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WPS6515

Policy Research Working Paper 6515

How Much Does an Increase in Oil Prices Affect the Global Economy?

Some Insights from a General Equilibrium Analysis

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Development Research Group
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June 2013

Policy Research Working Paper 6515

Abstract

A global computable general equilibrium model is used to analyze the economic impacts of rising oil prices with endogenously determined availability of biofuels to mitigate those impacts. The negative effects on the global economy are comparable to those found in other studies, but the impacts are unevenly distributed across countries/regions or sectors. The agricultural sectors of high-income countries, which are relatively energy intensive, would suffer more from rising oil prices than would those in lower-income countries, whereas the reverse is true for the impacts across manufacturing sectors. The impacts are especially strong for oil importers with relatively energy-intensive manufacturing and trade, such as India and China. Although the availability of biofuels does mitigate some of the negative impacts of rising oil prices, the benefit is small because the capacity of biofuels to economically substitute for fossil fuels on a large scale remains limited.

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Produced by the Research Support Team

How much does an increase in oil prices affect the global economy? Some insights from a general equilibrium analysis

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Key words: Oil price, CGE model, Global economy, International trade

JEL Classification: Q43

Sector: Energy and Mining

How much does an increase in oil prices affect the global economy?
Some insights from a general equilibrium analysis

Govinda R. Timilsina[1]

1. Introduction

A good understanding of adverse impacts of oil price rise in an economy is essential to design policy responses to reduce those impacts. However, the impact of oil price shocks on the global economy is debated in the literature. A significant body of literature argues that the overall economy is sensitive to the prices of oil. For example, Sanchez (2011) shows, using a dynamic computable general equilibrium model, that the oil price rise during the 2002-2008 period would have caused a decrease of 2% to 3% of GDP annually in six oil importing countries (Bangladesh, El Salvador, Kenya, Nicaragua, Tanzania and Thailand). Similarly, using a CGE model, Aydın and Acar (2011) show that a doubling of oil prices could cause 14% loss of economic outputs in Turkey in 10 years. Using Multivariate VAR analysis, an econometric technique, Jimenez-Rodrıguez and Sanchez (2005) find that an increase in oil prices would negatively impact GDP in OECD countries; the impacts of oil price decline would be, however, smaller compared to that of rising oil prices. Hamilton (2011) uses time series analysis to find nonlinear but significant effects of sudden and relatively short-term oil price shocks on US GDP since World War II.

Other studies show less of a relationship between oil price increases and economic growth. Balke, Brown and Yucel (2008) find a much weaker impact of oil prices on US GDP since the 1990s compared to the 1970s and 1980s. Using a stochastic dynamic general

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equilibrium model, they conclude that domestic drivers rather than oil price shocks are primarily responsible for explaining US GDP fluctuations more recently. Kilian (2008) argues based on time series estimates that the GDP impacts of oil price shocks depend significantly on whether the observed oil price changes were exogenous or endogenously induced by other factors.

This study uses a multi-country, multi-sector, recursive dynamic, global computable general equilibrium model to examine the impact of projected oil price increases on the global economy as well as specific regional/national economies. The model differs from existing ones in that it models the land-use sector in depth by disaggregating land supply in each country or region into 18 agro-ecological zones. It also explicitly represents major biofuels and their feedstock, and explicitly models the tradeoff between fossil fuels and biofuels so that the indirect effects of oil price on the agricultural sector through changes in biofuel production are captured. The study first projects the price of crude oil up to year 2020 and posits alternative scenarios where that price is 25%, 50% and 100% higher, then examines the impact of increased oil price on various economic indicators in 2020. Our study finds that GDP elasticity with respect to world oil price (i.e., ratio between percentage change in GDP and percentage change in world oil price) are roughly comparable with that of existing studies which also use CGE models to analyze macroeconomic impacts of oil price increases (e.g., Sanchez, 2011; Aydın and Acar, 2011). The effect of biofuels in mitigating the impacts of rising oil prices is relatively small because the capacity of biofuels to economically substitute for oil at a global scale remains limited.

The paper is organized is as follows. Section 2 briefly presents the CGE model developed for the study. This is followed by the presentation of key results in Section 3, particularly the assessment of the impact of increased oil prices on GDP, sectoral outputs and international trade in Section 4. Finally, Section 5 concludes the paper.

2. Model and Data

We developed a multi-country, multi-sector, recursive dynamic, global computable general equilibrium model for the purpose of this study. The model is flexible enough to accommodate new regions/countries or sectors. Although the database represents 57 sectors and commodities, we have aggregated some sectors and disaggregated other to arrive at the 27 sectors and commodities as needed for this study. Similarly, the database includes 113 countries, but we have regrouped the countries into 25 countries/regions in the present version of the model[2]. The key features of the model are as follows[3]: (i) it has flexible production structures with nested constant elasticity of substitution (CES) representation thereby allowing different substitution possibilities at different tires; (ii) it fully disaggregates the energy sector identifying biofuels as separate sub-sector to incorporate feedback of oil price shock through the substitution possibility between petroleum products and biofuels; (iii) it explicitly represents all energy-intensive manufacturing sectors, such as iron & steel, pulp & paper; (iv) it has a fuller representation of land types and uses, including crop lands, forest lands, grass lands, etc., as this feature is also essential to capture the substitution possibility between biofuels and petroleum products; (v) it assumes a representative household maximizing its utility, using a non-homothetic Constant Difference of Elasticities (CDE) function, subject to the budget constraint; (vi) it represents both bilateral and international trade through Armington assumption; (vii) it differentiates capital by vintage allowing new capital to move perfectly across sectors thereby insuring a uniform rate of return; and (viii) it follows the macroeconomic balance where total investment equals to total savings including household savings, government savings and foreign borrowings.

The model uses the GTAP database. However, the database has been substantially updated for the purpose of this study. For the detailed discussion on data update, please refer to Timilsina et al. (2010).

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[2] Please see Figure 2 and Table 3 of this paper for the list of sectors/commodities and countries/regions represented in the model.

[3] For details of the model, please refer to Timilsina et al. (2012) and Timilsina et al. (2011a, b).

3. Definitions of Baseline and Scenarios

We use historical data and projections from the U.S. Energy Information Administration (EIA) on the average price of crude oil. According to the EIA reference case projection made in 2010, the oil price would reach $107 per barrel (in 2009US$) in 2020. We also assumed the EIA projection of the oil price in our baseline case. We then considered three alternative scenarios to represent an increase in oil prices by 25%, 50% and 100% from the corresponding baseline values starting from 2012. Besides EIA, other organizations, such Internal Energy Agency (IEA) also project energy prices. However, the projection between EIA and IEA do not vary much. Moreover, the reference case oil price, which is exogenous to our model, is not very important in our study because we are measuring the impacts of deviations of oil prices from the reference case.

Table 1 presents percentage changes in oil prices from the 2009 level under the baseline and various oil price increase scenarios. For example, a 50% increase in oil price from the baseline in 2020 refers to a 147% increase compared to the 2009 level.

Table 1: Percentage change in oil price from the current (i.e., 2009) price level

Year	Baseline	Scenario		
		+25%	+50%	+100%
2009	0			
2010	19			
2015	54	92	131	208
2020	65	106	147	230

Note: the scenarios are implemented starting from 2012.

4. Simulation Results

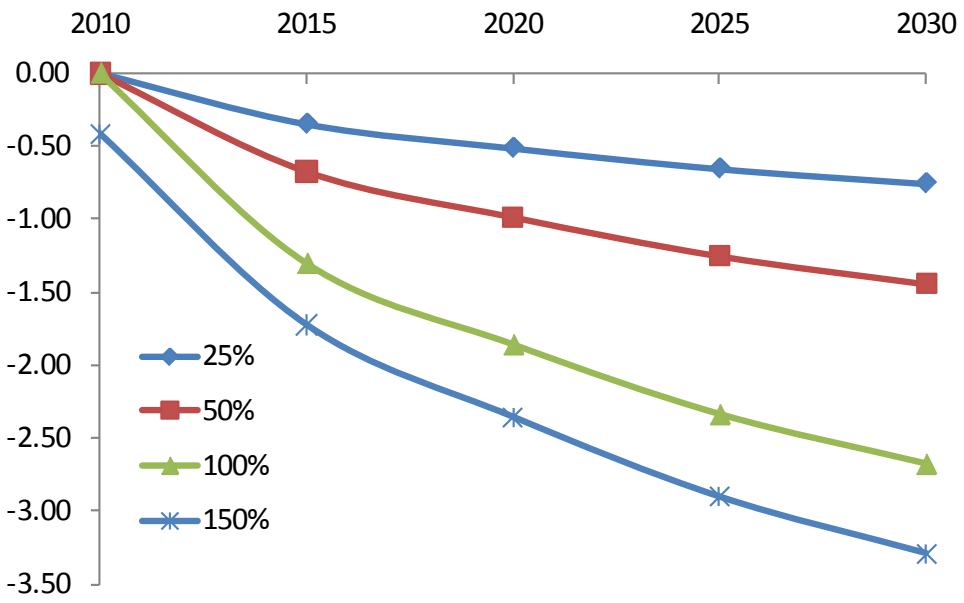
In this section we present key results obtained from the simulations of increased oil prices. The results include impacts on GDP, sectoral outputs and international trade.

4.1 Impact on Gross Domestic Product (GDP)

Figure 1 presents the impacts on real global GDP of 25%, 50%, 100% and 150% increases in the world oil price. The change in global GDP is inversely related to the changes in oil price. In

2020, an increase in the world oil price by 25% from the baseline would cause about 0.5% loss of global GDP. The loss increases to about 1% if oil price increase 50% from the baseline. The swiftest reductions in global GDP under all scenarios occur during the early part of the time horizon, given the relatively inelastic demand for oil in the short run. By 2015, global GDP is already 0.35%, 0.67% and 1.3% lower than in the base case when oil price is 25%, 50% and 100% higher, respectively. After 2015, global GDP can be seen to decrease further relative to the baseline but not as quickly as before, indicating adaptation to higher oil prices in the global economy.

Figure 1: Change in global real GDP under various scenarios (% change from the baseline)

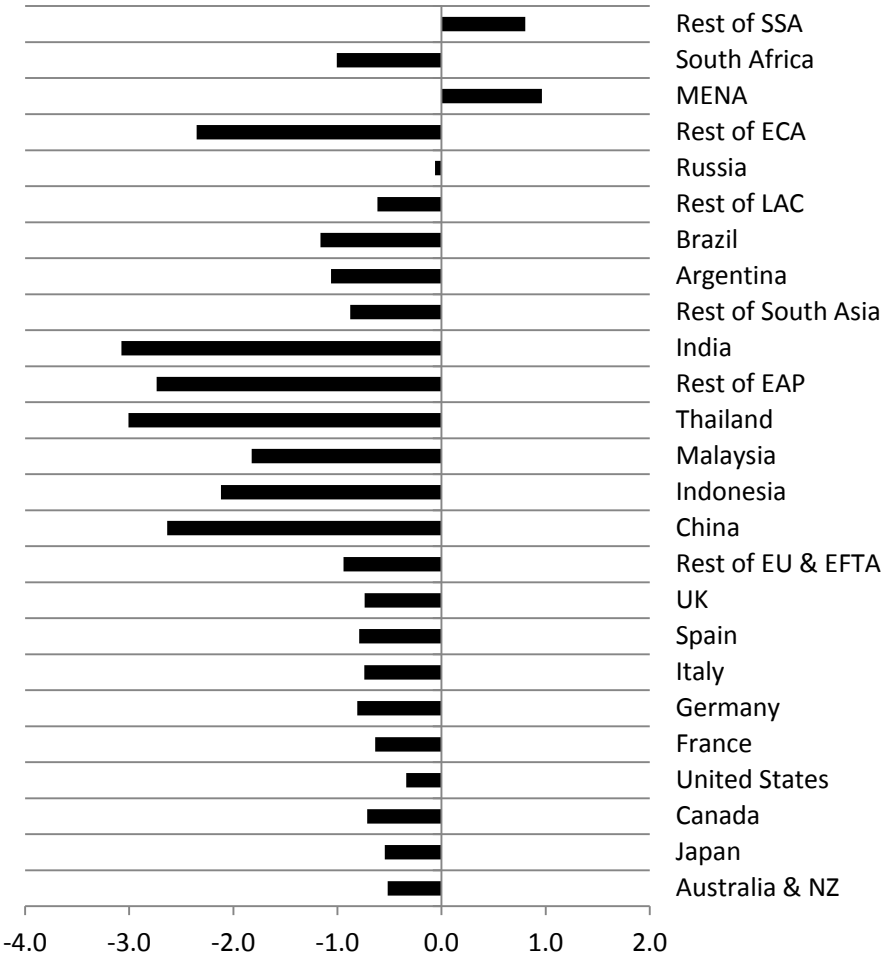


While the global GDP is expected to decline if the oil price were to rise, not all countries or regions are affected in the same manner. Figure 2 presents changes in national/regional GDP in 2020 when oil is raised by 25% to 100% from the baseline scenario. For a 50% rise in the world oil price from the baseline in 2020, GDP reductions would be smaller than 1% in most developed countries or regions. However, the GDP loss would be much higher in emerging developing economies, such as China, India, Thailand, Indonesia, Malaysia, and economies in transition. This is because oil intensive manufacturing industries account for relatively higher

shares in their GDP. On the other hand, service sectors, which are relatively less oil intensive, have relatively higher shares in GDP in most OECD countries; the effect of oil prices in these countries' GDP would be smaller compared to that of emerging developing countries and economies in transition. For the least developed countries, where agriculture sector is the key contributor to GDP and the sector is relatively less oil intensive due to less dependence on agriculture machinery and chemical fertilizers, the GDP impacts of increased world oil price are found to be relatively smaller compared to those of emerging developing countries. However, the percentage GDP losses in these countries are still higher compared to those of developed countries.

Although the vast majority of countries/regions will experience a reduction in their GDP, a few countries would see their GDP rise along with higher oil price in 2020. These are the net oil exporting countries and mostly from Middle East and North Africa (MENA) region. This is intuitive as the economy of these countries is highly dependent on oil exports and an increased world oil price is good for them. Note however, the rest of SSA also exhibits an increase in GDP due to the increased oil prices. This phenomenon is caused by two reasons. First, due to the size of the Nigerian economy in the Sub-Saharan Africa (excluding South Africa) group, the results for the group are heavily skewed by Nigeria, which being a net oil exporting country, gains from an increase in oil prices. Second, Sub-Saharan Africa is also relatively less reliant on oil than most other developing economies, therefore the GDP of this region would be less impacted by oil prices compared to other economies with a higher oil intensity.

Figure 2: Impact of a 50% increase in oil prices on GDP in 2020 (% change from the baseline)



It would be interesting to compare the results with those of comparable studies (i.e., CGE studies) although studies are not strictly comparable due to differences in assumptions, data, time horizon and so on. Nevertheless, a rough comparison is possible. Using a CGE model, Sanchez (2011) estimates annual GDP loss due to oil price change between 2002 and 2006 for six countries (Bangladesh, El Salvador, Kenya, Nicaragua, Tanzania and Thailand). If we calculate average annual GDP elasticity with respect to (w.r.t.) oil price between 2002 and 2006 based on their results (Table 3, p.334), we find that their GDP elasticity would vary between -0.007 (Tanzania) to -0.195 (Nicaragua). Similarly, using a CGE model, Aydın and Acar (2011) show that a doubling of oil prices (i.e., 100% change) could cause a 14% loss of economic outputs in Turkey in 10 years. This implies -0.014 annual average GDP elasticity w.r.t. oil price. Our study

finds that the GDP elasticity varies between -0.0064 (U.S.) to -0.0579 (India).[4] While the results (GDP elasticities w.r.t. oil price) of our study are comparable to those from the existing literature, all studies (this study as well), converge on the fact that the GDP elasticity would vary across countries depending upon their adjustment capacity to oil price shocks. The availability of biofuels to substitute petroleum for transportation in our study implies higher adjustment capacity compared to that in existing studies.[5]

4.2 Impact on Sectoral Outputs

Figure 3 presents impacts on sectoral outputs at the global level of 50% oil price increase in year 2020. It can be seen that production of crude oil and refined petroleum products derived from it are considerably reduced, whereas ethanol and biodiesel production undergo an almost proportionate increase to the rise in oil price. Some substitution of oil with natural gas is also observed.

Note that while the increase in biofuels output is on the order of 40%, while the decrease in petroleum sector output is only about 15%, the baseline level of petroleum output is much larger than the baseline output of biofuels – roughly 20 times in energy-equivalent terms. These figures highlight the limited capacity of biofuels globally to mitigate the effects of rising oil prices. Even with oil prices considerably higher than along the baseline path, the opportunity cost of increases in biofuels becomes uneconomic well before the volume of output is large enough to offset the decline in demand for petroleum products.

[4] Countries with positive GDP impacts due to oil price increase are excluded from this discussion for better comparison with existing studies.

[5] Precisely speaking the GDP elasticities in most countries in our study are slightly lower than that of Sanchez (2011) and Aydın and Acar (2011); this could be the effect of substitution possibilities between biofuels and petroleum products considered in our study.

Figure 3: Impacts of a 50% increase in oil prices on sectoral outputs at global level in 2020 (% change from the baseline)

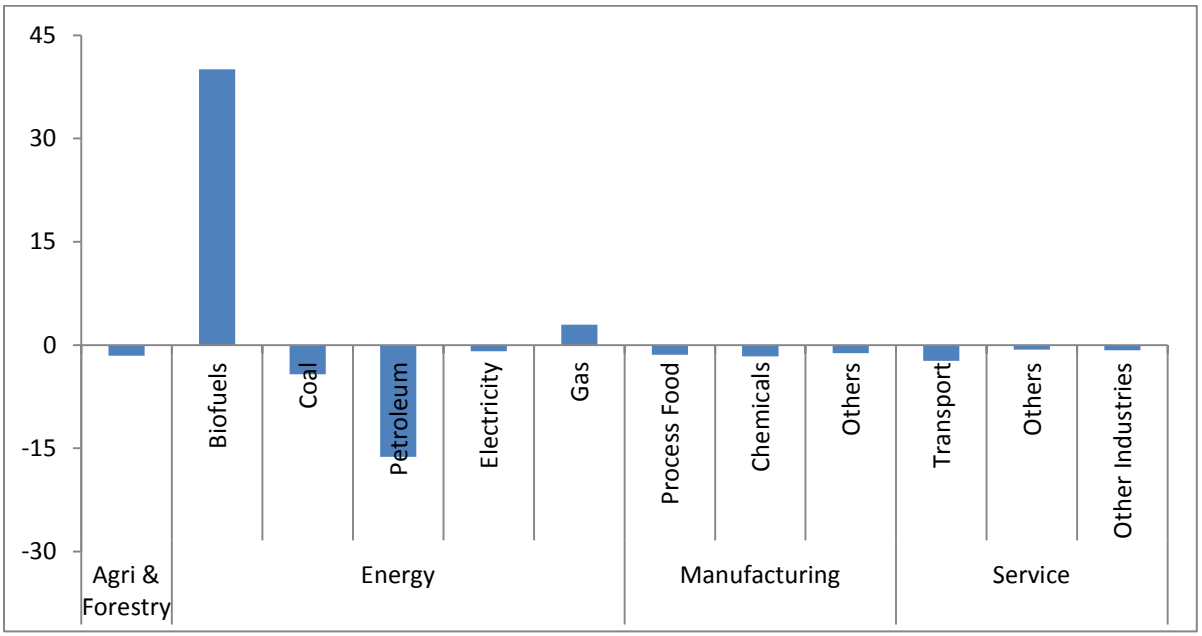


Table 2 presents the impacts of a 50% increase in world oil price on gross outputs of various economic sectors at the country/regional level. As illustrated in the table, the increase in the world oil price affects the output of the industrial and service sector more than the agricultural sector.

The impact of oil price increases on industrial and service sector output is imbalanced in that high-income countries (and South Africa) are only slightly affected, while most middle and low-income countries and regions sustain significant losses as demonstrated in Table 2. One reason that high income countries sustain minor losses in industrial output may be that their industrial infrastructure is relatively energy efficient compared to that of developing countries, and therefore more able to absorb higher oil prices.

The rest of Sub-Saharan Africa and Middle East and North Africa actually would experience an improvement in industrial and service sector outputs when oil price increases. This is because not only do these two regions increase biofuel output like all other regions and

countries when oil prices rise, but they also increase their output in other industrial and service subsectors, such as construction and services other than transport.

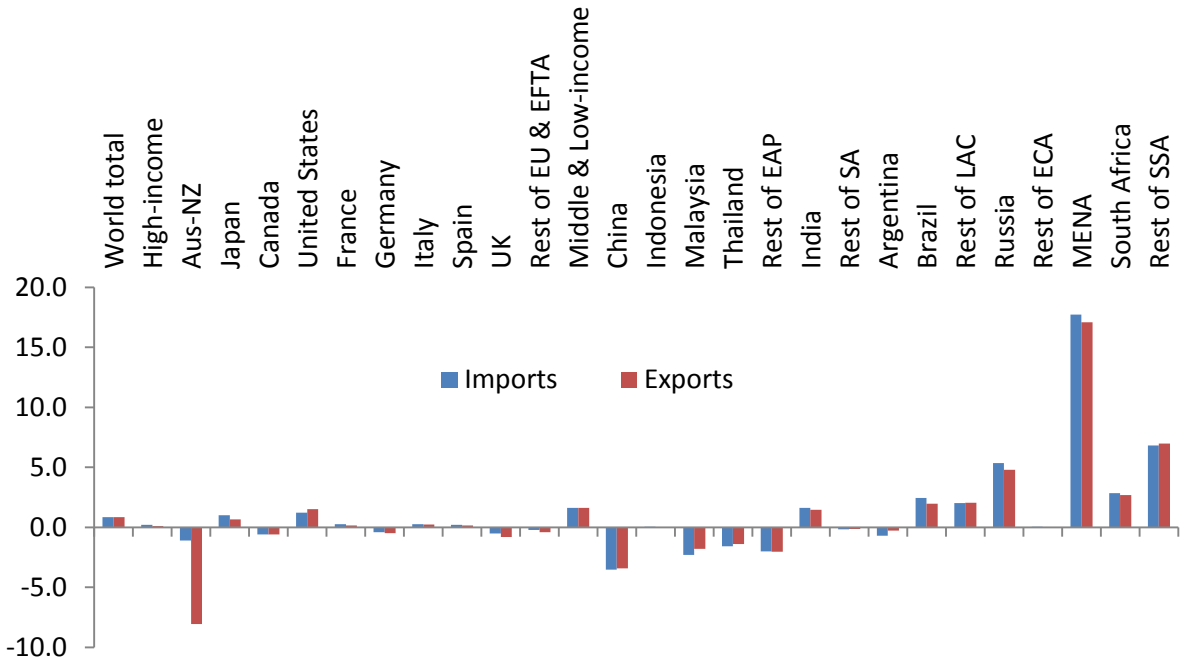
Table 2: Impacts on sectoral outputs of 50% increase in world oil prices in 2020 (% change from the baseline)

Country/Region	Agriculture	Manufacturing	Mining	Service	Others	Total
World total	-1.46	-1.67	-8.22	-0.84	-0.75	-1.29
High-income	-2.28	0.07	-6.03	-0.71	-0.53	-0.50
Australia and New Zealand	-1.98	1.54	-3.80	-0.73	-0.65	-0.30
Japan	-3.19	0.00	-0.29	-0.61	-1.02	-0.47
Canada	-1.57	-0.98	-9.59	-0.33	-0.66	-0.84
United States	-1.61	0.76	-6.96	-0.73	-0.14	-0.31
France	-3.27	0.46	0.74	-0.74	-0.42	-0.35
Germany	-2.05	0.22	0.03	-1.00	-1.15	-0.50
Italy	-3.10	-0.35	-0.47	-0.61	-0.67	-0.57
Spain	-1.23	-0.38	0.65	-0.97	-0.47	-0.70
UK	-0.80	0.45	-14.76	-0.77	0.06	-0.44
Rest of EU & EFTA	-3.06	-1.25	-4.60	-0.62	-0.95	-0.99
Middle & Low-income	-0.82	-3.57	-8.85	-1.14	-1.00	-2.51
China	-0.87	-4.14	-4.23	-2.53	-4.02	-3.55
Indonesia	-0.04	-1.57	-3.68	-3.14	-3.04	-2.31
Malaysia	0.91	-0.66	-15.01	-3.85	-2.91	-1.78
Thailand	-2.87	-2.03	0.24	-3.95	-4.91	-2.88
Rest of East Asia & Pacific	-1.06	-2.80	-0.95	-2.79	-4.70	-2.93
India	-0.87	-3.57	-8.06	-3.37	-4.40	-3.45
Rest of South Asia	-0.45	-1.18	-1.38	-1.35	-0.54	-1.11
Argentina	-3.34	-5.01	-4.99	0.05	-0.26	-1.93
Brazil	-0.64	-0.62	-9.37	-1.40	-1.76	-1.23
Rest of LAC	-0.57	-1.99	-10.65	0.10	1.18	-1.29
Russia	0.22	-8.11	-11.19	2.12	4.05	-1.60
Rest of ECA	-1.89	-3.97	-9.04	-1.85	-1.63	-2.85
MENA	-1.18	-9.60	-12.87	6.71	14.14	0.33
South Africa	-3.18	1.17	-4.29	-1.33	-1.48	-0.47
Rest of Sub-Saharan Africa	1.16	-1.25	-9.95	2.19	3.41	0.42

4.3 Impact on International Trade

Increases in oil price will have considerable impact on global trade patterns. Figure 4 shows the breakdown of the impact of an increase in oil price by 50% on international trades of various countries/regions. A huge increase in international trade in MENA and SSA observed due to increased oil prices. International trade of high income countries is less affected as they are more less oil intensive service based economies. Middle income countries lose more international trade due to their oil based manufacturing base economy.

Figure 4: Impact of a 50% oil price increases on international trade in 2020 (% change from the baseline)



5. Conclusions

Given its role as a critical input into so many production processes and its ubiquity in transportation systems, it is to be expected that an increase in the price of oil would have adverse impacts on the global economy. We apply a multi-country, multi-sector, recursive dynamic, global computable general equilibrium model to simulate various future oil price scenarios and assesses the corresponding impacts on the global economy.

The study shows that global GDP contracts due to higher oil prices, and contracts more in the years close ahead, given the relatively inelastic demand for oil in the short run, and its reduction further out in the horizon is mitigated by adaptations to higher oil prices. Importantly, the role of biofuels in mitigating the effect of rising oil prices is limited because of its economic cost. Whereas developed countries/regions encounter modest reductions in GDP because of an increase in oil prices, the largest GDP losses are borne in emerging economies like China, India and Thailand, as they depend on imports for their oil supply and their economic structures are manufacturing based. With the increased prices, oil exporting countries in the

Middle Eastern and North Africa region would gain the most. The increased oil price would adversely impact the demand for oil at the global level and consequently cause a drop in outputs from the petroleum refinery sector at the global level. Global outputs from oil intensive industries such as transport and chemicals would also drop. On the other hand, the increased oil price would cause a significant boost in the biofuel industry. The natural gas industry would also gain but on a lesser scale compared to biofuels. Oil exporting countries, particularly Middle Eastern countries and Nigeria, would experience a gain in their international trade. Like existing studies analyzing macroeconomic impacts of oil price shocks using a CGE model, our study also concludes that the impacts of oil price shocks to economic output measured as GDP elasticity with respect to oil price change, would vary significantly across countries depending upon their adjustment capacity to the oil price shocks.

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