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Impacts of the Russia-Ukraine War Price Shocks on the Bangladesh Economy

A General Equilibrium Analysis

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ABSTRACT

The spike in global commodity prices caused by the Russia-Ukraine war has had major adverse impacts on many developing countries, including Bangladesh, that still depend heavily on energy and food imports. Although the Bangladesh economy has rebounded after the COVID-19 pandemic, the latest global trade shock has threated to increase food insecurity and poverty. This study utilizes the Bangladesh RIAPA economywide model to assess the impact of increases in global commodity prices and explores potential policy interventions to reduce negative impacts. Simulation results show that increases in international commodity prices create a GDP loss of 0.36 percent and an increase of three million in the number of poor (mainly rural poor). Energy price shocks account for most of this decline in real GDP (0.28 percent). The fertilizer subsidy helps spur agriculture production which leads to an increase in crop GDP by 0.78 percent and total agricultural GDP by 0.43 percent.

Changes in policy could help mitigate the effects of these price shocks. In particular, petroleum subsidies would help increase production in both agriculture and services, leading to a 0.3 percent increase in household consumption, considerably more than the gain under a targeted cash transfer policy of equal cost. However, given that the petroleum subsidy does not specifically target the poor, it only reduces poverty by a fraction of what a targeted cash transfer would. Moreover, as illustrated by the experiences of other countries, increases in a fuel subsidy, once introduced, are likely to be very difficult to reverse. This suggests that if the major policy goal is to reduce poverty, a direct cash transfer would be more effective than the other policy options considered here. Combining these policies, however, would be even more effective than any single intervention, reducing poverty incidence by around 2.5 million people, and thereby preventing nearly all of the potential increase in poverty resulting from global price shocks.

Keywords: Russia-Ukraine War, Global Price

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1. INTRODUCTION

Bangladesh recently achieved real GDP growth of 7.1% (ADB, 2023) despite two major global shocks: the on-going Russia-Ukraine war and the coronavirus pandemic. Though the high GDP growth may indicate otherwise, these unexpected external shocks had major adverse effects on the domestic economy, including balance of payments deficits, a drawdown in foreign exchange reserves, rising unemployment, and increased inflation leading to uncertainty on potential growth. Despite food production in the country being quite resilient during the pandemic, rising global energy and food prices caused by the Ukraine war have created food security and poverty concerns. This situation requires well informed policy responses to help mitigate the negative impacts on the economy and provide assistance to the poor who are most vulnerable to economic shocks.

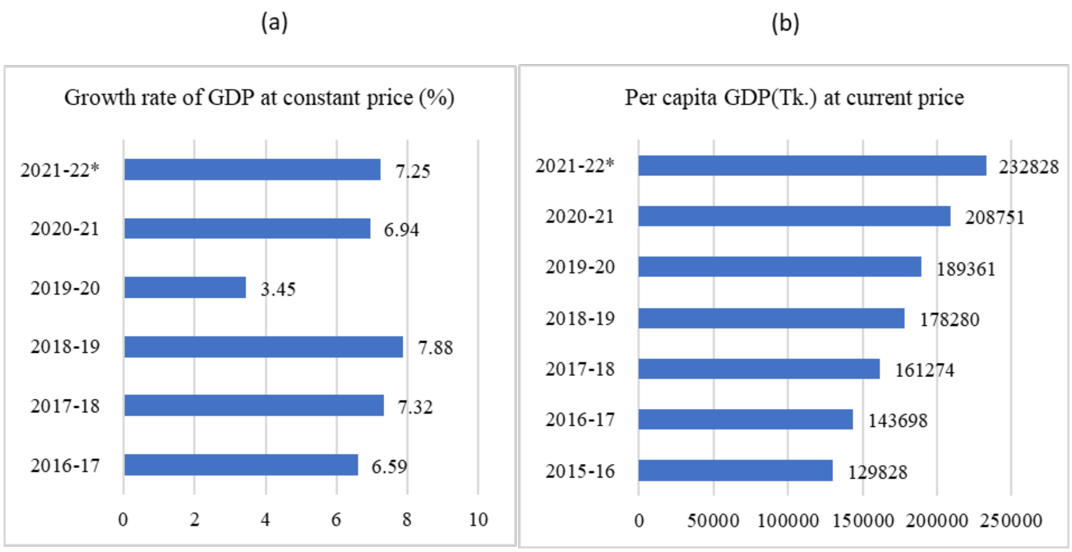
In this paper, we analyze how the Ukraine war affected the Bangladesh economy through external price shocks. In order to understand the economy-wide impact of these negative shocks, we utilize a Computable General Equilibrium (CGE) model (RIAPA) following Diao and Thurlow (2012) to simulate the potential impacts of increases in international prices of petroleum, fertilizer, and major food commodities, as well as a depreciation of the exchange rate on the Bangladesh economy and household welfare. We use the 2019 Social Accounting Matrix (SAM) for Bangladesh, which is adopted from Dorosh, Pradesha, Raihan and Thurlow (2021) to calibrate the CGE model to capture the recent economic structure of Bangladesh under normal circumstances. We use recent international price data and government reports to construct both the simulation and policy scenarios.

Following the introductory section, chapter 2 of this paper contains an overview of different macroeconomic indicators of the country. Chapter 3 presents a description of the model equations, along with a discussion of the base data in the Social Accounting Matrix and key model parameters. Chapter 4 describes the different simulation results while Chapter 5 provides some potential policy responses and Chapter 6 includes a summary of the findings and suggestions for further research and analysis.

2. OVERVIEW OF THE BANGLADESH ECONOMY

The economy of Bangladesh has been going through remarkable changes in recent years. By attaining higher GDP growth rates (see Figure 1, panel a) and increasing per capita incomes (Figure 1, panel b). In fact, the country is now on a path to recover from the global pandemic. Despite the changing scenario, the country is still struggling with an increasing negative trade balance and fluctuating domestic inflation. Furthermore, the share of imports has always been higher than that of exports with an increasing gap.

Figure 1: GDP Growth Rate and GDP Per Capita Value

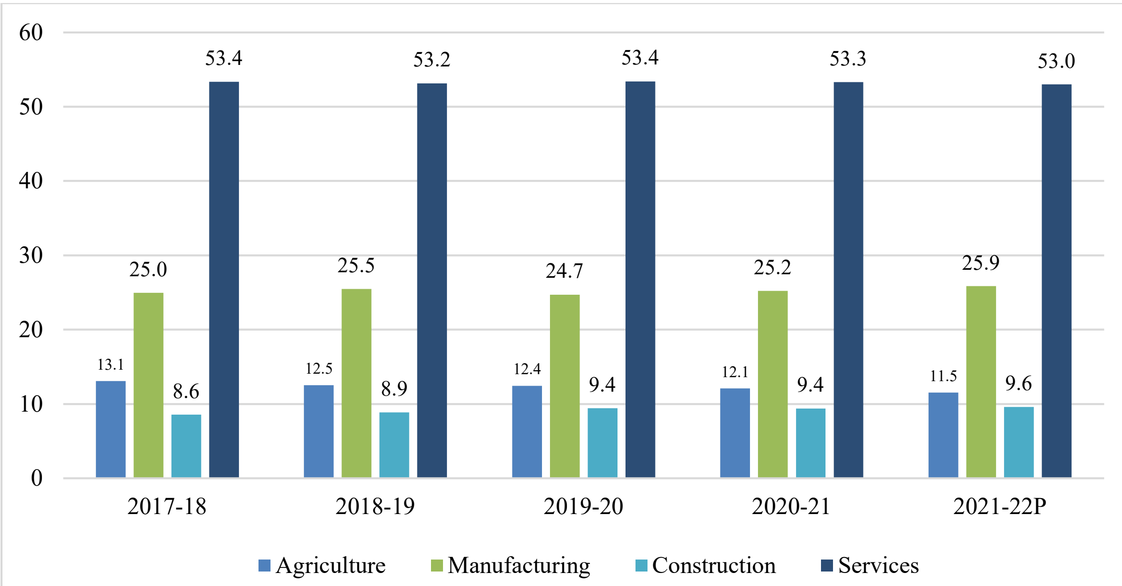


Source: MoF (2022)

The increase in import prices has escalated production costs for industries using imported goods as intermediates inputs or raw materials. On the one hand, increased imports create a rise in demand for dollars which in turn begets depreciation of the domestic currency. At the same time, an increase in import costs leads to rise in domestic price further pushing inflation up as evident in national data.

Figure 2 shows the sectoral GDP contribution from major sectors between 2018 to 2022. Among the major three sectors, the share of agriculture in GDP is the lowest, while the share of services is the highest accounting slightly more than half of the economy. As the share of agriculture declines, the two sub-sectors of industry, i.e. manufacturing and construction, have increased in recent years. This sectoral shift in activity is expected to continue as the economy matures and shifts from agricultural toward a more industrial one.

Figure 1: Sectoral Share of GDP

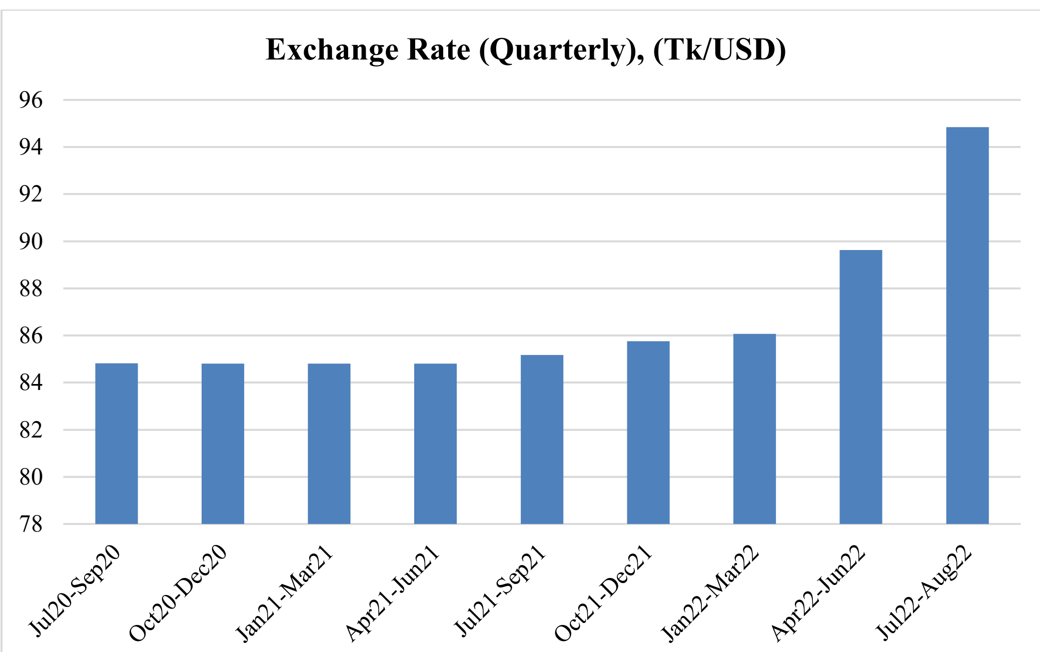


Source: BBS (2022a)

Bangladesh is a net importer with a current account deficit that heavily depends on remittance earnings to maintain its stability. Petroleum products, crude oil, fertilizer, food grains (rice and wheat), consumer goods (milk, sugar, edible oil, pulses), raw materials for the Ready-Made-Garment (RMG) industry are major imports contributing to production in agriculture and the industry sector. All these imported products directly or indirectly affect consumption and economic investments. Petroleum products are used in agriculture for irrigation, generating electricity and mainly in the transport sector. Therefore, an increase in the global price of petroleum products can lead to lower productivity in agriculture caused by inadequate irrigation from groundwater pumping as well as slowing industrial activities caused by power shortages. The increase in price of petroleum products also affects the transportation sector that ultimately leads to a rise in price of most goods and further increases in inflation.

Given the high share of imported wheat and edible oils in domestic supply, any rise in the global price of these commodities can also lead to further price inflation. Furthermore, agriculture activities in Bangladesh still depend heavily on inorganic fertilizer with most fulfilled through imports. Therefore, any price shock in the international fertilizer market can raise import costs, which then leads to widening trade deficits. On the other hand, the export sector of Bangladesh is highly concentrated upon the RMG industry, which is dependent on imports of raw materials and an adequate supply of electricity. Any global price shocks that affect supplies of these commodity inputs will potentially disrupt the export sector as well. On top of that, Bangladesh has experienced a massive shortage of foreign currency after the Russia-Ukraine war crisis which inadvertently resulted from increased import costs, reduced export earnings, and remittance flows. The combined effect gradually depletes foreign exchange reserves, raising the concern of weakening macroeconomic stability as shown by the depreciation of country's exchange rate (Figure 3).

Figure 2: Quarterly Nominal Exchange Rate to US Dollar (July 2020 to August 2022)



Source: BB (2022)

3. METHODOLOGY

Data and Model Structure

The Rural Investment and Policy Analysis (RIAPA) model is used as a simulation tool in this study by calibrating it to the 2019 Social Accounting Matrix (SAM) of Bangladesh constructed following Dorosh, Pradesha, Raihan and Thurlow (2021). The model follows a neo-classical approach with parameters describing responsiveness of demand and supply across different sectors with the main objectives of maximizing utility and profit. RIAPA also measures how impacts of policies and external shocks are mediated through prices and resource reallocations and ensures that resource and macroeconomic constraints are respected. The model consists of both behavioral equations that describe the economic decisions related to production, marketing, and consumption of economic agents (firms, households, and institutions) and structural equations that specify accounting relationships between the incomes and expenditures of individual agents within the macroeconomy[1].

The Bangladesh RIAPA model divides the economy into 26 agricultural, 38 industrial, and 12 service sectors for a total of 76 sectors. There are 15 household groups considered in the model that act as individual economic agents, earning income from labor and capital markets by providing inputs into different production activities. As part of the production system, all producers maximize profits and supply output to national markets by choosing different levels of inputs. Based on the technology available, as determined by a constant elasticity of substitution, producers are allowed to substitute input factors following relative factor price changes. However, producers' demand for intermediate inputs is determined by fixed input-output coefficients. Producers then combine factors and intermediate inputs using sector-specific technologies. On the other hand, consumer demand is determined by (linear expenditure system) demand equations that implicitly maximize utility given budget constraints. Income (expenditure) elasticities for various food commodities used in this study follow Diao et al. (2022).

[1] Model equations are presented in Annex A. Please refer to Diao and Thurlow (2012)

Both producers and households pay taxes from their income to the government, which uses these and other revenues to finance public services and social transfers. Remaining revenues are added to private savings and foreign capital inflows to finance investment. National market prices adjust to clear the overall supply and demand for each product. Domestically produced goods and services are modeled as imperfect substitutes for goods and services that are exported or imported. World prices are fixed (exogenous) under the assumption that changes in Bangladesh's demand for imports or supply of exports do not affect world prices (i.e., a small country assumption).

There are eight types of labor considered in the model following their highest level of education completed (less than primary school, primary school, secondary school, more than secondary school) and their location (rural and urban). Total supply of labor of each type is fixed, with wage rates adjusting in each period to equate supply and demand. All labor income goes to households following a fixed income allocation share based on household characteristics. In this model, the households are differentiated by five income quintiles at the national level and then separated by two geographical areas (rural and urban) and main earning activities (farm and non-farm) for rural household groups creating 15 household groups in total.

To satisfy the macroeconomic accounting identity of equalizing total saving with investment, the model assumed fixed private savings rate and allow investment to adjust following total savings. On the other hand, for international transactions we set exchange rate to adjust, driving export and import to move in order to meet the fixed current account. This means that we fixed foreign savings in the model to limit the country for making any international borrowing or lending with the rest of the world. We also assume government keeps the tax rates and public spending constant, while allowing public savings to adjust as total revenue change. This means that any financing needed to meet the government spending or new policy interventions has to come from budget deficit. This will eventually affect the national savings pool and drive total spending on investment goods.

The demographic data in the model follows the 2019 data year, where total population is set around 163 million people. We differentiated population according to their household group following the geographical area and income classifications as mentioned earlier. Majority of people in the country still lives in rural area, setting the total rural population to around 119 million with 68 million people engaged in only farm activity, while the remaining involve in both farming and non-farming activities. On the other hand, urban population only accounts for about 27 percent of total population where most of them engage in in industry and service sectors.

In the model, the poverty rate indicator is calculated using household consumption per capita data based on the most recent household survey (BBS 2017), where we use international poverty line of US$ 1.9 per day as the threshold to determine the poor status. Given we have multiple simulations in this study, the poverty rate is recalculated in every simulation to generate changes in percentage term and in number of people. Negative change in consumption value generated by the model simulation will push more people to live below the poverty line and increase poverty rate, while increase in household consumption value will bring more people out of poverty status and decrease poverty rate.

Design of Model Simulations

The Ukraine war caused a significant spike in global energy and food prices affecting the Bangladesh economy that depends on imports of these commodities. To analyze how these external shocks affect the domestic economy, we first measured the magnitude of the global price changes during the war period against a baseline. We use the April-June 2021 international price data as the base period, considering that major macroeconomic indicators of Bangladesh and external economies were relatively stable in the post-Covid period. External prices shock for each commodity is measured as the percentage change of the three-month average price from April-June 2021 to July-September 2022 (a fifteen-month period).

Three energy-related simulations and four commodity price shocks are considered in this study given their significant price movements after the start of Ukraine war including the effect from currency exchange movement (Table 1). In the model, global commodity price movements are introduced in each simulation by changing the world price given that these are assumed to be exogenous in the model.

Table 1: Simulation scenarios

Sim. No.	Scenarios	Exogenous Shocks on Global Commodity Prices							
		Crude oil	Petrol prod.	Ferti-lizer	Rice	Wheat	Maize	Edible oils	Ex. Rate
Sim1	Petroleum Price	47.7%	71.9%						
Sim2	Fertilizer Price			59.1%					
Sim3	Food Price				-18.1%	15.2%	-2.9%	-15.5%	
Sim4	Food Price (Hypothetical)				-15.6%	47.1%	8.0%	38.4%	
Sim5	All commodities	47.7%	71.9%	59.1%	-18.1%	15.2%	-2.9%	-15.5%	
Sim6	Sim 5 plus exchange rate devaluation	47.7%	71.9%	59.1%	-18.1%	15.2%	-2.9%	-15.5%	5%

Source: Authors' calculations.

Simulation 1-3 model the shocks to international petroleum, fertilizer and food prices in 2022. Simulation 4 is similar to Simulation 3, but it differs in that it assumes larger price shocks. This simulation is designed to explore a hypothetical worst case scenario in which domestic food price keep increasing after July 2022 due to friction in supply chains (lags in deliveries of imports), even after the initial reduction in world prices. Thus, in this worst-case scenario, prices fall only after September 2022. Simulation 5 models the combined effects of Simulations 1, 2 and 3 to capture the full impact of the global price shocks. Finally, simulation 6 captures the same shock as in simulation 5 assuming the country's currency is devaluated by 5 percent following the observed data.

Governments may undertake certain policy measures to maintain macroeconomic stability in the face of global price shocks. In our exercise, we also simulated different policy options against each price shock and explored how these options may protect against global price shocks focusing on affected sectors and vulnerable household groups. In the policy simulation scenarios, we assume the government provides certain subsidy amounts to the affected sectors and cash transfers to the lowest 20 percent income bracket in rural farm households as shown in Table 2. Each policy scenario is designed to respond to one of the simulation scenarios mentioned above with the expectation of reducing increases in commodity prices or maintaining the welfare of targeted poor households.

Table 2. Policy scenarios

Pol. No.	Scenarios	Amount of Subsidy and Cash Transfer (in Billion Taka)		
		Petrol products	Fertilizer	Poorest Households
Pol1	Petroleum Subsidy under Sim1 Scenario	110		
Pol2	Fertilizer Subsidy under Sim2 Scenario		40	
Pol3	Targeted Cash Transfer under Sim4 Scenario			26
Pol4	Combined Policy 1 (Sim5 plus Pol1, Pol2 & Pol3)	110	40	26
Pol5	Combined Policy 2 (Sim6 plus Pol1, Pol2 & Pol3)	110	40	26

Source: Authors' calculations

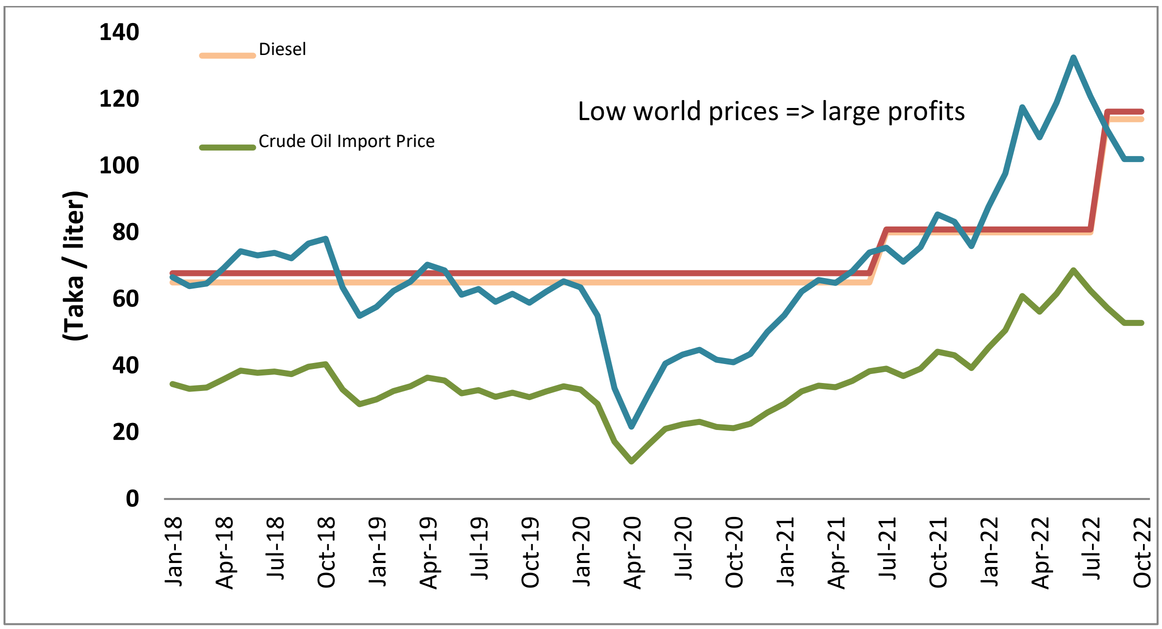
The first policy simulation scenario (Pol1) is designed to reduce the impacts of petroleum price increases by providing subsidies to the petroleum sector. Similarly, in the second policy scenario (Pol2), a subsidy is introduced to the fertilizer sector to avoid significant fertilizer price increases in domestic markets. The third policy scenario (Po3) does not relate to any specific commodity sector, but instead is designed to help protect the poorest household group in both rural and urban from increase in global food price, as captured in Sim4, by utilizing a cash transfer program to maintain income levels as in the base. Finally, the last two policy scenarios (Pol 4 and Pol5) consider all policy interventions introduced in the first three policy scenarios (Pol1, Pol2 and Pol3) in order to reduce negative impacts observed under Sim5 and Sim6.

The amount of subsidy provided to the petroleum sector is derived by comparing domestic price movement with the international price of crude oil that is used by Bangladesh Petroleum Corporation (BPC)[2] to produce petroleum domestically. Bangladesh imports most petroleum products to meet the domestic demand. The BPC is mandated to supply petroleum products in the country under a controlled price administered by Bangladesh Energy Regulatory Commission (BERC). Since all petroleum products are sold under an administered price regime controlled by the government, international price movements will drive the amount of profit or loss incurred by BPC.

[2] Bangladesh Petroleum Corporation is a statutory organization of the Government under the Ministry of Power, Energy & Mineral Resources (MPEMR) engaged to supervise, co-ordinate, and control all the activities relating to import, storage, marketing, and distribution of petroleum products in the country.

Figure 4 shows petroleum price movements from 2018 to 2022. The two flat lines show the price of petroleum and diesel sold domestically under the fixed price regime. The import price of crude oil is then used to calculate the cost paid by BPC to produce petroleum products domestically as shown by the top curved line. We use the share of crude oil from input-output data to estimate the cost, where cost of domestic petroleum is equal to twice the imported crude oil price. As shown in the graph, the cost of petroleum products from 2018 to 2019 moves along the fixed price, which suggests that the BPC did not incur any loss or profit. However, during the year 2020 when the price of crude oil slumped, the BPC potentially made profit.

Figure 4: Petroleum Price Movement Comparison Between Domestic and International Market



Sources: International commodity prices are based on WB (2022); Domestic petroleum price is constructed based on BPC (2022) and cost of petroleum production is derived from crude oil input share to total petroleum output following 2019 Bangladesh SAM database (Dorosh, Pradesha, Raihan and Thurlow 2021)

The price of domestic petroleum only increased in July 2021 and further increased in July 2022 a few months after the Russia-Ukraine war started. Despite the sharp rise in the import price, the domestic price did not increase immediately, and in the period January-June 2022 the BPC incurred losses given the cost of producing petroleum is higher than the sale price. According to TDS (2022a), BPC used half of its profits from the 2020 year (210 billion Taka) to finance the losses. However, BPC only had 190 billion Taka to pay import bills for the next two months of fuel consumption and the price of petroleum products had to be increased. Based on this information, we estimate the amount of subsidy provided to the petroleum sector during the 2022 period as Tk 110 billion that is then introduced in the model under Pol1 sim as a negative sales tax.

The size of the fertilizer subsidy modeled in the Pol2 simulation (Tk 40 billion)is based on information from DT (2022)[3] showing that the government provided Tk 40 billion of fertilizer subsidy during the year 2022. The amount of cash transfer in simulation Pol3 is calculated based on the income gap needed to maintain the consumption level of a household against Sim4. Overall, the total amount of resources requires to support all policy interventions is around Taka 176 billion, which is equivalent to about a half percent of total GDP.

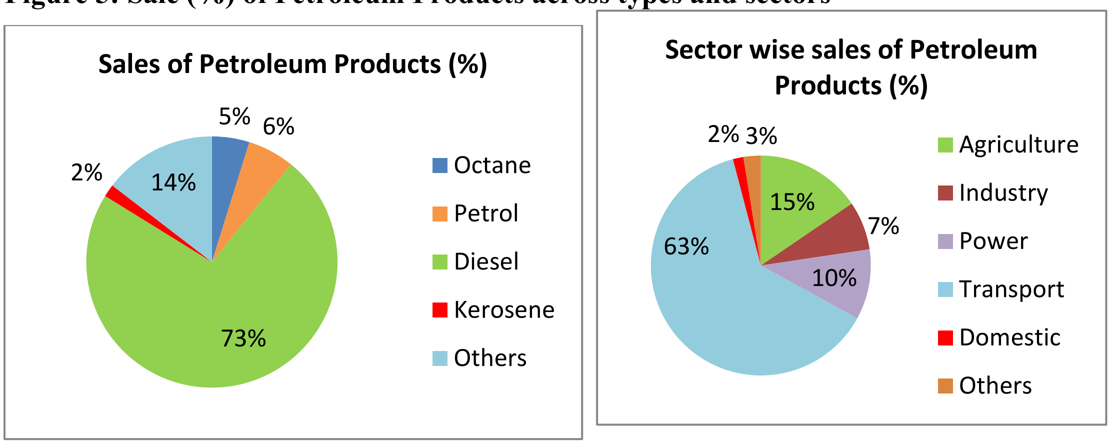
[3] In FY 2021-22, Tk 95000 million was allotted for subsidizing fertilizer which was around Tk.7717 million in FY 2020-21. Also, the government has increased the fertilizer subsidy by Tk. 40,000 million in the current fiscal year 2022-23.

4. GLOBAL PRICE SHOCKS SIMULATIONS

Petroleum Price Shock

Most petroleum products sold in Bangladesh are diesel, which comprises around 73% of total sales (Figure 5). Sixty-three percent of petroleum products are used in the transport sector, while 15 percent are used in agriculture. This indicates the potential for more significant impacts of increases in petroleum prices on agriculture and service sectors given their high dependency on petroleum to support production.

Figure 5: Sale (%) of Petroleum Products across types and sectors



Source: Bangladesh Petroleum Corporation (BPC 2022a)

As shown in Table 3, import costs of crude oil and refined petroleum products increased by 62.5% and 89.1% respectively in 2022. The increase in the average retail price of refined petroleum products in the domestic market was smaller (43.6 percent), as prices of for diesel and kerosene rose 51 percent and prices of octane and petrol rose 42.5 percent) – a reflection of the Bangladesh Petroleum Corporation's policy of limiting domestic price increases (Figure 6).

In Sim1, we do not take into account the BPC policy of stabilizing domestic energy prices and only consider increases in real (inflation-adjusted) international prices of crude oil and refined petroleum products. Thus, in Sim1 we model price shocks of 47.7 percent for crude oil and 72.0 percent for refined petroleum products.

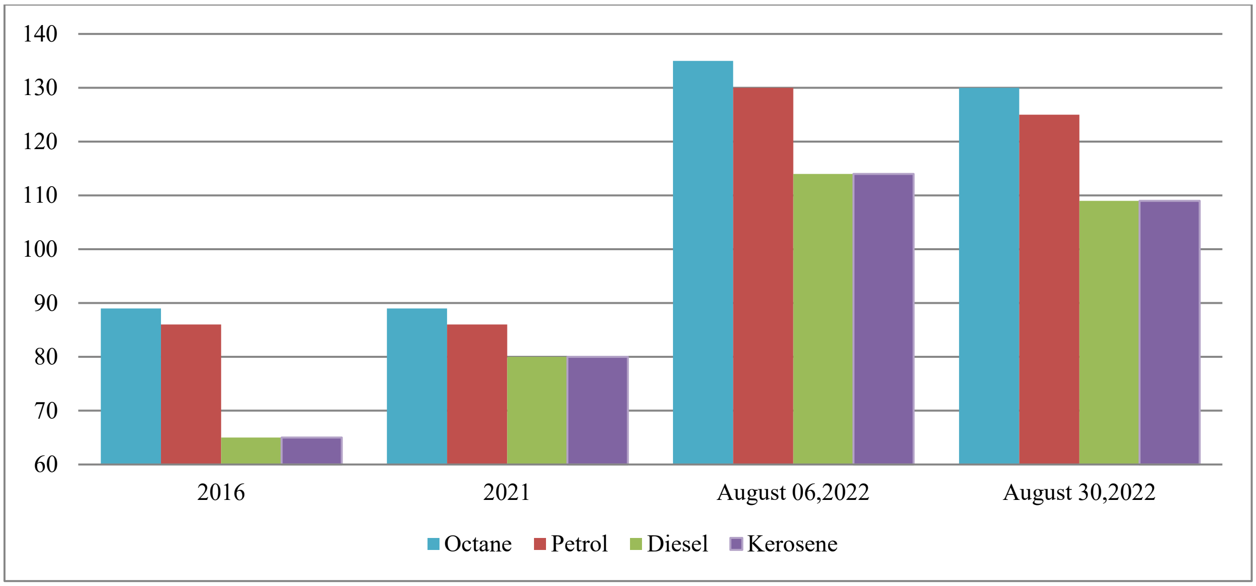
Table 3: Import Cost of Crude Oil and Refined Petroleum Products

	Nominal Price (USD/MT)	Real (2021-22) Price (USD/MT)	Nominal Price Change (%)	Real Price Change (%)
Crude oil	404.1	656.5	62.5	47.7
Refined Petroleum Products.	472.5	893.7	89.1	72.0

Source: Authors' calculation based on BPC (2022b)

Note: Real price international prices in US dollars are calculated using the US CPI as deflator.

Figure 6: Retail Prices (Tk/Liter) of Petroleum Products in the Domestic Market



Source: Bangladesh Petroleum Corporation (BPC 2022c) and TDS (2022b)

Overall, the economy is negatively affected by the increase in international petroleum prices as reflected in the 1.6 percent reduction in absorption (Table 4). The service and agriculture sectors, however, are the most affected with sectoral GDP reduction of 0.46 and 0.36 percent respectively because of their dependency on petroleum products (Table 5). Industrial GDP falls least in part because the real exchange rate depreciation of 3.95 percent increases profitability of ready made garmetns and other exports. The simulated rise in international petroleum prices leads also to a reduction in the quantity of petroleum product imports, but a slight increase in crude oil imports since as demand for crude oil as an intermediate input in domestic production of petroleum products increases.

Table 4: Impact on Macroeconomic Indicators (percentage change from base)

	Sim 1: Petroleum Price Shock	**Sim 2:** Fertilizer Price Shock	**Sim 3:** Food Price Shock	**Sim 4:** Food Price Shock (Hypothetical)	**Sim 5:** Combined Price Shocks	**Sim 6:** World Price Shock and Exchange Rate Depreciation
Total Absorption	-1.60	-0.27	0.39	-1.06	-1.49	-1.99
Household Consumption	-1.94	-0.44	0.72	-1.87	-1.67	-2.24
Total Investment	-1.27	-0.01	-0.14	0.25	-1.43	-1.92
Total Exports	3.26	1.11	-0.51	2.13	3.87	4.82
Total Import	-3.25	-0.42	1.03	-2.40	-2.66	-4.73
Real Exchange Rate	3.95	-1.84	-0.70	2.43	1.30	3.82
Import Index	2.50	0.39	-0.58	1.43	2.31	7.31
CPI	-1.91	-0.38	0.13	-0.61	-2.17	-0.35
Investment-GDP ratio	0.22	0.06	-0.08	0.19	0.20	0.21

Source: CGE Model Simulations

Table 5: Impact on National and Sectoral GDP (percentage change from base)

	Sim 1: Petroleum Price Shock	**Sim 2:** Fertilizer Price Shock	**Sim 3:** Food Price Shock	**Sim 4:** Food Price Shock (Hypothetical)	**Sim 5:** Combined Price Shocks	**Sim 6:** World Price Shock and Exchange Rate Depreciation
GDP	-0.28	-0.06	-0.02	-0.02	-0.36	-0.20
Agriculture GDP	-0.46	-0.94	0.15	-0.39	-1.27	-0.86
Crop GDP	-0.53	-1.66	0.15	-0.24	-2.05	-1.27
Industry GDP	-0.07	0.25	-0.17	0.39	0.02	0.19
Service GDP	-0.36	-0.02	0.03	-0.15	-0.35	-0.27

Source: CGE Model Simulations

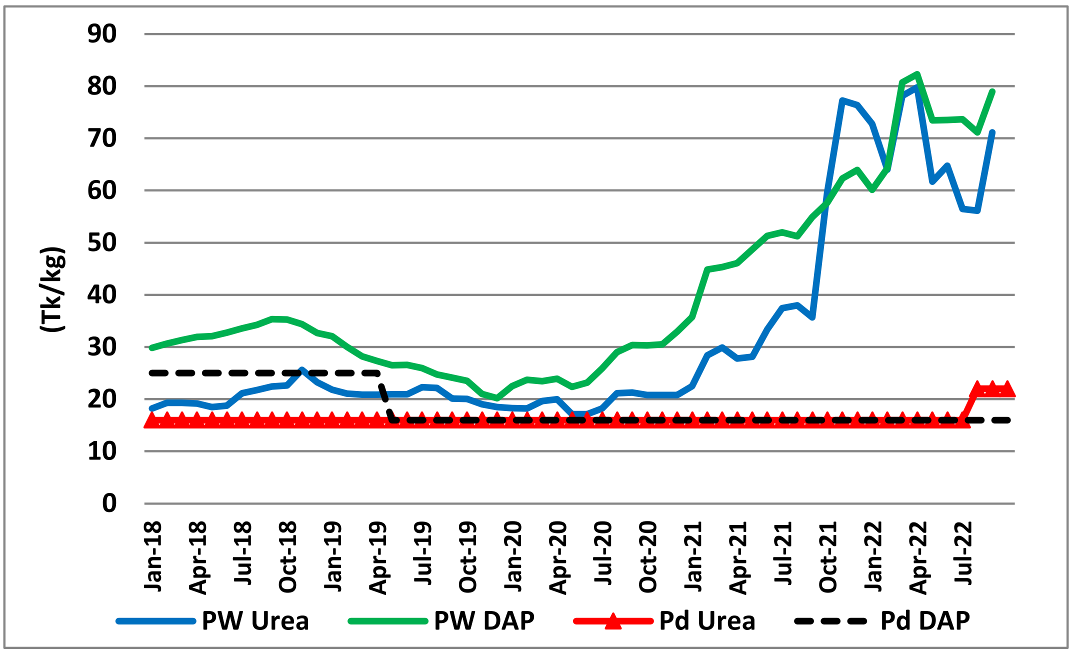
As incomes decline, an additional 2.1 million people nationally fall below the poverty line. Most of this increase in poverty occurs in rural areas (1.68 million people); urban poverty rises by 453 thousand people. Overall, the national poverty rate increases by 1.33 percentage points, as rural and urban poverty rates increase by 1.44 and 1.04 percentage points, respectively.

Fertilizer Price Shock

Fertilizer prices in Bangladesh have also been controlled by the government to maintain price stability. As shown in Figure 7, prices of urea and DAP rose steeply in world markets beginning of mid-2020 and kept rising substantially until mid-2022. Table 6 shows the average fertilizer price in Bangladesh from 2018 to 2022. Between January 2021 and June 2022, the international price of urea rose from Tk 27.8 to Tk 73.7

per Kg. The domestic price, however, was held at Tk 16.0 per Kg throughout this period. As a result, the ratio of the domestic price to the border price fell sharply from 0.58 to 0.22. The government shouldered this burden to maintain the domestic urea price over time. Only in July 2022 did the government raise the price of urea to Tk 20.5 to reduce the cost of the subsidy. However, the border price of urea dropped to Tk 65.2 per Kg in this same period pushing the ratio of the domestic price to the international price to 0.27, which still indicates the large amount of subsidy provided by the government.

Figure 7: Bangladesh: Wholesale and Import Prices of Urea and DAP 2018 – 2022 (Tk/kg).



Source: Authors' calculations using IMF (2022) and BFA (2022)

Table 6: Average Fertilizer Prices in Taka (World vs Bangladesh)

Time Period	World Price	Domestic Price	Price Ratio	World Price	Domestic Price	Price Ratio
	PCIF Urea (Tk/kg)	Pdom Urea (Tk/kg)	Pdom / PCIF	PW DAP (Tk/kg)	Pdom DAP (Tk/kg)	Pdom / PCIF
2018-19	25.3	16.0	0.632	34.7	23.5	0.677
2019-20	22.8	16.0	0.703	26.6	16.0	0.601
2020-21	27.8	16.0	0.575	41.0	16.0	0.391
July-Dec '21	57.4	16.0	0.279	22.0	16.0	0.727
Jan-June '22	73.7	16.0	0.217	45.4	16.0	0.352
July-Sep '22	65.2	20.5	0.315	59.0	16.0	0.271

Source: Authors' calculations based on World Bank Commodity Price (WB 2022) & BFA (2022).

Simulation result shows that increase in world fertilizer prices would lead to a reduction in domestic fertilizer use. As a result, agricultural crop production falls given the importance of fertilizer. Fertilizer-intensive crops such as rice, wheat, pulses, and vegetables suffer the largest production decline. Lower agriculture production decreases agriculture GDP by 0.9 percent as shown in Table 4. However, industrial GDP increases slightly by 0.25 percent mainly due to higher production of domestic fertilizer stimulated by the price increase. As overall production decreases, incomes fall, leading to lower household consumption by 0.4 percent and a slight reduction in investment of 0.01 percent. As a result, total absorption, which reflects total domestic final consumption falls by 0.3 percent, indicating the negative effect of increase in fertilizer price on national welfare.

Increase in international fertilizer prices decrease households' overall consumption with the largest declines observed among the rural poor given their high food expenditure share. Table 7 shows there are 892 thousand people that fall below the poverty line, which increases rural poverty more than urban poverty.

Table 7: Impacts on Poverty (Simulation Results)

	Sim 1: Petroleum Price Shock	Sim 2: Fertilizer Price Shock	Sim 3: Food Price Shock	Sim 4: Food Price Shock (Hypothetical)	Sim 5: Combined Price Shocks	Sim 6: World Price Shock and Exchange Rate Depreciation
Change ('000 people) in the number of poor compared to base						
National	2128	892	-548	1539	2444	2993
Urban	453	131	-86	341	450	553
Rural	1675	762	-461	1198	1994	2440
Change (percentage points) in poverty rate compared to base						
National	1.33	0.56	-0.34	0.96	1.53	1.88
Urban	1.04	0.30	-0.20	0.78	1.04	1.27
Rural	1.44	0.66	-0.40	1.03	1.72	2.10

Source: CGE Model Simulations

Food Price Shocks

We simulate two global price shocks on food commodities. In the first simulation (simulation 3), we capture the actual price changes of rice, wheat, maize, and edible oils (see Figures 8a, 8b and 8c), while in simulation 4, we assume a worst-case scenario by imposing higher price shock due to frictions in the global supply chains causing a delay in delivery of imports that extends the duration of the price shock.

In contrast to energy price shocks, the prices for all commodities except wheat declined under Sim3. The increased price of wheat and reduced prices of rice, maize, and edible oils results in a reduction of imported wheat and increased imports of rice, maize, and edible oils. The fall in world rice prices does not significantly change the domestic price because of the small share of imported rice (3.96 percent) in total domestic supply. Therefore, both domestic production of rice and household consumption only increase slightly. On the other hand, imported wheat and edible oil account for around 79.4 percent and 68 percent of domestic supply respectively so large changes occur in their pricing.

Figure 8a: Prices of Rice in International and Domestic Markets, 2021-2022

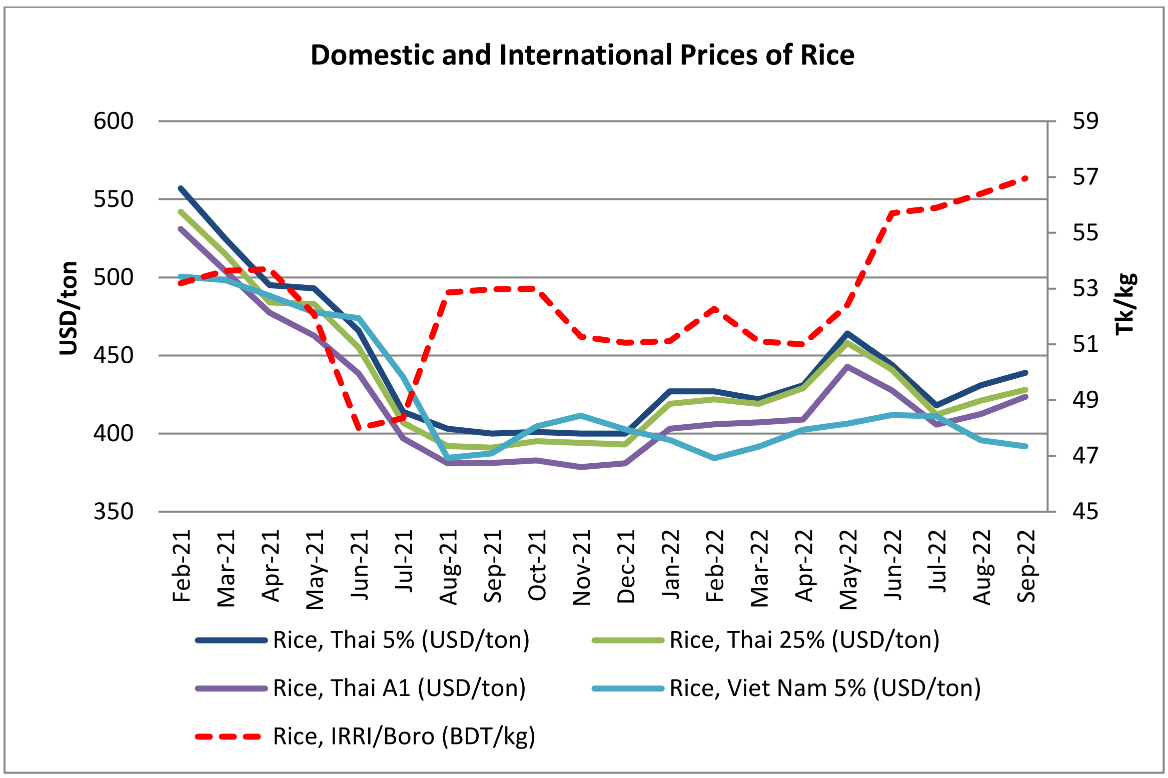


Figure 8b: Prices of Wheat in International and Domestic Markets, 2021-2022

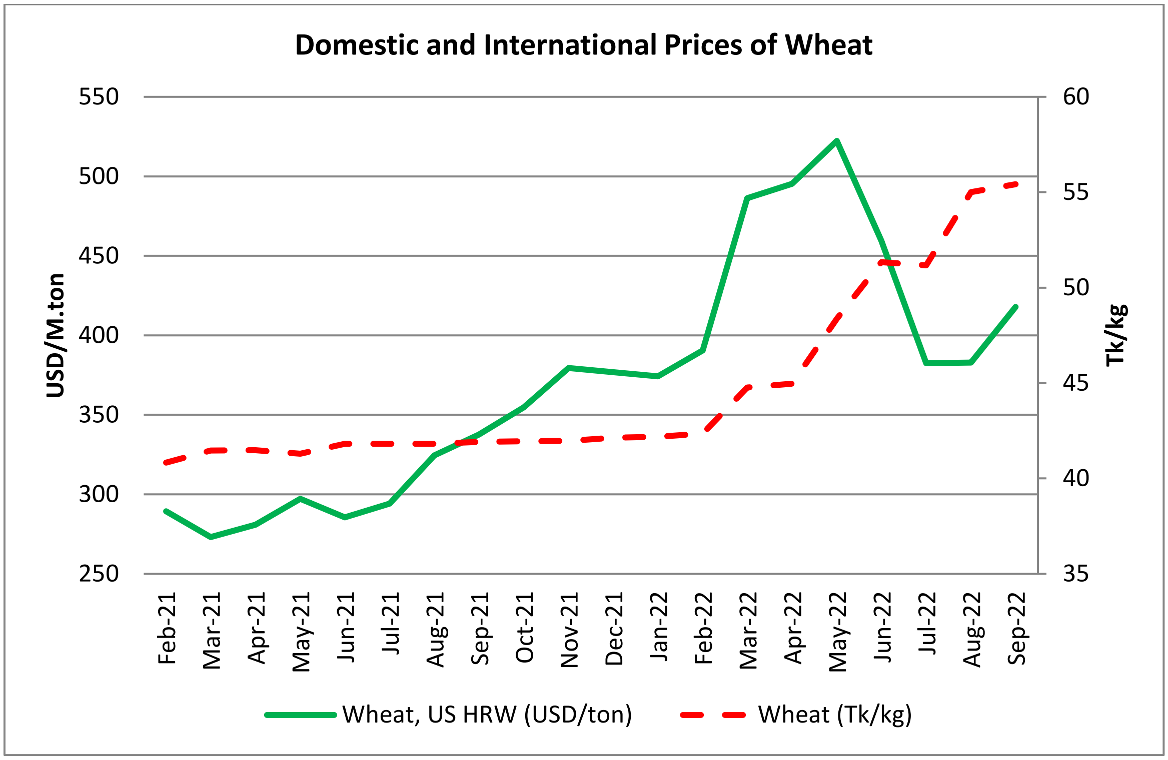
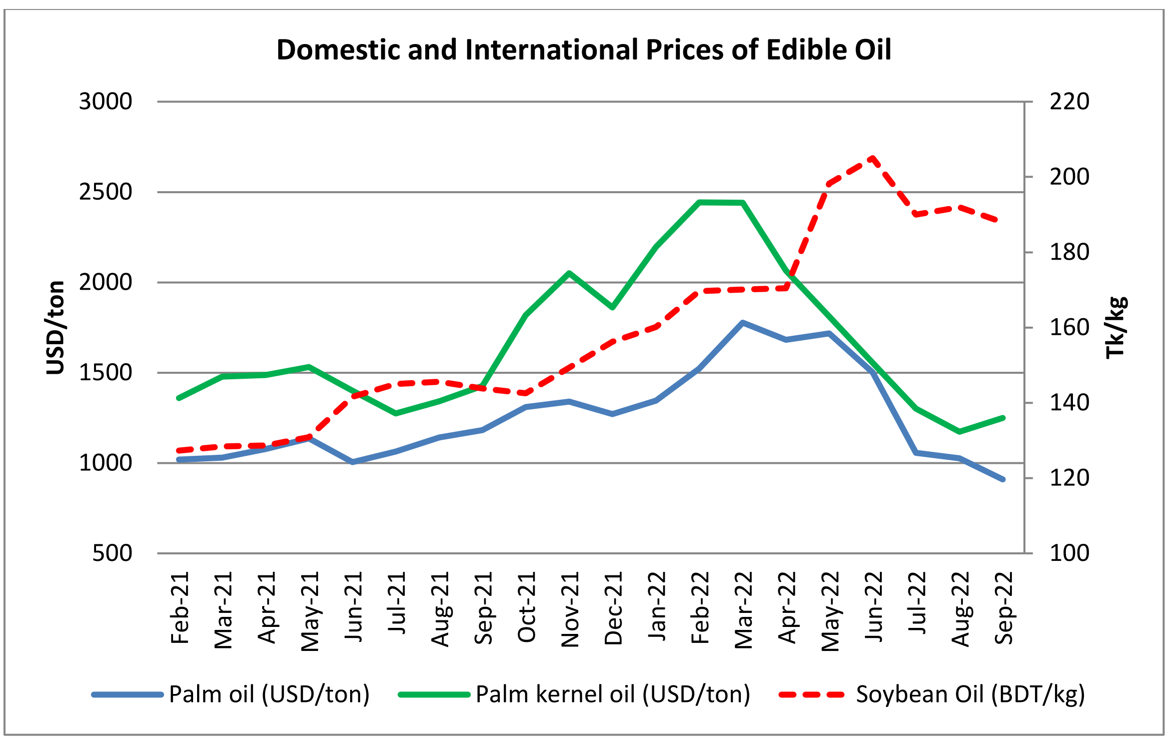


Figure 8c: Price of Edible Oils in International and Domestic Markets, 2021-2022



Source: Domestic price data is based on BBS (2022b); international price data is derived from World Bank (2022).

Overall, lower global food prices push down the average price of imports (index) by 0.58 percent, decreasing the total value of imports, necessitating a real exchange rate appreciation (0.7 percent) to balance supply and demand for foreign exchange as shown in Table 3. However, this appreciation of exchange rates deteriorates export opportunities, which is evident from the decrease in exports. The lower export performance of these major trading sectors contributes to an overall decline of manufacturing that leads to the decline in industrial GDP as shown in Table 4. Agriculture GDP, however, slightly increases by 0.15 percent with crop GDP also increasing by 0.15 percent. With almost no change in the service sector GDP, total GDP only slightly decreases by 0.02 percent.

Since the overall world price shocks lead to lower average import prices, total imports increase by 1.03 percent. This leads to an increase in total household consumption of 0.7 percent (Table 3). However, investment goes down by 0.14 percent because of the price increase of investment goods which is mainly driven by lower industrial production. The net effect of increased consumption and reduced investments leads to an increase in absorption by 0.4 percent. Given the increase in total consumption, the number of rural poor decrease by 461 thousand and urban poor by 86 thousand. Overall, we observe a reduction in the national poverty rate of 0.34 percentage points as shown in Table 5.

Food Price Shock (Hypothetical)

In this hypothetical price shock simulation, we model price shocks for wheat (47.1 percent) and edible oils (38.4 percent), while the world price of rice decreases by 15.6 percent[4]. In the simulation, the quantity of rice imports increases, while imports of maize, wheat and edible oil decrease.

As global food prices increase, import prices rise by an average of 1.4 percent. Given the assumption of fixed foreign capital inflows, the real exchange rate depreciates by 2.4 percent (Table 4.2), spurring a 2.1 percent increase in total exports and an increase in industrial GDP (Table 4.3). The increase

[4] This simulation assumes worst case scenario where global food price reduction started in July 2022 was slowly transmitted to domestic market considering persistence issues on global supply chain as well as the fact that majority of people in Bangladesh live in rural area, which further requires longer time to transport imported commodities across the rural regions and eventually alters domestic prices.

in world food prices reduces total imports by 2.40 percent, however, which leads to a decrease in total household consumption by 1.9 percent.

As expected, the decline in economic activity and real household consumption translates into more people falling below the poverty line: 1.2 million people (1.03 percentage points) and 341 thousand people (0.78 percentage points) in rural and urban regions, respectively (Table 4.4).

Combined Global Price Shocks

In this simulation, we combine all commodity price shocks introduced in the previous simulations as a single price shock to estimate the total impact of changes in international commodity prices caused by the Ukraine war. This simulation better reflects how petroleum, fertilizer, and commodity markets were simultaneously impacted by the changes in international prices.

Simulation results show that combined commodity price shocks increase the import price index by 2.3 percent leading to reduction in total imports by 2.7 percent (Table 3). This also means that imported goods become more expensive and require exports to increase by 3.9 percent to generate additional foreign currency to finance more expensive imports. Given the dependency of many sectoral activities in Bangladesh on energy and fertilizer, less availability of each translates into a reduction in the economy's ability to produce goods and services, especially in agriculture and services sectors that needs these intermediate inputs in the production processes. This effect is reflected by the decline in agriculture and service GDP by 1.3 and 0.3 percent, respectively, as shown in Table 3. On the other hand, industry sector GDP grows slightly by 0.02 leading to a net decline in total GDP by 0.36 percent.

As shown in table 4.1, a reduction in national income leads to decline in household consumption, investment, and total absorption by 1.7, 1.4 and 1.5 percent, respectively. Reduction in households' consumption consequently pushes 2.4 million people into poverty, due to these combined global price shocks. The distribution is higher in rural areas with nearly 2 million newly poor, while around 553 thousand additional poor from urban areas. Compared to the previous simulation results, the combined effect of global price shock on total poverty rate is worse than any of the individual simulations suggesting the more detrimental impacts of the combined shocks on vulnerable household group.

Combined Price Shocks and Exchange Rate Depreciation

We add another simulation to capture the same global price shock as simulated in Sim5 but assume that the country also experiences five percent exchange rate devaluation during the Ukraine war. The rate of devaluation is calculated based on exchange rate movement from April to August 2022. We assume the Ukraine war is considered as the plausible reason for the rise in the exchange rate as considered in Sim6.

Simulation result shows an increase in the import price index leading to a reduction in total imports by 4.7 percent, which is higher than what was observed in Sim5 (Table 4.2). The real exchange rate also devalues more strongly under Sim6 pushing exports to increase by 4.8 percent. Given that most export commodities in Bangladesh are industrial products, we observe a 0.2 percent increase in industrial GDP, as shown in Table 4.3. Given the high dependency of the agriculture and service sector on fertilizer and petroleum products, we observe a reduction in GDP in both and an overall reduction in total GDP by 0.2 percent.

A reduction in national income leads to lower investment and household consumption by 1.9 and 2.2 percent, respectively. Total absorption also falls by 2 percent showing larger reduction in national welfare compared to Sim5. A more detrimental impact is also observed among the poor, with three million more people falls into poverty, of which the majority are located in rural areas. Overall, the national poverty rate increases by 1.9 percentage points with both rural and urban poverty rising by 1.3 and 2.1 percentage points, respectively.

5. POLICY SIMULATIONS

In this chapter we examine the role of subsidies for sectors affected by international price increases and cash transfers provided to targeted households as policy responses to help reduce adverse economic outcomes. Simulation values presented in this section are the net effects of the policy response compared to the corresponding simulation explained in the earlier section.

Table 9 presents simulation results showcasing how each policy that is implemented impacts the targeted sectors in the economy based on the policy's objective. The first policy simulation captures the impact of a petroleum subsidy that reduces domestic petroleum prices. The subsidy reduces the domestic price of petroleum by 12.6 percent compared to the Sim1 scenario. As a result, domestic demand for petroleum increases by 2.6 percent. Similarly, in the fertilizer subsidy policy scenario (Pol2), the government provides a subsidy which reduces domestic fertilizer prices by 14 percent. This consequently increases domestic demand for fertilizer by 0.8 percent. The third policy scenario simulates the impact of targeted cash transfers to poor households in the lowest 20 percent income bracket to insulate them from the negative impact of global food price shocks as simulated in Sim4. It shows that average incomes increase by around 2 percent with the introduction of cash transfer. Finally, the last two scenarios show the combine effects of all policies on Sim5 and Sim6, which capture similar changes on the targeted variables as observed in the first three policy simulations.

Table 9: Exogenous Shocks in Simulations Pol 1 – Pol 5: (percent)

	Pol 1: Petroleum Subsidy	Pol 2: Fertilizer Subsidy	Pol 3: Targeted Cash Transfers	Pol 4: Combined Policy Option 1	Pol 5: Combined Policy Option 2
Petroleum Price	-12.6			-12.6	-12.6
Petroleum domestic consumption	2.6			2.5	2.5
Fertilizer Price		-14.0		-14.1	-14.1
Fertilizer domestic consumption		0.8		0.7	0.7
Poor household income			1.9	2.4	2.5
Poor Rural farm			2.3	3.1	3.2
Poor Rural Non-farm			1.7	2.0	2.1
Poor Urban			1.6	2.1	2.1

Source: CGE Model Simulations

The impact of the policies on real GDP is presented in Table 10, where changes in total GDP are quite small, but some effects are observed at the sectoral level. In the first policy scenario (Pol1), we observed a slight positive impact from the petroleum subsidy on agriculture and services by 0.05 and 0.04 percent respectively, while industrial GDP decreases by 0.15 percent. This is because of the reduction in total investment demand (Table 10) for commodities produced by the industrial sector such as machinery, vehicles, and construction goods. The reduction in investment demand is caused by the increase in government deficit that is used to finance the subsidy. This in turn reduces the total available savings in the economy that determines total investment demand.

Table 10: Impacts on National and Sectoral GDP (Simulation Results)

	Pol 1: Petroleum Subsidy	Pol 2: Fertilizer Subsidy	Pol 3: Targeted Cash Transfers	Pol 4: Combined Policy Option 1	Pol 5: Combined Policy Option 2
GDP	-0.02	-0.01	-0.02	-0.08	-0.08
Agriculture GDP	0.05	0.43	0.05	0.34	0.36
Crop GDP	0.08	0.78	0.08	0.59	0.61
Industry GDP	-0.15	-0.18	-0.08	-0.44	-0.45
Service GDP	0.04	-0.01	0.00	0.02	0.02

Source: CGE Model Simulations

As shown in Table 11, total investment decreases by 0.67 percent while household consumption increases by 0.29, resulting in a 0.04 percent change in total absorption. Increases in household consumption are mainly driven by increases in wage rates for all types of workers as shown in Table 11 with larger changes observed among high-skilled labor. Increases in wage rates are caused by a higher demand of labor, that mainly originated from the increase activities in the agriculture and service sectors as reflected by changes in GDP. Even though production activities in the industrial sector decline, the net demand for workers is still positive given both agriculture and service sectors are more labor intensive than the industry. The increase in household consumption reduces the national poverty rate by 0.23 percentage points, while rural and urban poverty decreases by 0.27 percentage points and 0.13 percentage points. This reduction also means that the petroleum subsidy helps protect 374 thousand people from falling into poverty, of which 318 thousand live in rural areas and 57 thousand are in urban areas.

In the second policy scenario (Pol2), simulation result shows that the fertilizer subsidy directly benefits the agricultural sector, especially the crop sub-sector as shown in table 5.2, where agriculture and crop GDP increase by 0.43 and 0.78 percent, respectively. There is no significant change on service sector GDP, while industrial GDP decreases by 0.18 percent. The decline in industrial GDP is again caused by the reduction in total investment demand as shown in Table 5.4 that decreases by 0.38 percent. The fertilizer subsidy spurs production in the agriculture sector creating more demand for labor leading to increased wages. This trend is reflected in Table 11, where labor wages mainly increase among rural households who engage in the agriculture sector. Higher wages coupled with reductions in the CPI lead to increases in total consumption by 0.14 percent but a slight reduction in total absorption by 0.04 (Table 12). Increases in total consumption help prevent some households from falling below the poverty line. Table 13 shows that the poverty rate could be reduced by 0.17 percentage point in urban areas and 0.29 percentage point in rural areas with the fertilizer subsidy. In total, there are 406 thousand people that could be saved from becoming poor, of which most live in rural areas.

Table 11: Impacts on Wage Rates by Region and Labor Type (Simulation Results)

		Pol 1: Petroleum Subsidy	Pol 2: Fertilizer Subsidy	Pol 3: Targeted Cash Transfers	Pol 4: Combined Policy Option 1	Pol 5: Combined Policy Option 2
Rural	low-skilled	0.17	0.11	0.02	0.33	0.34
	high-skilled	0.37	0.18	0.04	0.66	0.68
Urban	low-skilled	0.21	0.05	0.01	0.26	0.27
	high-skilled	0.35	0.05	-0.01	0.38	0.40

Source: CGE Model Simulations

The third policy scenario focuses on the impact of cash transfer targeted to households in the lowest 20 percent income bracket. Given the large allocation of expenditure on food among the poor, it is expected that the increase income from the transfer is mostly spent to purchase more food by the poor. This in turn stimulates production of food commodities as reflected by the increase in crop and agriculture GDP by 0.08 percent and 0.05 percent respectively. The reduction in industrial GDP by 0.08 percent leads to a decline in total GDP by 0.02 percent, while there is barely any change observed on service GDP. The increase in agriculture production and the reduction in industrial activities are also reflected in wage rate changes. Table 13 shows the rural low-skilled and high-skilled labor wage rate increase by 0.02 percent and 0.04 percent, respectively, while the urban high skilled wage rate (that mainly involves in industrial sector) declines by 0.01 percent.

Table 12: Macroeconomic Indicators (Simulation Results)

	Pol 1: Petroleum Subsidy	Pol 2: Fertilizer Subsidy	Pol 3: Targeted Cash Transfers	Pol 4: Combined Policy Option 1	Pol 5: Combined Policy Option 2
Total Absorption	-0.04	-0.04	-0.02	-0.13	-0.13
Household Consumption	0.29	0.14	0.06	0.46	0.46
Total Investment	-0.67	-0.38	-0.19	-1.25	-1.26
Total Exports	0.31	-0.11	-0.02	0.16	0.15
Total Import	0.03	-0.11	-0.02	-0.09	-0.09
Real Exchange Rate	0.15	1.27	-0.03	1.33	1.38
Import Index	0.00	0.00	0.00	0.00	0.00
CPI	-0.43	-0.16	0.00	-0.55	-0.57
Investment-GDP ratio	-0.33	-0.13	-0.09	-0.56	-0.57

Source: CGE Model Simulations

Since the cash transfer is financed by the government, it reduces government savings. Consequently, since we assume in the model that investment is driven by the amount of total savings available in the country, total investment demand declines by 0.19 as shown in table 12. This is one of the main reasons why industrial GDP declines given most of investment demand is in the form of industrial goods. Overall, total absorption declines by 0.02 percent while household consumption increases by 0.06 percent. Increases in household consumption helps some households avoid falling into poverty. Table 13 shows there are around 1.7 million people that could escape from poverty with a cash transfer program, while there is around 1.5 million people that fall into poverty with the global food price shock as shown in Sim4. This means that the cash transfer program could neutralize the impact of global food price shock under worst-case scenario on the poor by maintaining their welfare level. Since more poor people live in rural areas, the reduction of poverty in rural households is much larger with net reduction in the national poverty rate by 1.14 percentage point.

Table 13: Impacts on Poverty: Simulation Results

	Pol 1: Petroleum Subsidy	Pol 2: Fertilizer Subsidy	Pol 3: Targeted Cash Transfers	Pol 4: Combined Policy Options	Pol 5: Combined Policy Options
‘Change ('000 people) in the of number persons living below poverty line against the corresponding simulation					
National	-374	-406	-1692	-2403	-2448
Urban	-57	-72	-374	-454	-472
Rural	-318	-333	-1319	-1949	-1976
Change (Percentage points) in poverty rate against the corresponding simulation					
National	-0.23	-0.25	-1.06	-1.51	-1.53
Urban	-0.13	-0.17	-0.86	-1.04	-1.09
Rural	-0.27	-0.29	-1.14	-1.68	-1.70

Source: CGE Model Simulations

The last two policy simulations include the policy interventions introduced in the previous three policy scenarios. However, these are imposed on combined global price shocks (as simulated in Sim5 and Sim6), which generated more detrimental effects on the economy as discussed in the previous chapter. The cash transfers included in both policy simulations is meant to offset the adverse effects on poor households of the global price shock. Table 10 shows the impact of the combined policy on total and sectoral GDP. The positive impact on crop and agriculture GDP is observed on both combined policy simulations with larger effects shown in the Pol5 scenario. Like the previous three policy simulations, services GDP shows slight positive change while industrial GDP declines by around 0.45 percent. Since there is not much difference in magnitude observed between Pol4 and Pol5 results on these two sectors' GDP, total GDP in both policy scenarios slightly decreases by 0.08 percent.

Increases in agriculture and services GDP lead to more hiring of labor and the use of other input factors. This positive trend is reflected in increases in wage rates for all types of workers. However, rural labor shows a larger wage rate increase compared to urban labor because of their stronger engagement in the agriculture sector that performs better than other sectors. Higher incomes, coupled with a reduction in the CPI consequently leads to increase in household consumption by 0.46 percent, while total absorption decreases by 0.13 precent in both policy scenarios due to a much lower reduction observed in total investment. Less reduction in total investment observed under Pol4 is in line with a decreased devaluation value as shown in Table 12.

Increase in income helps more people to escape poverty as shown in Table 13. Simulation results show that both policies reduce the poverty rate but with a slightly larger decline observed under Pol5. Even though poverty reduces less in urban areas than in rural areas, we still observe high poverty reduction in both policy scenarios. Overall, there are about to 2.4 million people that are saved from becoming poor under each combined policy scenarios of Pol4 and Pol5. Looking at the impact of these combined policies on poverty reduction, the magnitude is closer to the poverty impact of the cash transfer than the subsidy scenarios. This again reemphasizes that cash transfers provide a more effective way to reduce poverty compared to the sectoral subsidy approach.

6. SUMMARY AND CONCLUSIONS

The spike in global commodity prices caused by the Russia-Ukraine war has created concern among many developing countries including Bangladesh that still heavily depend on energy and food imports. Despite recovering strongly after the COVID-19 pandemic, the shock from the Ukraine War has created uncertainty about the county's food security and its impacts on the poor who are more vulnerable to price fluctuations. Utilizing Bangladesh RIAPA economywide model, this study assesses how international price shocks are transmitted to domestic prices and alter production in various sectors in the economy. Impacts on income distribution across households is also captured to estimate welfare effects and amount of people that fall into poverty. It is essential to mention that even though the SAM and model structure provide a framework that guarantees the consistency of assumptions, there remain many uncertainties in the data. Thus, the results presented here should be interpreted as approximate estimates rather than the exact effects of different shocks and policy choices.

Simulation results show that increase in international commodity prices creates a GDP loss of 0.36 percent. The impact from energy price shocks is found to be the most significant accounting for 0.28 reduction in real GDP. Unfortunately, agriculture and services are highly affected due to their dependency on petroleum products. Increases in international fertilizer prices also negatively affect the agriculture sector, especially those that use it most intensely such as rice farmers who majority apply fertilizer in growing the crops. Even though the magnitude of the food price shocks is not large, we still observe small negative effects on GDP. As national income decreases, we find a reduction in total welfare and household consumption that leads to more people falling into poverty. It is estimated that the number of people that become poor due to global commodity price shocks is around three million with the majority living in rural areas.

It is imperative to explore how the government could reduce or even eliminate these negative impacts keeping in mind resource limitations. To do so, we explore the potential impact of subsidy and cash transfer policies that have been used in the past to help reduce the negative effects caused by the increase in international commodity prices considering the amount of government budget available to the sector.

Despite generating a slight reduction in GDP, the combined policy scenarios help improve agriculture and services sectors that are heavily affected by global price shocks. Agricultural GDP increases by 0.43 percent, as the increased fertilizer subsidy helps spur agriculture production which then leads to an increase in crop GDP by 0.78 percent. A petroleum subsidy helps increase total household consumption by 0.29 percent which is much higher than the result shown by utilizing a cash transfer policy. However, given that the nature of the policy is not solely focused on helping the poor, it is significantly less effective in reducing poverty in comparison with a cash transfer policy could provide. Moreover, as illustrated by the experiences of other countries, increases in a fuel subsidy, once introduced, are likely to be very difficult to reverse. This suggests that if the country aims to reduce impacts on poverty, a direct cash transfer would be a better policy intervention than other options. Overall, we find the combined policies could significantly reduce poverty incidence by around 2.6 million people, saving almost all people affected by the global price shock from falling into poverty.

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ANNEX A: THE BANGLADESH ECONOMY-WIDE MODEL

Consumer and producer behavior

Representative consumers and producers in the model are treated as individual economic agents. We assume that households (consumers) make decisions so as to maximize welfare (utility) subject to a budget constraint. For this we employ a linear expenditure system (LES) of demand:

$$P_i \cdot C_{ia} = P_i \cdot \gamma_{ia} + \beta_{iha} \cdot \left(\frac{(1 - s_a - td_a) \cdot Y_a}{LS_a} - \sum_{i'} P_{i'} \cdot \gamma_{i'a} \right) \tag{1}$$

where *C* is per capita consumption of good *i* in area *a* (i.e., cities, towns or rural areas), *γ* is a minimum subsistence level, *β* is the marginal budget share, *P* is the market price of each good, *Y* is total household income, *LS* is total labor supply (a proxy for population), and *s* and *td* are savings and direct tax rates, respectively. Our demand functions allow consumption patterns and income elasticities to vary across households in cities, towns and rural areas.

We assume producers maximize profits subject to input and output prices. A constant elasticity of substitution (CES) function determines output quantity *X* from sector *i* in area *a*:

$$X_{ia} = \alpha_{ia} \cdot \left(\delta_{ia} \cdot L_{ia}^{-\rho_{ia}} + (1 - \delta_{ia}) \cdot K_{ia}^{-\rho_{ia}} \right)^{-1/\rho_{ia}} \tag{2}$$

where *α* reflects total factor productivity (TFP), *L* and *K* are labor and capital demands, and *δ* and *ρ* are share and substitution parameters. Our production functions permit technologies to vary across producers and areas. Maximizing profits subject to Equation 2 gives the factor demand equations:

$$\frac{L_{ia}}{K_{ia}} = \left(\frac{r \cdot D_{ia}}{W_a} \cdot \frac{1 - \delta_{ia}}{\delta_{ia}} \right)^{1/(1+\rho_{ia})} \tag{3}$$

where *W* is the labor wage in area *a*, and *r* is a fixed economywide capital rental rate adjusted by a sector/area-specific distortion term *D*. The factor substitution elasticity is a transformation of *ρ*. Higher elasticities means *producers* can more readily substitute between labor and capital when relative prices change. We do not show intermediate demand in the equations, although this is included in our model. The producer price *PX* is the sum of factor payments per unit of output:

$$PX_{ia} \cdot X_{ia} = W_a \cdot L_{ia} + r \cdot D_{ia} \cdot K_{ia} \tag{4}$$

National product markets and international trade

Products are traded in national markets at a single market-clearing price *P*. The national market assumption is needed because internal trade data is unavailable. Output from each area is combined into a composite national good *Q* using a CES function:

$$Q_i = \phi_i \cdot \left(\sum_a \lambda_{ia} \cdot X_{ia}^{-\tau_i}\right)^{-1/\tau_i} \tag{5}$$

Equation 5 permits imperfect substitution between goods from different areas. Relative producer prices are determined by the following first order condition, derived from minimizing the composite supply price of each good:

$$PX_{ia} = P_i \cdot (1 - ti_i) \cdot Q_i \cdot \left(\sum_{a\prime} \lambda_{ia\prime} \cdot X_{ia\prime}^{-\tau_i}\right)^{-1} \cdot \lambda_{ia} \cdot X_{ia}^{-\tau_i - 1} \tag{6}$$

where *ti* is the indirect tax rate applied to domestic sales. This function implies that demand for an area's output rises when its supply price falls relative to those in other areas.

We do not show the equations governing international trade. However, our model permits two-way trade assuming imperfect substitution between domestic and foreign goods. A constant elasticity of transformation (CET) function determines exports and a CES function determines imports. World commodity prices are fixed under a small country assumption. The current account balance is fixed in foreign currency units and the real exchange rate is flexible (i.e., a price index of tradable to non-tradable goods).

Government and investment demand

Assuming all factors in an area are owned by households in that area, then total income *Y* is

$$Y_a = \sum_i (W_a \cdot L_{ia} + r \cdot D_{ia} \cdot K_{ia}) + h_a \cdot LS_a \tag{7}$$

where *h* is per capita transfer payments from the government. The government is treated as a separate agent. Total domestic revenue is the sum of direct and indirect taxes, as shown on the left-hand side of the following equation:

$$\sum_a td_a \cdot Y_a + \sum_i ti_i \cdot P_i \cdot Q_i = \sum_i P_i \cdot A \cdot g_i + \sum_a h_a \cdot LS_a + B \tag{8}$$

The government uses revenues to purchase goods and make transfers (i.e., recurrent spending) and to save (i.e., finance public capital investment). This is shown on the right-hand side of Equation 8. Our macroeconomic closure for the government account assumes that public consumption spending is equal to base-year quantities *g* multiplied by an exogenous adjustment factor *A*. The fiscal balance *B* adjusts to equalize total revenues and expenditures.

We assume a saving driven closure, i.e., investment demand adjusts following the available savings in the economy. As shown below, a national savings pool finances investment:

$$\sum_a s_a \cdot Y_a + B = \sum_i (P_i \cdot I \cdot ip_i + P_i \cdot G \cdot ig_i) \tag{9}$$

where *ip* and *ig* are fixed base-year quantities of private and public investment, respectively, multiplied by adjustment factors *I* (endogenous) and *G* (exogenous).

Factor and product market equilibrium

We assume labor is fully employed. As such, total labor supply *LS* in each area is fixed and, in equilibrium, must equal the sum of all sector labor demands:

$$LS_a = \sum_i L_{ia} \tag{10}$$

Unlike labor, which is mobile across sectors, capital is sector/area-specific. Both factor demand *K* and the economywide rental rate *r* are therefore fixed (see Equation 3) and the rental rate distortion term *D* adjusts so that sectoral profit rate equate capital demand and supply.

Finally, product market equilibrium requires that the composite supply of each good *Q* equals total private and public consumption and investment demand:

$$Q_i = \sum_a C_{ia} \cdot LS_a + A \cdot g_i + I \cdot ip_i + G \cdot ig_i \tag{11}$$

Market prices *P* adjust to ensure equilibrium is achieved. Together, the above 11 equations simultaneously solve for the values of 11 endogenous variables (i.e., *C*, *X*, *L*, *D*, *Q*, *PX*, *Y*, *B*, *I*, *W* and *P*). The national consumer price index (CPI) is our numéraire.

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