Impacts of increasing oil and gas prices on poverty and hunger

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Abstract

Since 2004 the price of crude oil increased rapidly, reaching an historical height of $147 per barrel in July 2008. Although since then the prices of oil decreased significantly, there is serious concern that oil prices will increase again and remain high. In general, increasing oil prices impact on economic growth, with people in developing countries expected to suffer most. In this paper we develop a tool to assess the impacts of increasing oil and gas prices on poverty and hunger. For this purpose we have linked a recursive dynamic general equilibrium model with a system dynamic modeling framework developed to address long-term human development in relation to socio-economic and environmental changes.

The modeling framework is used to assess the impacts of an exogenous price shock for oil and gas prices on the macro-economy, poverty and hunger, by uniformly reducing the fixed factor of oil and gas across regions. The reader should be aware that in this analysis we do not to analyze or reproduce high oil price spikes, but instead we analyze the structural changes in the economy by assuming a structural price increase, with oil prices reaching $100 per barrel in 2020.

High energy prices entail the largest GDP losses in energy exporting countries although these losses may be partly or completely be offset with respect to expenditures by high terms-of-trade gains. However, sectoral reallocation of capital inputs from energy-intensive sectors may compensate part of the GDP losses and even increase the production in energy-extensive sectors, including the agriculture sector. In countries with high oil intensity and a high export dependence on oil, this effect might be hampered, resulting in an overall capital flee. Energy importing countries are confronted with lower GDP losses, but gain much less from capital reallocation and are confronted with terms-of-trade losses.

Impacts on poverty are relatively high compared to the changes in income and expenditures. Oil and gas exporting countries can decrease their poverty numbers when expenditures increase, while oil and gas importing countries see their poverty increase. The impacts on hunger rely on changes in food availability. Most energy exporting countries see their food availability increase. Capital reallocation to agriculture increases productivity, while changes in terms-of-trade increase food imports. Oil and gas importing countries see their overall availability drop. Agriculture in India and Central Asia is relatively energy intensive and might therefore suffer from higher energy prices.

The applied methodology has several shortcomings, mainly with respect to the way inequality is addressed and the representation of agriculture sectors in the CGE model. Furthermore, the analysis is done for large aggregate regions which are not always homogeneous with respect oil and gas importers and exporters. This is especially apparent in the Sub-Saharan African regions. Finally, the flexibility of reallocation of capital between agricultural and non-agricultural sectors could be interpreted as extremely optimistic. Therefore, results should be interpreted with care, and the reader should mainly focus on the described mechanism.

1 Introduction

Since 2004 the price of crude oil increased rapidly, reaching an historical height of $147 per barrel in July 2008. In 2004, the IEA estimated that, compared to pre-2004 levels, an increase in oil price of $10 per barrel in the 2005-2008 period would result in a lost of 0.3% economic growth per year in OECD countries, more than 1.5% in oil importing developing countries and an even bigger loss of more than 3% per year in Sub-Sahara Africa (IEA, 2004). There is significant concern that especially the poor people suffer most from this projected price increase. Saghir (2006) estimates that, as a result of the high and fluctuating oil prices in 2005, the total population living in poverty rose by 4-6%. Although since the peak in 2008 the oil prices significantly decreased, in their most recent Energy Outlook, the International Energy Agency (IEA, 2009) expects a rebound of crude oil prices, reaching $100 per barrel by 2020 and $115 per barrel by 2030 (real 2008 dollars).

In general, increasing oil and gas prices impact on economic growth. They lead to a transfer of income from importing countries to exporting countries through a shift in terms of trade. For oil-importing countries, the immediate magnitude of the direct effect on national income depends on the ratio of oil imports to GDP (oil intensity and import dependency). However, there are many more factors, related to the demand side, the supply side or external, that determine the overall impact (Kilian, 2008). On the short term price increases generally decrease employment and production and increase inflation. On the longer term, however, the impact might be reduced due to national responses, i.e. reduced consumption, switch to other sources and increased domestic production. For net oil-exporting countries, increasing oil prices increases real national income through higher export earnings. In the longer term, however, part of this gain would be offset by lower demand, generally due to the decline in GDP suffered by trading partners, and possibly to a fall in non-oil exports caused by a rise in the exchange rate (“Dutch disease”). Impacts are greater if the price increase is sudden and sustained, and are magnified by the negative impact of increasing prices on consumers and business confidence.

People in developing countries suffer from direct impacts as decreased use of energy and transport facilities, and indirect due to increasing government expenditures for oil subsidies - impacting on expenditures on health services and education – and increasing reliability on biomass for cooking and heating, impacting on their health status.

PM: Impacts on food availability and link to MDG1

In this report we develop a tool to assess the impacts of increasing oil and gas prices on poverty and hunger. For this purpose we have linked the WorldScan model (Lejour et al., 2006), a recursively dynamic general equilibrium model for the world economy, with the GISMO1.0 model (Hilderink and Lucas, 2008), a system dynamic modeling framework developed to address long-term human development in relation to socio-economic and environmental changes. The GISMO1.0 model has been used to assess MDG achievement beyond 2015 (PBL, 2009). The paper focuses on the modeling tool, more specifically the link between WorldScan and GISMO1.0. Furthermore, the models are applied to assess the impacts of an exogenous price shock for oil and gas prices on the macro-economy, poverty and hunger. The focus of the analysis is on developing countries in Asia and Africa. The reader should be aware that in this analysis we do not to analyze or reproduce high oil price spikes for, but instead assume a structural price increase for oil and gas towards 2020.

2 Modelling tools

To assess the macro-economic and poverty impacts of increasing oil and gas prices an integrated modelling framework is used, which consists of the WorldScan model (Lejour et al., 2006), and the Global Integrated Sustainability Model (GISMO) (Hilderink and Lucas, 2008). The WorldScan model is an applied general equilibrium model, which reflects the global economy with multi-region and multi-sector detail, the regions being connected by bilateral trade flows at industry level. The GISMO model is a multi-region platform for analyzing the changes in Quality of Life in relation to social, economic and environmental changes. The WorldScan model is used to assess the macro-economic and sectoral impacts of high oil price shock. The GISMO model is used to assess the impacts on income poverty (proportion of the population living with less than $1.25 per day, corrected for purchasing power) and on the level of undernourishment (proportion of the population with food consumption below the minimum dietary energy requirement). Here, we briefly describe both models.

2.1 The WorldScan model

The WorldScan model fits into the tradition of applied general equilibrium models. It builds upon neoclassical theory, has strong micro-foundations and explicitly determines simultaneous equilibrium on a large number of markets. The model is solved as an equation system and thus is cast in a Computable General Equilibrium (CGE) format rather than in a welfare maximisation format. The structure of WorldScan's core version is very similar to the GTAP model (Hertel, 1997). The most important difference is that GTAP is a static model whereas WorldScan is recursively dynamic.

WorldScan reflects the global economy with multi-region and multi-sector detail, the regions being connected by bilateral trade flows at industry level. The model uses the GTAP-7 database of the Global Trade Analysis Project (GTAP) (see Badri Narayanan and Walmsley, 2008). In general, simulations will not show the full detail that this database could provide (87 regions and 57 sectors), but rather – for economy reasons – show outcomes for aggregated sector and country classifications. In this exercise, 20 sectors and 20 countries or country aggregates are distinguished (see Appendix A).

Production

Each sector within a region produces a unique variety of a good. There is one representative firm per sector within a region. Factor demand is derived from cost minimisation, given production technology. Output equals demand, which, in turn, is determined by the producer prices, besides other factors. The production technology is represented by a production function which relates output to factor inputs and intermediate inputs. The main factor inputs are high- and low-skilled labour, and capital. Supplies of skilled and unskilled labour are exogenous. They depend upon demography, participation rates and the share of the high skilled in the total workforce. The volume of investment in region equals the volume of savings. The capital owners buy investment goods, and a part of these investment goods is exported to or imported from other countries. In this way capital is mobile across regions. The investment goods are assumed to be a Cobb-Douglas aggregate of investment goods from all sectors. Intermediate inputs are goods, services and energy. The inputs are to some extent substitutable. The relevance of each of these inputs for production and their substitutability is represented in the production function. The production technology is modeled as a nested structure of constant elasticities of substitution (CES) functions. We assume the same production structure for all sectors and regions. The values of the substitution parameters reflect the substitution possibilities between inputs. These values may differ across sectors reflecting the different substitution possibilities of (factor) inputs within the producing sectors.

Value added in sector equal the value of production minus the costs of intermediate products, including taxes on intermediate products. Gross Domestic Product (GDP) in market is defined as the sum of sectoral value added in producer prices plus taxes. Tax proceeds are added because GDP is measured in market prices. Moreover, GDP is derived in constant prices, to compare real GDP at different time periods. The value of GDP (in current market prices) is also equal to the value of consumption, investment and exports minus imports (GDP in expenditures).

Consumption

Consumers decide how to spend their earned income in three stages; distribution over consumption (private and government) and savings, allocating consumption income to consumer goods and services, and international trade. On the basis of their preferences consumers decide how to spend their budget on consumer goods and services, using a Linear Expenditure System (LES). An extension of the GTAP-database provides a sound empirical underpinning for calibration of the LES. The Armington assumption is used to calibrate and stimulate bilateral trade.

Energy

The energy part distinguishes six energy carriers: coal, petroleum products, gas (including gas distribution), electricity, modern biomass and non-fossil-fuels (nuclear, geothermal, solar and wind energy). The demand for these energy carriers derives foremost from the production sectors (70-85%), which use energy as an intermediate input, but also from the households, who consume energy directly. Large differences exist among sectors: the chemical and basis metal sectors have 30-50% of their production costs made up of energy, while services use relatively little energy. The model distinguishes three fossil energy sectors: coal, petroleum products and gas (including gas distribution). Furthermore, electricity is modeled as a separate sector. The production and demand structures of these fossil energy carriers and electricity closely follow the functional specification of the other goods and services sectors. The modeling of the resource depletion roughly follows the approach of the EPPA model (Babiker et al., 2001).

2.2 The GISMO model

The GISMO model aims to address sustainable development by focussing on the two-way relationship between global environmental change and human development. It allows to asses human development by specifically addressing changes in Quality of Life as a consequence of changes in the three sustainability domains (social, economic and environmental). The model builds on the long history of Integrated Assessment modelling, including the PHOENIX model (Hilderink, 2000) covering the human/social domain, the WorldScan model (Lejour et al., 2006) covering the economic domain and the IMAGE model (Alcamo, 1994; MNP, 2006) covering the environmental domain. Quality of life is modeled for 27 world regions (see Appendix A), focusing on income, education and health and their underlying dynamics. Here, the focus is on poverty and hunger. Therefore, only the methodology to determine poverty and prevalence of undernourishment is described. For an in-debt description of the GISMO1.0 model see Hilderink and Lucas (2008).

Poverty

Most methods to measure poverty are based on income or expenditure levels. People are considered poor if their income or expenditures level falls below some minimum level necessary to meet basic needs, the "poverty line". In general, poverty lines vary in time and place, and each country uses lines which are appropriate to its level of development, societal norms and values. However, when estimating poverty worldwide, the same reference poverty line has to be used, and expressed in a common unit across countries. Here, we use the commonly accepted World Bank poverty line of $1.25 per day at 2005 Purchasing Power Parity (Ravallion et al., 2008), which is also part of the MDG indicator framework (MDG 1).

Poverty headcount, people below the poverty line, is dependent on total income and its distribution over a population. Most commonly, distribution is expressed using the GINI coefficient, a statistical summary of the Lorenz curve (Cypher and Dietz, 1997). The GINI coefficient has values between zero and 100, with zero being total equality and 100 total inequality. Distribution of income over a population is shown to be lognormally distributed (Heaps et al., 1998; Kemp-Benedict et al., 2002). Using a lognormal distribution, the income distribution can be fully specified with only two parameters: mean income and the standard deviation (see Figure 1 and van Ruijven, 2008). Following Aitchison and Brown (1957) the standard deviation (σ_x) can be determined from the GINI coefficient:

$$\sigma_x = \sqrt{2} N^{-1}\left(\frac{1+GINI}{2}\right),$$

in which $N^{-1}(x)$ is the inverse of the cumulative normal distribution. The mean for the lognormal distribution (μ_x) can then be determined from the mean income (μ) and the standard deviation:

$$\mu_x = \ln(\mu) - \frac{1}{2}\sigma_x^2 .$$

The model is initialized using per capita GDP (2005$) from the WorldBank (2009) and UNstat (UNSTAT, 2010), and poverty data ($1.25 per day at 2005 PPP and GINI coefficients) from the World Bank's Povcal*Net* database (Chen and Ravallion, 2008). The PPP conversion factors are, to transfer GDP in market exchange rates to purchasing power parity dollars, taken from the 2005 International Comparison Program (World Bank, 2008). Future regional expenditures are taken from the WorldScan model, while the PPP conversion factors are kept constant in time.

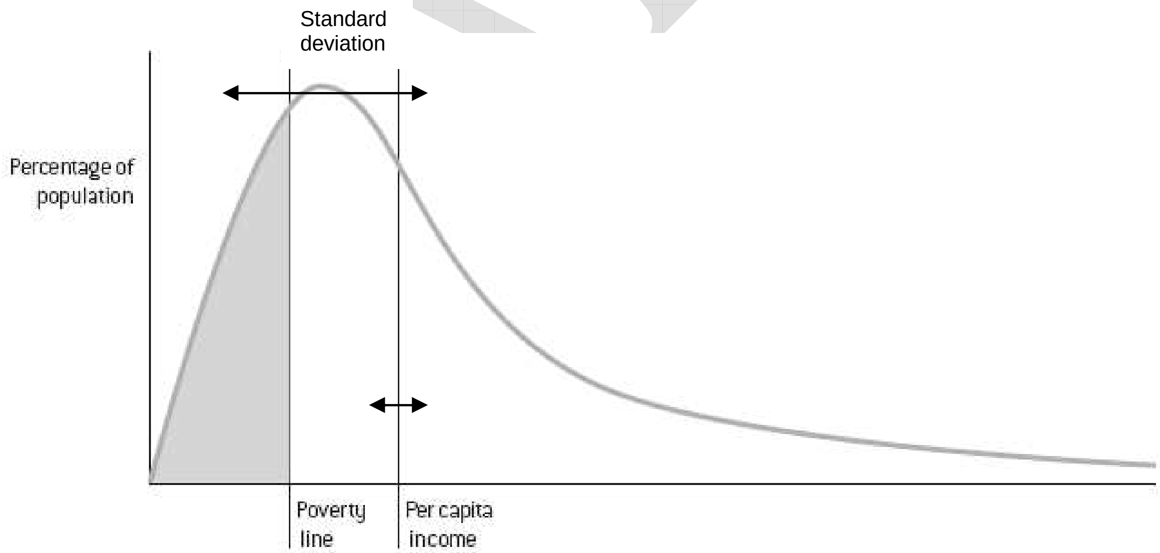


Figure 1 Determining poverty headcount using a lognormal distribution function, specified with per capita income and the standard deviation (modified from Hughes et al., 2008)

Change in the GINI-coefficient is estimated from the shares in labour and in wage sum of both low and high skilled labour from the WorldScan model (see Figure 2). The estimated GINI's are calculated as the area between the straight line and the dotted line, divided by the area under the dotted line. The estimated GINI-coefficients are generally much lower than the GINI's from the Povcal*Net* database. Nevertheless, compared to each other they represent moreover the same pattern, i.e. with the Latin American countries having the largest GINI's, while the GINI's of the central European are among the lowest in the world. To determine future GINI-coefficients for the poverty calculations, the absolute difference compared to the 2004 values are added to the 2004 GINI's from the Povcal*Net* database.

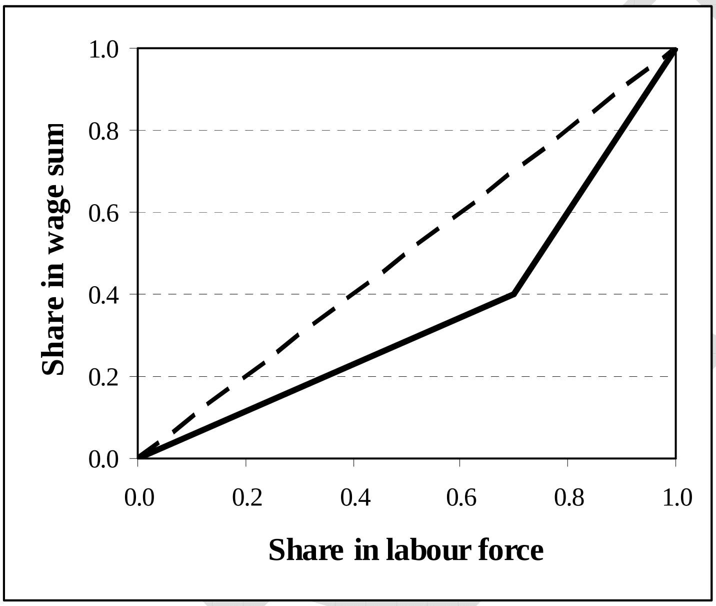


Figure 2 GINI-coefficient calculation from WorldScan results

Prevalence of undernourishment

Undernourishment refers to a nutritional intake below the daily energy requirement of the human body. Here we use the prevalence of undernourishment, which is part of the MDG indicator framework (MDG 1). The prevalence of undernourishment is defined as the number of people with a lower calorie-intake than is required to perform basic activities (on average around 1800-2000 kcal per person per day). Our calculations follow the FAO methodology (FAO, 2003). The prevalence of undernourishment is determined using a lognormal distribution of food intake, estimated on the basis of the mean consumption, and a coefficient of variation. The calculations are based on a similar methodology as used for the poverty calculations.

For the mean dietary energy consumption, historic consumption levels in Kcal/cap/day from FAOSTAT (2010) together with future trends in food consumption from WorldScan. To determine food consumption the following formula is used:

$$C_{r,fs} = P_{r,fs} - \sum_{j} X_{r,j,fs} + \sum_{j} M_{j,r,fs} - \sum_{ss \neq fs} INT_{r,fs,ss} \ ,$$

In this formula, C is consumption, P is production, X are the exports, M are the imports and INT are the intersectoral flows, all in volume terms. Furthermore, the subscripts r and j represent regions, fs are the food sectors (cereals, animals and other agricultural products) and ss are all sectors excluding the food processing industry.

The coefficients of variation were taken from FAOSTAT (2010) and kept constant in time. The minimum dietary energy requirement is derived by aggregating the region specific sex-age energy requirements weighted by the proportion of each sex and age group in the total population using FAO data and methodology (FAO, 2004).

3 Business as usual and the high oil and gas variant

The business as usual macro-economic projection is based on the projection of the OECD Environmental Outlook OECD (2008). In this projection, oil and gas prices drop from approximately $38 per barrel in 2004 to $25 per barrel in 2020 (2004$US).

Table 1 presents the main economic indicators for 2020, including population and per capita income, but also indicators that describe the vulnerability of regional economies for increasing oil prices. The main oil and gas exporting countries are found in the Middle East, Africa (North, West en Rest of Africa) and Central Asia, while China, India and rest of Asia are mainly net energy importers. The Sub-Saharan Africa regions (West en Rest of Africa) are mixed regions, with large oil exporters (Nigeria in West Africa and Angola in rest of Africa) but also many oil importing countries. Nevertheless, as a whole both Sub-Saharan Africa regions export more than 90% of its aggregate oil and gas production to countries outside Africa.

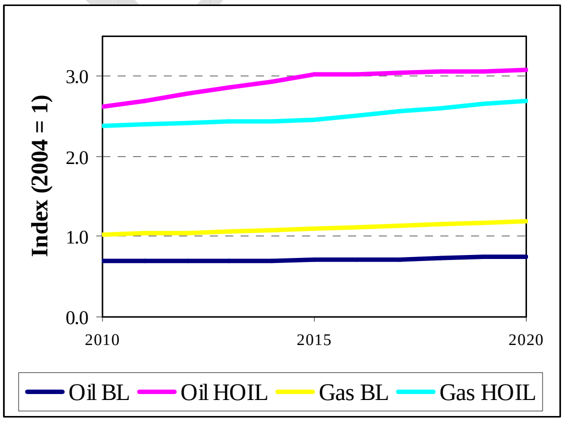
Table 1 Population, income and oil price vulnerability in 2020 for the baseline scenario

	Population (million people)	GDP/cap ($2004)	Oil import dependency (%import of use)	Oil and gas intensity (mtoe/GDP)	Oil and gas share in primary energy use (%)	Poverty (%)	Hunger (%)
Middle East	260	6395	1	0.423	94	3	7
China	1487	4945	54	0.124	27	2	4
India	1334	1503	71	0.102	30	9	5
Indonesia	256	2628	32	0.200	62	9	2
Rest of Asia	892	2118	69	0.185	70	8	7
North Africa	194	3209	10	0.348	88	1	1
West Africa	365	849	2	0.136	89	28	4
Rest of Africa	619	803	12	0.074	61	23	19
South Africa	49	7262	96	0.075	19	18	0
Central Asia	60	2793	4	0.775	69	3	7
World	7614	9071	-	0.101	53	8	5

In the business as usual projection, in 2020 the two Sub-Saharan Africa regions (West Africa and rest of Africa) are still the poorest regions in the world. They have the highest poverty numbers and the highest prevalence of undernourishment. Although Sub-Saharan Africa's energy consumption is largely dependent on oil and gas, their oil and gas intensity is relatively low as well as their import dependency (both regions are net oil and gas exporters). On the contrary, China's and India's energy consumption is more dependent on coal than on oil and gas, with energy intensity only slightly higher than that of Sub-Saharan Africa. Nevertheless, both countries have a relatively high import dependency, especially for oil, making them vulnerable for price increases. For the net oil and gas exporting regions (especially Central Asia) the oil and gas intensities are among the highest in the world, as well as their dependence on oil and gas for their primary energy production. Increasing oil and gas prices might therefore increase their export revenues, while their energy intensive production sectors might suffer significantly.

For the high oil and gas price variant, oil and gas prices are exogenously shocked according to the high variant of van Ruijven et al (2009), which is based on IEA (2008). In this variant the price of oil triples compared to 2004 levels, i.e. from 38$ per barrel to slightly more than 100 US$ per barrel in 2020 (both 2004US$). The higher prices of oil and gas are simulated in the WorldScan model by uniformly reducing world oil reserves (the fixed factor) across regions, i.e. regional percentage adjustment of the fixed factors (oil and gas) are the same to match the prescribed global prices of oil and gas. In Figure 2 the index of the oil and gas price to 2004 prices for both the business as usual projection and high oil and gas price variant are presented.

Figure 2 also presents the volumes of oil and gas for both the business as usual projection and the high oil and gas price variant. Global electricity use decreases with 10%, while the use of oil and gas reduces with 30% and 40%, respectively. The responses of gas are larger than those for oil, probably because there are more alternatives for gas in the mid-term. Gas is employed by both consumers and electricity producers, and oil mainly by consumers (transport services).



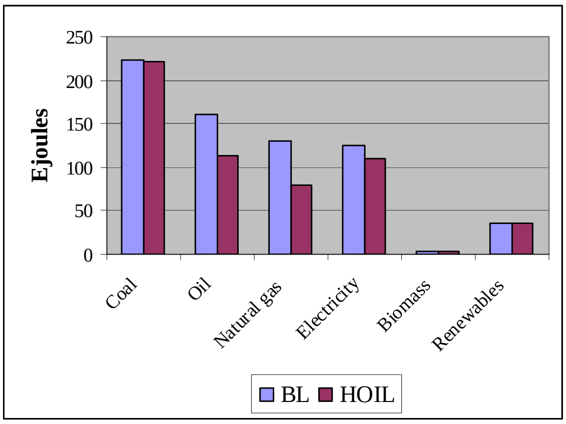


Figure 3 Indexed development of the price of oil and gas (price = 1 in 2004) (left) and global demand for energy in 2020, both for the business as usual projection and for the high oil and gas price variant

4 Results

In this chapter we will present simulation results. We start with the macro-impacts, followed by the sectoral impacts and trade impacts and finalise the analysis with the closely linked poverty impacts (income poverty and hunger).

4.1 Macro-economic impacts

Table 2 presents the percentage differences of key macro-economic indicators in 2020 of the high oil price variant compared to the business as usual projection. The table includes changes in GDP and consumption, as well terms of trade (the relative prices of a country's export to import), poverty and hunger. Only African and Asian regions are reported here. GDP in the high oil price variant is lower in all regions compared to the business as usual projection. The largest decrease occurs in the energy exporting regions as production drops due to decreasing global demand for oil. The Middle East and Central Asia are the hardest hit, due to their high oil intensity and large share of oil and gas in total export. Although most African regions are also net oil and gas exporters, the impacts on their GDP is much lower, which might also be the result of the mix of net importers and exporters. The GDP of the other, oil and gas importing, regions decreases as a larger share of their production costs are devoted to oil imports. The impacts are however dampened as these regions import less oil and gas and move their production away from oil and gas.

Table 2 Macro-economic impacts of the high oil prices variant compared to the business as usual projection in 2020

	GDP (%)	Consumption (%)	Terms of trade (%)
Middle East	-13	5	59
China	-2	-5	-7
India	-5	-8	-14
Indonesia	-4	-3	1
Rest of Asia	-5	-6	-2
North Africa	-9	0	33
West Africa	-7	7	45
Rest of Africa	-5	3	29
South Africa	-2	-4	-7
Central Asia	-19	-6	45
World	-3	-3	-

Compared to the business as usual projection, regional production of oil and gas drops with 30% to more than 40% (see Figure 3 and Table 3). The net effect for the oil exporters is not only increases in total revenue, but also gains in terms of trade. Gains in terms of trade (the increase of the ratio) offers an advantage as countries pay less for the products they import, or it they have to give up fewer exports for the imports they receive, making imports more attractive. Oil importing regions generally loose in terms-of-trade. Increasing import prices put upwards pressure on total import expenditures, while export prices increase much less, making import less attractive. These terms-of-trade effects offset or even reverse the negative GDP impacts with respect to total consumption for the oil and gas exporting countries, while the importing countries see their total consumption drop further than their drop in GDP. Middle East and Africa (especially West Africa) gain from this terms-of-trade effect as their total consumption increases. India is confronted with the largest terms-of-trade and consumption losses.

4.2 Sectoral impacts

The GDP or production losses do not imply that there will be losses in every sector. Labour and capital may be reallocated. Hence, macro-losses due to large losses in energy production and in energy-intensive sectors can be offset by production increases in energy extensive sectors. Table 3 shows changes in sectoral production for the main food, energy and services sectors. The largest decreases in sectoral output are of course the oil and gas sectors. Also electricity production and the energy intensive sectors show significant production losses, with the largest impacts in the regions with the highest oil intensity (Middle East, North Africa and Central Asia). Increases in sectoral output can, mainly in the African regions, be observed in energy extensive sectors, i.e. agriculture, food processing and public administration. Although not shown in Table 3, the transport and capital goods sectors are also confronted with lower production. In the latter case, reduced production is direct result of lower production in the energy (-intensive) sectors, which are relatively capital-intensive. Lower production in these sectors goes hand in hand with lower demand for capital goods.

Table 3 Percentage change in sectoral production of the high oil prices variant compared to the business as usual projection

	Middle East	China	India	Rest of Asia	North Africa	West Africa	Rest of Africa	Central Asia
Cereals	-8	-2	-4	-2	4	7	5	-4
Other agriculture	2	-2	-1	-1	2	-3	-1	-11
Animals	1	-1	-1	-1	1	5	2	0
Coal	-18	-1	-4	-3	-11	0	7	-9
Oil	-44	-25	-33	-35	-38	-33	-31	-34
Natural Gas	-49	-44	-38	-36	-38	-24	0	-37
Electricity	-39	-9	-12	-24	-37	-14	-9	-40
Energy intensive	-64	-5	-15	-16	-27	-2	-1	-18
Food processing	0	-3	-6	-4	3	10	5	0
Other services	9	-2	3	-2	1	1	-2	-9

Table 4 provides an indication of sectoral capital changes as percentage of total production of the high oil prices variant compared to the business as usual projection. Including total production gives an indication of how important the capital changes are to a specific sector.

Generally, large decapitalisation occurs in energy producing sector (oil and natural gas), mostly drive by large production losses. Although energy intensive sectors are also hurt by the high energy prices, capital might be increased in these sectors, thereby mitigating the price increases and substitute energy inputs for capital inputs. In Sub-Saharan Africa, the energy intensive sector increases production. Of the energy exporting regions Sub-Saharan Africa has the lowest energy intensity. Here, increasing production costs due to higher oil and gas prices can to some extent be offset by increasing capital input through reallocations of redundant capital investments from the energy and electricity sectors. The substitution away from energy-intensive production does not always imply more production in energy extensive sectors. In oil and gas importing regions, the share of energy related sectors is small compared oil and gas exporting sectors. Therefore, the reallocation of capital will also be smaller, which reduces the effect of the mitigating mechanism to offset the price increase of energy through capital investments.

Table 4 Absolute real capital changes of the high oil prices variant compared to the business as usual projection as percentage of total production in the business as usual projection

	Middle East	China	India	Rest of Asia	North Africa	West Africa	Rest of Africa	Central Asia
Cereals	10	0	-2	3	13	10	8	5
Other agriculture	24	0	0	4	14	5	4	2
Animals	13	0	0	1	6	10	4	7
Oil	-117	-83	-101	-115	-98	-140	-80	-17
Coal	-28	0	-5	-9	2	51	24	0
Petroleum	8	-17	-16	-23	19	-12	-7	-5
Natural Gas	-101	-78	-74	-94	-125	-75	5	-37
Electricity	16	-10	-13	-8	17	29	8	-33
Energy intensive	-81	2	-7	2	-8	12	6	-1
Food processing	13	-2	-3	3	13	31	9	7
Other services	66	-3	6	3	10	1	3	10

With respect to the agricultural sectors (cereals, animals and other agriculture), production increases in Africa and in Indonesia. This is the result of very low energy inputs in these sectors, especially for these regions, and increased capital inputs as a result of to the above described mechanism. This mechanism does no work in areas where the energy inputs in agriculture are high, which is mainly the case in areas where agriculture depends highly on irrigation (mainly arid areas), i.e. Middle East and Central Asia. See also Table 5 for energy shares in agricultural production.

Table 5 also shows the price increase of energy in production and the composite of energy and value added (including capital) in the high oil prices variant compared to the business as usual projection. The table shows that price increases of energy may accrue to 20%, whereas the composite will increase at a much lower rates, or even decline. Most regions show that the cost price increase is more than mitigated by increased demand for capital. Remarkably the price of energy in India is already reduced, which results from a sharp increase of lower priced coal in electricity production.

Table 5 Changes on the price of energy in production in agricultural sectors, value share of energy in production in the business as usual projection and the changes of the prices of the composite of energy and value added in production

	Middle East	China	India	Rest of Asia	North Africa	West Africa	Rest of Africa	Central Asia
Price of energy in production compared to business as usual projection (%)								
Cereals	57	28	0	39	44	27	22	45
Other agriculture	56	30	0	44	45	31	27	42
Animals	55	23	4	38	42	17	29	43
Share of energy in production in the business as usual projection (% value)								
Cereals	18	14	26	12	4	0	0	43
Other agriculture	8	6	5	4	2	0	0	37
Animals	6	3	1	2	1	0	1	32
Price of composite of energy and value-added compared to business as usual projection (%)								
Cereals	11	2	-4	3	0	3	2	15
Other agriculture	3	-1	-6	-2	-1	3	1	12
Animals	1	-3	-6	-4	-2	3	2	10

4.3 Trade impacts

Table 6 and Table 7 present changes in sectoral import and export, respectively. In general, the trade in oil (oil and petroleum) and natural gas decrease significantly, which is the result of the higher oil and gas prices. For almost all sectors in the reported African and Asian regions, export decreases. Only India increases export of energy-extensive sectors. Changes in import are in line with the terms of trade gains and losses. Oil and gas exporters increase imports of energy-extensive products and of electricity. Importers of oil and gas reduce imports of all commodities.

Table 6 Percentage change in imports of the high oil prices variant compared to the business as usual projection

	Middle East	China	India	Rest of Asia	North Africa	West Africa	Rest of Africa	Central Asia
Cereals	21	-10	-29	-7	-4	14	5	23
Other agriculture	15	-18	-32	-17	-6	16	0	18
Animals	15	-12	-26	-14	5	29	10	3
Oil	-38	-24	-33	-34	-33	-28	-26	-29
Coal	-25	-7	-11	-9	-18	4	0	-17
Petroleum	-17	-39	-40	-27	-7	-22	-21	-13
Natural Gas	-49	-31	-15	-37	-45	-26	-70	-28
Electricity	398	-30	-36	110	384	160	29	222
Energy intensive	20	-15	-4	-4	12	2	-4	-6
Consumer processing	20	-11	-16	-8	-1	7	8	11
Other services	8	-8	-11	-5	17	32	12	47

Table 7 Percentage change in exports of the high oil prices variant compared to the business as usual projection

	Middle East	China	India	Rest of Asia	North Africa	West Africa	Rest of Africa	Central Asia
Cereals	-29	-3	22	-2	0	-12	-7	-20
Other agriculture	-22	-6	16	-6	-10	-21	-16	-31
Animals	-24	6	27	0	-9	-29	-17	-22
Oil	-28	-30	-33	-27	-26	-31	-27	-27
Coal	-6	-2	-11	-15	-9	-4	-6	-8
Petroleum	-44	-9	-26	-34	-43	-25	-34	-36
Natural Gas	-30	-42	-40	-28	-28	-19	83	-29
Electricity	-87	136	134	-42	-32	-49	13	-70
Energy intensive	-69	-2	-18	-20	-35	-10	-5	-21
Consumer processing	-21	-2	5	-3	0	-4	-10	-17
Other services	0	8	15	4	-13	-23	-12	-37

4.4 Poverty and hunger impacts

Poverty levels change due to changes in inequality and overall expenditure levels. Inequality is proxied here by changes in employment and real wages of low and high skilled labour. Table 8 presents change in poverty and the underlying dynamics.

In most regions, real wages decrease, except for West Africa. Furthermore, in most regions the wages of high skilled labour decrease more than the wages of low-skilled labour, thereby decreasing inequality. However, in the Middle East, India and West Africa inequality is increasing. The largest decrease is observed in Central Asia, where the high-skilled wages decrease more than the low-skilled wages. West Africa is confronted with the largest increase in inequality. Here, the high skilled wages increase more than the low-skilled wages. Changes in expenditure levels are much larger.

As a result, large poverty increases are observed in Asia, especially in China, India and Central Asia. In Sub-Saharan Africa a decrease in poverty is observed, which is mainly the result of increasing expenditures (terms-of-trade gains and successful reallocation of capital). The projected increases in poverty are however much higher than the decreases, which still results in a global increase of poverty. Asia is mainly hit. Also China shows a high increase percentagewise, but due to very high poverty reduction already in the business as usual projection, the absolute increase is relatively low and accounts for only a small share in the global increase.

Table 8 Poverty impacts and the underlying determinants of the high oil and gas price variant compared to the business as usual projection in 2020

	Wages LSL (%)	Wages HSL (%)	GINI (%)	Expenditures (%)	Poverty (%)
Middle East	-2.6	-2.2	0.4	5	-23
China	-3.7	-4.2	-0.2	-5	17
India	-6.4	-6.3	0.1	-8	22
Indonesia	-3.5	-4.4	-0.6	-3	8
Rest of Asia	-6.5	-7.0	-0.2	-6	14
North Africa	-3.0	-4.0	-0.4	0	-1
West Africa	1.5	2.0	0.7	7	-10
Rest of Africa	0.0	-1.8	-0.5	3	-3
South Africa	-1.8	-3.2	-0.2	-4	5
Central Asia	-12.3	-14.8	-2.2	-6	19

Hunger levels change due to changes in the average food availability, which is the result of change in regional production and trade. Within the WorldScan model we take changes in availability of cereals, animal products and other agricultural products into account. Table 9 presents change in the prevalence of undernourishment (hunger) and the underlying dynamics with respect to food availability.

Table 9 Hunger impacts and the underlying determinants of the high oil and gas price variant compared to the business as usual projection in 2020

	Cereals (%)	Other agriculture (%)	Animal products (%)	Food availability (%)	Hunger (%)
Middle East	0.0	5.9	3.4	1.3	-8
China	-3.2	-3.2	-2.6	-2.6	21
India	-4.8	-2.7	-2.3	-3.3	34
Indonesia	-0.3	0.1	-0.5	-0.2	2
Rest of Asia	-3.5	-2.2	-1.9	-2.5	19
North Africa	3.4	3.7	2.5	2.7	-25
West Africa	8.0	7.7	6.4	6.7	-39
Rest of Africa	5.6	5.8	4.6	4.8	-21
South Africa	-5.8	-5.8	-3.5	-4.2	0
Central Asia	-1.7	-1.7	1.8	-0.6	6

The largest decreases in food availability are found in Asia, i.e. India, China and Rest of Asia. Most African regions (North, West and Rest of Africa) and the Middle East show large increases. Changes in Central Asia are negative but relatively small. Food availability is the combined effect of change in production and changes in trade. In general, only the African regions increase production in the food sectors, while all other regions production is decreased (see Table 3). Furthermore, trade in food commodities mainly restricts to increased imports for Sub-Sahara Africa (West and Rest of Africa), the Middle East and Central Asia and increased exports mainly only for India (Table 6 and Table 7).

Increased food availability for the African regions is thus the combined effect of increased production and imports and decreased export. The Middle East can fully offset food production losses with import increases, while Central Asia only partly offsets the production losses with imports. Decreased food availability for China and Rest of Asia is the result of reduced production and exports, while India is also confronted with export increases, further impacting on the food availability.

5 Discussion

PM: Comparison with earlier analysis

The model result should be interpreted with care. The reported regions are highly aggregated. Especially the regions in Africa consist of both oil exporting and oil importing countries. This makes conclusions not generally applicable to the countries within the regions. Furthermore, many farmers in countries facing food-security problem are not integrated in the market and are therefore not part of this economic analysis. The projected impacts might be different for different groups of producers and consumers within a region. Farmers are impacted differently than urban slum dwellers, where the former might gain due to higher food prices, while the latter have to buy their food on the market. Farmer's choices to consume own-produce or sell it on the market might depend on its profitability. Finally, the flexibility of reallocation of capital between agricultural and non-agricultural sectors could be interpreted as optimistic, although the price shock is also assumed to be structural and enduring. Of course, the shortly enduring oil price spikes in recent years hardly compares with capital mobility.

In the poverty and hunger calculations, the distribution effect is only partly represented. Both calculations use a log-normal distribution to describe how food and income are distributed over the population. However, in the hunger calculations, the coefficient of variation does not change in our future projections, thereby only taking an average change in food availability into account. In the poverty calculations a GINI-coefficient is used to parameterise the skewness of the distribution. We distinguish in this paper only two household groups, namely low and high skilled labour, which is too course to properly proxy inequality. Furthermore, we do not account for heterogeneity of consumption and production in rural and urban areas.

A methodology than addresses these shortcomings is the Global Income Distribution Dynamics (GIDD) tool of the WorldBank, which allows to measure the effects of economic policies on poverty and on the distribution of welfare among individuals and households (Bussolo et al., 2008). The methodology links to a CGE model that shares large similarities to the WorldScan model. It distinguishes, next to a division between low and high skilled labour, also agricultural and non-agricultural labour and uses changes on the labor market (allocation and wages), changes in the relative price of food and non-food consumption baskets and change in per capita income/consumption growth rates to re-weight household survey data and determine for example poverty headcount. Using this methodology would serious improve our model framework, without having to fully change the model structures.

With respect to food consumption, WorldScan distinguishes three agricultural sectors accounting for the most fundamental food classes (cereals and animal products), while the income elasticities are the same for all three classes. This does not allow including changing food consumption patterns when people get richer. Next, future consumption may prove to be unrealistic (for example compared to forecasts by the FAO).

6 Conclusions

In this paper we have linked the WorldScan model, a recursive dynamic general equilibrium model, with the GISMO1.0 mode, a system dynamic modeling framework developed to address long-term human development in relation to socio-economic and environmental changes. The modeling framework is used to assess the impacts of an exogenous price shock for oil and gas prices on the macro-economy, poverty and hunger, by uniformly reducing the fixed factor of oil and gas across regions in the WorldScan model. Output from the WorldScan model (expenditures, GINI-coefficient and food availability) is used as input in the GISMO1.0 model to determine change in poverty and hunger, which is also addressed in MDG1.

It should be noted that the applied methodology has several limitations, mainly by the aggregated representation of income classes and agriculture sectors. Furthermore, the analysis is done for large aggregate regions which are not always homogeneous with respect oil and gas importers and exporters. This is especially apparent in the Sub-Saharan African regions. Finally, the reader should be aware that in this analysis we do not to analyze or reproduce high oil price spikes (short to medium term), but instead look at structural changes in the economy from long term price increases, with oil prices reaching $100 per barrel in 2020.

In our analyses, increased energy prices entail the largest GDP losses in energy exporting countries with GDP losses ranging between -5% Sub-Saharan Africa and -19% in Central Asia. Nevertheless, these losses may partly or completely be offset by terms-of-trade gains, which lead to income gains ranging between -6% in Central Asia to +7% in West Africa. Furthermore, sectoral reallocation of capital inputs from energy-intensive sectors may even increase the production in energy-extensive sectors (including agriculture). In countries with high oil intensity and a high export dependence on oil, this effect might be hampered, resulting in an overall capital flee. Energy importing countries are confronted with lower GDP losses (ranging between -5% in India to -2% in China), but gain much less from capital reallocation. Furthermore, they are confronted with terms-of-trade losses resulting in even larger income losses (ranging between -8% in India to -5% in China).

Impacts on poverty are relatively high compared to the changes in income and expenditures. Oil and gas exporting countries can decrease their poverty numbers when expenditures increase (ranging between +19% in Central Asia to -23% in the Middle East), while oil and gas importing countries see their poverty increase (ranging between -22% in India to -16% in Rest of Asia). The impacts on hunger rely on changes in food availability. Most energy exporting countries see their food availability increase. Capital reallocation to agriculture increases productivity, while changes in terms-of-trade increase food imports. Oil and gas importing countries see their overall availability drop. Agriculture in India and Central Asia is relatively energy intensive and might therefore suffer from higher energy prices. Hunger in Africa is project to decrease most due to the imposed oil and gas price increase, reaching almost -40% in West Africa. India is projected to show the largest increase with +34%, while also China is impacted significantly with +21%.

The results of this international energy price shock should be interpreted with care. The price shock cannot be interpreted as short term impact of a high oil price spike and the reader should realize that this paper analyzes the structural adjustments of a sustained energy price shock. Nevertheless, the proposed modelling framework and the mechanisms described address important elements and fuel the discussion on the impacts of increasing energy prices on development.

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Appendix A: WorldScan and GISMO regions and sectors

Table 10 WorldScan and GISMO regions and WorldScan sectors

WorldScan regions	GISMO1.0 region	WorldScan sectors
OECD Europe	Western Europe	Cereals (wheat and cereal grains nec)
Eastern Europe	Central Europe	Oilseeds
Former Soviet Union	Russia+	Sugar crops (sugar cane, sugar beet)
	Eastern Europe	Other agriculture
United States	US	Animal products
Other OECD	Canada	Minerals NEC
	Turkey	Oil
	Japan	Coal
	Korea	Petroleum, coal products
Brazil	Brazil	Natural gas (incl gas distribution)
Other South America	Rest of South America	Electricity
Mexico	Mexico	Energy Intensive
Other Central America	Rest of Central America	Vegetable oils and fats
Middle East	Middle East	Capital goods and durables
China	China+	Public administration
India	India	Consumer food products
Indonesia	Indonesia	Other consumer goods
Other South East Asia	Rest of South-East Asia	Road and rail transport
	Rest of South Asia	Other Transport (water and air)
North Africa	North Africa	Other services
West Africa	West Africa	
Rest of Africa	Central Africa	
	East Africa	
	Rest of Southern Africa	
South Africa	South Africa	
Oceania	Oceania	
Central Asia	Central Asia	