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Implications of Public Investments and External Shocks on Agriculture, Economic Growth and Poverty in Papua New Guinea

An Economywide Analysis

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INTRODUCTION

Policymakers in Papua New Guinea face difficult choices as to how best to promote economic growth and reduce poverty in the context of vast differences in technology and infrastructure across the country. Fluctuations in world prices of petroleum, minerals, and export crops complicate the management of the economy because of their large impacts on export earnings and government revenues, as well as household welfare. Moreover, other shocks, such as the Covid-19 pandemic that shut down major parts of the economies of PNG and the rest of the world, have far-reaching effects on various economic sectors, as well as the health and welfare of the population.

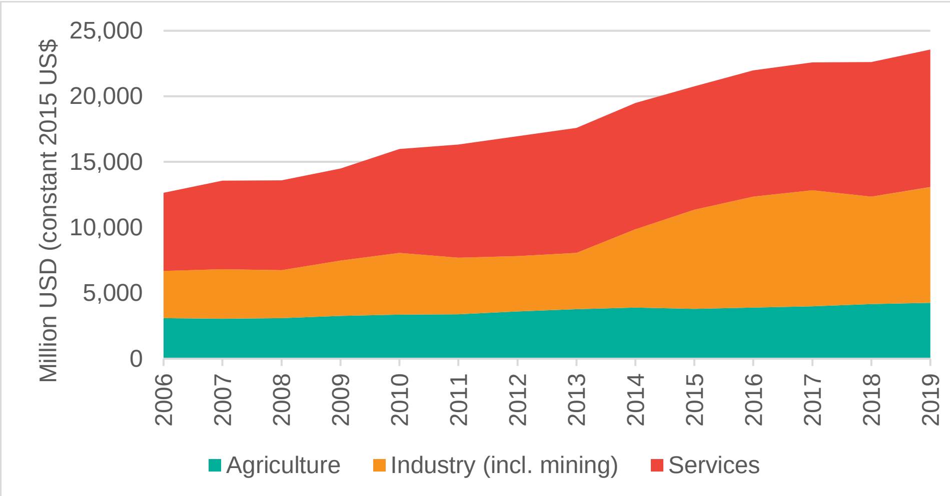
This paper presents an analysis of investment options in the agricultural sector and the effects of major economic shocks to the PNG economy using an economy-wide computable general equilibrium (CGE) model that provides estimates of the economic linkages between production, household incomes, consumption, investment, and trade. The model's base data, a Social Accounting Matrix (SAM) for 2019, and many of the parameters are derived from the national accounts, household surveys and other data for PNG. It is important to realize, however, that even though the SAM and model structure provide a framework that guarantees a consistency of many of the assumptions, there remain many uncertainties in the data. Thus, the results presented here should not be interpreted as exact estimates, but only approximations of potential effects of policies and external shocks.

The plan of this paper is as follows. Chapter 2 provides an overview of agriculture and economic growth in PNG over the last two decades, highlighting the declining share of agriculture in GDP despite positive agricultural GDP growth rates and changes in the real exchange rate that have major implications for incentives in the economy. Chapter 3 then presents a summary of the economy-wide model used in the analysis. Details of the model are found in the annexes and in the references included in the paper. Design of the model simulations and model results are discussed in Chapter 4. These simulations cover various investments in agriculture and transport infrastructure, increases in world prices of petroleum and natural gas, price increases for agricultural exports and hypothetical carbon credits tied to a reduction in exports of forestry products. Chapter 5 concludes with a summary of the main findings, policy implications and suggested areas for further work.

AGRICULTURE AND ECONOMIC GROWTH IN PNG

Although the petroleum and natural gas sectors have accounted for most of the growth in the PNG economy since 2013, the agricultural sector remains central to the livelihoods of most households. Approximately 87 percent of the population lives in rural areas, and more than 80 percent of inhabitants either directly or indirectly depend on subsistence agriculture (Gibson, 2012; Bourke, 2009). Annual GDP per capita (real 2015 values) grew approximately 2.7 percent per year in the last decade, increasing from approximately 1,950 to 2,800 USD between 2006 and 2019, respectively (World Bank, 2022a). PNG continues to develop its mining sector, which has driven most of GDP growth since 2013. Growth in the service and agriculture sectors grew at a slower rate, with the service sector increasing from $USD 5,950 to 8,820 million and agriculture increasing from $USD 3,090 to 4,260 million (real 2015 US dollars) between 2006 to 2019, respectively (Figure 2.1).

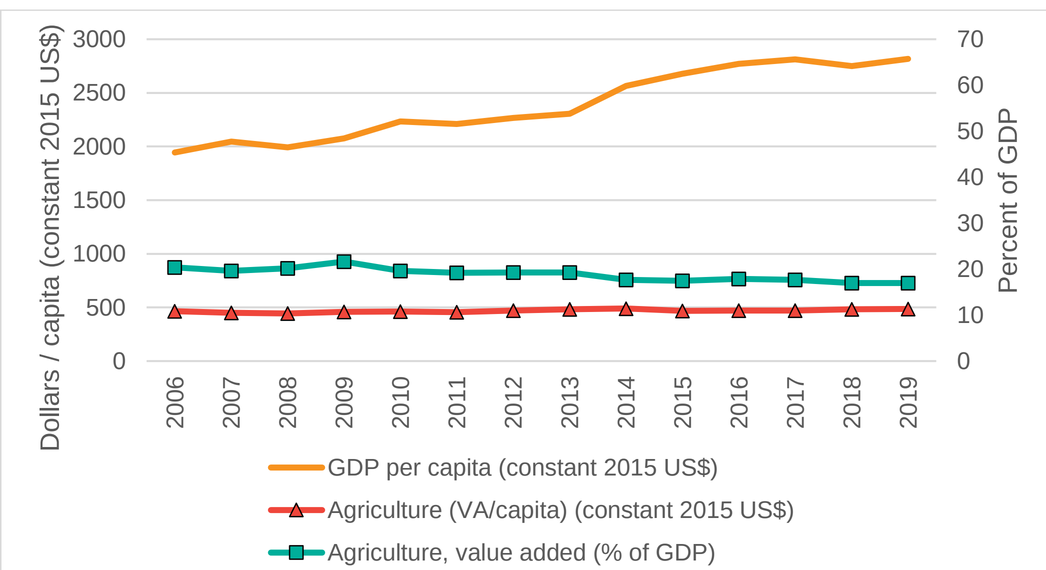
Figure 2.1: Real (2015) GDP by sector (2006-2019) in PNG



Source: Authors' calculations using World Development Indicators (World Bank, 2022a)

Economic growth is often accompanied by structural transformation, whereby a country transitions from lower-productivity agriculture labor and output to higher-value manufacturing and services output, displacing agricultural GDP as the primary economic driver. However, this transformation is not yet occurring in PNG. This may reflect the high capital and relatively low labor intensity of the extractive resources sector, resulting in few rural households diversifying out of the agriculture sector. Although the share of agriculture contributing to the overall economy decreased from 23.9 percent in 2006 to 17 percent in 2019, the rural sector is not transforming to fulfill higher-value labor and productivity demand (World Bank, 2022a; Figure 2.2).

Figure 2.2: Agriculture contribution to GDP and Agricultural GDP per capita (2006-2019)



Source: Authors' calculations using World Development Indicators (WB, 2022a)

With per capita gross national income (GNI) at more than $2,000 USD at the current price, PNG is classified by the World Bank as a low-middle-income country for the current 2022 fiscal year (WB

2022b). However, only a small percentage of the population have middle or high-level incomes. Most PNG households can be categorized as poor or low-income. In 2009/10, the richest top 10 percent of the population accounted for almost one-third of total national income and the top 20 percent accounted for almost 50 percent. On the other hand, the poorest 10 and 20 percent of the population accounted for only 1.9 and 5.1 percent of national income, respectively (NSO 2011).[1]

The agriculture sector in PNG has the potential to be a driver for economic growth, but perhaps more importantly, it is also an important lever for poverty reduction within the country. While agri-food trade (particularly in cocoa, coffee and oil palm) continues to increase, comprising over 10 percent of total export earnings (Schmidt and Fang, 2021)[2], total growth in agricultural output was just 2.7 percent per year between 2006-2019, only slightly higher than the population growth rate of 2.0 percent in the same period. Given this stagnant growth in agriculture, we expect that the majority of rural households, and especially poor and low-income households, have not experienced a significant improvement in welfare since the last nationally representative Household Income Expenditure Survey (HIES) in 2009/10. This suggests food security continues to challenge many PNG households. Based on recent analysis of a 2018 household survey conducted by the International Food Policy Research Institute (IFPRI) in 4 areas of PNG, approximately half of the sample didn't have sufficient income to ensure sustainable food security (Schmidt et al., 2020).

Higher productivity levels for many of the crops produced in PNG could expand agricultural GDP, increase household welfare, and decrease food insecurity (temporal and sustained). Coupled with investments to improve local market access and performance, transportation and storage infrastructure, and marketing logistics, agriculture productivity growth has the potential to significantly increase rural and urban household incomes. The relatively low crop yields realized by farmers in PNG (discussed in the following section) and the declining importance of agriculture in the national economy represent important opportunity costs for rural smallholders and commercial farmers as well. A central objective in efforts to further develop the agricultural sector must be to enable PNG's farmers to realize crop yields that are much closer to what they might achieve with the use of improved crop germplasm, sustainable soil fertility management techniques, effective control of crop pests and diseases, and timely crop management operations.

However, increasing agriculture productivity confronts both supply and demand side constraints. Schultz (1964) and others have demonstrated that rural farmers are economically efficient in choosing the appropriate production techniques to maximize benefits. Subsistence and commercial farmers must carefully assess: the costs of available technologies, the perceived or realized production risks related to specific farming choices, and the available incentives that shape farmer decisions on what to produce and at what level of production. Farmers allocate their available labor, land, and other factors of production up to a level at which the returns are no greater than the value of output they obtain from the use of each factor in their farming. We explore these issues, focusing on crop productivity in the following section.

1 These figures are based 2009/10 HIES data that were collected when per capita PNG's Gross National Income (GNI) was approximately $1,500.

2 PNG is a net exporter of agricultural goods.

Macroeconomic drivers/constraints for agricultural growth

Under World Trade Organization (WTO) rules, developed countries are limited in their policy support to agriculture, particularly, in terms of interventions that distort agricultural prices and affect international trade. Developing countries are generally exempt from these limitations on various types of agricultural subsidies. Nonetheless, it is important to understand the magnitude of price distortions in the economy, some of which may be unrecognized. In particular, trade and macro-economic policies that influence the relative price of tradable to non-tradable goods (the real exchange rate) often have far-reaching effects on agriculture.[3]

Real exchange rates in PNG are heavily influenced by natural resource (oil and gas) exports, which account for nearly 90 percent of export earnings.[4] These exports, while providing government revenues and foreign exchange to finance imports, can also distort prices in the broader economy. To the extent these export earnings are spent on local (non-tradable) goods and services (including root crops, housing rents, transport, domestic labor, material costs of large investment projects, etc.), their prices tend to rise. Prices of non-oil and gas export goods (such as coffee, cocoa, palm oil, etc.) and import substitutes (including domestically-produced rice), which are determined by world prices, nominal exchange rates and trade policies (e.g. import tariffs and export taxes), tend to remain stable, however. As a result, incentives for producing non-tradable goods and services improve while incentives for producing non-oil and export goods decline.[5]

To a large extent, PNG has avoided sharp changes in nominal and real exchange rates through careful management of macro-economic policy. Export earnings, mainly from the resource sector, are consistently far larger than import expenditures, resulting in sizeable current account surpluses equal to a projected 5.4 percent of GDP in 2021. However, capital outflows mainly in the form of repayments of private sector loans and other private capital outflows are almost equally large (IMF 2020). The annual average nominal exchange rates appreciated by 31.8 percent from 3.06 kina/USD in 2006 to 2.08 kina/USD in 2012, but has since depreciated by 68.4 percent to 3.51 kina/USD in 2021 (Table 2.1 and Figure 2.3).[6]

Over these periods, there has been steady domestic inflation, however, averaging 5.6 percent per year from 2006 to 2012 and 5.0 percent per year in from 2012 to 2021, so that consumer prices rose by a total of 114.7 percent between 2002 and 2021. Thus, the real exchange rate (a measure of the average relative price of tradable goods to non-tradables) appreciated by 53.5 percent between 2006 and 2012 sharply reducing the profitability of production of export crops and other tradables (including rice). The subsequent depreciation of the real exchange rate by 8.5 percent from 2012 to 2021 lessened this

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[3] The real exchange rate is an indicator of the relative price of tradable goods (importables and exportables) to non-tradables. A basic measure of the real exchange rate is the nominal exchange rate adjusted for inflation in the domestic economy and the international economy: $RER = ER * CPI^w / CPI^d$, where RER is the real exchange rate, ER is the nominal exchange rate measured as domestic currency per unit of foreign currency (e.g. kina/USD), and CPI^w and CPI^d are consumer price indices in the world and domestic economies. See Anderson and Masters (2009) and Dornbusch and Helmers (1988) for detailed discussions.

[4] IMF estimates for resource exports in 2019 were 9.65 billion US dollars, 89.5 percent of total exports. The current account balance of 6.1 billion US dollars was 24.2 percent of GDP (IMF, 2020).

[5] The resulting stagnation is known as the "Dutch Disease", named after a stagnation of the Netherlands' economy following the discovery development of oil and natural gas in the North Sea in the 1970s (Fardmanesh, 1991).

[6] The 2021 figure is a ten-month average through October.

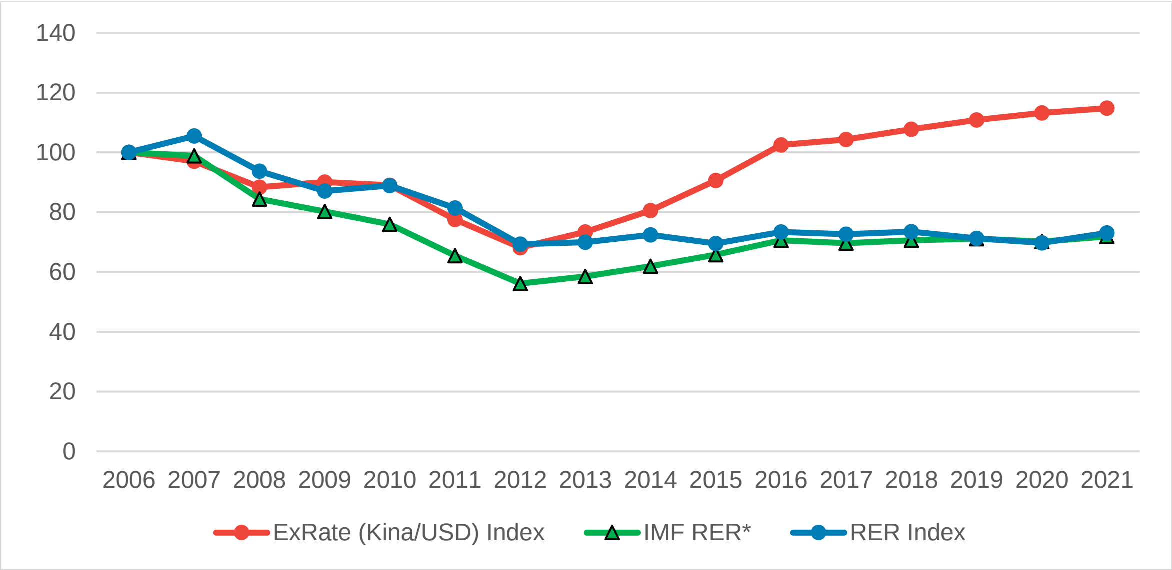
decline in profitability. Nonetheless, for the overall 2006-2021 period, PNG's real exchange rate appreciated by 28.1 percent implying a major deterioration in incentives for production of tradeable goods, including agricultural exports.[7]

Table 2.1: Nominal exchange rate and CPI (2006-2021)

	2006	2012	2021	2006-12	2012-21	2006-21
Nominal Exchange Rate (kina/USD)	3.06	2.08	3.51	-31.8%	68.4%	14.8%
Nominal ExRate Index (2006=100)	100.0	68.2	114.8	-31.8%	68.4%	14.8%
PNG CPI	100.0	138.3	214.7	38.3%	55.2%	114.7%
RER Index (USD) = ER/CPI	3.06	1.51	1.63	-50.7%	8.5%	-46.5%
US CPI = PW*	100.0	113.9	134.4	13.9%	18.0%	34.4%
RER Index = ER*PW/CPI	100.0	56.1	71.9	-43.9%	28.1%	-28.1%
IMF RER**	100.0	49.3	53.5	-50.7%	8.5%	-46.5%

Source: Authors' calculations from IMF International Financial Statistics data (downloaded April, 2022).

Figure 2.3: PNG Nominal and Real Exchange Rates, 2010-2020



Source: Authors' calculations from IMF International Financial Statistics data.

Changes in the real exchange rate over time are not necessarily bad. Over time, the equilibrium level of a country's real exchange rate changes because of changes in world prices, technical change in various sectors, developments in major trading partner countries and other factors. Taking into account a similar broad range of factors, the IMF estimated that the PNG kina was over-valued by around 11 to 18 percent in 2020 and by around 6 percent in 2021 (IMF, 2020 and 2022).

Thus, changes in the macro-economic incentives for production of tradable goods in PNG over the past decade have reduced the profitability of agricultural exports (e.g. cocoa, coffee, palm oil, etc.) and

[7] A simplified measure of the real exchange rate using the US CPI as a measure of the average world (trading partner) price of tradeables multiplied by the nominal kina/USD exchange rate and then divided by the PNG CPI shows a 43.9 appreciation followed by a 28.1 percent appreciation in the two periods, respectively (Table 2.1).

of production of import-substitutes (e.g. domestically produced rice). Appropriate non-price distorting PNG government interventions such as investments in road, power and ports can help address the disincentives faced by the agricultural tradable sectors. Notwithstanding, PNG has experienced growth in its agri-food trade, with agri-food exports increasing by 8 percent, and agri-food imports increasing by 13 percent between 2001-2016. Maintaining high levels of trade in agriculture products will require policies and investments to support domestic logistics and reduced transactions costs, thereby benefitting export-oriented smallholder farmers and household's dependent on staple food imports.

MODEL STRUCTURE

In this study, we use the Rural Investment and Policy Analysis (RIAPA) model, a neo-classical type of Computable General Equilibrium (CGE) model calibrated to data from the 2019 Social Accounting Matrix (SAM) of Papua New Guinea (Pradesha and Dorosh, 2022) and other parameters describing responsiveness of demand and supply across different sectors. RIAPA 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, consumption, etc. of economic agents (firms, households, and institutions) and structural equations that specify accounting relationships between the incomes and expenditures of individual agents and within the macroeconomy.[8]

The model divides the economy into sectors and household groups that act as individual economic agents. Producers maximize profits and supply output to national markets by choosing levels of inputs, given the technology available, as determined by constant elasticity of substitution functions that allow substitution between factors following relative factor price changes. Demand for intermediate inputs by producers, however, 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 follows Diao et al. (2021).

Producers and households pay taxes to the government, who 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 overall supply and demand for each product. Domestically produced goods and services are modeled as imperfect substitutes with goods and services that are exported or imported. World prices are fixed (exogenous) under the assumption that changes in PNG demand for imports or supply of exports do not affect world prices (i.e., a small country assumption).

We model eight types of labor: four skill types, according to highest level of education completed (less than primary school, primary school, secondary school, more than secondary school) in each of two areas (rural and urban). Total supply of labor of each type is fixed, with wage rates adjusting in each period to equate supply and demand. There are ten types of households in the model differentiated by two geographical areas (rural and urban) and five income quintiles with the first quintile representing the poorest households.

[8] Model equations are presented in Annex A. Please refer to Diao and Thurlow (2013) for more detailed explanation about the model. Benfica et al. (2019) provides application of the model.

SIMULATION RESULTS

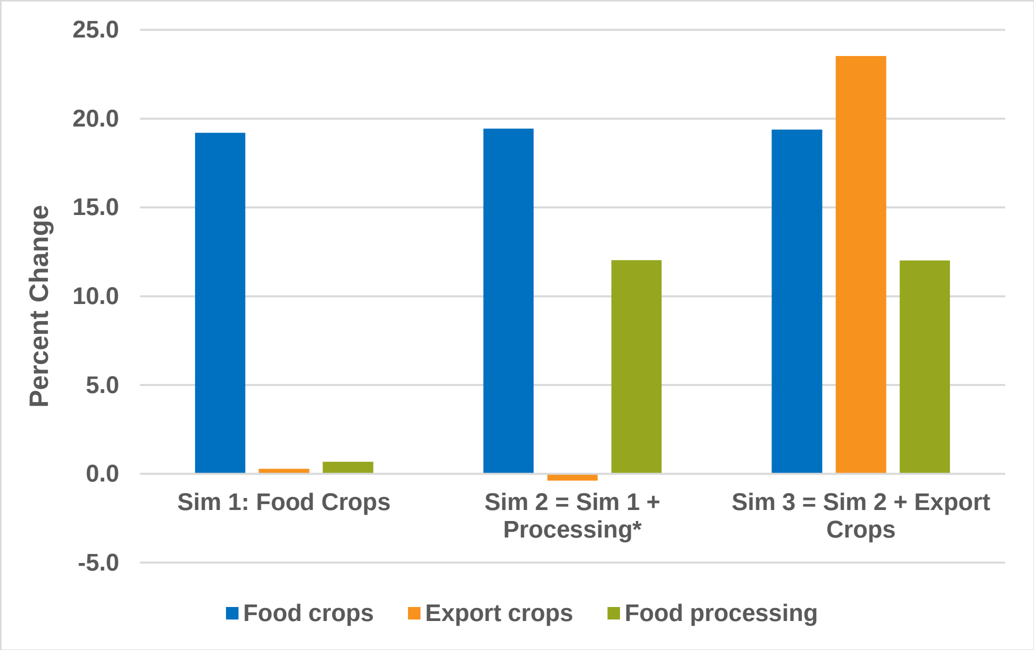
In this chapter, we present the results of seven simulations. Simulations 1-3 explore the effects of increased total factor productivity in agriculture and related sectors. Simulations 4 and 5 cover the implications of recent changes in world oil and natural gas prices with and without additional public investments in agriculture. Simulation 6 models the effects of increases in the prices of agricultural exports. Finally, Simulation 7 explores the potential effects of carbon credits for reducing deforestation together with a safety net.

Simulation 1 models the effects of a 20 percent increase in total factor productivity of food crops like that which can be achieved through new technology (e.g. improved seeds) and agricultural extension (including training on improved land management practices, etc.). In Simulation 2, we add the effects of complementary investments to reduce transport costs and to increase productivity of the food processing sector, modeled through 20 percent increases in total factor productivity of the transportation and food processing sectors. Simulation 3 adds a 20 percent increase in productivity of the export crop sectors.

In Simulation 1, the 20 percent increase in total factor productivity of food crops raises production of the sector by 19.1 percent (Figure 4.1).[9] Real incomes from agriculture change little, however, because food crop prices fall by 14 to 17 percent for most cereals and roots (producer prices of rice fall by only 6.2 percent, however, because domestic prices are closely linked with import prices given the large share of imports in total supply.) Overall, since agriculture accounts for only 18.0 percent of GDP in the base SAM, total real GDP rises by only 1 percent and total real consumption rises by 4.3 percent (Figure 4.2). Incomes of the rural poor are essentially unchanged and incomes of the rural non-poor rise by only 0.5 percent (Figure 4.3). Urban households actually gain more than rural households (by 1.2 percent for the poor and 1.4 percent for the nonpoor), in large part because of an increase in urban wage rates and returns to capital.

[9] The slightly smaller increase in value added in comparison to the increase in total factor productivity is due in part to a slight decline in output prices and therefore incentives for productions for most agricultural commodities.

Figure 4.1: Impacts of Productivity Shocks on Crop Production and Processing

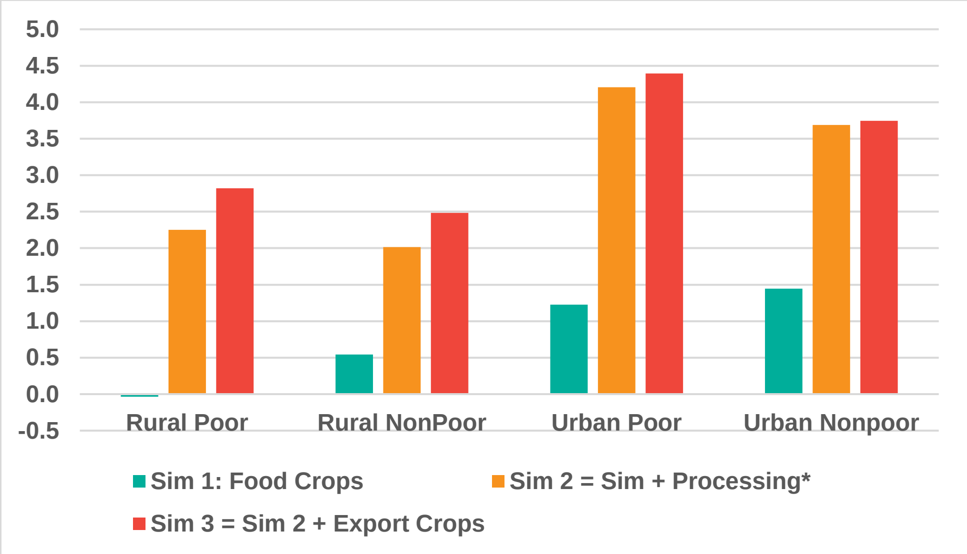


Source: CGE Model simulations.

Figure 4.2: Macro-economic Impacts of Agricultural Productivity Shocks

Source: CGE Model simulations.

Figure 4.3: Impacts of Agricultural Productivity Shocks on Household Incomes (percent change)



Source: CGE Model simulations.

If increases in food crop productivity are accompanied by increases in productivity of processing and transport (Simulation 2), the declines in prices are about two percentage points less than in Simulation 1, i.e. overall declines of 12 to 15 percent for most cereal and root crops. Output of the food processing sector rises by 12 percent (Table 4.1) and total real GDP increases by 2.6 percent, 1.6 percentage points more than in Simulation 1 (Table 4.2). With reduced transport costs, imports also become cheaper and since the total value of imports is greater than the total value of exports, the reduced price of imports results in an increase in demand for foreign exchange and a 1.0 appreciation of the real exchange rate. The productivity gains in food processing sectors results in a 10.6 percent gain in value added for these sectors as a whole (Table 4.3). Incomes of the urban poor and nonpoor households rise by 4.2 and 3.7 percent, respectively (Figure 4.3).

Table 4.1: Impacts on Total Production (percent change) – Sim1 to Sim3

	base	Sim1 (Food Crops)	Sim2 (Sim1 + Processing)	Sim3 (Sim2 + Export Crops)
Agriculture	**20.10**	**11.25**	**11.10**	**11.89**
Food crops	11.77	19.20	19.43	19.39
Export crops	0.71	0.28	-0.38	23.52
Other agriculture	7.62	-0.01	-0.69	-0.78
Forestry	3.01	0.01	-1.31	-1.50
Non-agriculture	**117.83**	**0.02**	**1.25**	**1.18**
Industry	57.07	-0.11	-0.11	-0.21
Food processing	4.20	0.69	12.04	12.01
Other industry	52.87	-0.17	-1.07	-1.18
Services	60.76	0.15	2.53	2.49
Total Output	**137.93**	**1.66**	**2.69**	**2.74**

Source: CGE Model simulations.

Table 4.2: Macroeconomic Indicators (percent change) – Sim1 to Sim3

	base	Sim1 (Food Crops)	Sim2 (Sim1 + Processing)	Sim3 (Sim2 + Export Crops)
GDP at market price	**83.9**	**0.99**	**2.59**	**2.82**
Consumption	**47.3**	**4.32**	**5.71**	**5.88**
Real exchange rate	**100.0**	**0.75**	**-1.03**	**-1.35**
Household consumption	**47.3**	**4.32**	**5.71**	**5.88**
Rural Poor	3.3	-0.04	2.25	2.82
Rural NonPoor	24.0	0.54	2.02	2.48
Urban Poor	0.6	1.22	4.20	4.39
Urban Nonpoor	19.8	1.44	3.69	3.75

Source: CGE Model simulations.

Increases in total factor productivity of export crops also raise GDP and household incomes, but given the small size of the sector, the effects are smaller than for food crops (Simulation 3). Thus, the gains in real GDP and household incomes are only slightly larger in this simulation than in Simulation 2 despite a 23.5 percent increase in export crop production (Figure 4.1).

In Simulation 4, we model the effects of sharp increases in real international prices of crude petroleum and natural gas between 2019 and March 2022 of 64.9 percent and 70.5 percent, respectively.[10] In the absence of changes in quantities of exports or other price effects, this price shock would increase PNG's export revenues by 14.6 bn kina (3.2 bn kina for oil and 11.4 bn kina for natural gas). In the simulation, one-half of these projected revenues are assumed to enter the PNG economy (with the other half used to reduce the government foreign debt or kept as savings in foreign accounts). This 7.3 billion Kina increase in the pool of total savings could finance an increase in private investment of 85.6 percent.

Table 4.3: Macroeconomic Indicators (percent change) – Sim4 to Sim7

	base	Sim4 (Oil Price Increase)	Sim5 (Sim 4 + Investment)	Sim6 (Higher Export Crop Price)	Sim7 (Carbon Credits)
GDP at market price	**83.9**	**2.81**	**5.61**	**0.35**	**0.11**
Consumption	**47.3**	**10.64**	**21.39**	**0.29**	**0.20**
Real exchange rate	**100.0**	**-12.61**	**-12.24**	**0.29**	**-0.36**
Household consumption	**47.3**	**10.64**	**21.39**	**0.29**	**0.20**
Rural Poor	3.3	10.23	11.44	0.55	4.38
Rural NonPoor	24.0	7.40	9.73	0.68	0.13
Urban Poor	0.6	7.42	11.03	0.21	3.44
Urban Nonpoor	19.8	6.29	10.05	0.17	0.01

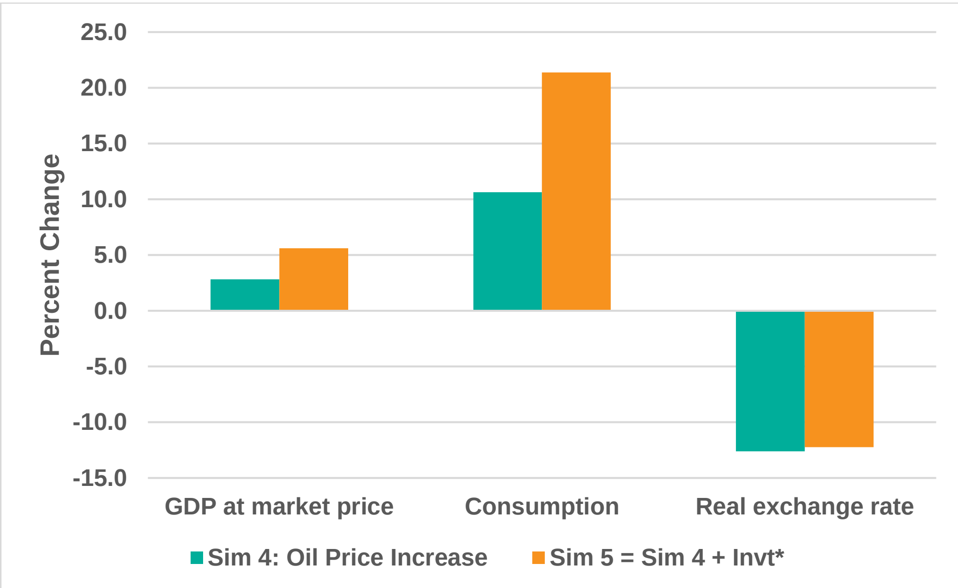
Source: CGE Model simulations.

In the simulation, the real exchange rate appreciates by 12.6 percent due to the foreign exchange inflow (Figure 4.4). As a result, incentives for exports are reduced and the quantity of exports falls by

[10] Price data for Simulations 3 and 6 are from the World Bank (2022) "Pink Sheet" data base. The consumer price index is from IMF (2022) International Financial Statistics. We obtain real price estimates by adjusting the nominal price changes by the 11.0 percent inflation in the US CPI (a measure of overall inflation) in this period.

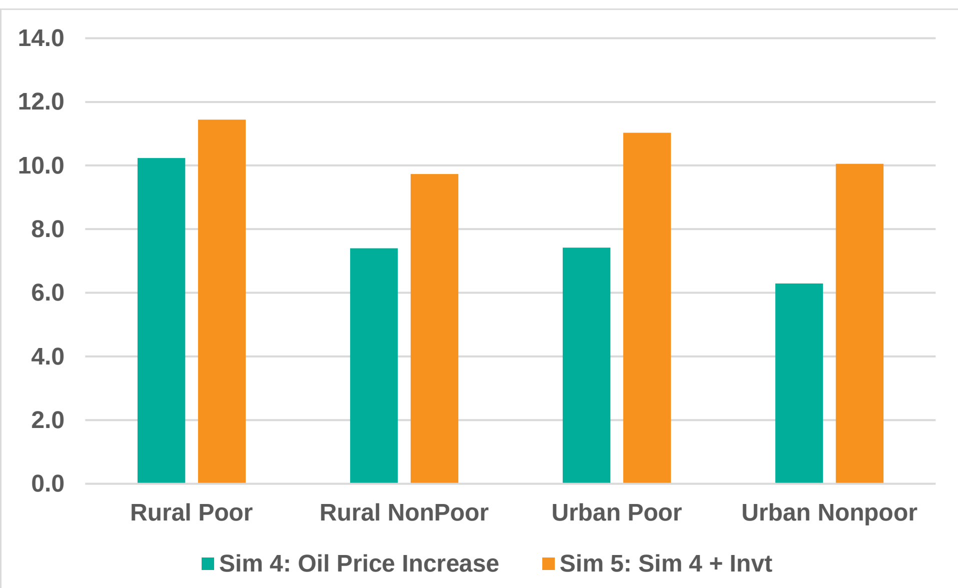
6.7 percent. In contrast, the real exchange rate appreciation encourages imports, which increase by 15.2 percent in quantity terms. Total consumption rises by 10.6 percent (Table 4.3), in large part because of cheaper imports. All households enjoy sizeable gains in real incomes, including the rural poor, who benefit from increased demand for agricultural products they sell. Their incomes rise by 10.2 percent, compared to gains of 7.4 percent for both the rural nonpoor and the urban poor, and 6.3 percent for the urban nonpoor (Figure 4.5).

Figure 4.4: Macro-economic Impacts of Oil Price Shocks



Source: CGE Model simulations.

Figure 4.5: Impacts of Oil Price Shocks on Household Incomes (percent change)



Source: CGE Model simulations.

In Simulation 5, we assume five percent of the increase in total savings (364 bn kina) is used to finance new investments in agriculture and another five percent is used to finance new investments in roads. Assuming a TFP-investment elasticity of 0.150 in agriculture,[11] (i.e. a one percent increase in agricultural investment results in a 0.150 percentage point increase in TFP), the 307 percent increase in agricultural investment increases TFP in agriculture by 46.1 percent. The direct impact of this investment on agriculture sector leads to increase in agriculture production by 28 percent, contributed mainly by food and export crops (Table 4.4). Similarly, with a TFP-investment elasticity of 0.139 in transportation, the 365 billion (48 percent) increase in investment in transportation results in a 6.6 percentage point increase in TFP in the transport sector.[12] Given this large increase in investment and TFP, real GDP surges by 5.6 percent and consumption rises by 21.4 percent. All household groups again enjoy large gains in real incomes, ranging from 9.7 percent for the rural nonpoor to 11.4 percent for the rural poor.

Table 4.4: Impacts on Total Production (percent change) – Sim4 to Sim7

	base	Sim4 (Oil Price Increase)	Sim5 (Sim 4 + Investment)	Sim6 (Higher Export Crop Price)	Sim7 (Carbon Credits)
Agriculture	**20.1**	**0.2**	**28.1**	**-0.6**	**0.0**
Food crops	11.8	1.8	46.3	0.0	0.2
Export crops	0.7	-4.4	51.0	7.1	-0.2
Other agriculture	7.6	-1.7	-2.1	-2.4	-0.2
Forestry	3.0	-5.9	-6.8	-6.1	-0.3
Non-agriculture	**117.8**	**-1.9**	**-1.8**	**0.0**	**-0.1**
Industry	57.1	-3.6	-4.4	0.0	-0.1
Food processing	4.2	-0.6	0.5	-0.1	-0.1
Other industry	52.9	-3.9	-4.8	0.1	-0.1
Services	60.8	-0.2	0.7	-0.1	0.0
Total Output	**137.9**	**-1.57**	**2.60**	**-0.11**	**-0.04**

Source: CGE Model simulations.

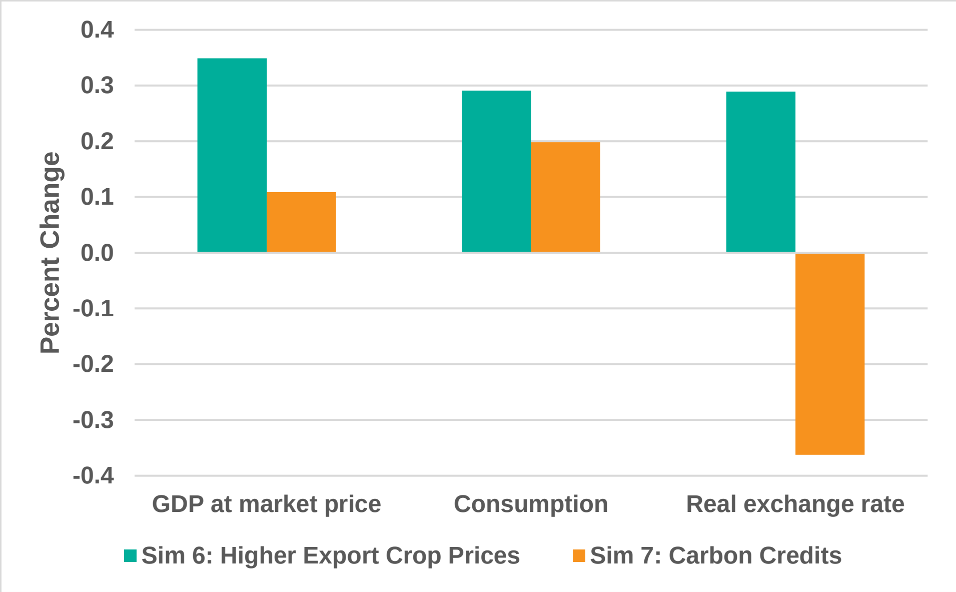
In simulation 6, we model the effects of recent shocks to world prices on PNG's agricultural exports between 2019 and March 2022, raising the real prices of coffee (mild arabica) by 78.3 percent and the price of rubber (TSR20) by 11.5 percent, while lowering the price of logs (Malaysia) by 17.2 percent and the price of cocoa by 5.3 percent. We also adjust the world price of rice (using the Vietnam price as a benchmark) by 0.3%.

These shocks have relatively small effects on PNG's economy given the relatively small size of these sectors. Real GDP and consumption increase by only 0.35 and 0.3 percent, respectively, and the real exchange rate depreciates by only 0.3 percent (Figure 4.6). Effects on household incomes are likewise small, ranging between about 0.2 and 0.7 percent for all groups (Figure 4.7).

[11] The TFP-investment elasticity for agriculture is calculated from Benin and Randriamamonjy (2008).

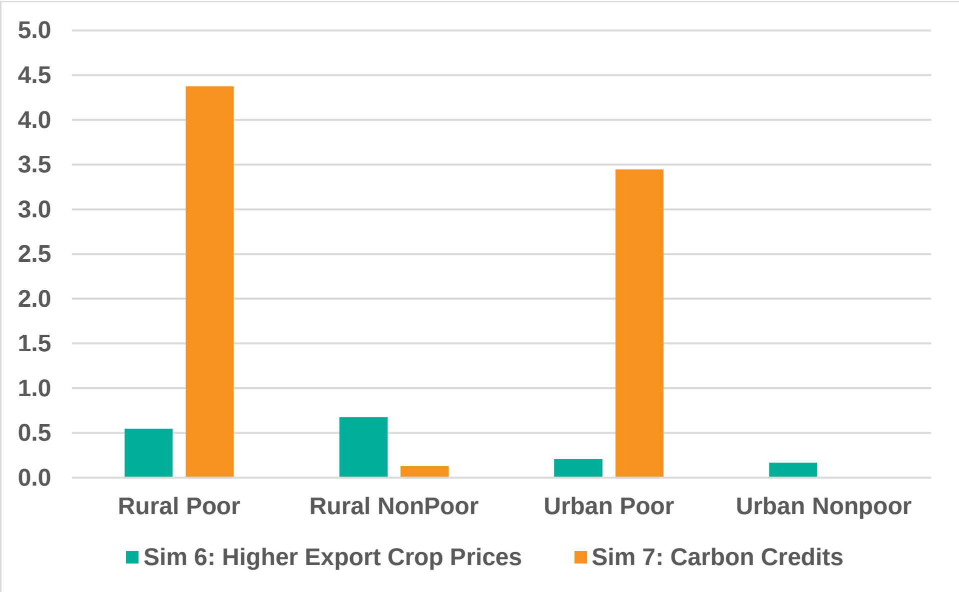
[12] The TFP-investment elasticity value for road infrastructure is adopted from Fan, S. and Zhang, X. (2008)

Figure 4.6: Macro-economic Impacts of Higher Export Crop Prices and Carbon Credits



Source: CGE Model simulations.

Figure 4.7: Impacts of Higher Export Crop Prices and Carbon Credits on Household Incomes (percent change)



Source: CGE Model simulations.

Simulation 7 models a hypothetical reduction in forestry output in exchange for a carbon credit for protecting 117,400 hectares of forest per year (the average annual rate of forest loss in 2016-2020), (Table 4.5). Assuming an absorption rate of 10 kgs of carbon dioxide per tree per year and an average planting density of 1,000 trees per hectare (=10 tons CO2 / hectare / year), each hectare of forest absorbs 20 tons of CO2 per year.[13] At a carbon price of $20 / ton of C02, the potential value of the carbon credit is $46.96 million or 159.2 million kina at the 2019 average exchange rate of 3.39 Kina/USD. These carbon credit revenues are then assumed to be used to finance cash transfers to the poorest 20% of rural and urban households. In the simulation, we also introduce a negative productivity shock of 16 percent to the forestry sector, equal to the size of the annual carbon credit divided by the total value added of the sector.

Table 4.5: Annual Average Area Deforested in PNG, 2016-2020

	Primary Forest Loss	Other Forest Loss	Total Tree Cover Loss
Deforested Area			
Thousand Hectares	323.9	263	586.9
Thousand Ha's / Year	64.7	52.6	117.3
Share of Total Forest	0.15%	0.12%	0.27%

Source: Data from Global Forest Watch and authors' calculations.

The 47 USD million foreign exchange inflow results in small exchange rate appreciation (0.3 percent) that contributes to a decline in exports and an increase in imports. The cash transfers raise incomes of the rural and urban poorest households by about 13 percent, though the average income of the bottom 40 percent of households rises by around 4 percent (Figure 4.7). Total consumption in the economy, however, only rises by about 0.2 percent and real GDP is essentially unchanged. Thus, the magnitude of a possible carbon credit transfer is sufficient to make a significant difference for the poorest households if accurately targeted, but the total transfer is small relative to overall economy.

SUMMARY AND CONCLUSIONS

The policy simulations presented in this paper highlight the important linkages between the agricultural and non-agricultural sectors of the PNG economy and suggest that there are potentially major benefits of increased agricultural productivity, especially when it is coupled with reduction in transport and processing costs.

Simulation 1, which models an increase in agricultural productivity of food crops makes clear the importance of ensuring sufficient market demand. Here, higher productivity of the food crop sector has almost no effect on rural incomes of rural households because increased supply leads to a sharp decline in market prices. Lowering the cost of transport and increasing productivity in the agricultural processing sectors helps spur demand for additional agricultural production (Simulation 2), but overall, gains in rural incomes are small (about 2.0 percent). Urban households actually benefit more, with real incomes nearly double those of rural households in percentage terms, mainly because of lower agricultural product prices. Productivity gains for export crops do not face a severe demand constraint as does most of food crop agriculture. Because the sector is small, increases in productivity have only minor impacts on the overall rural economy and average rural incomes (Simulation 3). Likewise, because of the

[13] Bernet (2021) uses a conservative estimate of the carbon absorption rate of 10 tons CO2 / hectare / year, assuming a tree density of 1,000 trees per hectare and an average absorption rate per tree of 10 kgs of carbon dioxide per year for the first twenty years. He notes, however, that a figure of 48 pounds (about 22 kgs) per tree is commonly cited. Our calculations assume a relatively high carbon absorption rate of 20 tons per hectare per year.

relatively small size of the sector, increases in world prices of export crops have small macro-economic effects and only minor impacts on average household incomes (Simulation 6).

Shocks to the oil and natural gas sector, however, have major macro-economic consequences than affect agriculture and rural households, as well. Simulation 4 shows that even if only half of the increase in oil and natural gas revenues resulting from a 65 to 70 percent increase in real international prices is absorbed into the PNG economy, the real exchange rate appreciates by 13 percent. This change in relative prices leads to increased demand for tradeable goods but reduced incentives for tradeable production, so that the quantity of imports rises by 15.2 percent while the quantity of exports falls by 6.7 percent. Although tradeable agricultural sub-sectors, such as export crops and rice, do not fare well in this scenario, increased demand for non-tradable agriculture (including root crops, vegetables, and fruits) leads to increases in real prices and agricultural incomes. Incomes of the rural poor rise by 10 percent, compared to gains of 6 to 8 percent for other household groups. The extent of the income gains experienced by particular rural communities depends to a large extent on the degree to which they are connected to the national PNG market. For isolated communities, the impacts of an oil and natural gas revenue shock are considerably smaller. Using a portion of increased oil and natural gas revenues to finance new investments in crop agriculture, processing, and transport, as in Simulation 5, provides even greater benefits, however, spurring real GDP growth and raise real incomes for rural households by 10 to 11 percent.

Finally, Simulation 7 shows that a carbon credit arrangement in which PNG stops deforestation in exchange for a cash transfer which is then used to finance cash transfers to the poorest 20 percent of both urban and rural households could raise the incomes of these groups by about 13 percent. The magnitude of these benefits to the poorest depends on the price of carbon in the carbon credit arrangement, as well as the accuracy of the targeting of the transfers. Nonetheless, the simulation suggests that there are potentially large gains for the poor from carbon credits with appropriate policies.

The above simulations show the importance of economic linkages between agriculture and the overall economy in PNG in determining policy outcomes. Further analysis is needed to refine the simulations described above, particularly by improving the household data used to create the Social Accounting Matrix and for refinement of model parameters. Other scenarios could also be analyzed, including policies related to greater use of fertilizer, alternative world price shocks to key commodities and productivity shocks to various sectors. A dynamic version of the model could be used for scenarios in multi-year development plans. For all of this work, more capacity strengthening would be important to enhance the usefulness of the model and simulations to PNG analysts and decision-makers.

ANNEX A: THE PAPUA NEW GUINEA 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:

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

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:

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

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

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

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:

$$\sum\nolimits_a td_a \cdot Y_a + \sum\nolimits_i ti_i \cdot P_i \cdot Q_i = \sum\nolimits_i P_i \cdot A \cdot g_i + \sum\nolimits_a h_a \cdot LS_a + B \tag{8}$$

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 balance closure, i.e., share of consumption, government and investment are fixed while savings in the economy adjust to finance investment demand. As shown below, a national savings pool finances investment:

$$\sum\nolimits_a s_a \cdot Y_a + B = \sum\nolimits_i (P_i \cdot I \cdot ip_i + P_i \cdot G \cdot ig_i) \tag{9}$$

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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