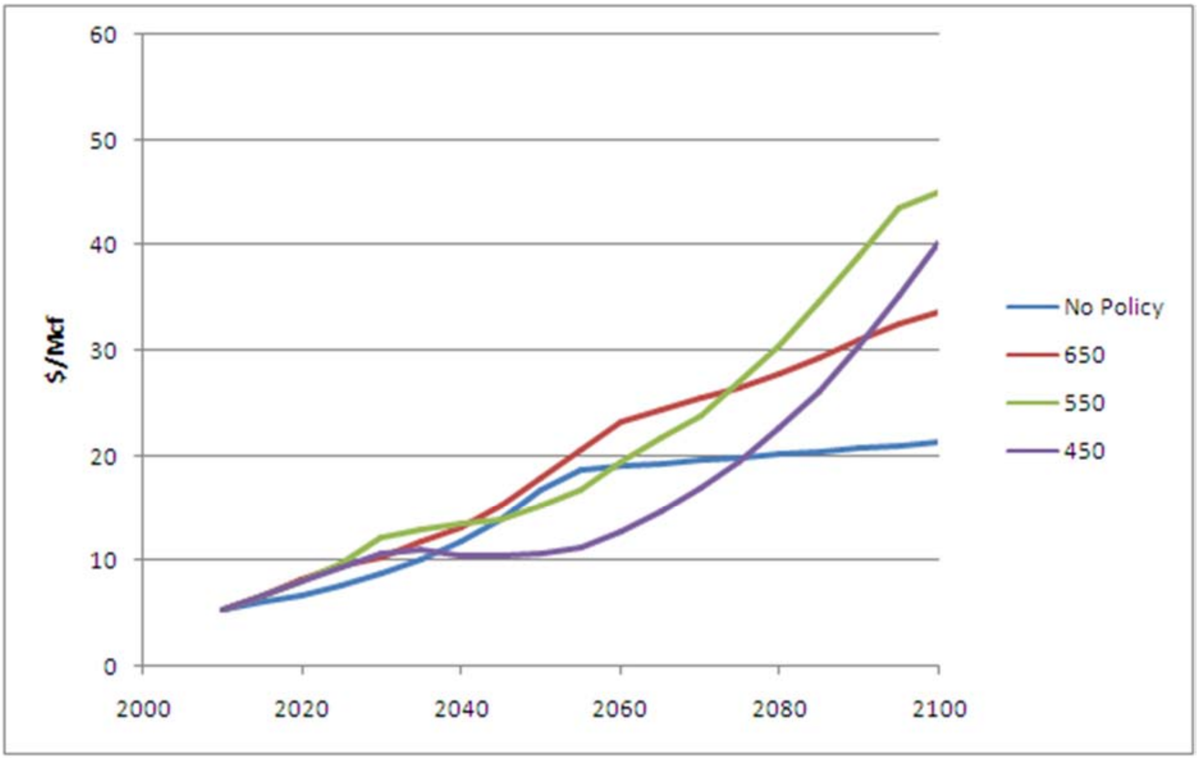
Figure 5: Carbon inclusive natural gas prices in alternative scenarios



Source: EPPA model results.

As for net of carbon prices for natural gas, some producers (like prodders from the Middle East) have substantial margins as in the situation with oil, so they are able to optimize to keep the overall demand to earn the highest profits. As depicted in Figure 6, with less stringent mitigation policy (like 650 scenario), producers are able to get higher prices due to an increase in demand for natural gas as a substitute for coal. Tighter emission targets make natural gas less attractive as it still emits carbon, and there is a need to move to even less carbon emitting technologies (like wind, solar, and bioenergy). Due to intermittency and supply constraints, renewables do not completely substitute for natural gas, and natural gas producer price rises again by the end of the century to $33–45/Mcf in the mitigation policy scenarios.

Figure 6: Natural gas prices (net of carbon change) in alternative scenarios



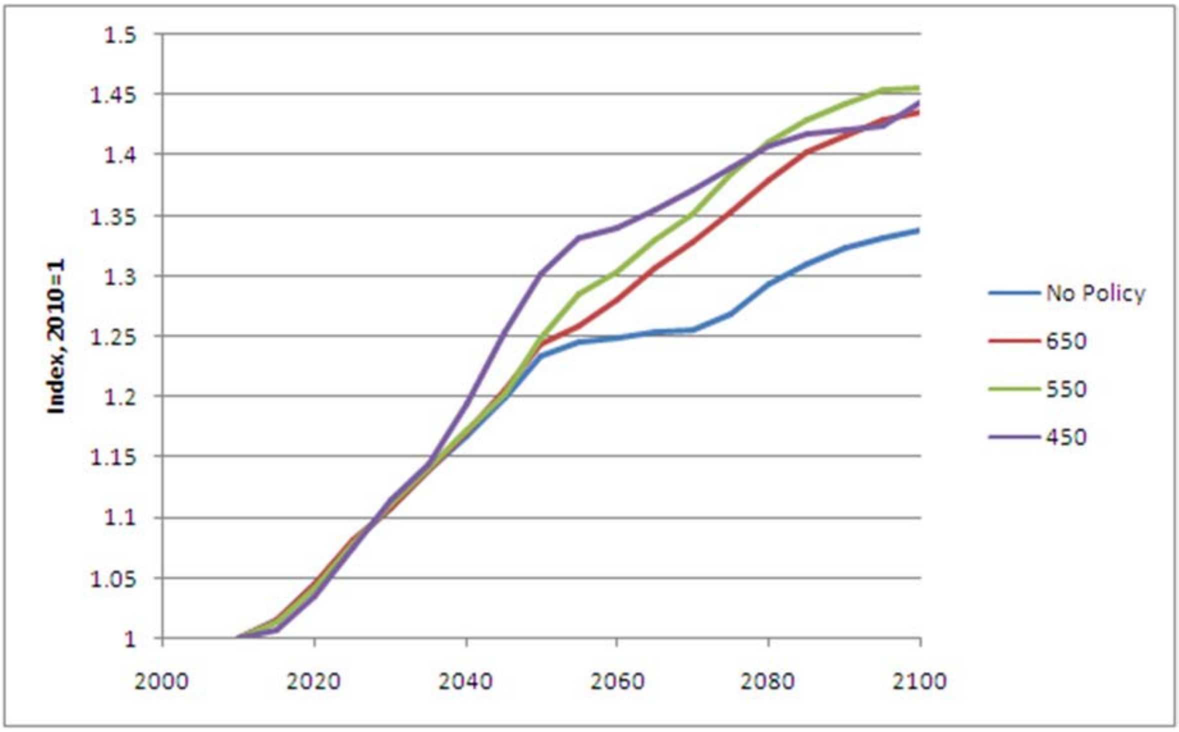
Source: EPPA model results.

Overall, energy consumers should expect to pay higher prices for coal and natural gas and lower prices for oil in emission mitigation scenarios. If a region is abundant with renewable energy and able to move out of coal and natural gas, it may reduce its overall energy payments under a climate policy. Compared to a No Policy situation, fossil fuel producing regions will almost certainly see a reduction in their earnings related to production in exports of fossil fuels.

4 Agricultural prices

As mentioned in the introduction, the impacts of mitigation policies on agricultural prices are controversial. There are many complex interactions that can affect agricultural prices, such as increasing energy prices for inputs to agriculture, change in crop yields due to climate change, CO_2 fertilization effect, ozone damage, relocation of land for different uses, change in patterns of agriculture production due to changes in precipitation and temperature. Some effects will be due to regional changes and some effects will be due to a changing situation in international markets. The resulting signs and magnitudes of price changes depend on how these driving forces interact with each other. Figure 7 shows the resulting impacts in the EPPA model.

Figure 7: Index of agriculture prices in alternative scenarios



Source: EPPA model results.

In the EPPA model agricultural prices include the impacts of carbon pricing. We report global agricultural prices as an index to 2010 (2010 = 1). As shown in Figure 7, the index is not changing drastically in the scenarios that are considered here. It implies that agriculture will be able to adapt to climate change, and that the adaptation potential of the agricultural sector is considerable— most yield effects are offset leaving very little change in agricultural prices. But as discussed in more detail in Reilly et al. (2007), this comes about through resource reallocation from or to the rest of the economy and so focusing only on the changes in the agricultural sector might underestimate damages (or benefits) of the climate change. Another aspect to note is that the price index is rising in the 21st century in all scenarios. This is in contrast to much of the 20th century when real agricultural prices declined. Emissions mitigation policies increase agricultural prices, which means that increases in costs of energy and other inputs as well as increases in land prices due to competition with biofuels outweigh positive gains in yields due to reduced negative impacts of climate change. Agriculture in some regions still might benefit from mitigation policies as they might be influenced by trade effects. Yield effects that are positive for a region, may lead to negative economic effects if the other countries gain more. Or, countries can gain through trade even if yield effects are negative if other regions are more severely affected by, for example, high ozone levels. Thus, analysis that purports to estimate economic effects for a nation or region, absent a consideration of the effects on global markets or interaction with the rest of the economy, may be in error not only in the magnitude of the effect but of its direction.

5 Sensitivity analysis

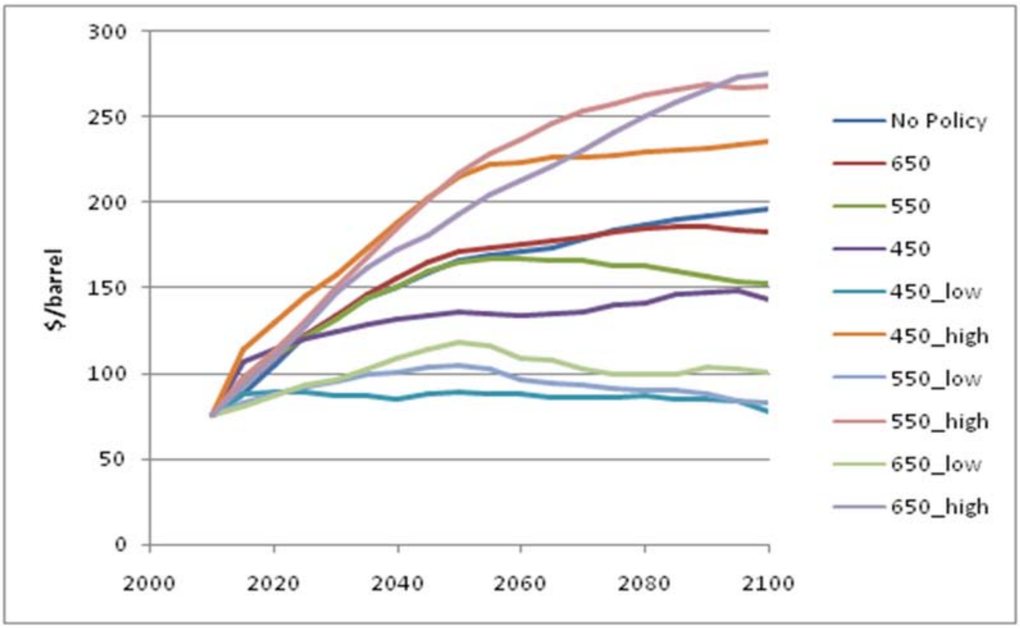
The stabilization scenarios are dependent on many underlying assumptions. In this section we perform a sensitivity analysis with respect to the cost of advanced biofuels.

In the emissions mitigation scenarios that we have discussed above (650, 550, 450 ppm), advanced biofuels are getting competitive when oil prices are around $150/barrel or higher. We add two variants to the mitigation scenarios—'high' and 'low'. In the 'low' scenarios, advanced biofuels become economic when oil price is about $85/barrel, while in the 'high' scenarios biofuels are economic only when oil prices are higher than $220/barrel.

Figure 8 provides the results for consumer prices for oil. As expected, when biofuels are economic at much higher price, consumer prices for oil are rising. In 'high' scenarios oil prices are in the range of $245–275/barrel by 2100, while availability of lower cost biofuels limits price increases to less than $100/barrel in the 'low' scenarios. The prices still rise above the $85 and $220 marks because of biofuels supply constraints.

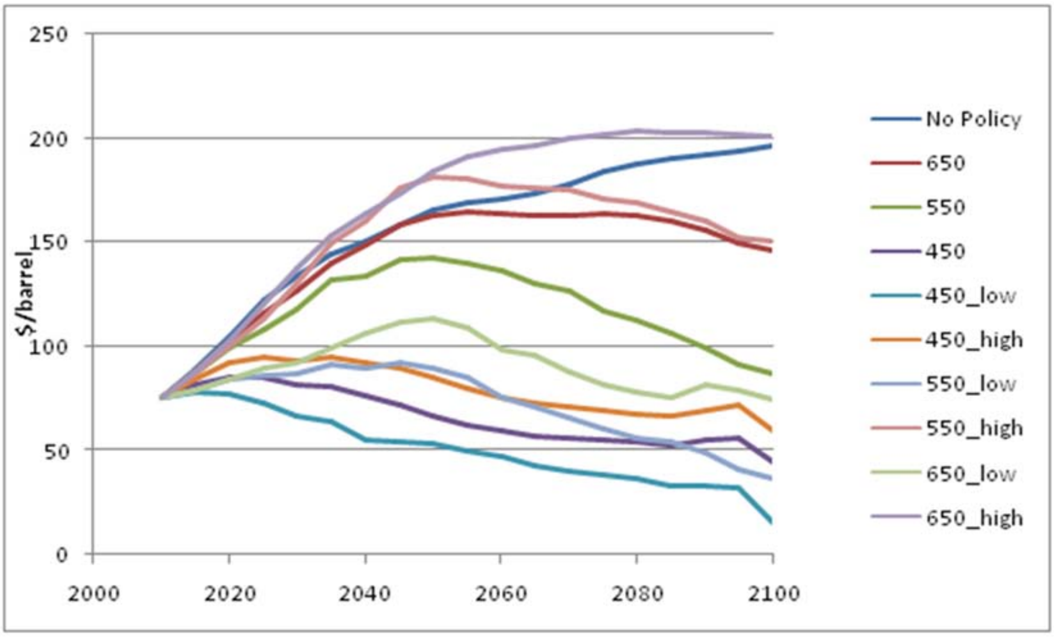
A similar situation is depicted in Figure 9 where net of carbon prices for oil are shown. When relatively cheaper biofuels are available, producer prices are much lower as they are constrained by biofuel substitute. When biofuels are more expensive, oil producers receive higher prices for their products.

Figure 8: Carbon inclusive oil prices in alternative scenarios and different assumptions about biofuels production costs



Source: EPPA model results.

Figure 9: Oil prices (net of carbon change) in alternative scenarios and for different assumptions about biofuels production costs

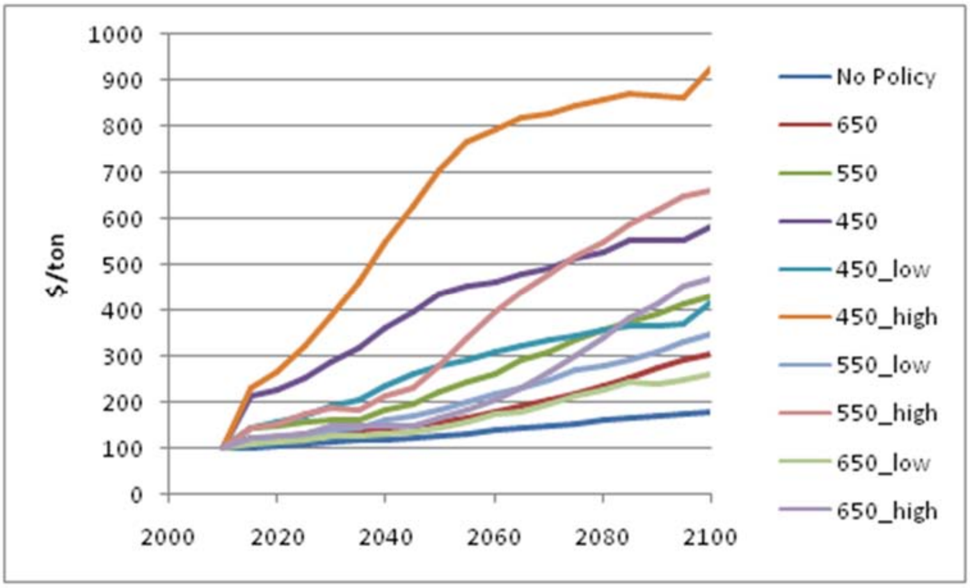


Source: EPPA model results.

Figure 10 shows an interesting aspect of availability of low-carbon alternative technology. Substitution between coal and oil is lower than between oil and biofuels, but biofuels still affect consumers price for coal in mitigation scenarios. If it is harder to get carbon from the transportation sector where most of oil is used, then higher carbon charge and higher coal price is required to achieve the same emission goal. As a result, with no cheap biofuel alternative, oil is reduced by carbon pricing but still widely used. To make up for emission reductions coal is forced out of the energy system by higher carbon prices and higher resulting coal prices. Net of carbon coal prices (not shown here) are still not much different in the 'high' and 'low' scenarios as coal producers do not have much economic rent and price according to marginal cost of production.

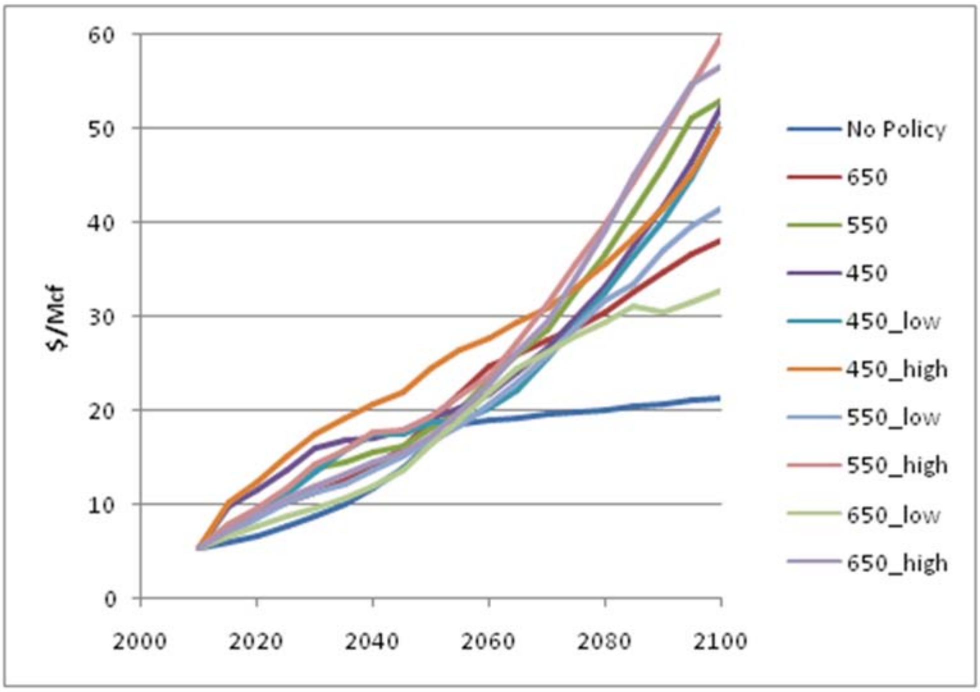
Natural gas prices (Figure 11) also show some sensitivity to assumptions about availability of low-cost biofuels. They are impacted by several channels; higher oil prices make natural gas-based transportation an option, earlier and higher coal prices induce greater substitution of coal for gas. But at tighter emissions constraints even natural gas is 'too dirty' in terms of carbon and to meet the constraints it has to be replaced by even lower carbon options. In general, in the high-cost biofuels scenario, natural gas producers are able charge higher prices.

Figure 10: Carbon inclusive coal prices in alternative scenarios and for different assumptions about biofuels production costs



Source: EPPA model results.

Figure 11: Carbon inclusive natural gas prices in alternative scenarios and for different assumptions about biofuels production costs

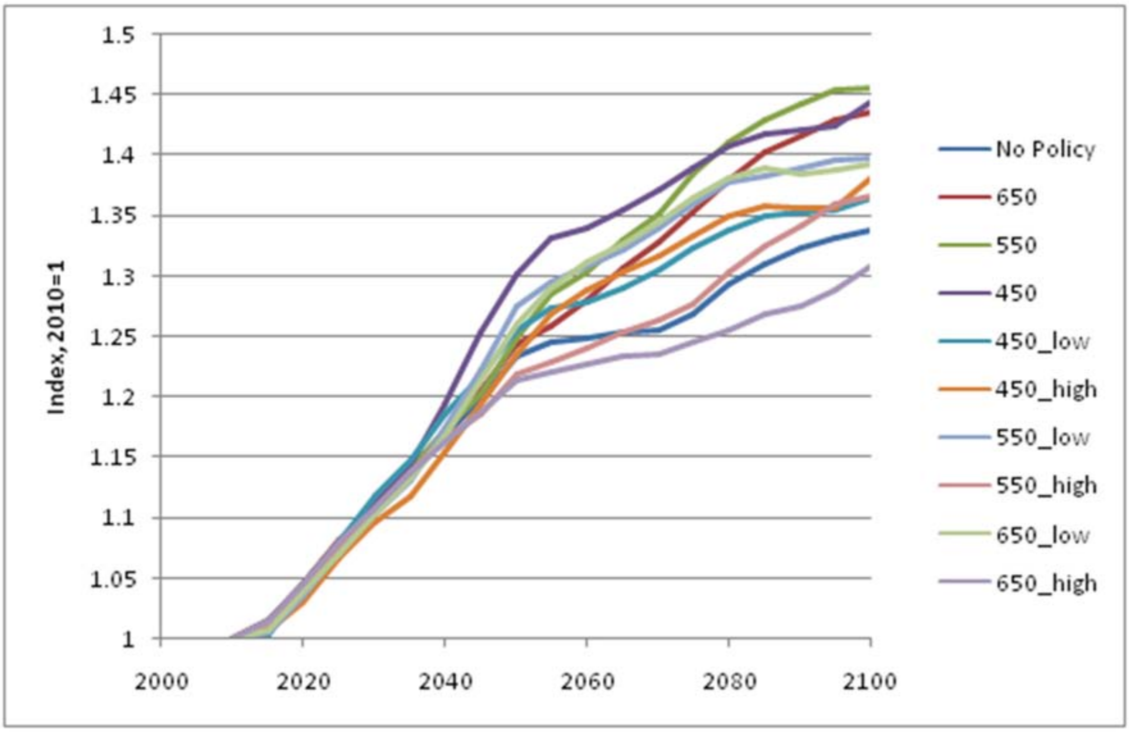


Source: EPPA model results.

Agriculture prices in emissions mitigation scenarios are also sensitive to biofuels production. The resulting effects again depend on many factors, but when biofuels are not as competitive, they are not produced as widely, therefore, relieving some pressure on land use, as more land is available for agriculture. As a result, in 2050 a difference in agriculture price indices between 'high' and 'low' scenarios is 4 percent, 5 percent, and 2 percent for 650, 550, and 450 stabilization scenarios, respectively. By 2100, the difference are 6 percent and 5 percent for 650 and 550 scenarios, while in 450 stabilization scenario other effects play a bigger role and agricultural prices are not that different (in fact they are slightly lower) when cheaper biofuels are available.

Another interesting aspect of our sensitivity analysis is that in the 650 scenario with high cost biofuels agriculture prices are lower than in the No Policy scenario. It comes from the fact that in this scenario costs of fuel inputs have not risen as high, biofuels do not provide additional pressure on land use, and emissions mitigation reduced some negative yield effects of climate change. So while in most of the scenarios emission mitigation policies increase agricultural prices, it is possible that for some scenarios agricultural prices will be lower than in the no-climate policy case.

Figure 12: Index of agriculture prices in alternative scenarios and for different assumptions about biofuels production costs



Source: EPPA model results.

As discussed in Section 4, it should be stressed that we report here global price index while regional prices might differ and some regions might gain while another regions might lose from different mitigation policies. To estimate an impact on a particular region, region-specific studies are required that also consider trade and other links with other regions of the world.

6 Conclusion

Emissions mitigation policies affect prices, including prices for fossil fuels and agricultural products. Consumer prices for coal and natural gas are expected to rise when climate policy is implemented, while oil prices may be reduced or remain the same in comparison to a no policy scenario. Impacts on agricultural prices are more controversial as reduced negative productivity impacts on yields are somewhat compensated by increased costs of energy inputs to agriculture, lower CO_2 fertilization effect, and a competition for land from biofuels. In most of the mitigation scenarios considered in the paper, mitigation policies increase agricultural prices in comparison to the no policy scenario, although we also constructed a scenario with limited biofuels that reduces agricultural prices. The net economic effect due to changes in agriculture, pasture, and forestry productivity are a complex combination of a changing pattern of trade among regions and resource reallocation between the agriculture sector and other sectors of the economy. It should be noted that in this sensitivity analysis we do not assign any probabilities to any particular scenario.

Alternative assumptions about biofuel production costs provide a wider range of potential price paths in the 21st century. Availability of low-cost biofuels puts a downward pressure on fossil fuel prices. At the same time, agriculture prices are generally higher with a larger biofuels production due to a competition for land. In most of the scenarios that we consider here, biofuels increase agriculture prices by 5 percent. However, in some scenarios the impacts are smaller. The results suggest that the adaptation potential of the agricultural sector is quite considerable, at least in the way how it is formulated in the EPPA model.

References

Abbott, P., C. Hurt, and W. Tyner (2009). 'What's Driving Food Prices?'. Farm Foundation Issue Report.

Babcock, B. (2009). 'Costs and Benefits to Agriculture from Climate Change Policy'. *Iowa Ag Review*, 15 (3).

Baier, S., M. Clements, C. Griffiths, and J. Ihrig (2009). 'Biofuels Impact on Crop and Food Prices: Using an Interactive Spreadsheet'. International Finance Discussion Paper 967. Board of Governors of the Federal Reserve System.

Birur, D., T. Hertel, and W. Tyner (2008). 'Impacts of Biofuel Production on World Agricultural Markets: A Computable General Equilibrium Analysis'. Working Paper 53. West Lafayette, Indiana: Purdue University.

Clarke, L., J. Edmonds, H. Jacoby, H. Pitcher, J. Reilly, and R. Richels (2007). 'Scenarios of the Greenhouse Gas Emission and Atmospheric Concentrations'. Sub-report 2.1A. Washington: Department of Energy, Office of Biological and Environmental Research.

Chakravorty, U., M. Hubert, M. Moreaux, and L. Nostbakken (2011). 'Will Biofuel Mandates Raise Food Prices?'. Working Paper 2011–01. University of Alberta: Department of Economics.

Gerber, N., M. van Eckert, and T. Breuer (2008). 'The Impacts of Biofuel Production on Food Prices: a Review'. Discussion Paper on Development Policy 127. ZEF Bonn: University of Bonn.

Gurgel, A., J. Reilly, and S. Paltsev (2007). 'Potential Land Use Implications of a Global Biofuels Industry'. *Journal of Agricultural & Food Industrial Organization*, 5 (9).

Gurgel, A., T. Cronin, J. Reilly, S. Paltsev, D. Kicklighter, and J. Melillo (2011). 'Food, Fuel, Forests and the Pricing of Ecosystem Services'. *American Journal of Agricultural Economics*, 93 (2): 342–48.

International Energy Agency (IEA) (2010). 'World Energy Outlook'. Paris: IEA/OECD.

Intergovernmental Panel on Climate Change (IPCC) (2007). 'Fourth Assessment Report'. Geneva: IPCC.

Narayanan, B., and T. Walmsley (2008). 'Global Trade, Assistance, and Production: the GTAP 7 Data Base'. Center for Global Trade Analysis. West Lafayette, IN: Purdue University.

Nelson, G., M. Rosegrant, A. Palazzo, I. Gray, C. Ingersoll, R. Robertson, S. Tokgoz, T. Zhu, T. Sulser, C. Ringler, S. Msangi, and L. You (2010). 'Food Security, Farming, and Climate Change to 2050: Scenarios, Results, Policy Options'. Washington, DC: International Food Policy Research Institute.

Paltsev S., J. Reilly, H. Jacoby, R. Eckaus, J. McFarland, M. Sarofim, M. Asadoorian, and M. Babiker (2005). 'The MIT Emissions Prediction and Policy Analysis (EPPA) Model: Version 4'. MIT Joint Program on the Science and Policy of Global Change Report 125. Cambridge: MIT.

Paltsev, S., J. Reilly, and Gurgel (2009). 'Commercial Viability of Second Generation Biofuel Technology, in the Biofuels Market: Current Situation and Alternative Scenarios'. Geneva and New York: United Nations.

Prinn, R., S. Paltsev, A. Sokolov, M. Sarofim, J. Reilly, and H. Jacoby (2011). 'Scenarios with MIT Integrated Global System Model: Significant Global Warming Regardless of Different Approaches'. *Climatic Change*, 104 (3–4): 515–37.

Radetzky, M. (2002). 'What Will Happen to the Producer Prices of Fossil Fuels if Kyoto is Implemented?'. *Energy Policy*, 30: 357–69.

Reilly, J., and K. Fuglie (1998). 'Future Yield Growth in Field Crops: What Evidence Exists?'. *Soil and Tillage Research*, 47: 275–90.

Reilly, J., S. Paltsev, B. Felzer, X. Wang, D. Kicklighter, J. Melillo, R. Prinn, M. Sarofim, and C. Wang (2007). 'Global Economic Effects of Changes in Crops, Pasture and Forests Due to Changing Climate, Carbon Dioxide and Ozone'. Energy Policy, 35: 5370–83.

Rutherford, T. F. (1995). 'Extension of GAMS for Complementarity Problems Arising in Applied Economic Analysis'. *Journal of Economic Dynamics and Control*, 19 (8): 1299–1324.