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RWANDA

Systematic Analysis of Domestic Production and World Market Shocks

Askar Mukashov, James Warner, Eleanor Jones, and James Thurlow

This study is part of a series of country briefs by IFPRI that leverages economywide models to deliver detailed risk assessments of key economic indicators. This initial analysis evaluates vulnerabilities in countries and across key population groups to answer two questions: (1) What is the country's current vulnerability to world market prices and domestic production risks that are consistent with historical data? (2) How much do these shocks contribute to the country's current vulnerability, and which shocks contribute most to economic uncertainty?

Abstract

This study explores Rwanda's vulnerability to economic shocks and identifies those contributing most to economic uncertainty. The Rwandan Computable General Equilibrium (CGE) model was employed to simulate a range of potential economic outcomes under various sampled shock scenarios developed using historical data to capture domestic agricultural yield volatilities and world market prices uncertainty for traded goods. Data mining and machine learning methods were applied to quantify the contribution of each shock to the uncertainty of economic outcomes (gross domestic product [GDP], private consumption, poverty, and undernourishment). Key findings suggest that domestic root and cereal yield volatility risks are the most important for GDP, poverty, and undernourishment outcomes, while external factors like world energy prices pose the most significant risks to high-income households' consumption. Understanding how possible shocks would impact various segments of the Rwandan economy and population is a critical first step in facilitating discussions on relevant risk mitigation strategies, such as increasing average crop yields, adopting technologies and practices that narrow yield uncertainties, or diversifying production away from risky crops and sectors.

Keywords: risk profiling; yield volatility; world market uncertainty; CGE modeling, machine learning.

1. Analyzing the impacts of simultaneous variability of exogenous shocks

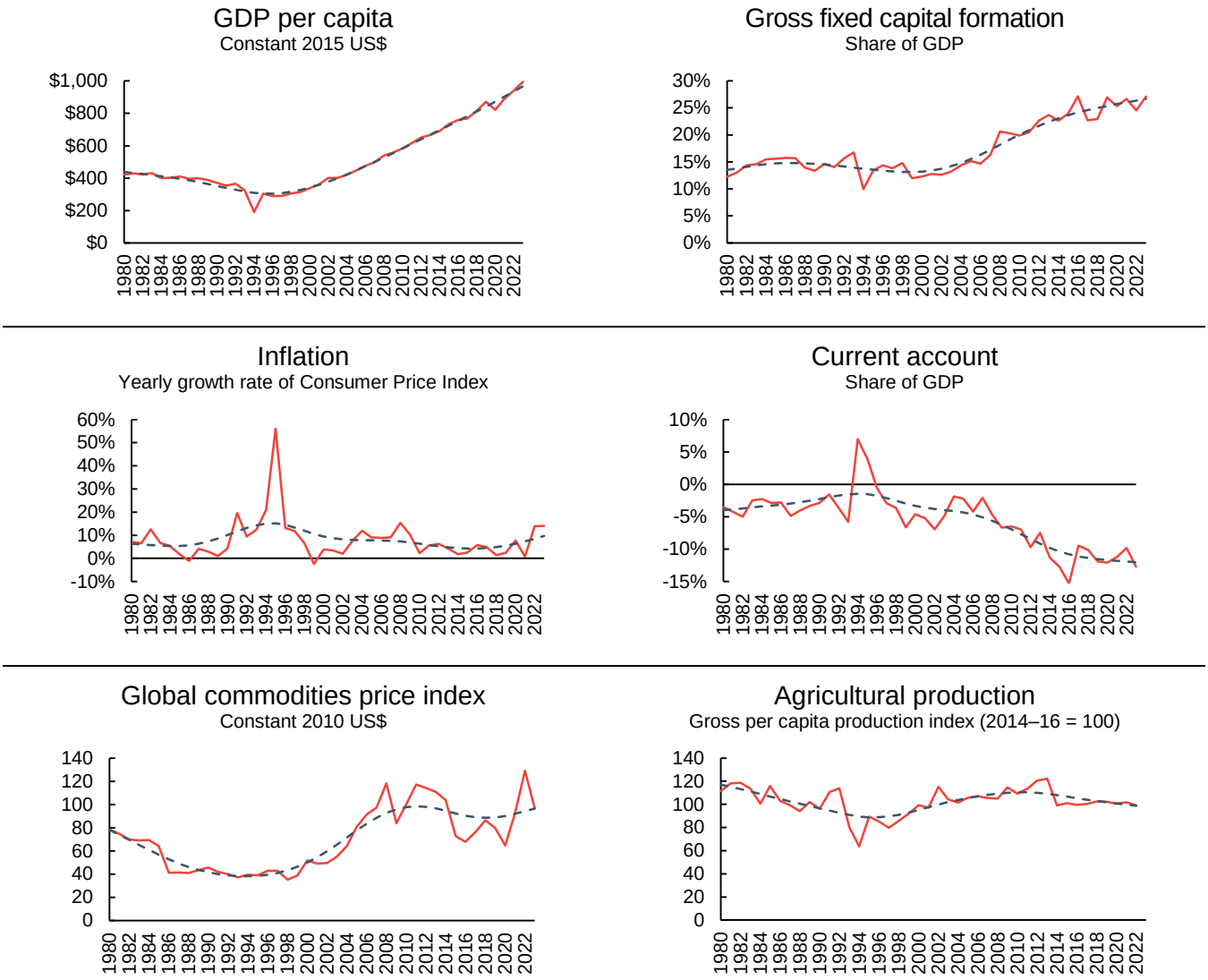
An examination of the historical dynamics of Rwanda's key economic indicators helps identify some of the main influences regarding the country's development (Figure 1). Since the structural trend break in the early 2000s, the country has developed rapidly. At the same time, periodic shocks—such as the 2008 spike in world market prices, and drought-caused low agricultural yields between 2003–06 and 2013–17 (Niyonsenga et al. 2024)—were usually accompanied by increasing macroeconomic instability, such as gross domestic product (GDP) declines, inflation, or current account volatility. According to the Systematic Country Diagnostic by the World Bank (2019), besides long-term fundamental developmental factors such as governance, institutions, infrastructure, and demographic and social challenges, exogenous risks such as droughts, unstable world market prices, and dependence on foreign aid flows remain highly influential for Rwanda.

In this context, our goal is to create a realistic map of the country's exogenous shocks and develop a detailed risk profile of the country's baseline economic structure. The methods and analyses used in this note seek to answer two questions:

- What is the country's current vulnerability to world market prices and agricultural risks that are consistent with *historical data*?
- How much do these shocks contribute to the country's current vulnerability, and which shocks contribute most to economic uncertainty?

To answer these and related questions, we use a novel methodology for country Systematic Risk Profiling (SRP). The method uses machine-learning and data-mining techniques to dissect complex relationships between sampled shocks and outcome variables in an economywide Computable General Equilibrium (CGE) model constructed for Rwanda. Our SRP approach consists of three sequential steps: (1) we first use historical data and sample scenarios that sufficiently and realistically represent the parameter space of potential exogenous shocks; (2) we then create potential shock scenarios and supply them to the CGE model of Rwanda to estimate the economic outcomes corresponding to sampled shock scenarios; and (3) we use machine-learning and data-mining methods to quantify the contribution of each shock to the uncertainty of various economic outcomes. For details on SRP, see Mukashov et al. (2024).

Figure 1. Historical dynamics of key indicators (long term trend line in dashed blue)



Note: Trend calculation using Hodrick–Prescott filter for yearly data (see Hodrick and Prescott 1997).
Source: Own calculations using World Bank (2024a) data (GDP per capita, gross fixed capital formation), IMF (2024) data (inflation, current account), World Bank (2024b) data (global commodities price index), and FAO (2024) data (agricultural production).

2. Current economic structure and shock scenarios

2.1 The Structure of the Rwandan Economy

Rwanda is a low-income African country with a GDP per capita of US$806 (in 2019), a national poverty rate of 38.2 percent (in 2015), and a national undernourishment rate[1] of 32.7 percent (in 2019) (World Bank 2024a).

1 Share of the population whose adult-equivalent daily consumption below the minimum calorie requirement defined by the Food and Agriculture Organization of the United Nations.

The sectoral structure is typical of a low-income country (Table 1a) in which primary agriculture accounts for a significant share of Rwanda's economic activity, contributing 25.7 percent of GDP and employing 62.3 percent of the workforce. The industrial sector remains less developed, with non-food manufacturing accounting for only 3.9 percent of GDP, despite its share in total demand being 23.1 percent. Overall, Rwanda is a net importer, with non-food manufacturing goods constituting the largest share of imports (75.8 percent). Beverage crops (i.e., coffee) and mining (i.e., metals and minerals) are the most export-intensive sectors (in terms of export share of output); however, the services sector holds the greatest overall export weight due to its sheer size.

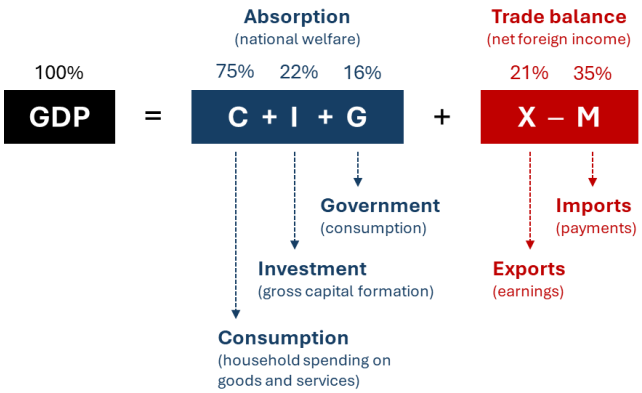
On the demand side, Rwanda's economy also exhibits characteristics typical of a low-income country (Table 1b). Notably, the country has a relatively high share of investment demand (22 percent of GDP, primarily for construction goods and imported machinery), a significant share of net import expenditures (exports account for 21 percent of GDP, while imports represent 35 percent of GDP), and a substantial public sector, with government consumption expenditure amounting to approximately 16 percent of GDP.

Table 1. Structure of Rwanda's Economy

a. Sectoral decomposition

	% of total GDP	% of employment	% of total demand	Export		Import	
				% of sectoral output	% of total export	% of sectoral demand	% of total import
Primary Agriculture	25.7	62.3	9.4	17.0	15.7	2.0	0.8
Crops	16.1	39.0	6.5	22.8	15.7	2.9	0.8
Roots	6.0	14.5	2.3				
Fruits	3.7	8.8	1.4	17.6	2.5		
Cereals	1.8	4.3	1.1			12.8	0.6
Beverage crops	1.6	3.9	0.3	79.8	9.6		
Livestock	2.8	6.8	1.7				
Forestry	6.4	15.5	0.9				
Fishing	0.4	1.0	0.2				
Mining	1.6	1.0	0.7	75.7	8.5	27.9	0.8
Manufacturing	9.1	3.8	30.8	9.8	9.5	65.1	81.0
Agroprocessing	5.2	2.6	7.7	5.3	3.0	16.9	5.2
Other manufact.	3.9	1.2	23.1	16.5	6.4	81.1	75.8
Utilities	1.7	1.1	1.9				
Construction	8.2	5.4	11.7				
Services	53.6	26.4	45.5	14.8	66.3	9.4	17.4
Food services	2.0	0.4	4.0	5.8	2.1	8.8	1.4
Social services	11.0	5.5	10.8	16.3	19.4		
Other services	40.6	20.5	30.8	15.3	44.9	12.8	15.9
Total	**100.0**	**100.0**	**100.0**	**12.9**	**100.0**	**24.7**	**100.0**

b. GDP decomposition by expenditure



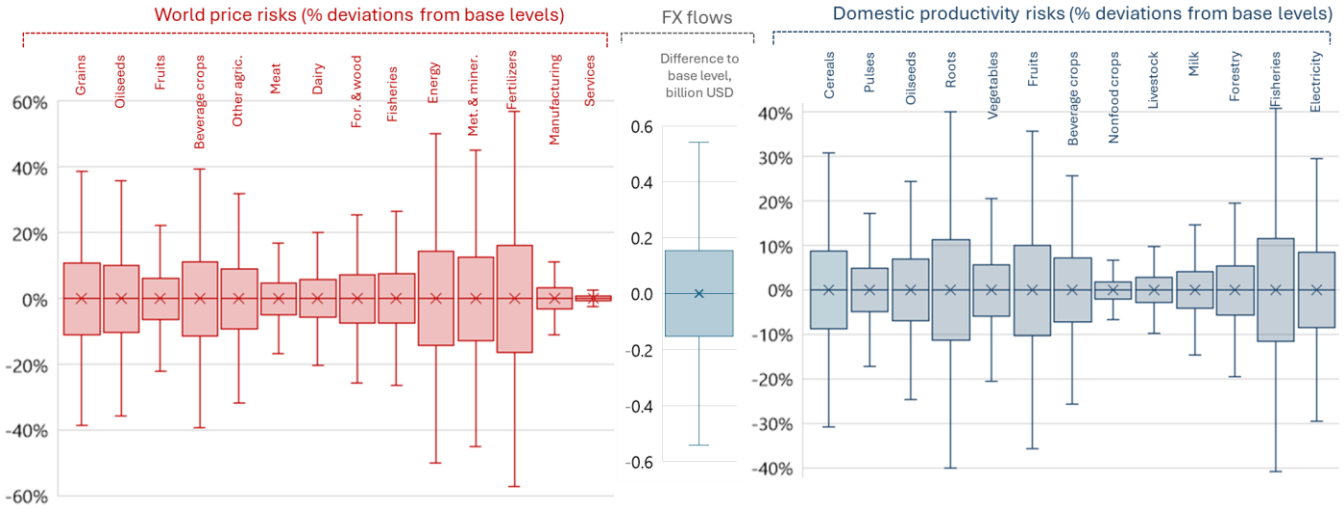
Source: Own calculations based on official national accounts data for 2019 presented in the form of the Social Accounting Matrix (for details, see Diao et al. 2022).

2.2 Characteristics of sampled shocks

In this context, the first step of the SRP—estimating the historical volatility of shocks—helps us understand the scale of potential shocks that the *current* economy faces. We consider two broad categories of shocks: (1) changes in world prices of goods and services in which Rwanda trades and that are mostly affected by global business cycles; and (2) abrupt shifts in domestic production[2], often linked to droughts and other natural shocks such as pest infestations and diseases. Although the variation of shocks around historical trends is not strictly symmetric around zero, we remain agnostic about *future* shocks. We draw random hypothetical scenarios from a multivariate normal distribution with zero means and a history-based estimated variance-covariance matrix depicted in Figure 2 (panel A shows the modeled individual (marginal) distributions of sampled shocks, and panel B shows correlation structure of sampled shocks).

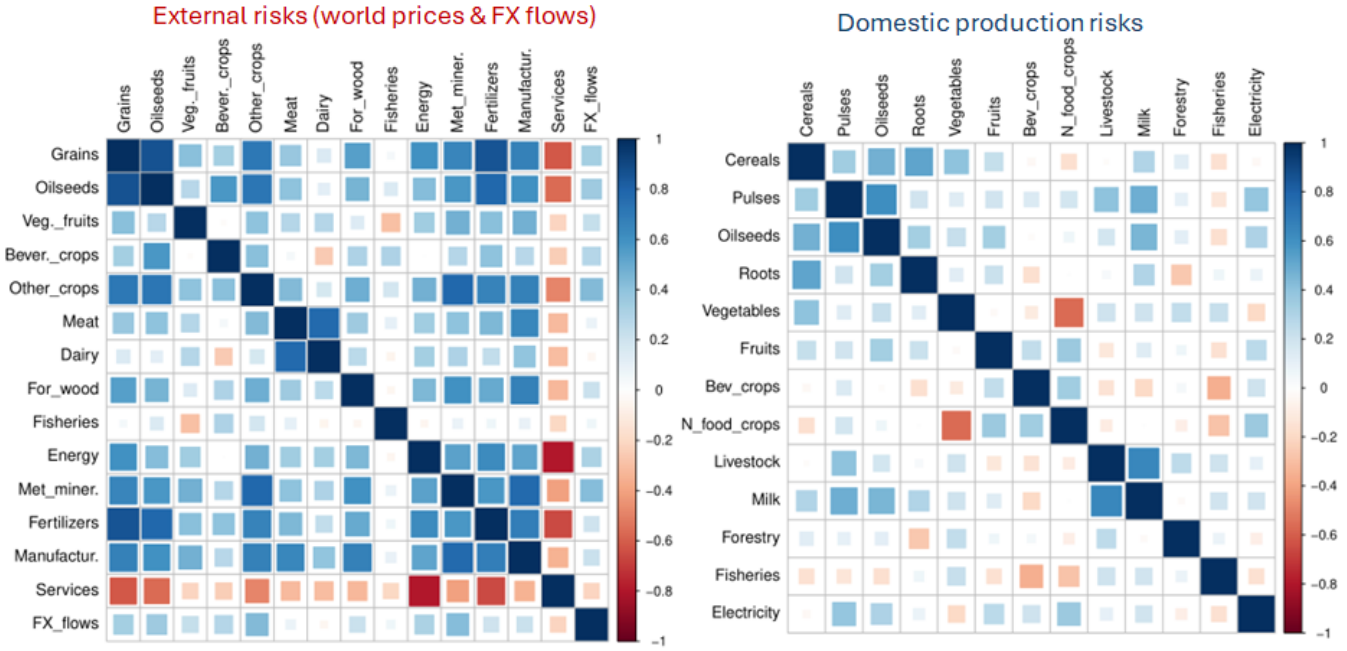
Figure 2. Sampled risks

a. Marginal distributions



2 Whenever possible, we use yields agricultural yield as a measure of productivity. For some sectors where historical yield data do not exist (livestock, milk, forestry, electricity), we use historical per capita production as a proxy for total factor productivity (see Mukashov et al. (2024) for details).

b. Correlation structure



Note: Each cell in the correlation figure is a correlation between two variables, with cell sizes ranging from empty (0 correlation) to full squares (max correlation=1) and colors ranging from red (-) to blue (+).

Source: Own calculations using World Bank (2024a, 2024b), FAO (2024), and IMF (2024) data.

World price volatility: World prices of primary commodities are highly volatile, whereas manufactured goods and ser-vices exhibit much greater stability (Figure 2a). Among agricultural commodities, beverage crop prices are the most volatile, followed by grains. The prices of primary commodities show a strong positive correlation (Figure 2b), suggesting that price shocks often occur simultaneously due to their dependence on global business cycles (see Erten and Ocampo, 2013). In contrast, services exhibit a moderate negative correlation with most commodities, suggesting that when the prices of other commodities rise in real USD terms, the price of services in real USD may sometimes decline (however, the overall variation in service prices remains very low, see Figure 2a).

Volatility of FX flows: We assume that foreign exchange (FX) flows enter the economy as foreign savings denominated in USD, influencing both the exchange rate and investment demand (primarily in construction). To estimate changes in FX flows, we use current account data from the IMF (2024), which indicates that FX flows deviate by approximately ±0.5 billion 2019 USD (equivalent to 5.4% of 2019 GDP).

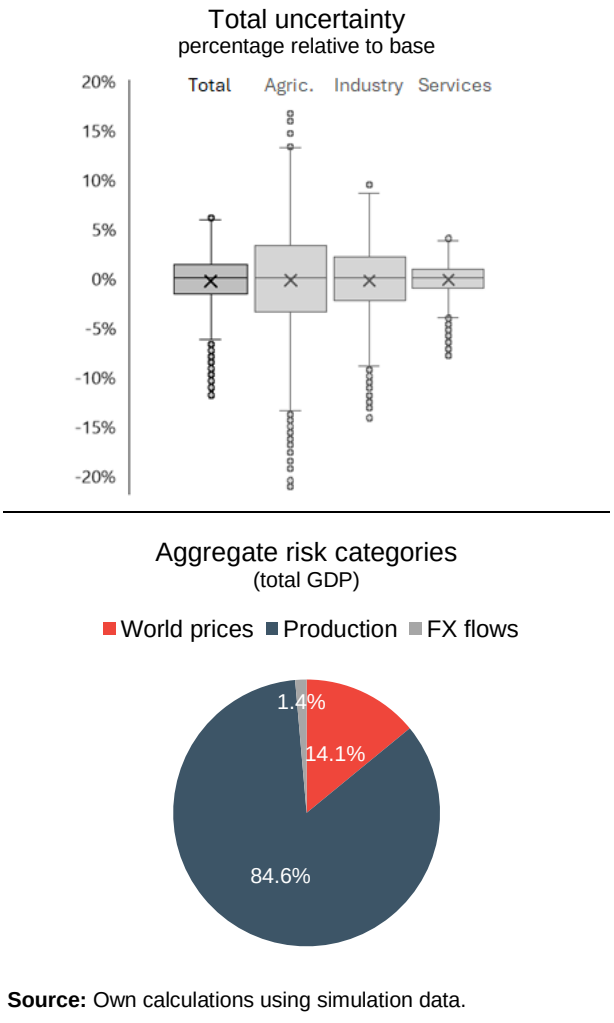
Domestic production volatility: According to our analysis based on FAO (2024) data, the yields of roots, fruits, cereals, and the production of fisheries in Rwanda have historically been the most uncertain (Figure 2a). Additionally, most yields in Rwanda exhibit moderate positive correlations (Figure 2b), indicating that production shocks are likely to occur simultaneously.

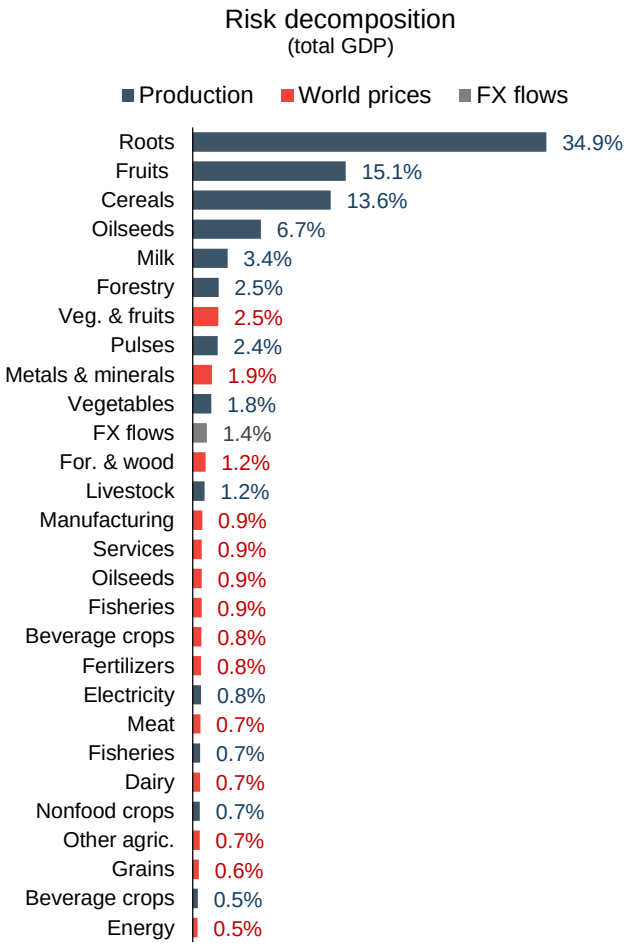
3. Measuring and understanding Rwanda's economic uncertainty

The second step of the SRP models the economic uncertainty resulting from the 10,000 sampled scenarios supplied to the CGE model of Rwanda, while the third step employs machine-learning and data-mining methods to quantify each shock's contribution to outcomes' uncertainty[3]. Figures 3 to 6 represent the total uncertainty and its decomposition for GDP, private consumption, poverty, and undernourishment economic outcomes, respectively.

Potential Variation of GDP (Figure 3): Total GDP can fluctuate from -11.9 percent (worst case) to +6.1 percent (best case) relative to base year GDP. Agriculture, directly exposed to productivity shocks, is the most uncertain sector, with the potential growth rate ranging from -21.1 to +16.7 percent relative to the sector's base year value. Domestic yield volatility, particularly of roots, fruits, and cereals, dominates total GDP uncertainty, with total domestic production risks accounting for 84.6 percent of total GDP uncertainty.

Figure 3. Potential variation of GDP





Source: Own calculations using simulation data.

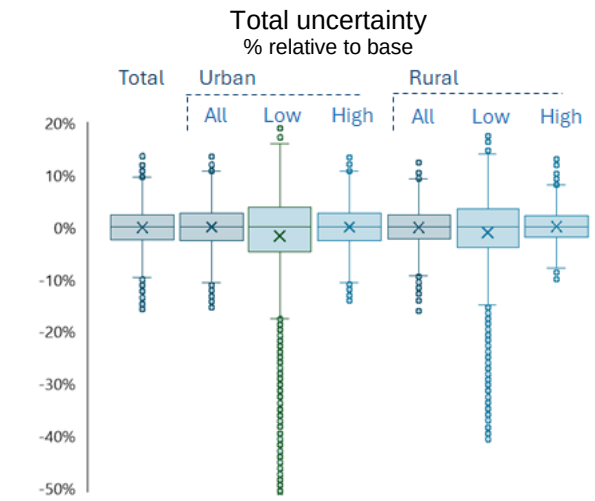
Potential variation of private consumption (Figure 4 and Table 2): Because of high import dependence, consumption is more uncertain than GDP, with total consumption ranging from -15.8 to +13.5 per-

3 We use Random Forest and Lindeman, Merenda, and Gold relative importance metrics; for details, see Mukashov et al. (2024).

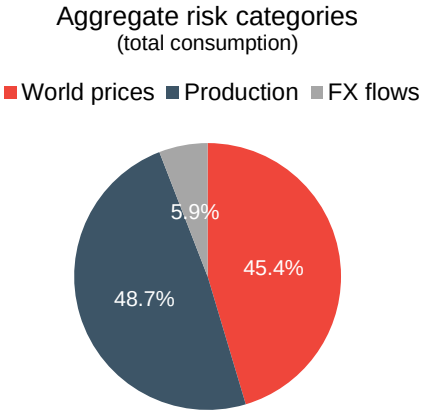
cent relative to base values (comparing standard deviations, private consumption is 1.5 times more uncertain than total GDP). In turn, low-income households' consumption is the most uncertain (comparing standard deviations, urban and rural low-income households' consumption are 2.4 and 1.9 times higher, respectively, than national variations), indicating that Rwanda's low-income households are the most vulnerable to potential shocks.

For total consumption uncertainty, external factors and domestic yield volatility are nearly equally important risk factors. However, significant differences exist across household types (Table 2).

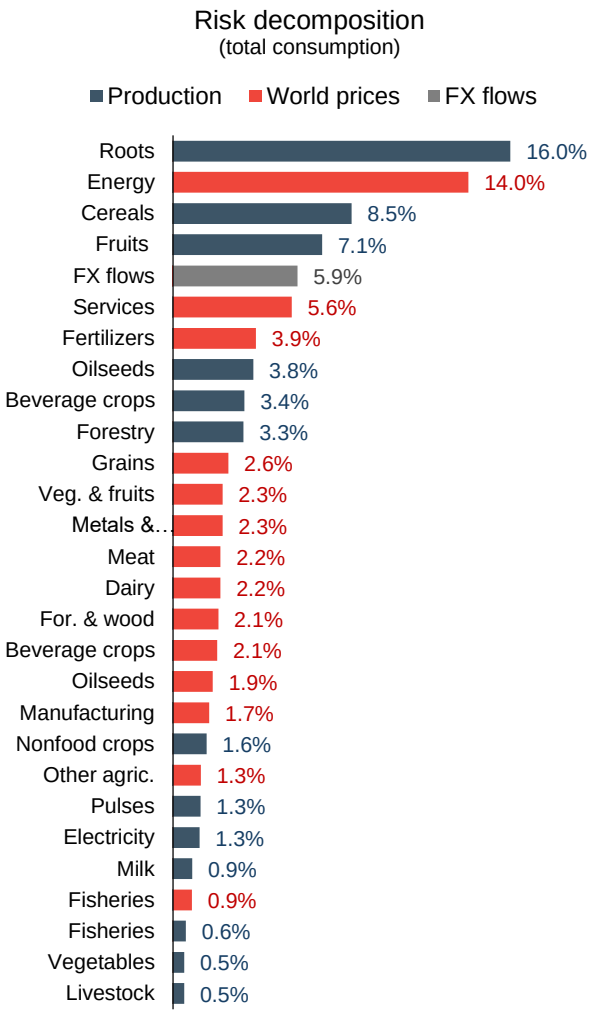
Figure 4. Potential variation of private consumption



Note: Low comprises the first- and second-income quintiles and high comprises the fifth income quintile of urban and rural households, respectively.



Source: Own calculations using simulation data.



In particular, low-income households (both urban and rural) are more dependent on domestic production risk factors (77.6 and 78.5 percent, respectively), with yield uncertainty of roots and cereals being the most important risk factors. High-income households, on the other hand, given their higher consumption of imported goods, are more exposed to external risks (67.1 percent for urban and 69.5 percent for rural households), with world energy prices the most important risk factor for their consumption uncertainty.

Table 2. Detailed risk decompositions of consumption uncertainty

		Total	Urban				Rural			
			Total	Low	Middle	High	Total	Low	Middle	High
Total external		**51.3**	**63.3**	**22.4**	**48.9**	**67.1**	**40.0**	**21.5**	**39.8**	**69.5**
World prices	Grains	2.6	4.0	0.9	2.5	4.3	1.4	0.6	1.3	3.2
	Oilseeds	1.9	3.1	1.0	1.9	3.3	1.1	0.5	1.0	2.0
	Vegetables & fruits	2.3	2.8	2.3	2.6	2.7	1.8	1.9	1.6	1.0
	Beverage crops	2.1	0.9	0.6	1.9	0.8	4.3	2.1	5.0	4.0
	Other agriculture	1.3	2.0	0.8	1.4	2.1	0.9	0.8	0.9	1.4
	Meat	2.2	2.2	0.7	2.2	2.2	2.1	0.8	2.2	3.4
	Dairy	2.2	2.0	0.5	2.1	2.1	2.3	0.8	2.4	3.7
	Forestry & wood	2.1	2.4	2.4	2.1	2.4	1.8	1.9	1.8	1.1
	Fish	0.9	0.6	1.5	0.9	0.6	1.2	1.7	1.2	0.4
	Energy	14.0	18.1	1.6	10.9	19.8	9.2	1.8	8.7	23.6
	Metals & minerals	2.3	2.8	1.6	2.2	2.9	1.8	1.5	1.8	2.0
	Fertilizers	3.9	6.0	1.3	3.4	6.5	2.1	0.8	1.9	4.9
	Manufacturing	1.7	2.1	0.8	1.5	2.2	1.3	0.8	1.3	2.6
	Services	5.6	9.2	1.3	4.4	10.5	2.8	1.4	2.5	12.0
FX flows		5.9	5.2	4.9	9.0	4.7	6.0	4.2	6.1	4.1
Total domestic		**48.7**	**36.7**	**77.6**	**51.1**	**32.9**	**60.0**	**78.5**	**60.2**	**30.5**
Domestic production	Cereals	8.5	5.2	13.9	9.1	4.3	11.4	15.6	11.7	1.2
	Pulses	1.3	0.8	1.6	1.3	0.7	2.0	1.9	2.1	0.8
	Oilseeds	3.8	3.1	5.0	3.7	2.9	4.2	5.1	4.1	1.1
	Roots	16.0	10.3	46.0	18.8	7.8	20.8	41.1	21.1	1.6
	Vegetables	0.5	0.5	0.7	0.5	0.6	0.7	1.1	0.7	0.6
	Fruits	7.1	7.3	4.4	7.4	7.1	6.1	4.6	5.7	4.6
	Beverage crops	3.4	3.4	0.4	3.2	3.7	3.0	0.5	3.4	9.0
	Nonfood crops	1.6	1.8	0.6	1.7	1.8	1.4	0.7	1.5	2.1
	Livestock	0.5	0.4	0.4	0.5	0.3	0.8	0.8	0.7	0.5
	Milk	0.9	0.7	2.0	0.8	0.7	1.1	1.8	1.0	0.5
	Forestry	3.3	1.2	1.1	1.9	1.1	6.6	4.1	6.5	6.6
	Fisheries	0.6	0.7	0.5	0.5	0.8	0.5	0.5	0.5	0.7
	Electricity	1.3	1.3	0.9	1.6	1.2	1.2	0.7	1.2	1.2

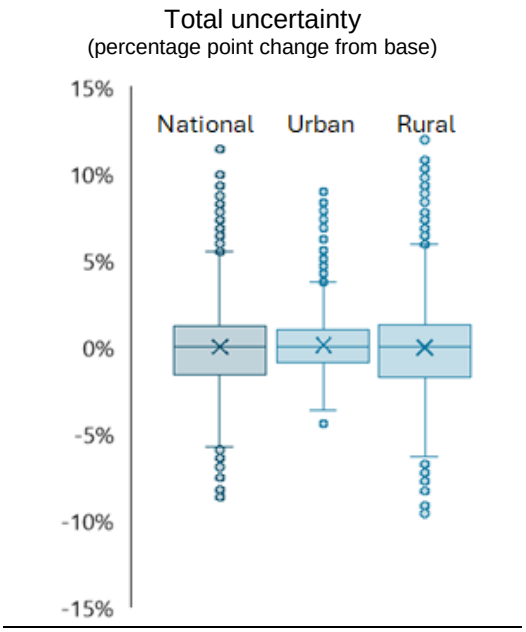
Note: Low comprises the first- and second-income quintiles, middle comprises the third- and fourth-income quintiles, and high comprises the fifth income quintile of urban and rural households, respectively.

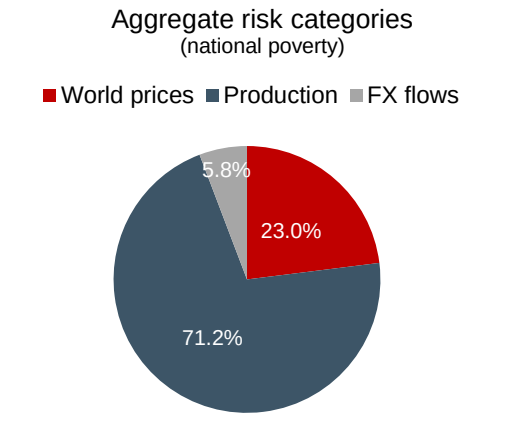
Source: Own calculations using simulation data.

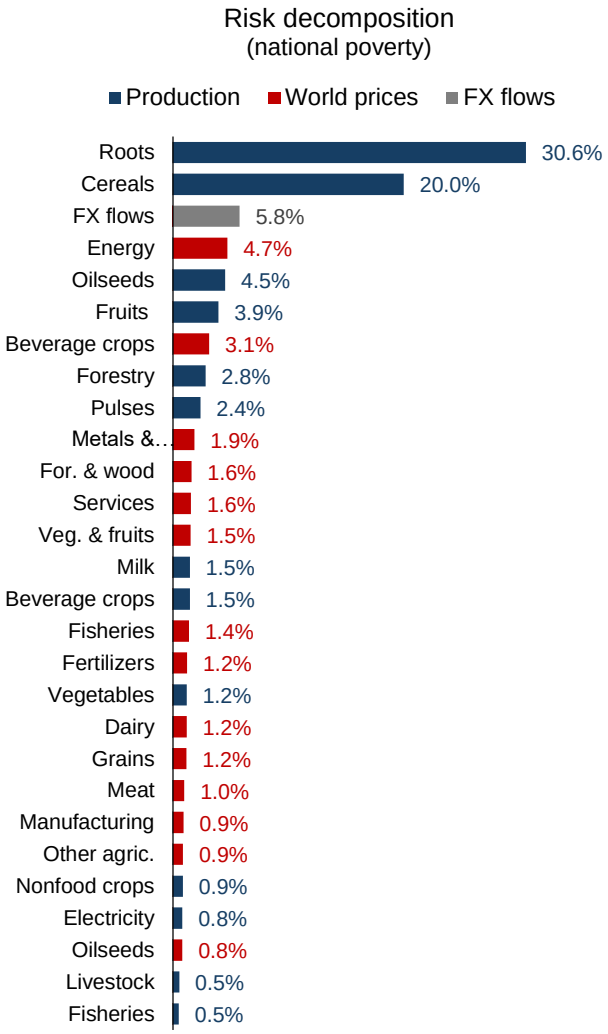
Potential variation of poverty headcount (Figure 5 and Table 3): The poverty rate fluctuates with low-income households' consumption, ranging from -8.7 to +11.4 percentage points relative to the baseline national poverty headcount rate of 38.2 percent. In absolute numbers, this equates to 1.1 million people above the poverty line in the best case and 1.5 million below the poverty line in the worst-case scenario. Nationally, domestic yield volatility is the dominant risk factor (71.2 percent of total risk), but some differences arise across household types (Table 3).

For urban poverty, domestic yield volatility constitutes 65.3 percent of risk, slightly lower than the 71.8 percent of risk for rural poverty. On the individual level, yield volatilities of roots and cereals are the most important risk factor for both urban and rural households, followed by FX flows.

Figure 5. Potential variation of poverty headcount rate



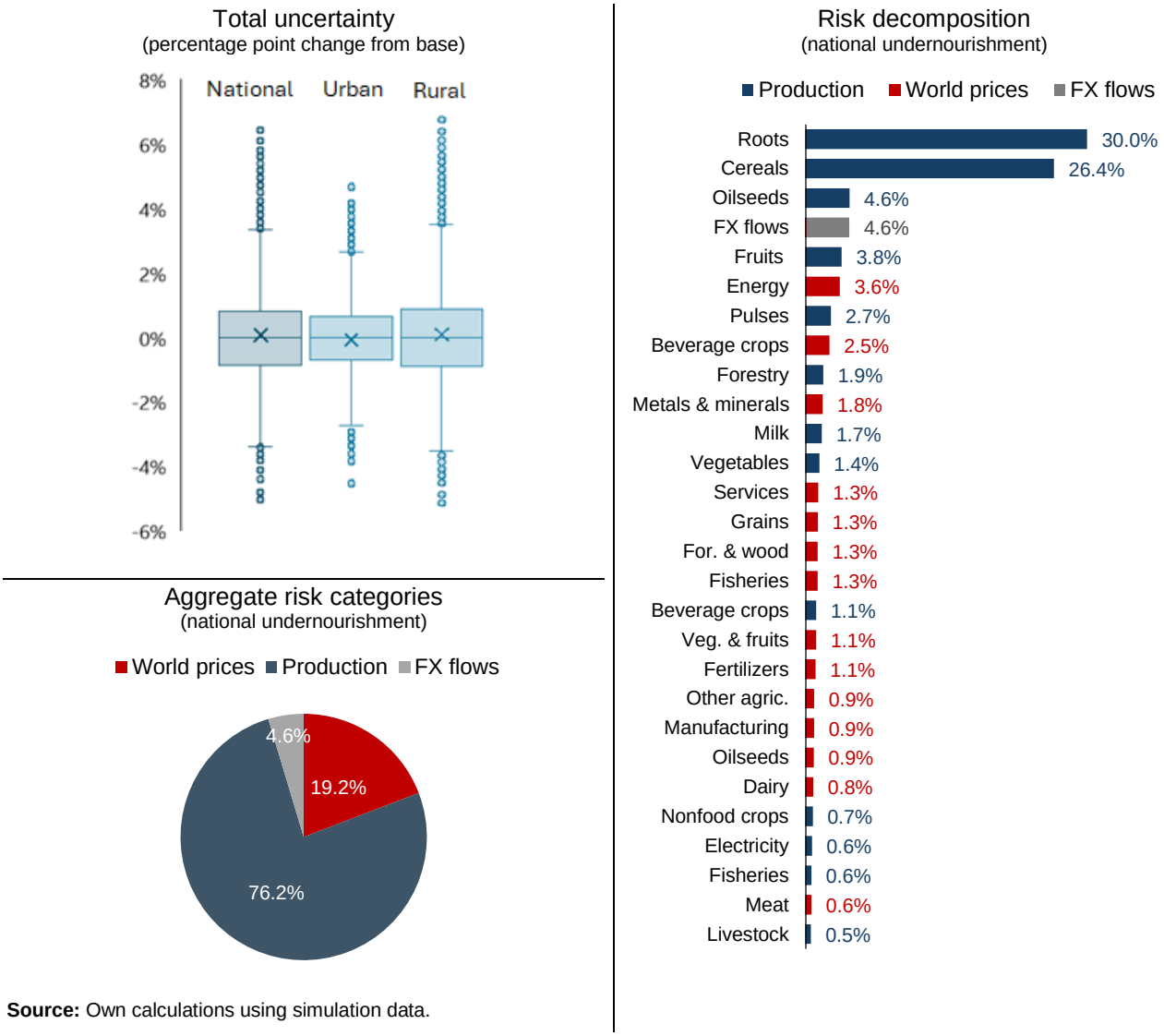




Source: Own calculations using simulation data.

Potential variation of undernourishment headcount (Figure 6 and Table 3): Undernourishment rates fluctuate from -5.0 to +6.4 percentage points relative to the baseline national undernourishment rate of 32.7 percent. This translates to 0.6 million people rising above the undernourishment line in the best case and 0.8 million sinking below in the worst-case scenario. Unlike other outcomes, undernourishment uncertainty is mostly similar across all households and primarily driven by a narrow set of risks. Yield variabilities of staple crops including roots and cereals are the most significant risk factor for all households (51.0 and 56.9 percent of risk for urban and rural households, respectively). Since staple food production drives calorie supply in Rwanda, it is unsurprising that these yields are the key risk factor for undernourishment levels of both urban and rural households.

Figure 6. Potential variation of undernourishment headcount rate



Source: Own calculations using simulation data.

Table 3. Detailed risk decompositions of poverty and undernourishment uncertainty

		Poverty			Undernourishment		
		National	Urban	Rural	National	Urban	Rural
Total external		28.8	34.7	28.2	23.8	30.7	23.0
World prices	Grains	1.2	2.0	1.1	1.3	2.6	1.1
	Oilseeds	0.8	1.6	0.8	0.9	1.9	0.7
	Vegetables & fruits	1.5	2.2	1.5	1.1	1.4	1.0
	Beverage crops	3.1	1.3	3.5	2.5	1.3	2.8
	Other agriculture	0.9	1.1	0.9	0.9	1.0	0.9
	Meat	1.0	1.2	1.0	0.6	0.7	0.6
	Dairy	1.2	1.1	1.2	0.8	0.8	0.8
	Forestry & wood	1.6	2.1	1.5	1.3	1.4	1.2
	Fish	1.4	1.2	1.4	1.3	0.9	1.3
	Energy	4.7	5.5	4.6	3.6	5.2	3.3
	Metals & minerals	1.9	2.2	1.8	1.8	2.2	1.7
	Fertilizers	1.2	2.2	1.1	1.1	2.1	0.9
	Manufacturing	0.9	1.1	0.9	0.9	1.0	0.8
	Services	1.6	2.2	1.5	1.3	2.3	1.2
FX flows		5.8	7.8	5.5	4.6	5.8	4.4
Total domestic		**71.2**	**65.3**	**71.8**	**76.2**	**69.3**	**77.0**
Domestic production	Cereals	20.0	15.6	20.5	26.4	24.2	26.6
	Pulses	2.4	1.7	2.5	2.7	2.1	2.7
	Oilseeds	4.5	4.2	4.5	4.6	4.0	4.7
	Roots	30.6	31.8	30.2	30.0	26.7	30.3
	Vegetables	1.2	0.7	1.3	1.4	1.0	1.5
	Fruits	3.9	4.3	3.9	3.8	4.5	3.7
	Beverage crops	1.5	1.4	1.5	1.1	1.4	1.0
	Nonfood crops	0.9	1.0	0.8	0.7	1.0	0.7
	Livestock	0.5	0.4	0.6	0.5	0.5	0.6
	Milk	1.5	1.4	1.5	1.7	1.5	1.7
	Forestry	2.8	0.9	3.2	1.9	0.8	2.2
	Fisheries	0.5	0.5	0.5	0.6	0.6	0.6
	Electricity	0.8	1.2	0.8	0.6	0.9	0.6

Source: Own calculations using simulation data.

4. Summary and next steps in the analysis

By analyzing historical data, we derive a consistent parameter space for both world market and domestic production volatility, sampling realistic shock scenarios that can impact the Rwandan economy. These scenarios are applied to the Rwandan CGE model to estimate economic uncertainty, and decomposition methods are used to identify the most important sources of uncertainty.

We find that for GDP uncertainty, domestic yield volatilities of roots and cereals are a key risk factor. Similarly, yields of roots and cereals are the most important risk factor for low-income households' consumption (and hence, poverty rates). At the same time, high-income households are more exposed to external risks, with world energy prices the most important risk to their welfare. For undernourishment outcomes, the volatility of staple crop yields—roots and cereals—is a key risk factor.

This study is part of a series by IFPRI that uses economywide models to provide detailed risk assessments of key economic indicators. The analysis presented here is an initial impact assessment aimed at gauging the vulnerability of countries and key population groups. Future analyses will focus on comparing risk management strategies, which fall into three main categories: (1) increasing average yields to reduce the impact of shocks; (2) adopting technologies and practices that narrow yield uncertainty; and (3) diversifying production toward less risky crops and sectors.

Acknowledgments

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1201 Eye Street, NW, Washington, DC 20005 USA | T. +1-202-862-5600 | F. +1-202-862-5606 | Email: ifpri@cgiar.org | www.ifpri.org | www.ifpri.info