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Macroeconomic and Welfare Consequences of High Energy Prices

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Abstract

The current wave of volatile international oil prices coupled with the low hydro-energy generation continues to exert negative impacts on the Ugandan economy. This paper analyses the extent to which changes in energy prices affect the economy and examines policy options that can be undertaken to circumvent the negative effects. The impact of higher oil prices takes a large toll on all sectors including agriculture, manufacturing and services. With the existing losses in productivity of generating hydro electricity, this has exacerbated the energy crisis. The combined output loss for the manufacturing sector due to increase in fuel prices and a shortage of electricity is estimated at 2 per cent on annual basis. While the government has little control on the international prices of oil, further private and public investments in the energy sector are called for to alleviate the shortages of energy.

A. Introduction

The impact of oil shocks on national economies has been of concern to many countries, as a constraint to economic development. Recently, international oil prices have risen sharply and reached record levels, and coupled with Uganda's reliance on oil imports, this has had an adverse impact on the country's economy. Although this is not limited to Uganda, the country's location and the recent natural and regional problems make it even more vulnerable to oil shocks.

Uganda has neither crude oil production nor a refinery and is entirely dependent on imports of petroleum products, although it has recently discovered some oil reserves in the western region of the country. With recent power shortages in the country (resulting from reduced electricity generation from the only two power stations), and a hike in global oil prices, there has been an increase in the oil imports especially diesel for thermal power generation. According to government statistics, Uganda consumed about 792,555m3 of petroleum products in 2006. Of the total, 28.5 per cent by volume was diesel, 25 per cent gasoline, 11.4 per cent aviation fuel, 5.4 per cent kerosene, and 1 per cent LPG (UBOS, 2007; Figure 1).

The increase in oil prices and reduced generation of electricity has had both direct and indirect effects on the economy. First, the reduction in electricity generation has significantly affected the manufacturing sector. This is due to the unexpected power outages and load shedding. In some cases companies have resorted to use of generators, albeit the increasing international prices of oil. This has resulted into lost output and in some instances bankruptcies. Increasing fuel prices have weighed heavily on the transportation sector while at the same time increasing the cost of generating thermal power.

Given that there are short and long-term implications of volatile fuel prices, we use a dynamic general equilibrium model to capture the effects especially at a sectoral level. For oil prices, we first assume that the increase is permanent, a

phenomenon which reflects what is on the ground in Uganda. The second simulation assumes that the oil prices revert back to their original levels in line with the international crude oil prices. The third simulation focuses on the marked reduction in electricity generated owing to the inefficiencies in the sector and the natural causes like the reduction of the water level of Lake Victoria. The fourth simulation assumes that the inefficiency in the utility sector is temporary and addressed by attracting private investments. Lastly, we explore the case where the government reduces tariffs on oil imports to circumvent the price increase.

The key results suggest that the changes in oil prices have sizable negative effects especially at the sectoral level. While at the aggregate level, GDP might not be affected as more activity is realised in the trading sector, increase in oil prices would significantly reduce the output for agriculture, manufacturing and transports. The reduction in output for these sectors is subdued when the oil price shock is temporary. On the other hand, the low efficiency in the electricity sector has also negatively affected the sectors. The combined effects of oil price shocks and reduction in electricity generated would reduce overall growth rate of the manufacturing sector by 2 per centage points on annual basis.

This paper has some policy implications. First, at a time of high oil prices, the government can intervene by lowering tariffs on oil products. However, this has to take into account the trade-off between the oil tariff revenues and taxes lost owing to reduced economic activity especially in the manufacturing sector. Second, the government should take a more active role on suppliers where prices should be adjusted downwards when international prices drop. As found, the output losses are much higher when the price increase remains permanent. Third, without addressing the inefficiencies in the electricity sector, this will continue to affect the output of manufacturing and other sectors that depend on electricity. More private-public investments should be encouraged to enhance the productivity of the sector.

B. Background

B.1 Volatility of World Crude Oil Prices

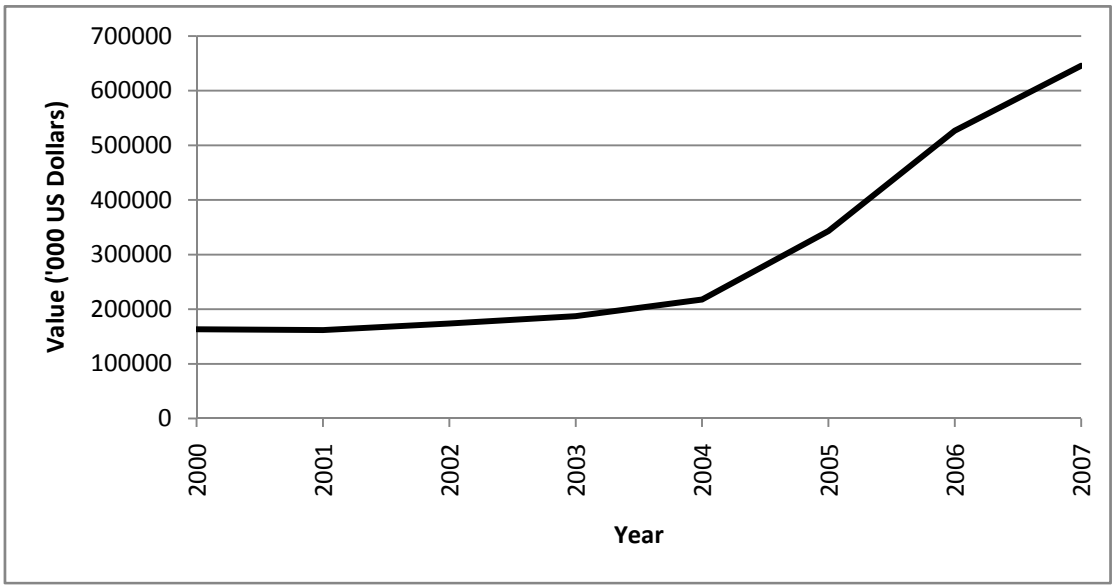
On average, the international spot prices of crude oil jumped from an annual average of $12 per barrel in 1998 to $94 in 2008, a phenomenal 780% increase in just 10 years (Energy Information Administration (EIA), 2008). Among factors that contributed to the hike was an unabated strong demand in the emerging economies and continuous tension in Middle-East region, the largest oil supplying region. Speculations on oil prices in future markets also played an important part in the price hikes, even though the supply seems to increase proportionally to meet demand in the last few years. Recently, the prices have been on a downward trend owing to the ongoing recession in the US and other developed countries. Various studies have suggested that any US$10 increase in oil price per barrel would cause about 1 per cent reduction in the world's gross national product (GDP) and a 0.6 per cent increase in the world price.

As far as Uganda is concerned, the component of retail prices of oil was demystified and its one-off affects on the economy can be explored. The spiral of higher oil prices has driven retail prices to record highs. The Government has made it clear to the market and consumers that there is nothing it can do to respond to the oil shocks. The entire dependence of the country on oil imports and inability to substitute consumption of oil products are also factors for suppliers to exhort higher prices on consumers. Moreover, it is very likely that the lack of fair competition has allowed all oil companies to collude to set higher prices simultaneously in order to keep their profit margins as high as possible. Indeed even as world prices of crude oil continue to fall, suppliers have maintained the old prices when the barrel of oil was trading at US$ 150 dollars. Evidently, the retail prices of gasoline and diesel have reached 2,563 and 2,350 Uganda Shillings per litre, respectively for the first quarter of 2008 compared with 1,763 and 1,513 per litre in 2004, nearly 50 per cent higher and there are no

signs of the prices dropping even when the crude prices have plummeted to a third of their record levels. Even though the impacts of this hike seem to be evident, the Government has yet to genuinely look for alternative policies. The justification of the Government's "laissez-fair" approach is the pronounced impact on tax revenue reduction, should it lower tariffs and taxes imposed on oil imports and consumption. Tax revenue from oil was about 535 Billion Uganda Shillings in 2007, accounting for more than 19 per cent of total tax revenue.

Because Uganda is landlocked, it depends largely on an oil pipeline from Mombasa to Eldoret, both in Kenya, from where products are trucked to Kampala. This has resulted in high import costs and uncertain in supply as is explained by the major fuel disruption that occurred at the end of 2007 in the aftermath of the Kenya's post-election violence.

Fig 1: Uganda Imports of Oil, January-December, 2007



Source: Uganda Bureau of Statistics (UBOS), 2008

B.2 The Oil Industry in Uganda

Uganda's downstream oil sector was liberalized in 1994, and price controls and bureaucratic resource allocation were abolished and a new petroleum supply act was promulgated in October 2003. This led to the licensing of several companies, including several international oil companies like Shell, Total, and Caltex to take part in the industry. Although the sector is fairly competitive with even smaller firms operating, the market is dominated by the few international ones the top three being Shell, Total and Caltex (Ministry of Mineral and Energy Development 2008). The persistently high prices of petroleum products in spite of the falls in the world crude prices have raised alarms in the population that the industry may be poorly regulated, making players to collude to cheat the motorists.

B.3 Energy Price Movements in Uganda[1]

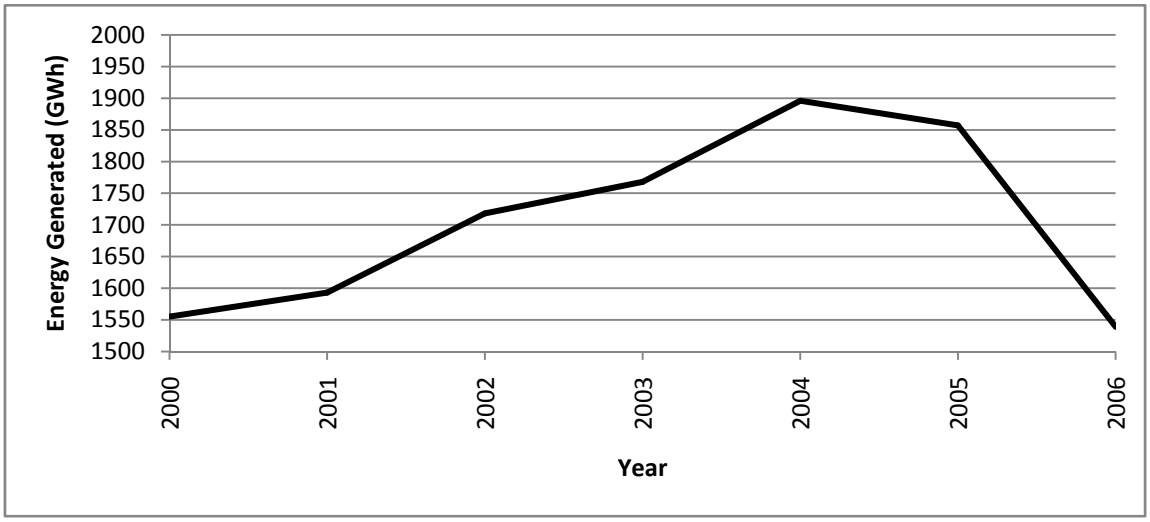
Uganda's fuel woes are closely linked to the recent power shortages that have increased the need for supplementary power to support the dwindling Hydroelectric Power (HEP) from the two dams in the country. The recent prolonged drought in East Africa and the derelict power grid has caused a serious shortage of electricity, and this pressure on the power system prompted the government to encourage the entry of private firms to generate power from diesel operated thermal generators and supply it to the national grid.

But in spite of this, power supply has lagged the power needs of the country resulting in a load-shedding program introduced in February 2006, that has often involved cutting power off for more than 12 hours every day to all consumers except certain key installations (such as hospitals). As of the end of 2006 the hydroelectric dams with an installed capacity of 356 MW were operating at less than one-half of the capacity, with the power generated being supplemented by a 100 MW diesel-fired generators (Fig.2). This shortage is aggravated by the fact

[1] Energy here refers to a combination of fuel for automobiles, manufacturing, etc and electricity

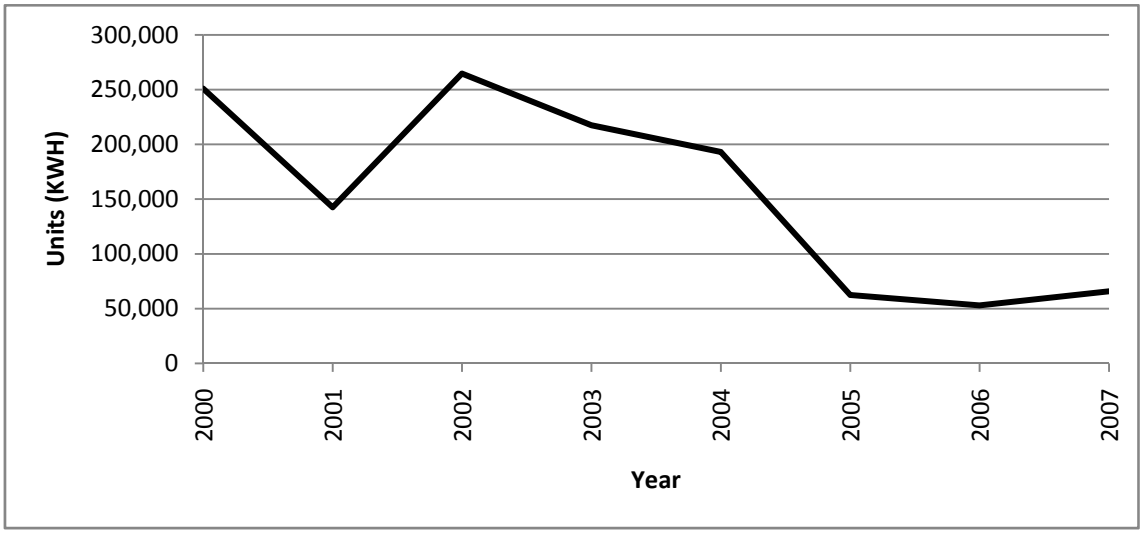
that some of the generated electricity is exported to neighbouring countries. But with a dwindling generation capacity, the amount of power being exported has also been trending down, only that the country with such severe power shortages cannot afford to export any power (Fig. 3).[2]

Fig 2: Uganda Electricity Generation, 2000-2006



Source: UBOS, 2007

Fig 3: Uganda Electricity Exports, 2000-2007

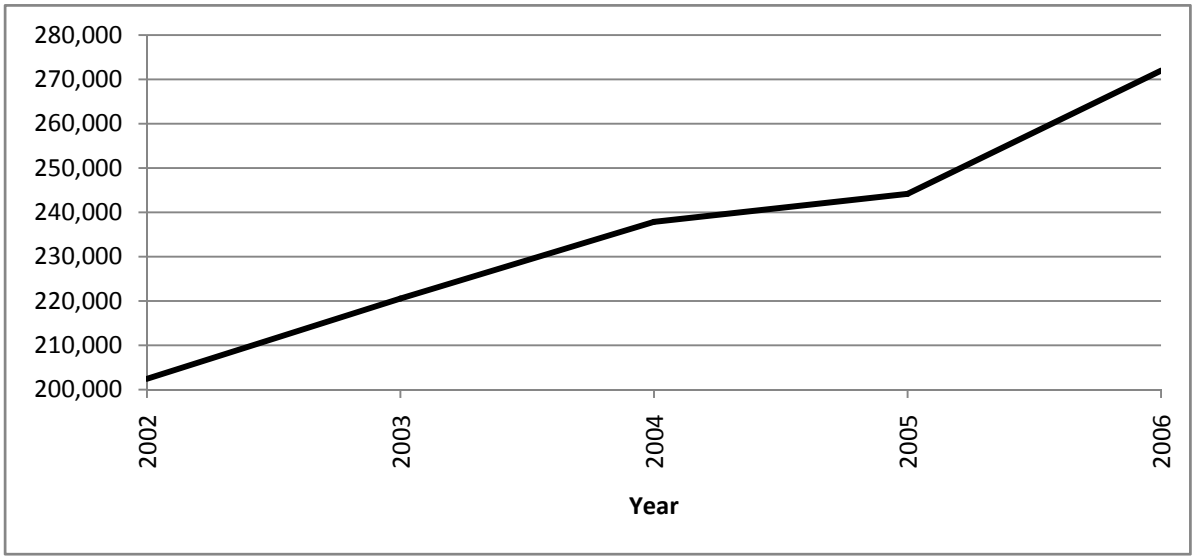


Source: UBOS, 2008

[2] This could be more complicated owing to the usually long-term bilateral agreements signed for such contracts.

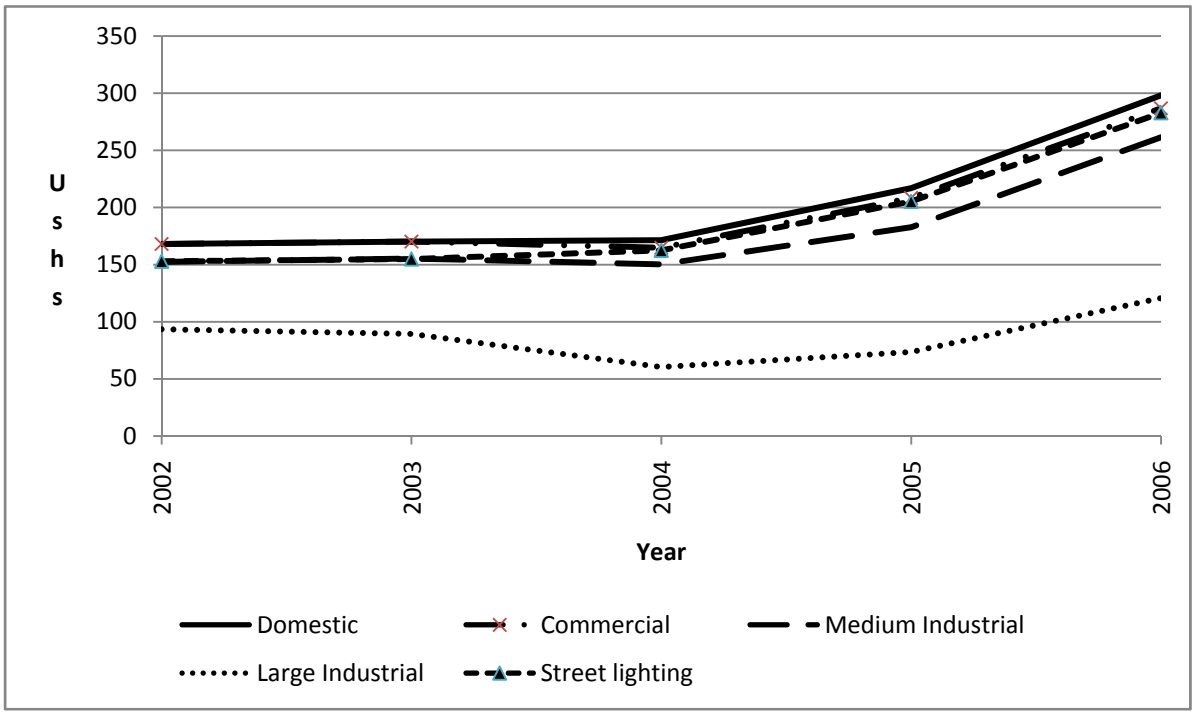
Inspite of the decreased exports of power, electricity prices have continiued to increase, mainly fueled by the incresese in the number of users that are coming onto the lectricity grid (Figures 4 and 5).

Fig.4: Number of electricity domestic tariff consumers in Uganda, 2002 – 2006



Source: UBOS, 2008

Fig.5: Uganda Power Tariff Rates, 2002 to 2006 (UGX/kWh)



Source: UBOS, 2008

In order to support the endeavour to solve the acute power shortage in the country through the encouragement of thermal power generation, the government agreed in February 2006 to waive taxes on diesel used by commercial generators above a certain capacity. But in spite of that, these fuel guzzling measures have adversely aggravated the fuel price hikes, as the country becomes more dependent on diesel powered thermal power, leaving Uganda with one of the most expensive fuel in Africa.

The other reason the price of fuel is high is the problematic supply from Kenya that has frequently caused supply shortages and, at times, rationing by fuel suppliers. This is mainly caused by inadequate pumping capacity of the pipeline to Eldoret that could not cope with the growing fuel demand in the countries in the hinterland that rely on Kenya for supply. This has been aggravated by acts of vandalism that have often damaged the pipeline in order to steal petroleum products and power failures that sometimes stop pipeline operations.

This together with relatively high excise duties and VAT on petroleum products has ensured that the mark-up on import oil is very high. The tax on petroleum products accounts for a large share of total government revenue, amounting to about19.4 per cent of the total revenue (Ministry of Mineral and Energy Development 2008). The VAT rate is now 18 per cent, and excise duties on gasoline were USh. 850 for a retail price of about Ushs 2650, and on diesel USh 530 per litre, for a retail price of about UShs. 2450, which accounts for up to 33 per cent of the final sale price. Added to import duties, the tax rate on fuel is estimated at over 80 per cent. These high taxes levied on petroleum products combined with the impacts of high transportation costs makes fuel prices in Uganda one of the highest in Africa (Tables 1).

Although the amount of petroleum products being imported into the country have continued to increase, and the world crude prices to plummet, local pump prices have continued to increase rising from Shs. 1095 per litre of diesel in January 2000 to Shs. 2,350 in May 2008. Petrol similarly rose from Shs 1305 per litre to Shs. 2650 during the same period (Figures 6 and 7).

Fig. 6: Sales of selected Petroleum Products in Uganda 2002 - 2006

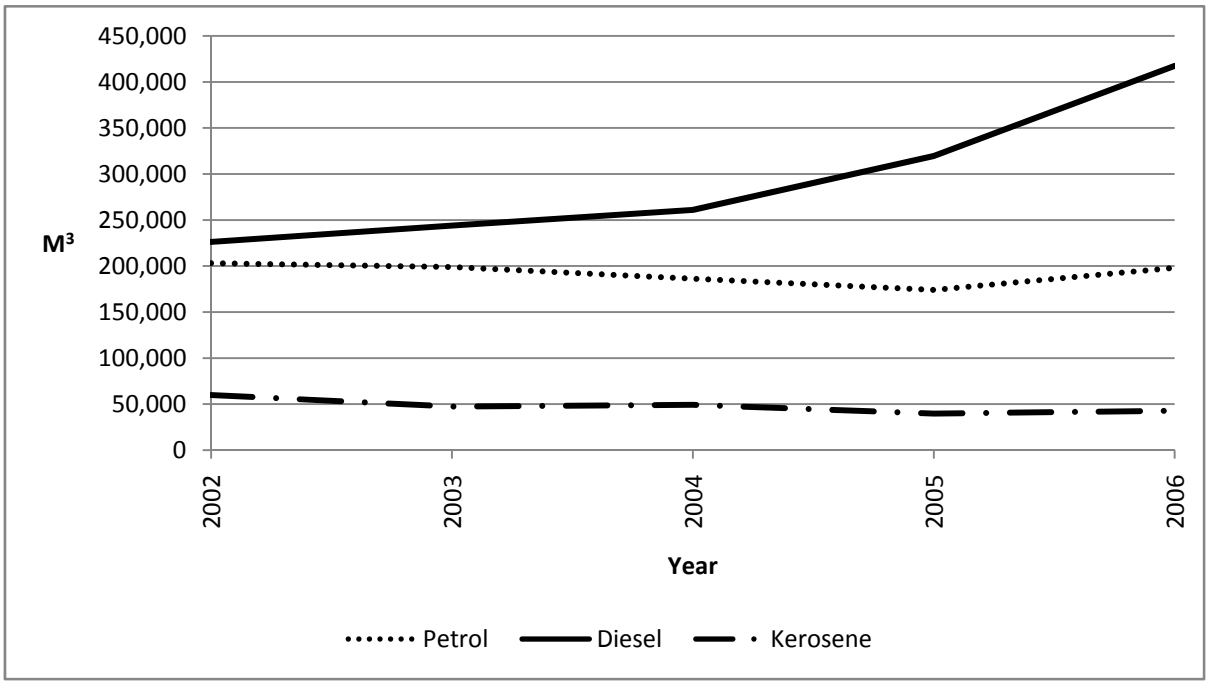
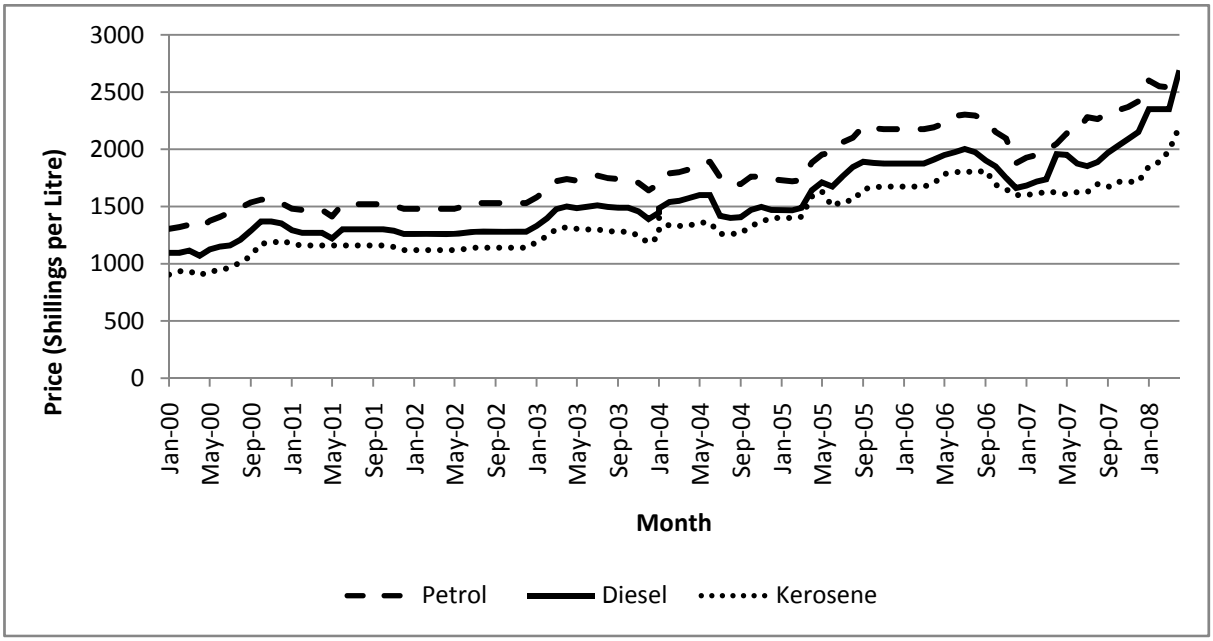


Fig. 7: Average Pump Prices for Petroleum Products in Uganda (Kampala Pump Prices, Shillings per Litre, January 2007-May 2008)



Source: Bank of Uganda and UBOS

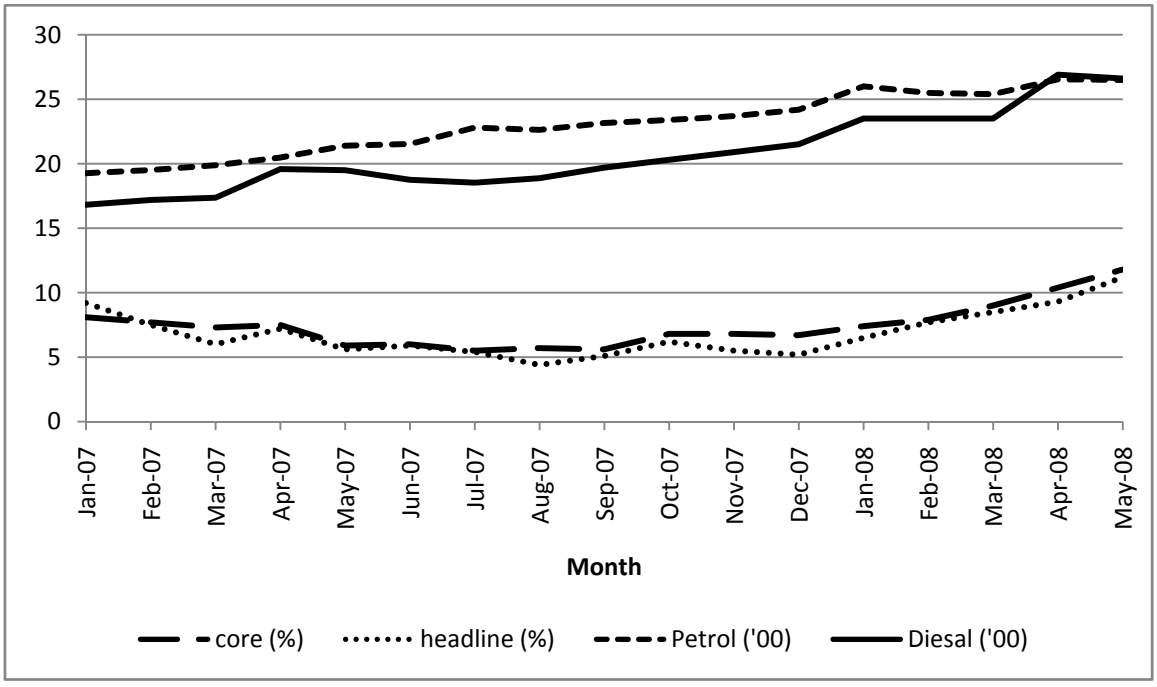
Table 1: Retail Regular Petrol and Diesel Prices per Litre for Selected Countries in US$ (April 2006)

Country	Price(US$)	
	Petrol	**Diesel**
Uganda	1.20	1.07
Rwanda	1.10	1.08
Kenya	1.04	0.88
Tanzania	1.03	1.03
Ghana	0.85	0.78
Ethiopia	0.63	0.50
Egypt	0.17	0.10
USA	0.73	0.72

Source: Energy Sector Management Assistance Programme (ESMAP), World Bank

The high fuel prices have led to inflationary pressures as indicated in Figure 5.

Fig. 8: Annual Inflation (%) and Average Monthly Prices of Petrol and Diesel ('00 Ushs.) January 2007-May 2008



Source: UBOS, 2008

B.4 Expected Impact of the Discovery of Oil in Uganda

Uganda recently discovered some potentially commercially viable quantities of oil in the western and northern parts of the country. The exploration work is being undertaken by mainly four firms, namely Heritage Oil and Gas Ltd, Tullow Oil, Dominion Petroleum and Tower Resources, UK. Most of the oil discoveries have been in the Albertine Graben Basin and so far 21 wells have been drilled in this basin of which more than 10 have come up with oil discoveries. As of the end of 2008, more than US $ 500 million had already been invested in the exploration of oil and gas. The discoveries so far made, indicate that Uganda's oil reserves may be more than 1 billion barrels of oil, with other opportunities for exploration yet to be tried. Estimates point to a possibility of the country annually receiving up to US$ 5 billion from oil exports when the oil production becomes fully operational.

To help speed up the relief to the over burdened energy sector, the government is working with Tullow Oil on what they are calling an early production scheme that will initially use more than 4,000 barrels of oil per day to produce diesel, Kerosene and Heavy Fuel Oil (HFO). It is expected that the production especially of the HFO that is cheaper to use in thermal generation than the diesel that is being used now, will help not only to reduce the amount of oil imports but also the price of electricity. It is expected that by the end of 2009, under the early production scheme, 50-85 MW of power will be generated using HFO, something that will relive the shortages in the power sector.[3] At the moment it is not yet clear how much revenue the country may eventually get from oil and it is therefore difficult to ascertain how much impact it will have on the energy sector. But what is clear is that if the production starts in earnest and as long as the proceeds are managed well, this is bound to have a significant positive impact on the energy sector through possibly cheaper fuel or reduced reliance on expensive diesel for thermal power generation.

[3] It must be understood however, that all these plans are still at proposal form and that the early production scheme may delay due to environment and economic reasons, including the continuous fall in global crude prices that may make the Ugandan oil industry unprofitable.

C. Objectives of the Study

The main objective of the study is to assess the impact of the high energy prices and reduced electricity generation on the Uganda economy especially on the manufacturing sector. The study seeks to investigate how the recent increases in the prices of energy and the low generation of electricity have affected the overall macro-economy, different sectors of the economy and the welfare of different sections of the population.

D. Justification of the Study

Whereas it is taken for granted that high energy prices have a detrimental impact on economies of oil importing countries like Uganda, there is a paucity of studies that have gone ahead to empirically prove this for Uganda. One of the reasons for this is because high energy prices have only recently become a global threat to economic growth. This has necessitated that the impact of these oil shocks be investigated to provide policy makers with evidence of efficacy of the energy policies that they are undertaking and how they affect both the economy and the welfare of the population. Although the Energy Sector Management Assistance Programme (ESMAP) of the World Bank has routinely been assessing the impact of energy prices on the world economies, it has been using only descriptive assessment without rigorous empirical assessment (See for Example, Bacon and Kojima, 2006; Bacon, R., and Mattar, A., 2005). Moreover, we do not know of any study that has empirically studied the impact of an increase in the price of both petroleum and electric power in Uganda. Based on an economy-wide extensive SAM which was recently released by the Uganda National Bureau of Statistics (UBOS), based on 2007 data, our CGE analysis empirically assesses the macroeconomic and welfare impacts of high energy prices in Uganda.

E. Literature Review

The impact of the high energy prices on the economy both at the macro and micro level is well documented in many studies. Not only does it affect the firms' activities but it also generally impact negatively on the whole economy. Lee and Ni, 2002 found that for industries that have a large cost share of oil, such as petroleum refinery and industrial chemicals, oil price shocks mainly reduce supply but for other industries, with the automobile industry being a particularly important example, oil price shocks mainly reduce demand, suggesting that oil price shocks influence economic activities beyond that explained by direct input cost effects, possibly by delaying purchasing decisions of durable goods.

Schneider, 2004 also found that oil price shocks affect the economy through the supply side (higher production costs, reallocation of resources), the demand side (income effects, uncertainties) and the terms of trade. The paper also found that an increase in the price of oil feeds through to GDP growth to a much larger extent than a decline, a phenomenon that can be attributed to adjustment costs associated with sectoral reallocations, the implications of uncertainties for spending on consumer durables and investment, and nominal wage rigidities. Furthermore, the element of surprise in oil price hikes seems to play a considerable role. Thus, the paper continues, when a rise in the price of oil occurs after a prolonged period of oil price stability, it has a larger impact than a price hike which immediately follows previous cuts.

To emphasize the importance of oil in the economic health of even developed countries, Carlstrom and Fuerst, 2005 contend that every U.S. recession since 1971 has been preceded by two things: an oil price shock and an increase in the federal funds rate.

Abeysinghe, 2001 measuring the direct and indirect effects of oil prices on GDP growth of 12 economies, finds that that the transmission effect of oil prices on growth may not be that important for a large economy like the US but it could

play a critical role in small open economies with the biggest impact being the effect of the shock and its interaction with consumer and investor confidence.

Using a GEM-E3 world model to carry out a comparative statics analysis of the potential impact of oil price rises on the EU economy, Ciscar., et. al, 2004, found out that crude petroleum, petroleum refineries and energy-intensive sectors undergo a significant fall in their value-added with almost 40 per cent of the overall GDP fall coming from other service sector, while the trade and transport sector and the other equipment goods sector represent each approximately 10 per cent of the overall GDP fall. They found that the GDP losses for the EU as a whole were 0.94 per cent in a scenario where oil was increased by $10 and 2.56 per cent in the second where the oil was increased by $30. Whereas they found that the macroeconomic impact is slightly lower in the USA (0.81 per cent and 2.21 per cent, respectively), Australia, the FSU, India and Japan had similar losses to that of the whole EU, while China and Africa experienced a bigger GDP drop. Taking the African case it seems to suggest that the pass-through effects of increased oil prices is particularly more harmful to African countries like Uganda.

Pradhan, and Sahoo, 2000, using CGE to analyse the impact of international oil price shock on the Indian economy found that it affects the welfare and poverty of households directly as well as indirectly. The paper found that oil shock leads to decline in household welfare and increase in poverty and that with the increase in elasticity of substitution of demand for imports to domestically produced crude oil, welfare loss for household groups goes on increasing. The paper found that the rise in rural poverty is concentrated among non-agricultural labour and other household groups, while that for urban area is reflected in non-agricultural household group.

Other researchers who have used CGE to study the impact on the economy of high oil prices are Adenikinju and Falobi, 2006 who find that the oil sector supply shocks in Nigeria are costly both directly and indirectly resulting in lower real GDP, higher average prices and greater balance of payment deficits. They also

find that other macroeconomic variables such as private consumption, investment, government revenue and employment also decline. In addition, they find that the distributional impact of the quantitative energy supply shocks is higher for poor households than rich households.

Nkomo, 2006 contend that in Southern African countries, energy shocks affect the economies because energy consumers and producers are constrained by their energy consuming appliances which are fixed in the short-run, thus making it difficult to shift to less oil intensive means of production in response to higher oil prices and thus oil price shocks increase the total import bill for a country largely because of the huge increase in the cost of oil and petroleum products that low-income countries with poorer households tending to suffer the largest impact from oil price rise.

The Provincial Decision-Making Enabling (PROVIDE) Project , 2005 using CGE to analyse the impact of an oil price increase in South Africa find that a 20 per cent oil shock to the economy results in a drop in GDP of 1 per cent. The paper finds that the major impact is to be found in the petroleum industry itself, whereas the effects on liquid fuel dependent industries such as transport are not as large as may be supposed. In agriculture, they find that the depreciating currency has a positive effect, offsetting most of the negative effects of higher petroleum prices, particularly in export-oriented areas.

Apart from oil or fuel prices, electricity shortage is as destructive, as found out by Guha, G. S, 2005. Using a CGE model to assess the economic impact of electricity outages arising from natural disasters in Memphis, Tennessee, the paper found that outages cause downstream effects (where customers are short-supplied), upstream effects (where suppliers are affected by cancelled orders), inflation effects (high cost of critical input), income effect (wage cuts lead to reduced spending and lower demand) and investment effect (lower surpluses).

F. The Uganda Social Accounting Matrix (SAM) 2007

A Social Accounting Matrix (SAM) is a table which summarizes the economic activities of all agents in the economy. These agents typically include households, enterprises, government, and the rest of the world (ROW). The relationships included in the SAM include purchase of inputs (goods and services, imports, labour, land, capital etc.); production of commodities; payment of wages, interest rent and taxes; and savings and investment. Like other conventional SAMs, the Uganda SAM is based on a block of production activities, involving factors of production, households, government, stocks and the rest of the world.

The Uganda SAM is a 120 by 120 matrix. The various commodities (domestic production) supplied are purchased and used by households for final consumption (42 per cent of the total), but also a considerable proportion (34 per cent) is demanded and used by producers as intermediate inputs. Only 7 percent of domestic production is exported, while 11 per cent is used for investment and stocks and the remaining 7 percent is used by government for final consumption. Households derive 64 per cent of their income from factor income payments, while the rest accrues from government, inter-household transfers, corporations and the rest of the world. The government earns 32 percent of its income from import tariffs – a relatively high proportion, but a characteristic typical of developing countries. It derives 42 percent of its income from the ROW, which includes international aid and interest. The remainder of government's income is derived from taxes on products (14 percent), income taxes paid by households (6 percent) and corporate taxes (5 percent).

Investment finance is sourced more or less equally from government (26 per cent), domestic producers (27 per cent) and households (26 per cent), with enterprises providing only 21 per cent. Imports of goods and services account for 87 percent of total expenditure to the ROW. The rest is paid to ROW by domestic household sectors in form of remittances; wage labour from domestic

production activity; domestic corporations payments of dividends; income transfers paid by government; and net lending and external debt related payments.

The extent of household dis-aggregation is very important for policy analysis, and involves representative household groups as opposed to individual households. Pyatt and Thorbecke (1976) argue persuasively for a household dis-aggregation that minimizes within-group heterogeneity. This is achieved in the Uganda SAM through the disaggregating of households by rural and urban, and whether households are involved in farming or non farming activities.

The Uganda SAM identifies three labour categories disaggregated by skilled, unskilled and self employed. Land and capital are distributed accordingly to the various household groups.

G. Salient Features of the CGE Model

The CGE model used in the present study is based on a standard CGE model developed by Lofgren, Harris, and Robinson (2002). This is a real model without the financial or banking system (See Table A1). It cannot be used to forecast inflation. The CGE model is calibrated to the 2007 SAM. GAMS software is used to calibrate the model and perform the simulations.

Productions and commodities

For all activities, producers maximize profits given their technology and the prices of inputs and output. The production technology is a two-step nested structure. At the bottom level, primary inputs are combined to produce value-added using a CES (constant elasticity of substitution) function. At the top level, aggregated value added is then combined with intermediate input within a fixed coefficient (Leontief) function to give the output. The profit maximization gives the demand for intermediate goods, labour and capital demand. The detailed disaggregation

of production activities captures the changing structure of growth due to the pandemic.

The allocation of domestic output between exports and domestic sales is determined using the assumption that domestic producers maximize profits subject to imperfect transformability between these two alternatives. The production possibility frontier of the economy is defined by a constant elasticity of transformation (CET) function between domestic supply and export.
On the demand side, a composite commodity is made up of domestic demand and final imports and it is consumed by households, enterprises, and government. The Armington assumption is used here to distinguish between domestically produced goods and imports. For each good, the model assumes imperfect substitutability (CES function) between imports and the corresponding composite domestic goods. The parameter for CET and CES elasticity used to calibrate the functions used in the CGE model are exogenously determined.

Factor of production

There are 6 primary inputs: 3 labour types, capital, cattle and land. Wages and returns to capital are assumed to adjust so as to clear all the factor markets. Unskilled and self-employed labor is mobile across sectors while capital is assumed to be sector-specific.

Institutions

There are three institutions in the model:, households, enterprises and government. Households receive their income from primary factor payments. They also receive transfers from government and the rest of the world. Households pay income taxes and these are proportional to their incomes. Savings and total consumption are assumed to be a fixed proportion of household's disposable income (income after income taxes). Consumption demand is determined by a Linear Expenditure System (LES) function. Firms receive their income from remuneration of capital; transfers from government and

the rest of the world; and net capital transfers from households. Firms pay corporate tax to government and these are proportional to their incomes.

Government revenue is composed of direct taxes collected from households and firms, indirect taxes on domestic activities, domestic value added tax, tariff revenue on imports, factor income to the government, and transfers from the rest of the world. The government also saves and consumes.

Macro closure

Equilibrium in a CGE model is captured by a set of macro closures in a model. Aside from the supply-demand balances in product and factor markets, three macroeconomic balances are specified in the model: (i) fiscal balance, (ii) the external trade balance, and (iii) savings-investment balance. For fiscal balance, government savings is assumed to adjust to equate the different between government revenue and spending. For external balance, foreign savings are fixed with exchange rate adjustment to clear foreign exchange markets. For savings-investment balance, the model assumes that savings are investment driven and adjust through flexible saving rate for firms. Alternative closures, described later, are used in a subset of the model simulations.

Recursive Dynamics

To appropriately capture the dynamic aspects of aid on the economy, this model is extended by building some recursive dynamics by adopting the methodology used in previous studies on Botswana and South Africa (Thurlow, 2007). The dynamics is captured by assuming that investments in the current period are used to build on the new capital stock for the next period. The new capital is allocated across sectors according to the profitability of the various sectors. The labour supply path under different policy scenarios is exogenously provided from a demographic model. The model is initially solved to replicate the SAM of 2007.

H. Simulation Results

This section undertakes several simulations to understand the direct and indirect effects of oil price changes and shortages in electricity generation on the economy. First, we run a simulation where we assume that the oil price increase is permanent. We then run another simulation where we assume that prices of oil increase are temporary reverting back to their earlier prices. This simulation would capture the actual trend that has recently been observed, where prices increased to US$150 dollars and are now back to US$50 dollars per barrel. The third simulation looks at the declining productivity of the electricity sector that has resulted into shortages of electricity. In this simulation we assume a status quo where nothing is done by the government. The fourth simulation is where we assume that the government attracts investments into the energy sector so as to revamp the generation of electricity. The fifth simulation considers a case where the government reduces its tariffs on oil products to circumvent the price increases and the effect on the rest of the economy. This simulation is run simultaneously assuming that oil prices have increased either on a permanent or temporary basis.

H.1 Permanent Oil Price Increase

We start with a permanent increase in prices of oil. While this is a hypothetical scenario, it indeed reflects the current situation in Uganda given that albeit the decline in world prices of crude oil, the suppliers have deliberately kept the prices at the same levels and in some cases even higher than when international prices were on the rise.

From a macro perspective, an increase in prices of oil would affect the economy through various channels. First, being that oil is such an important item in the consumers basket, the first immediate impact is the pressure it puts on domestic prices. The higher price of oil imports pushes the consumer price index (CPI) up by 7 percentage points above its pre-shock level. With the real consumption wage assumed fixed, the nominal wage must move with CPI. Thus, average

nominal wages increase by 7 per cent. However, producers can raise their prices by only 1 per cent (GDP deflator at factor cost) compared with a 7 per cent hike in nominal wages causing producer real wages to rise. As a result, the demand for labour decreases leading to more than a 1 per cent reduction in aggregate employment.

On the demand side of the economy, we also notice that total absorption reduces by 2 per cent mainly due to the decline in private consumption which declines by 3 per cent. In addition, private investments also grow at a slower rate given the overall reduction in income levels as will be discussed in the subsequent sections. Overall, the private savings would decline by 1 per cent of GDP every year. Notwithstanding the negative effects on private consumption and investments, the government benefits significantly as its import duties increases by 1 per cent on an annual basis.

The surge in prices could also put more pressure on the exchange rate as the country would be faced with a higher import bill that requires more foreign exchange. This would result into the depreciation of the currency by 5.2 per cent. The depreciation could indeed be a welcome development especially for exporters. Indeed we find that exports are boosted by 3 per cent on annual basis during the period 2008-2012.

There are two main issues regarding the impacts of the increase in oil price. First, how significant is the increase for the cost of a particular industry as a result of higher prices of oil. Second, how the output of each industry responds to cost increases. The oil shock causes devastating impacts across industries.

Table 3. Average Growth Rate by Sectors (2008-2016)

	BASE	OILPERM	OILTEMP	ELECPERM	ELECTEMP	OILECPERM	OILECTEMP	OILTAX
Overall GDP	5.43	5.56	5.65	5.31	5.36	5.48	5.60	5.23
Agriculture	3.6	(0.3)	2.2	3.6	3.6	(0.3)	2.2	0.6
Of which								
Cereals	2.2	4.0	2.4	2.2	2.2	4.0	2.4	3.6
Root Crops	3.9	2.7	3.7	3.9	3.9	2.7	3.7	2.8
Pulses	2.3	3.0	2.6	2.3	2.3	3.0	2.6	3.2
Matooke	4.1	1.9	3.6	4.1	4.1	1.9	3.6	2.3
Horticulture	4.5	(5.2)	1.6	4.5	4.5	(5.2)	1.6	(3.3)
Export Crops	2.7	4.2	3.3	2.7	2.7	4.2	3.3	4.2
Livestock	3.4	0.0	2.7	3.4	3.4	(0.0)	2.7	3.7
Forestry	4.3	(9.9)	(0.6)	4.3	4.3	(9.9)	(0.6)	(7.5)
Fishing	5.3	(8.4)	0.6	5.2	5.2	(8.4)	0.5	(5.3)
Industry	5.0	3.5	5.2	4.6	4.7	3.3	5.0	0.3
Of which								
Mining	5.4	74.1	33.5	5.3	5.3	73.9	33.5	62.8
Manufacturing	5.3	(1.8)	2.8	5.2	5.2	(1.8)	2.8	(1.8)
Food Processing	5.3	(4.5)	2.2	5.2	5.3	(4.5)	2.2	(2.3)
Meat Processing	3.3	(2.3)	2.6	3.4	3.4	(2.4)	2.6	0.6
Fish Processing	5.3	(8.4)	0.6	5.2	5.2	(8.4)	0.5	(5.3)
Grain Processing	5.3	(1.6)	3.2	5.3	5.3	(1.7)	3.2	(0.1)
Feed Processing	3.7	(1.8)	2.5	3.7	3.7	(1.8)	2.5	1.6
Other Food Processing	4.8	(6.4)	1.3	4.7	4.7	(6.4)	1.3	(3.9)
Beverages and Tobacco	6.0	(4.1)	2.7	5.9	5.9	(4.1)	2.7	(2.2)
Non-Food Processing	5.3	0.7	3.5	5.2	5.2	0.6	3.5	(1.2)
Textiles and Clothing	5.6	(12.7)	(1.4)	5.6	5.6	(12.8)	(1.4)	(9.6)
Wood and Paper	3.7	(8.7)	0.4	3.6	3.6	(8.8)	0.4	(8.0)
Fertilizer	4.2	(20.1)	(4.8)	4.0	4.1	(20.2)	(4.9)	(15.6)
Other chemicals	5.8	(7.2)	1.5	5.6	5.7	(7.2)	1.5	(5.2)
Machinery & equipment	4.9	(6.8)	2.5	4.5	4.7	(7.1)	2.3	(7.4)
Furniture	5.1	(1.1)	4.2	5.0	5.1	(1.2)	4.2	(2.9)
Other manufacturing	5.5	(0.1)	5.2	5.3	5.4	(0.2)	5.2	(1.8)
Utilities	6.2	1.0	4.4	4.0	4.9	(0.4)	3.4	1.5
Construction	4.4	2.0	5.7	4.4	4.4	1.9	5.7	(2.9)
Services	6.4	8.8	7.4	6.4	6.4	8.8	7.3	9.3
Private	7.5	11.5	9.0	7.5	7.5	11.5	9.0	11.9
Trade	5.0	11.0	4.7	5.0	5.0	10.9	4.7	7.7
Hotels & catering	17.6	41.4	35.8	17.8	17.7	41.4	35.9	44.9
Transport	6.1	(31.4)	(13.4)	6.0	6.1	(31.5)	(13.4)	(27.6)
Communications	5.4	(6.7)	(0.7)	5.3	5.3	(6.8)	(0.8)	(5.9)
Banking	4.1	4.8	3.4	4.0	4.0	4.7	3.4	4.2
Real estate	6.8	4.6	5.7	6.7	6.7	4.6	5.6	4.4
Community services	5.2	(6.6)	1.6	5.1	5.1	(6.6)	1.5	(4.3)
Public	3.4	(0.2)	2.3	3.4	3.4	(0.2)	2.3	0.5

Table 4: Macroeconomic Developments under Various Energy Shortages
(Average Growth 2008-2016)

	INITIAL	BASE	OILPERM	OILTEMP	ELECPERM	ELECTEMP	OILECPERM	OILECTEMP	OILTAX
Absorption	26446	5.0	-1.5	3.1	4.9	4.9	-1.6	3.0	-1.8
Consumption	18743	5.5	-3.1	2.3	5.4	5.5	-3.2	2.2	-1.8
Investment	5014	3.9	1.6	5.9	3.9	3.9	1.5	5.9	-4.5
Exports	2689	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Imports	3335	9.2	18.8	15.5	9.1	9.1	18.8	15.4	21.5
Real exchange rate	9190	5.5	5.2	4.4	5.5	5.5	5.2	4.4	2.9
Nominal exchange rate	66	-1.0	21.8	4.0	-1.1	-1.0	21.8	3.9	23.2
Industrial Production Price	151	-0.1	0.7	0.2	-0.1	-0.1	0.7	0.2	0.6
CPI	100	-0.1	7.1	2.6	-0.1	-0.1	7.1	2.6	5.9
Investment to GDP	22	-0.5	-0.3	0.1	-0.5	-0.5	-0.3	0.1	-1.2
Private Savings to GDP	8	0.0	-0.1	-0.1	0.0	0.0	-0.1	-0.1	0.0
Foreign Savings to GDP	10	-0.3	0.1	-0.2	-0.3	-0.3	0.1	-0.2	0.2
Trade Deficit to GDP	25	-0.7	1.9	0.3	-0.7	-0.7	1.9	0.3	0.4
Government Savings to GDP	5	-0.3	-0.2	0.3	-0.3	-0.3	-0.2	0.3	-1.4
Import duties to GDP	5	0.0	1.1	0.7	0.0	0.0	1.1	0.7	-0.3
Direct Taxes to GDP	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

For the case of Uganda, overall we do not see a noticeable change in total GDP. This is partly because there would be a reallocation of resources between the sectors with a major boost to trade (which is part of services). However, a detailed look at the sectoral level reveals a lot more. For instance, for the case of manufacturing, there would be a total reduction in output of 7 per cent during the period 2008-12. This output loss is witnessed amongst all the subcategories including both the agro-processing and non-agro-processing industries. There are several explanations for this. First, the manufacturing sector relies a lot on transport so this becomes an increased cost in the process of production. Second, a lot of factories are now relying on generators owing to the frequent power outages.

Also of interest is that the agricultural sector is also affected. The total output loss due to the permanent price increase is estimated at 0.3 per cent of GDP over the period 2008-12. Agriculture depends a lot on the transportation sector especially while transporting goods to the intended markets. However, within agriculture, we find that the horticulture industry is most affected owing to the heavy use of generators for this industry. Also, the heavy use of transport and generators is portrayed for the fishing industry which declines by 8.4 per cent due to higher oil prices.[4]

The overall impact on services is positive. However, it's important again to scrutinize the individual sectors in services. Transport which is so dependent on oil is the worst affected. Overall we notice that the output of transport would decline by 30 per cent. This is substantial given that there are so many other sectors that are dependent on the transportation sector. On the other hand, trade would be significantly boosted as a result of the fluctuations in oil prices. Indeed for the case of Uganda, this is evidenced by the high number of petrol stations being opened.

[4] The increase in production costs due to high oil prices, high electricity tariffs and reduction of stocks of fish in Lake Victoria partly explains the recent bankruptcies and closure of several fish factories.

Fig. 9: Oil Price Shock and Agriculture Growth

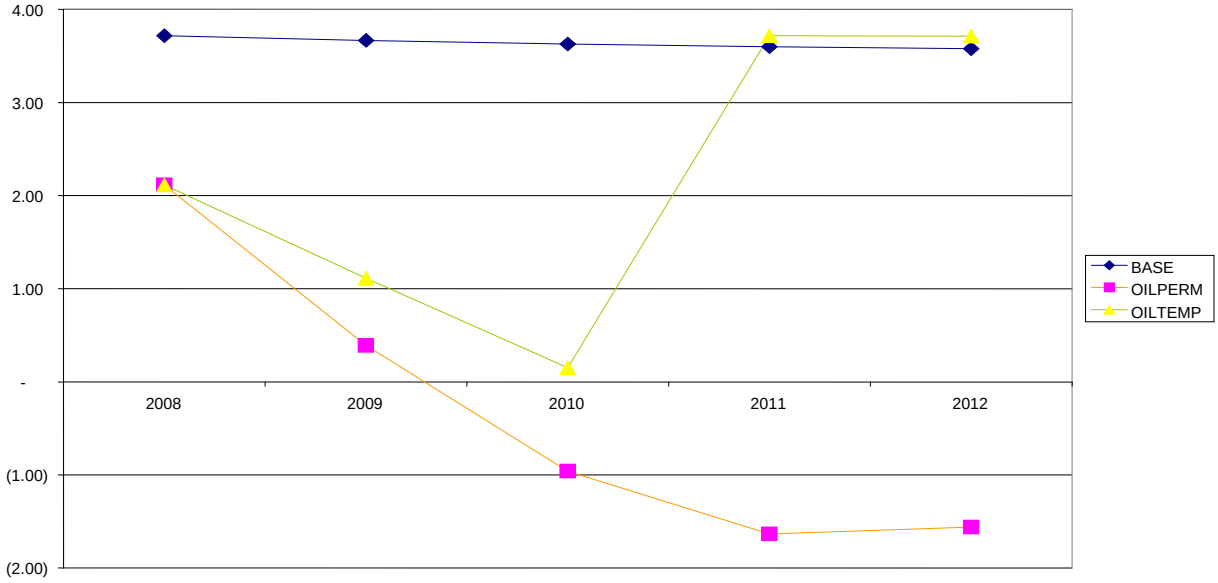


Fig. 10: Oil Price Shock and Manufacturing Growth

Fig. 11: Oil Price Shock and Private Services Growth

Fig. 12: Oil Price Shock and Trading Growth

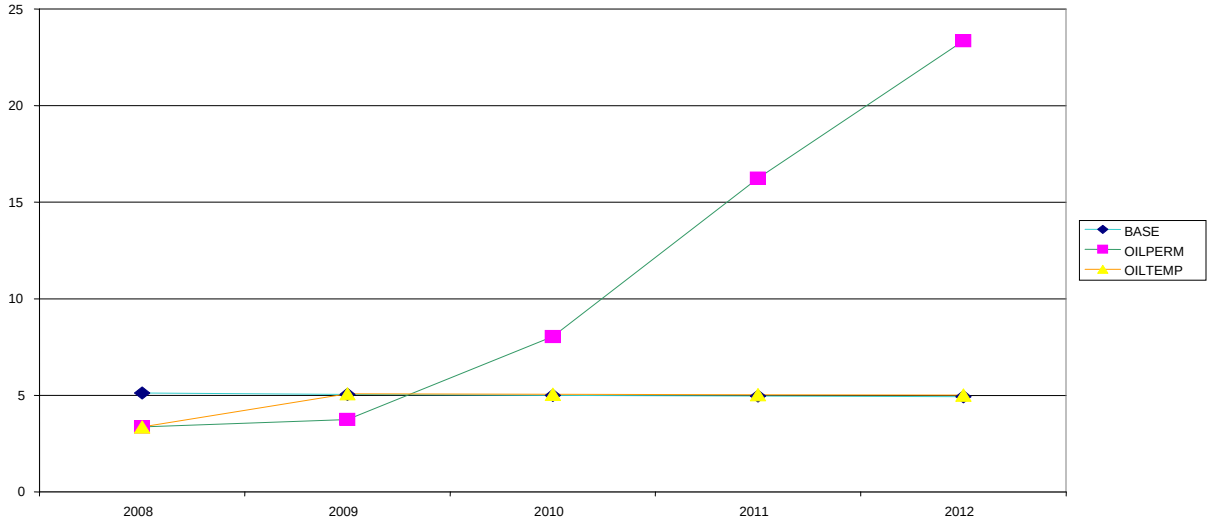


Fig. 13: Oil Price Shock and Transport Growth

In summary, a permanent increase in oil prices would put more pressure on domestic prices and the exchange rate. Higher oil prices would also result into significant reductions of output especially for the manufacturing, agriculture and transportation sector which are so much dependent on oil. At the macro level, higher prices would also lower private investments and due to lower incomes and output this would reduce the levels of investments. On positive note, higher oil prices would result into high import duties and thereby contribute to the reduction in the deficit.[5]

H.2 Temporary Price Increase

We now consider the case where prices increase but later drop back to their earlier levels. This simulation reflects what would be considered the actual patterns in the international movement of prices. We therefore consider a case where prices first

[5] An increase in import duties due to higher world prices could however create laxity to improve on the tax collection of other sources of revenues.

increase by 50 per cent during 2008 and in the subsequent years start falling back to the original levels.

From a macro perspective, the effects of a temporary increase in oil prices are very different from the permanent case scenario. In general, the effects would not be as negative compared to the earlier results. The CPI would only increase during the year we witness a price surge, but prices would ten normalize back to the original levels.

On the demand side of the economy, total absorption is much higher than for the permanent increase but still lower than the baseline where prices do not change at all. The change in total absorption is a reflection of the reduction in private consumption during the year when prices increase significantly. The pressure that is put on the exchange rate is also less with the currency only depreciating by 5 per cent per year.

The overall impact of a temporary increase in prices of oil also depends so much on the sector in question. For the case of manufacturing, there would be a total reduction in output of 2.2 per cent during the period 2008-12. This is much lower output loss to the economy compared to the previous scenario. This output loss is also witnessed amongst all the subcategories including both the agro-processing and non agro-processing industries. Likewise transport which is so dependent on oil would be negatively affected but the effect would be subdued.

This simulation reveals that the government should indeed intervene with the traders of oil products in Uganda in the event that it's the case that they manipulate prices. Indeed, there is considerable output to be gained if prices were being adjusted in line with international crude oil prices. While there could be other reasons why prices have remained high, government should come up with a clear policy on price of oil vis-à-vis the international prices.

H.3 Permanent Reduction in Productivity of the Electricity Sector

We now consider the case where productivity in the electricity sector has declined significantly. The permanent deterioration of the sector presumes that that are no additional investments in the sector especially in upgrading and addition of generation capacity. The objective of this simulation is to assess the extent to which this sector is important to other sectors especially manufacturing. The permanent reduction in productivity of the sector presumably portrays the current inefficiency levels of the sector where there is considerable load shedding and high prices of tariffs owing to the fact that the country now largely depends on thermal generators which tend to be more expensive.

At the aggregate level, we find that Uganda looses about 0.1 per cent of GDP on annual basis due to the inefficiency in the energy sector. The losses are more pronounced in the sectors which depend a lot on electricity. Of particular interest is the manufacturing sector. For industries, there are two channels through which they get affected. First, the energy losses due to poor transmission and other innefffciencies affect the productivity of these factories. Second, when they resort to use of generators, this significantly increases their production cost. The sector looses about 0.1 per cent in production as a result of inefficiencies in the electricity sector. On a cumulative basis, this would translate into lost production of 5 per cent over the period 2008-12.

Fig. 14: Electricity Shortage and Agricultural Growth

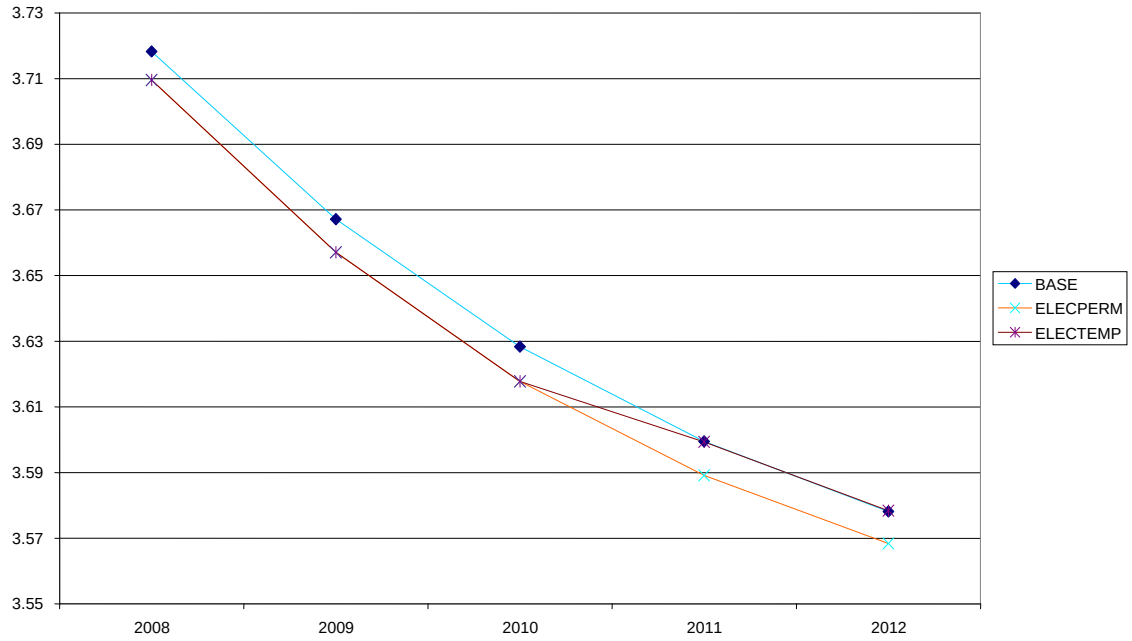


Fig. 15: Electricity Shortage and Manufacturing Growth

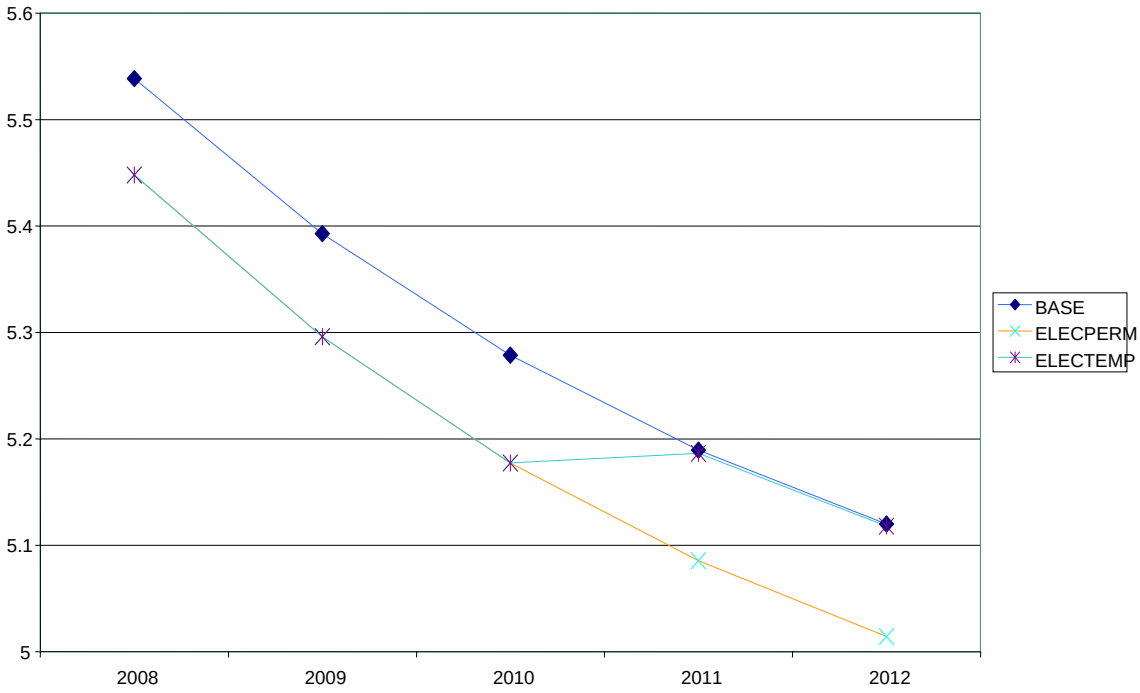
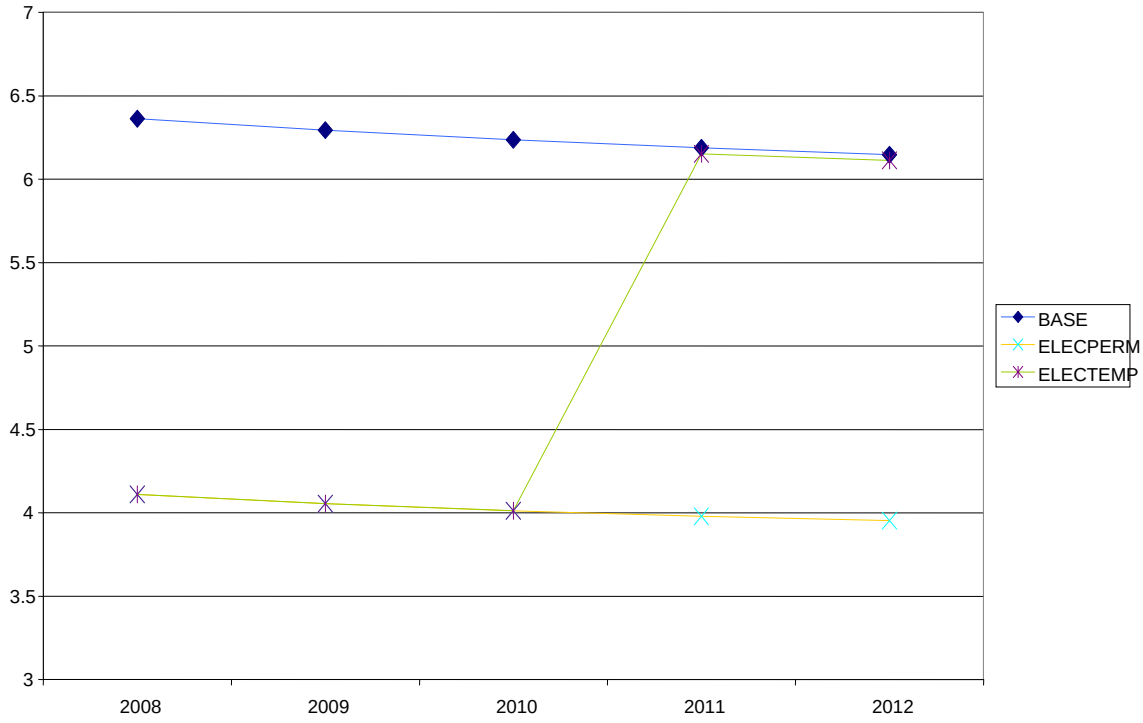


Fig. 16: Electricity and Utilities Growth



H.4 Increased Investment in the Energy Sector

We now consider a case where the government and private sector mobilizes resources to revamp the sector. To a certain extent this simulation portrays what is currently happening. The government is currently putting up several dams to increase the capacity of electricity generated from 416 to 666 MW. In partnership with the Aghakan Foundation, the government is constructing a new dam at Bajagali falls which will add an additional 250 MW of power to the national grid. This will also enable thermal generators which are too costly to be phased out over time. It's presumed that in addition to the increase of power generated, this will improve the efficiency of the energy sector. For purposes of the simulation, we assume that the productivity of the sector will improve by 2 per cent.

As a result of the additional investments in the energy sector, this would result into higher output growth when compared to the case when the sector remains

inefficient, the country can recover more than 5 per cent growth in GDP over the period 2009-2012. The recovery would mainly come from the sector itself and other sectors that use electricity as an intermediate input. The specific sectors like manufacturing would also be able to produce at a higher rate. This shows that there is a lot to gain when more investments are tailored to the sector.

H.5 Removal of Tariffs on Oil Commodities

From a policy perspective, the government could circumvent the increase in the oil prices by reducing the tariffs. However, before ascertaining whether this is the ideal option, we need to understand the impact of an oil shock on the demand. First, an oil price increase could potentially result into a decline in total demand for oil products. On the other hand there would be a value increase owing to the nominal price change. Therefore, while there would be an increase in the price the quantity demanded could actually drop resulting into an overall decline in value. Hence the reduction in tariff could indeed reduce the domestic price level which would stimulate further demand for oil.

From the simulation, we reduce tariffs by 50 per cent. This has several macroeconomic consequences. First, there is a direct loss in tariff revenues which results into a higher deficit. By running higher deficits which would require financing by the government results into crowding out of resources and reduces private investments by 1 per cent on an annual basis. However, this policy would circumvent some of the output losses at a sectoral level only in the short run. For instance the losses in agriculture and industry are less than when government does nothing. The benefits are short-lived though owing to the fact that the high deficits run by the central government would catch up with the private sector. From the consumption side, the households would also temporarily benefit in the year when the tariff reduction is implemented.

H.6 Poverty and High Energy Prices

We now examine the extent to which high energy prices affect households. At a national level, we observe that high energy prices indeed increase poverty. Whether these shocks are on a permanent or temporary basis, there is a marked increase in poverty levels. For the case where the increase is temporary, we observe that poverty at a national level would increase by 2 per cent during the year when the shock occurs. The increase in poverty is across the board whether the household is based in the rural or urban area. The intuition behind the increase is owing to the reduced incomes as most sectors particularly agriculture and manufacturing are negatively affected by the oil price shock.

Fig. 17: Impact of High Energy Prices on National Poverty Rates for the Year 2012

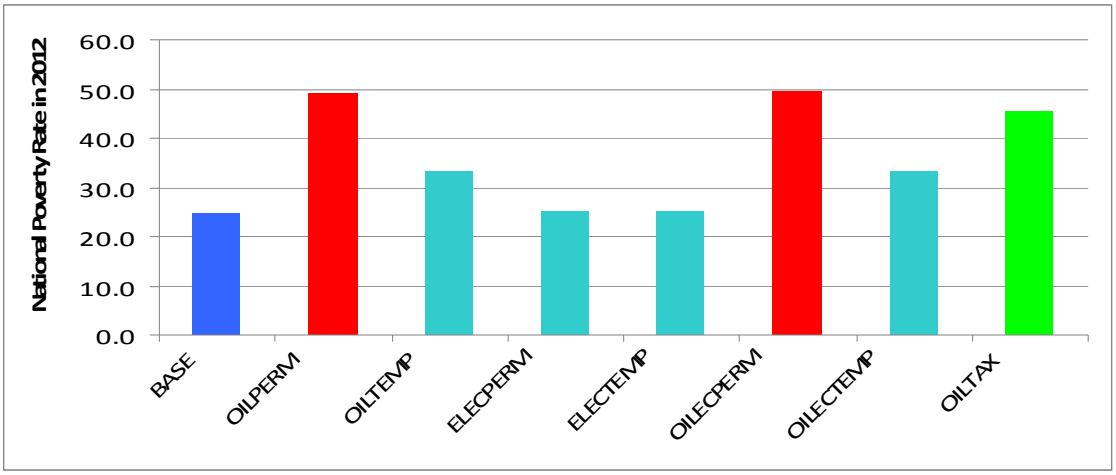


Fig. 18: Impact of High Energy Prices on Rural Poverty Rates for the Year 2012

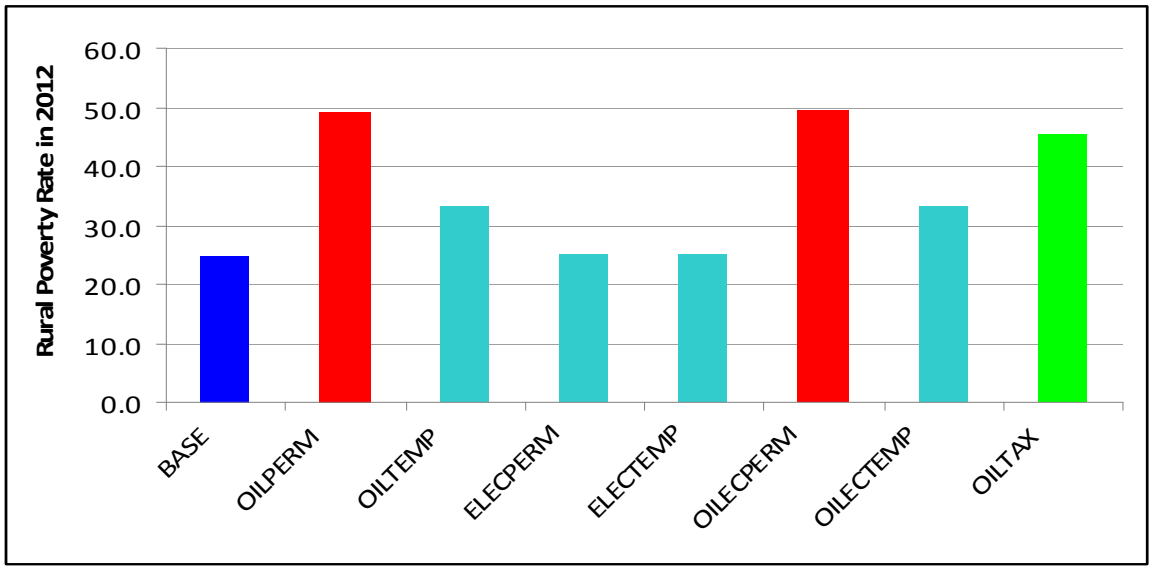
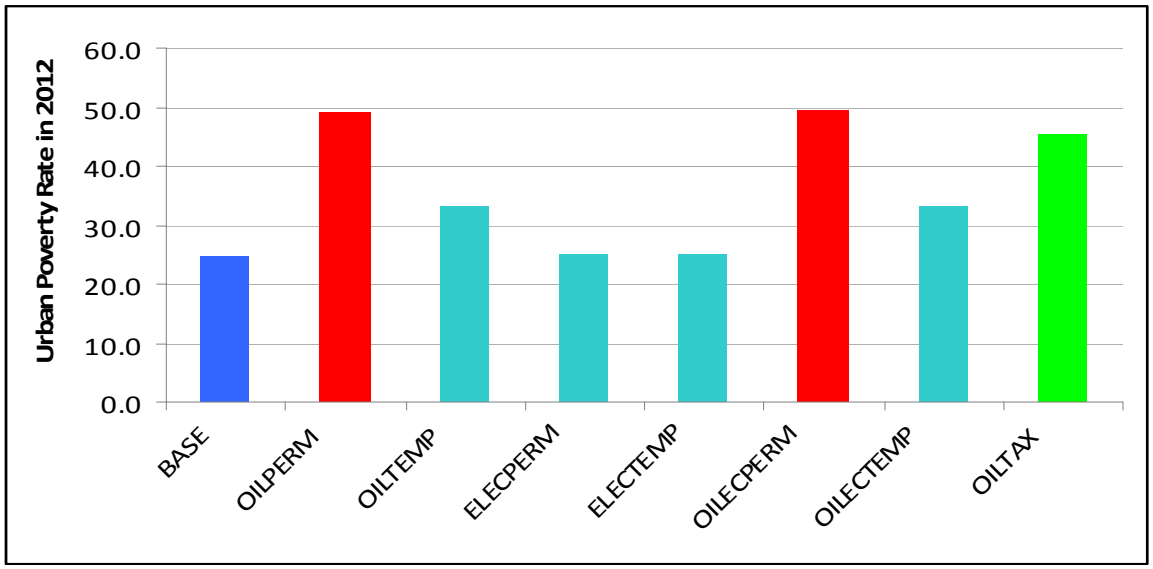


Fig. 19: Impact of High Energy Prices on Urban Poverty Rates for the Year 2012



For the electricity reduction in generation, the impact on poverty is rather small. This is due to the fact that technologies used by the agricultural sector are not so much dependent on electricity. Since the sector employs 70 per cent of the households who are subsistence farmers, the impact as expected should be small.

Table.5: Poverty Indices under Various Scenarios

	BASE	OILPERM	OILTEMP	ELECPERM	ELECTEMP	OILECPERM	OILECTEMP	OILTAX
				National Poverty (P0)				
2007	31.14	31.14	31.14	31.14	31.14	31.14	31.14	31.14
2008	29.89	32.42	32.42	29.93	29.93	32.43	32.43	31.59
2009	28.58	34.85	33.96	28.67	28.67	34.87	34.12	32.67
2010	27.17	38.80	36.38	27.28	27.28	38.83	36.48	35.29
2011	25.95	44.06	34.89	26.05	26.02	44.13	34.91	39.77
2012	24.90	49.27	33.15	25.01	24.94	49.33	33.29	45.34
				Rural Poverty (P0)				
2007	34.29	34.29	34.29	34.29	34.29	34.29	34.29	34.29
2008	33.02	35.57	35.57	33.07	33.07	35.57	35.57	34.68
2009	31.55	38.18	37.21	31.65	31.65	38.19	37.39	35.83
2010	29.98	42.26	39.77	30.10	30.10	42.30	39.85	38.62
2011	28.62	47.59	38.19	28.72	28.71	47.68	38.22	43.22
2012	27.53	53.05	36.31	27.63	27.55	53.10	36.47	48.92
				Urban Poverty (P0)				
2007	13.77	13.77	13.77	13.77	13.77	13.77	13.77	13.77
2008	12.61	15.09	15.09	12.61	12.61	15.11	15.11	14.53
2009	12.23	16.53	16.04	12.23	12.23	16.53	16.13	15.27
2010	11.73	19.73	17.74	11.73	11.73	19.73	17.92	16.92
2011	11.23	24.59	16.69	11.33	11.23	24.59	16.69	20.77
2012	10.37	28.41	15.73	10.55	10.55	28.51	15.73	25.63

I. Conclusion and Policy Implications

This chapter demonstrates that high energy prices have cost Uganda dearly in terms of output for some sectors. While at the aggregate level, GDP might not be affected as more activity is realised in the trading sector, increase in oil prices would significantly reduce the output for agriculture, manufacturing and transports. The reduction in output for these sectors is subdued when the oil price shock is temporary. On the other hand, the low efficiency in the electricity sector has also negatively affected the sectors. The combined effects of oil price shocks and reduction in electricity generated would reduce overall growth rate of the manufacturing sector by 2 percentage points on annual basis.

From the policy perspective, the government would have to make choices on the tariff regime for oil imports. First, at a time of high oil prices, the government can intervene by lowering tariffs in oil products. However, this has to take into account the trade-off between the oil tariff revenues and taxes lost owing to reduced

economic activity especially in the manufacturing sector. Second, the government should take a more active role on suppliers to ensure that prices are adjusted downwards when international prices drop. Whereas it is possible that lack of quick transmission of lower prices at the international level to the domestic market may be due to the physical bottlenecks alluded to in section B3, the inability of the players in the industry to reduce prices after months of a drop in international crude prices point more to an institutional problem that may be under the control of the government to address. As found, the output losses are much higher when the price increase remains permanent. Third, without addressing the inefficiencies in the electricity sector, this will continue affecting the output of manufacturing and other sectors that depend on electricity. More private-public investments should be encouraged to enhance the productivity and capacity of the sector.

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Table A1. CGE model sets, parameters, and variables

Symbol	Explanation	Symbol	Explanation
Sets			
$a \in A$	Activities	$c \in CMN (\subset C)$	Commodities not in *CM*
$a \in ALEO (\subset A)$	Activities with a Leontief function at the top of the technology nest	$c \in CT (\subset C)$	Transaction service commodities
$c \in C$	Commodities	$c \in CX (\subset C)$	Commodities with domestic production
$c \in CD (\subset C)$	Commodities with domestic sales of domestic output	$f \in F$	Factors
$c \in CDN (\subset C)$	Commodities not in *CD*	$i \in INS$	Institutions (domestic and rest of world)
$c \in CE (\subset C)$	Exported commodities	$i \in INSD (\subset INS)$	Domestic institutions
$c \in CEN (\subset C)$	Commodities not in *CE*	$i \in INSDNG (\subset INSD)$	Domestic non-government institutions
$c \in CM (\subset C)$	Aggregate imported commodities	$h \in H (\subset INSDNG)$	Households
Parameters			
$cwts_c$	Weight of commodity c in the CPI	$qdst_c$	Quantity of stock change
$dwts_c$	Weight of commodity c in the producer price index	$\overline{qg}_c$	Base-year quantity of government demand
ica_{ca}	Quantity of c as intermediate input per unit of activity a	$\overline{qinv}_c$	Base-year quantity of private investment demand
$icd_{cc'}$	Quantity of commodity c as trade input per unit of c' produced and sold domestically	$shif_{if}$	Share for domestic institution i in income of factor f
$ice_{cc'}$	Quantity of commodity c as trade input per exported unit of c'	$shii_{ii'}$	Share of net income of i' to i (i' $\in$ INSDNG'; i $\in$ INSDNG)
$icm_{cc'}$	Quantity of commodity c as trade input per imported unit of c'	ta_a	Tax rate for activity a

$inta_a$	Quantity of aggregate intermediate input per activity unit	$\overline{tins}_i$	Exogenous direct tax rate for domestic institution i
iva_a	Quantity of aggregate intermediate input per activity unit	$tins01_i$	0-1 parameter with 1 for institutions with potentially flexed direct tax rates
$\overline{mps}_i$	Base savings rate for domestic institution i	tm_c	Import tariff rate
$mps01_i$	0-1 parameter with 1 for institutions with potentially flexed direct tax rates	tq_c	Rate of sales tax
pwe_c	Export price (foreign currency)	$trnsfr_{i\,f}$	Transfer from factor f to institution i
pwm_c	Import price (foreign currency)		

Table A1 continued. CGE model sets, parameters, and variables

Symbol	Explanation	Symbol	Explanation
Greek Symbols			
α_a^a	Efficiency parameter in the CES activity function	δ_{cr}^t	CET function share parameter
α_a^{va}	Efficiency parameter in the CES value-added function	δ_{fa}^{va}	CES value-added function share parameter for factor *f* in activity *a*
α_c^{ac}	Shift parameter for domestic commodity aggregation function	γ_{ch}^m	Subsistence consumption of marketed commodity c for household h
α_c^q	Armington function shift parameter	θ_{ac}	Yield of output c per unit of activity a
α_c^t	CET function shift parameter	ρ_a^a	CES production function exponent
β^a	Capital sectoral mobility factor	ρ_a^{va}	CES value-added function exponent
β_{ch}^m	Marginal share of consumption spending on marketed commodity c for household h	ρ_c^{ac}	Domestic commodity aggregation function exponent
δ_a^a	CES activity function share parameter	ρ_c^q	Armington function exponent
δ_{ac}^{ac}	Share parameter for domestic commodity aggregation function	ρ_c^t	CET function exponent
δ_{cr}^q	Armington function share parameter	η_{fat}^a	Sector share of new capital
υ_f	Capital depreciation rate		
Exogenous Variables			
$\overline{CPI}$	Consumer price index	$\overline{MPSADJ}$	Savings rate scaling factor (= 0 for base)
$\overline{DTINS}$	Change in domestic institution tax share (= 0 for base; exogenous variable)	$\overline{QFS}_f$	Quantity supplied of factor
$\overline{FSAV}$	Foreign savings (FCU)	$\overline{TINSADJ}$	Direct tax scaling factor (= 0 for base; exogenous variable)
$\overline{GADJ}$	Government consumption adjustment factor	$\overline{WFDIST}_{fa}$	Wage distortion factor for factor f in activity a
$\overline{IADJ}$	Investment adjustment factor		
Endogenous Variables			
AWF_{ft}^a	Average capital rental rate in time period t	QG_c	Government consumption demand for commodity
$DMPS$	Change in domestic	QH_{ch}	Quantity consumed of

	institution savings rates (= 0 for base; exogenous variable)		commodity c by household h
DPI	Producer price index for domestically marketed output	QHA_{ach}	Quantity of household home consumption of commodity c from activity a for household h
EG	Government expenditures	$QINTA_a$	Quantity of aggregate intermediate input
EH_h	Consumption spending for household	$QINT_{ca}$	Quantity of commodity c as intermediate input to activity a
EXR	Exchange rate (LCU per unit of FCU)	$QINV_c$	Quantity of investment demand for commodity
$GSAV$	Government savings	QM_{cr}	Quantity of imports of commodity c
QF_{fa}	Quantity demanded of factor f from activity a		

Table A1 continued. CGE model sets, parameters, and variables

Symbol	Explanation	Symbol	Explanation
Endogenous Variables Continued			
MPS_i	Marginal propensity to save for domestic non-government institution (exogenous variable)	QQ_c	Quantity of goods supplied to domestic market (composite supply)
PA_a	Activity price (unit gross revenue)	QT_c	Quantity of commodity demanded as trade input
PDD_c	Demand price for commodity produced and sold domestically	QVA_a	Quantity of (aggregate) value-added
PDS_c	Supply price for commodity produced and sold domestically	QX_c	Aggregated quantity of domestic output of commodity
PE_{cr}	Export price (domestic currency)	$QXAC_{ac}$	Quantity of output of commodity c from activity a
$PINTA_a$	Aggregate intermediate input price for activity a	RWF_f	Real average factor price
PK_{ft}	Unit price of capital in time period t	$TABS$	Total nominal absorption
PM_{cr}	Import price (domestic currency)	$TINS_i$	Direct tax rate for institution i (i $\in$ INSDNG)

PQ_c	Composite commodity price	$TRII_{ii'}$	Transfers from institution i' to i (both in the set INSDNG)
PVA_a	Value-added price (factor income per unit of activity)	WF_f	Average price of factor
PX_c	Aggregate producer price for commodity	YF_f	Income of factor f
$PXAC_{ac}$	Producer price of commodity c for activity a	YG	Government revenue
QA_a	Quantity (level) of activity	YI_i	Income of domestic non-government institution
QD_c	Quantity sold domestically of domestic output	YIF_{if}	Income to domestic institution i from factor f
QE_{cr}	Quantity of exports	ΔK^a_{fat}	Quantity of new capital by activity a for time period t

Table A2. CGE model equations

Production and Price Equations

$QINT_{c\,a} = ica_{c\,a} \cdot QINTA_a$	(1)
$PINTA_a = \sum_{c \in C} PQ_c \cdot ica_{ca}$	(2)
$QVA_a = \alpha_a^{va} \cdot \left(\sum_{f \in F} \delta_{f\,a}^{va} \cdot \left(\alpha_{f\,a}^{vaf} \cdot QF_{f\,a} \right)^{-\rho_a^{va}} \right)^{-\frac{1}{\rho_a^{va}}}$	(3)
$W_f \cdot \overline{WFDIST}_{fa} = PVA_a \cdot QVA_a \cdot \left(\sum_{f \in F'} \delta_{f\,a}^{va} \cdot \left(\alpha_{f\,a}^{vaf} \cdot QF_{f\,a} \right)^{-\rho_a^{va}} \right)^{-1} \cdot \delta_{f\,a}^{va} \cdot \left(\alpha_{f\,a}^{vaf} \cdot QF_{f\,a} \right)^{-\rho_a^{va}-1}$	(4)
$QF_{f\,a} = \alpha_{f\,a}^{van} \cdot \left(\sum_{f' \in F} \delta_{f\,f'a}^{van} \cdot QF_{f'a}^{-\rho_{f\,a}^{van}} \right)^{-\frac{1}{\rho_{f\,a}^{van}}}$	(5)
$W_{f'} \cdot WFDIST_{f'a} = W_f \cdot WFDIST_{f\,a} \cdot QF_{f\,a} \cdot \left(\sum_{f'' \in F} \delta_{f\,f''a}^{van} \cdot QF_{f''a}^{-\rho_{f\,a}^{van}} \right)^{-1} \cdot \delta_{f\,f'a}^{van} \cdot QF_{f'a}^{-\rho_{f\,a}^{van}-1}$	(6)
$QVA_a = iva_a \cdot QA_a$	(7)
$QINTA_a = inta_a \cdot QA_a$	(8)
$PA_a \cdot (1 - ta_a) \cdot QA_a = PVA_a \cdot QVA_a + PINTA_a \cdot QINTA_a$	(9)
$QXAC_{a\,c} = \theta_{a\,c} \cdot QA_a$	(10)
$PA_a = \sum_{c \in C} PXAC_{ac} \cdot \theta_{ac}$	(11)
$QX_c = \alpha_c^{ac} \cdot \left(\sum_{a \in A} \delta_{a\,c}^{ac} \cdot QXAC_{a\,c}^{-\rho_c^{ac}} \right)^{-\frac{1}{\rho_c^{ac}-1}}$	(12)
$PXAC_{a\,c} = PX_c \cdot QX_c \left(\sum_{a \in A'} \delta_{a\,c}^{ac} \cdot QXAC_{a\,c}^{-\rho_c^{ac}} \right)^{-1} \cdot \delta_{a\,c}^{ac} \cdot QXAC_{a\,c}^{-\rho_c^{ac}-1}$	(13)
$PE_{cr} = pwe_{cr} \cdot EXR - \sum_{c' \in CT} PQ_c \cdot ice_{c'c}$	(14)
$QX_c = \alpha_c^t \cdot \left(\sum_r \delta_{cr}^t \cdot QE_{cr}^{\rho_c^t} + (1 - \sum_r \delta_{cr}^t) \cdot QD_c^{\rho_c^t} \right)^{\frac{1}{\rho_c^t}}$	(15)
$\frac{QE_{cr}}{QD_c} = \left(\frac{PE_{cr}}{PDS_c} \cdot \frac{1 - \sum_r \delta_{cr}^t}{\delta_c^t} \right)^{\frac{1}{\rho_c^t - 1}}$	(16)

Table A3. CGE model equations (continued)

$QX_c = QD_c + \sum_r QE_{cr}$	(17)
$PX_c \cdot QX_c = PDS_c \cdot QD_c + \sum_r PE_{cr} \cdot QE_{cr}$	(18)
$PDD_c = PDS_c + \sum_{c' \in CT} PQ_{c'} \cdot icd_{c'c}$	(19)
$PM_{cr} = pwm_{cr} \cdot (1 + tm_{cr}) \cdot EXR + \sum_{c' \in CT} PQ_{c'} \cdot icm_{c'c}$	(20)
$QQ_c = \alpha_c^q \cdot \left(\sum_r \delta_{cr}^q \cdot QM_{cr}^{-\rho_c^q} + (1 - \sum_r \delta_{cr}^q) \cdot QD_c^{-\rho_c^q} \right)^{-\frac{1}{\rho_c^q}}$	(21)
$\frac{QM_{cr}}{QD_c} = \left(\frac{PDD_c}{PM_c} \cdot \frac{\delta_c^q}{1 - \sum_r \delta_{cr}^q} \right)^{\frac{1}{1+\rho_c^q}}$	(22)
$QQ_c = QD_c + \sum_r QM_{cr}$	(23)
$PQ_c \cdot (1 - tq_c) \cdot QQ_c = PDD_c \cdot QD_c + \sum_r PM_{cr} \cdot QM_{cr}$	(24)
$QT_c = \sum_{c' \in C'} \left(icm_{cc'} \cdot QM_{c'} + ice_{cc'} \cdot QE_{c'} + icd_{cc'} \cdot QD_{c'} \right)$	(25)
$\overline{CPI} = \sum_{c \in C} PQ_c \cdot cwts_c$	(26)
$DPI = \sum_{c \in C} PDS_c \cdot dwts_c$	(27)
Institutional Incomes and Domestic Demand Equations	
$YF_f = \sum_{a \in A} WF_f \cdot \overline{WFDIST}_{fa} \cdot QF_{fa}$	(28)
$YIF_{if} = shif_{if} \cdot \left[YF_f - trnsfr_{row\,f} \cdot EXR \right]$	(29)
$YI_i = \sum_{f \in F} YIF_{if} + \sum_{i' \in INSDNG'} TRII_{ii'} + trnsfr_{i\,gov} \cdot \overline{CPI} + trnsfr_{i\,row} \cdot EXR$	(30)
$TRII_{ii'} = shii_{ii'} \cdot (1 - MPS_{i'}) \cdot (1 - \overline{tins}_{i'}) \cdot YI_{i'}$	(31)
$EH_h = \left(1 - \sum_{i \in INSDNG} shii_{ih} \right) \cdot (1 - MPS_h) \cdot (1 - \overline{tins}_h) \cdot YI_h$	(32)
$PQ_c \cdot QH_{ch} = PQ_c \cdot \gamma_{ch}^m + \beta_{ch}^m \cdot \left(EH_h - \sum_{c' \in C} PQ_{c'} \cdot \gamma_{c'h}^m \right)$	(33)
$QINV_c = IADJ \cdot \overline{qinv}_c$	(34)
$QG_c = \overline{GADJ} \cdot \overline{qg}_c$	(35)

Table A3. CGE Model Equations (continued)

$EG = \sum_{c \in C} PQ_c \cdot QG_c + \sum_{i \in INSDNG} trnsfr_{i\,gov} \cdot \overline{CPI}$	(36)
System Constraints and Macroeconomic Closures	
$YG = \sum_{i \in INSDNG} \overline{tins}_i \cdot YI_i + \sum_{c \in CMNR} tm_c \cdot pwm_c \cdot QM_c \cdot EXR + \sum_{c \in C} tq_c \cdot PQ_c \cdot QQ_c + \sum_{f \in F} YF_{gov\,f} + trnsfr_{gov\,row} \cdot EXR$	(37)
$QQ_c = \sum_{a \in A} QINT_{c\,a} + \sum_{h \in H} QH_{c\,h} + QG_c + QINV_c + qdst_c + QT_c$	(38)
$\sum_{a \in A} QF_{f\,a} = QFS_f$	(39)
$YG = EG + GSAV$	(40)
$\sum_{r\ c \in CMNR} pwm_{cr} \cdot QM_{cr} + \sum_{f \in F} trnsfr_{row\ f} = \sum_{r\ c \in CENR} pwe_{cr} \cdot QE_{cr} + \sum_{i \in INSD} trnsfr_{i\,row} + FSAV$	(41)
$\sum_{i \in INSDNG} MPS_i \cdot \left(1 - \overline{tins}_i\right) \cdot YI_i + GSAV + EXR \cdot FSAV = \sum_{c \in C} PQ_c \cdot QINV_c + \sum_{c \in C} PQ_c \cdot qdst_c$	(42)
$MPS_i = \overline{mps}_i \cdot \left(1 + MPSADJ\right)$	(43)
Capital Accumulation and Allocation Equations	
$AWF^a_{f\,t} = \sum_a \left[\left(\frac{QF_{f\,a\,t}}{\sum_{a'} QF_{f\,a'\,t}} \right) \cdot WF_{f\,t} \cdot WFDIST_{f\,a\,t} \right]$	(44)
$\eta^a_{f\,a\,t} = \left(\frac{QF_{f\,a\,t}}{\sum_{a'} QF_{f\,a'\,t}} \right) \cdot \left(\beta^a \cdot \left(\frac{WF_{f,t} \cdot WFDIST_{f\,a\,t}}{AWF^a_{f\,t}} - 1 \right) + 1 \right)$	(45)
$\Delta K^a_{f\,a\,t} = \eta^a_{f\,a\,t} \cdot \left(\frac{\sum_c PQ_{c\,t} \cdot QINV_{c\,t}}{PK_{f\,t}} \right)$	(46)
$PK_{f\,t} = \sum_c PQ_{c\,t} \cdot \frac{QINV_{c\,t}}{\sum_{c'} QINV_{c'\,t}}$	(47)
$QF_{f\,a\,t+1} = QF_{f\,a\,t} \cdot \left(1 + \frac{\Delta K^a_{f\,a\,t}}{QF_{f\,a\,t}} - \upsilon_f \right)$	(48)
$QFS_{f\,t+1} = QFS_{f\,t} \cdot \left(1 + \frac{\sum_a \Delta K_{f\,a\,t}}{QFS_{f\,t}} - \upsilon_f \right)$	(4

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