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Economic Effects of Climate Change and Food Insecurity in Niger

Niger

Diogo Baptista, Yoro Diallo, and Arsène Kaho

SIP/2023/009

***IMF Selected Issues Papers* are prepared by IMF staff as background documentation for periodic consultations with member countries.** It is based on the information available at the time it was completed on December 6, 2022. This paper is also published separately as IMF Country Report No 2023/029.

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Economic Effects of Climate Change and Food Insecurity in Niger
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SELECTED ISSUES PAPERS

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Niger

ECONOMIC EFFECTS OF CLIMATE CHANGE AND FOOD INSECURITY IN NIGER[1]

Niger's exposure to recurrent shocks, including climate shocks, increases its vulnerability to food insecurity. This paper aims to quantify the combined effects of climate shocks and food insecurity on key economic variables and identify the most effective mitigation policy responses using a general equilibrium model. Results indicate that rural households would be the most affected by a climate shock resulting in a decline in domestic agricultural production, which would reduce their consumption, erode their capital, and thus increase urban-rural inequalities. Simulations show that cash transfers and the reduction of internal mobility costs appear to be more effective in mitigating the impact on households of a climate shock on agricultural production.

A. Background

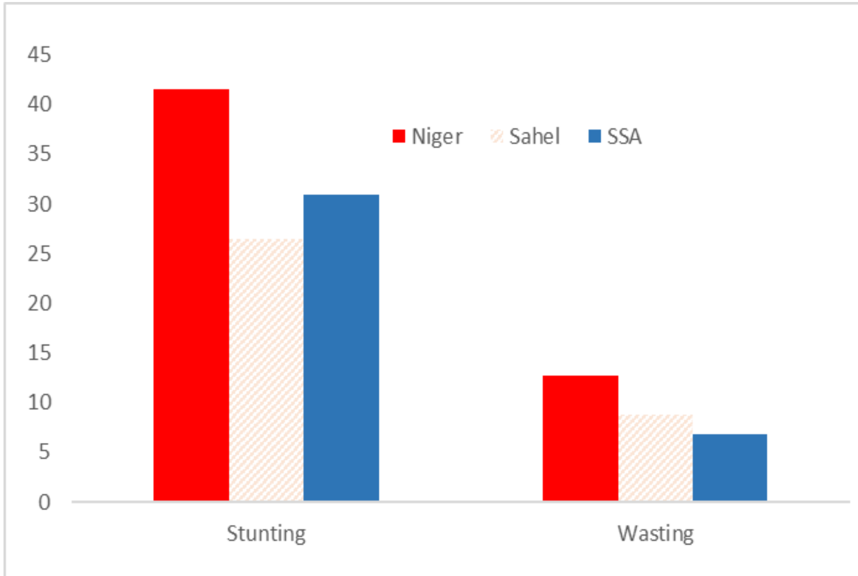
1. As a result of global warming, Niger is subject to frequent climate-related shocks in the form of protracted droughts or floods episodes as well as locust attacks often leading to food crises. Over the past two decades, the country has notably experienced nine episodes of acute drought and five major floods which have mainly affected rural populations and the agricultural sector—the country's largest sector of activity (36.4 percent of GDP in 2021), mostly relying on rainfed crops. Niger endures on average a food crisis every four years due to the vulnerability of its agriculture to climate hazards and its low productivity.

2. Niger's malnutrition and access to food indicators are among the worst in the world (Figure 1). Although in decline from 53.5 percent in 2000 to 44.4 percent in 2021, the rate of chronic malnutrition in Niger (measured by the percentage of stunted children under five) remains one of the highest in sub-Saharan Africa and the highest of the Sahel countries. The rate of acute malnutrition (measured by the percentage of wasted children under 5), equally down from 15.8 percent in 2010 to 11.5 percent in 2021, is still almost double the average for sub-Saharan African countries and the highest of the Sahel region. The same unfavorable trends are observed regarding the prevalence of children underweight.

[1] Prepared By Diogo Baptista (RES), Yoro Diallo, and Arsene Kaho (AFR). We are grateful to Pritha Mitra, Farida Mai, Cedric Okou, Chris Papageorgiou, John Spray, and Filiz Unsal for their valuable comments and suggestions.

3. Strengthening the country's food security exclusively through increased food staple imports appears challenging and unsustainable. The dependency rate to food imports stood around 15 percent of the country's net food supply value in 2020. Widespread poverty, a narrow export base as well as the country's remoteness and the fact that it is landlocked—on the fringes of major international supply chains—are significant impediments to access to lower cost imports to fill shortfalls in domestic food production when they arise and compound the country's vulnerability to food crises. Moreover, this vulnerability is exacerbated by a large weight of food in household consumption basket, low storage capacity, and the spillovers of Russia's war in Ukraine on the rising costs of agricultural inputs (energy, fertilizers, etc.).

Figure 1. Niger: Malnutrition Indicators, 2021
(percentage of total children under 5)



Source: World Food Program stats, and IMF staff calculation

4. Climate shocks and ensuing food insecurity compromise Niger's macroeconomic stability and weaken its long-term growth potential. Climate shocks create ample volatility in agricultural production and GDP as well as increased inflationary pressures. As a result of lower income and rising food prices, large swaths of the population are at risk of falling into precariousness and poverty. In addition, the roll out of authorities' relief plans and increased demand for imported foodstuff would widen the fiscal and current account deficits. Food insecurity also reduces the productivity of rural populations, eroding their physical and human capital, and thus undermines the country's long-term growth.

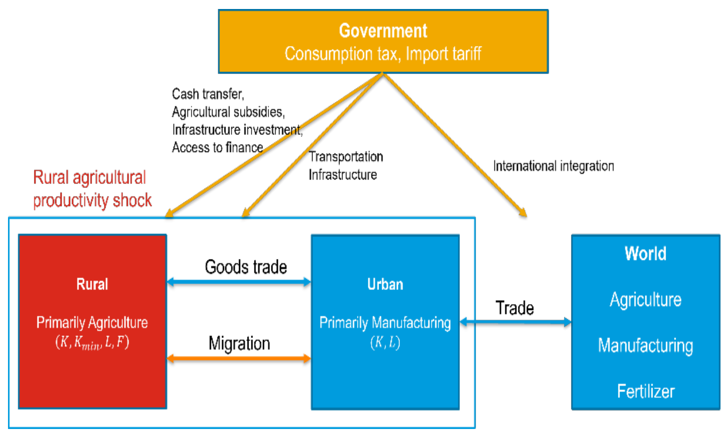
5. The objective of this paper is twofold: (i) quantify the combined effects of climate shocks and food insecurity on key economic variables and (ii) identify the most effective mitigation policy responses using a general equilibrium model of the Nigerien economy. The following section presents the model and the results of the simulations in more detail. The last section discusses public policy recommendations to better mitigate the effects of food crises in Niger.

B. Methodology and Simulations

Methodology

6. **A dynamic quantitative open economy spatial multi-sector macroeconomic model[2] is used to analyze the economic effects of climate shocks and food insecurity in Niger.** The model features both rural and urban locations. Food is produced in rural areas on household farms using labor, imported fertilizer, and capital. Urban areas specialize in non-farm activities, especially services and industry. Economic agents can trade and migrate across regions (with relative wages declining in the region where people are migrating to) subject to frictions and can import from abroad. Three features, prevalent in low-income countries, are included in the model: (i) subsistence consumption of food (which implies that households spend relatively more on food when incomes fall); (ii) limited access to finance (which introduces a trade-off between consumption today and production later); and (iii) high transportation costs and import tariffs (which results in limited internal mobility of labor and goods. Incorporating these frictions in a dynamic setting with important sources of spatial and income heterogeneity allow the model to consider the macroeconomic implications of food insecurity.

Figure 2. Niger: Spatial Multi-Sector Macroeconomic Model



7. **Climate shocks are modeled as a one-period temporary 25 percent decline in agricultural productivity—equivalent to two standard deviations of agricultural output.[3]** In order to simulate the effects of climate change on food insecurity, the model's output is directly linked to households' food consumption and the corresponding total number of calories. Furthermore, the model allows us to quantify the effect of climate shocks on (i) rural households' capital level, (ii) migration, (iii) urban/rural inequality, and (iv) food prices (domestic and imported). When hit by a negative agricultural shock, households may sell productive capital to meet a minimum food consumption requirement. If the shock is small and isolated, the economy adjusts relatively quickly. Rural households only temporarily migrate to urban areas; and these adjustments are easier when trade and migration frictions are small. However, If the shock is large, the household will give up substantial productive capital to meet the subsistence food requirement. In this case, the effects could be more persistent as the household will need

[2] The model is derived from Baptista, D., Spray, J. and Unsal, D.F. (2022). A Macroeconomic Spatial Model of Food Insecurity in Low-Income Countries.

[3] The main parameters of the model have been calibrated using the national survey ECHVM 2018/19 database, FAO stats, and literature findings.

several periods to rebuild the capital needed to operate a productive farm again and would be more likely to migrate to work in non-farm sector to make up for farm income shortages. A household facing lower farm production causes an aggregate "food price" pecuniary externality, as nationwide food shortages and rising prices increase the likelihood that other households will also be food insecure. The result is a permanent decline in agricultural production, higher food prices, lower food consumption, migration to urban areas, increased regional inequality, lower economic growth and productivity.

8. The model enables an assessment of the comparative effectiveness of various policy responses in mitigating the effects of the shock on households. These policies include:

- ***Cash transfers***: under this policy, the government taxes all households (urban and rural) up to 15 percent of their income and redistribute the revenue through cash transfers to rural households who are considered more vulnerable. The cash transfers scheme is considered well-defined by specifying beneficiaries/vulnerable groups to reduce leakages and increase the effectiveness of the transfers.

- ***Fertilizer subsidies*** consist of subsidizing rural households purchases of fertilizer inputs for agricultural production. This policy is financed in the same way as cash transfers.

- ***Trade liberalization*** involves eliminating import tariffs on staple food with aiming to support domestic food supply.

- ***Reduction in internal mobility costs*** implies the removal of mobility barriers between rural and urban areas. Households, goods, and services can therefore easily move from one locality to another at a lower cost. This policy not only reduces the vulnerability of localities to food shortages, but also facilitates the temporary migration of households to other localities to gain additional income in bad times.

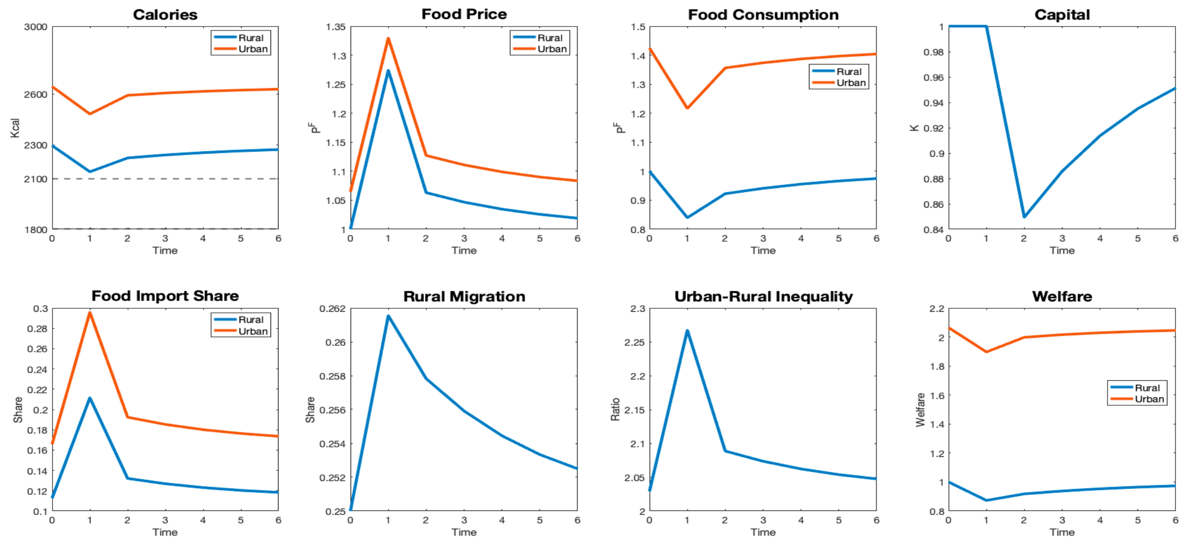
Simulations

9. Rural households would be the hardest hit by a drop in agricultural production caused by a climate shock (Figure 3). Their food consumption would decline following the shock by 18 percent against 14 for urban households, as the share of domestically produced food staples in their consumption basket is much higher. Also, the increase in food prices would be higher in rural areas (27 percent) compared to urban areas (24 percent) mainly because of relatively higher consumption of imported foodstuff by urban households. As a result, calorie consumption would fall for both groups, but to a larger extent for rural households, which would approach the 2100 kcal/day threshold.[4] This would lead to rising inequality in real consumption between rural and urban localities. In addition, the shock would entail an erosion of rural households' disposable capital (by 15 percent)—only partially rebuilt 5 years later. Indeed, to smooth consumption, rural households

[4] This threshold corresponds to a minimum food consumption requirement as defined by the FAO.

would sell part of their capital. Urban households, similarly, to their rural counterparts, tend to increase their consumption of imported food in response to the shock.

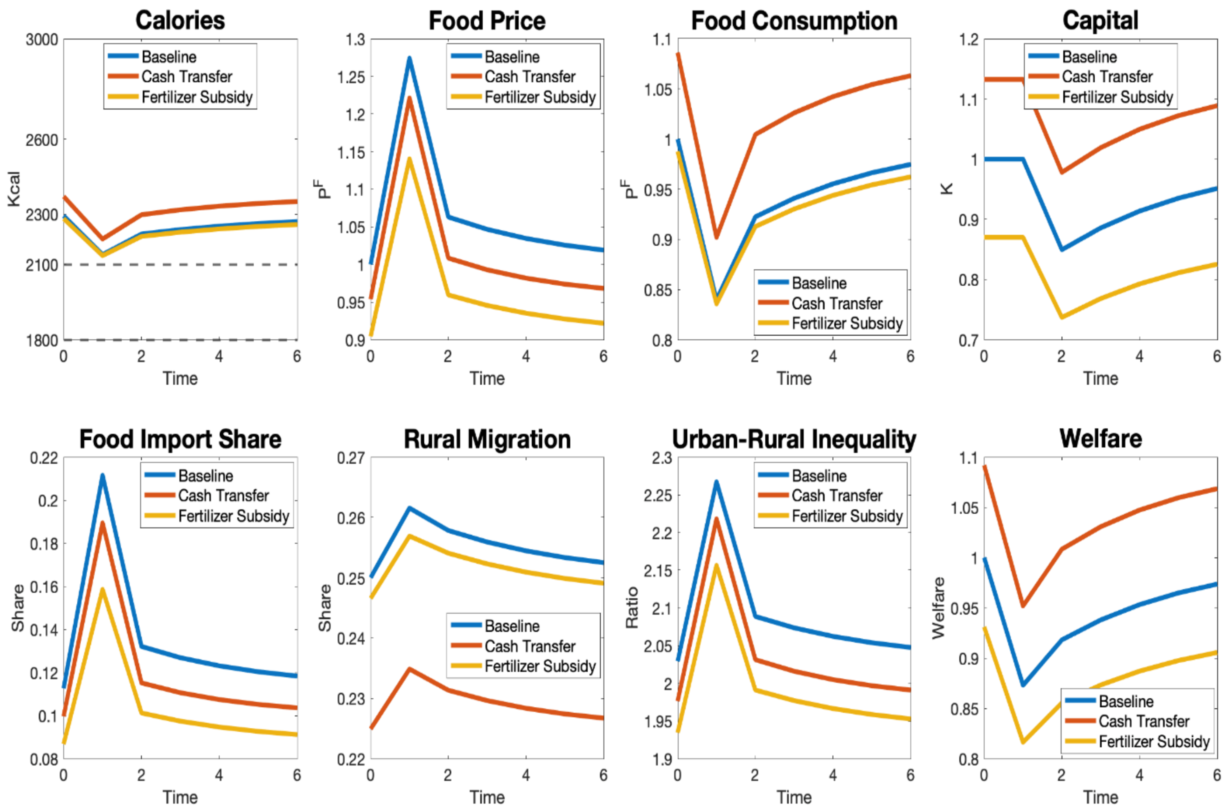
Figure 3. Niger: Impacts of a 25 Percent Decrease in Agriculture Production[1]



Source: IMF staff calculation
1/ Food price, food consumption, capital and welfare series are normalized, i.e., all values are expressed relative to baseline value in period 0.

10. Cash transfers appear more effective than fertilizer subsidies at safeguarding households' welfare. Simulations depicted in Figure 4 show that, overall, cash transfers raise consumption and utility for rural households as some of the extra cash is used to buy goods (food and non-food) and accumulate additional capital, which raises farm productivity and lowers food prices and migration as the urban-rural wage gap becomes smaller. In turn, fertilizer subsidies decrease the price of domestically produced food and the share of imported food, due to lower domestic food production cost. However, this policy appears costly on net terms as evidenced by the resulting reduction in welfare for both rural and urban households and the lower level of agriculture capital even relative to the baseline "no policy response" scenario as a result of farmers substituting capital for fertilizers— which have become relatively cheaper. In other words, the marginal cost of reducing household cash-in-hand is higher than the marginal benefit from increased fertilizer usage. In contrast, households have various options to use the cash transfer, which include not only purchasing fertilizer but also smoothing their consumption, and accumulating capital.

Figure 4. Niger: Cash Transfer vs Fertilizers Subsidies[1]

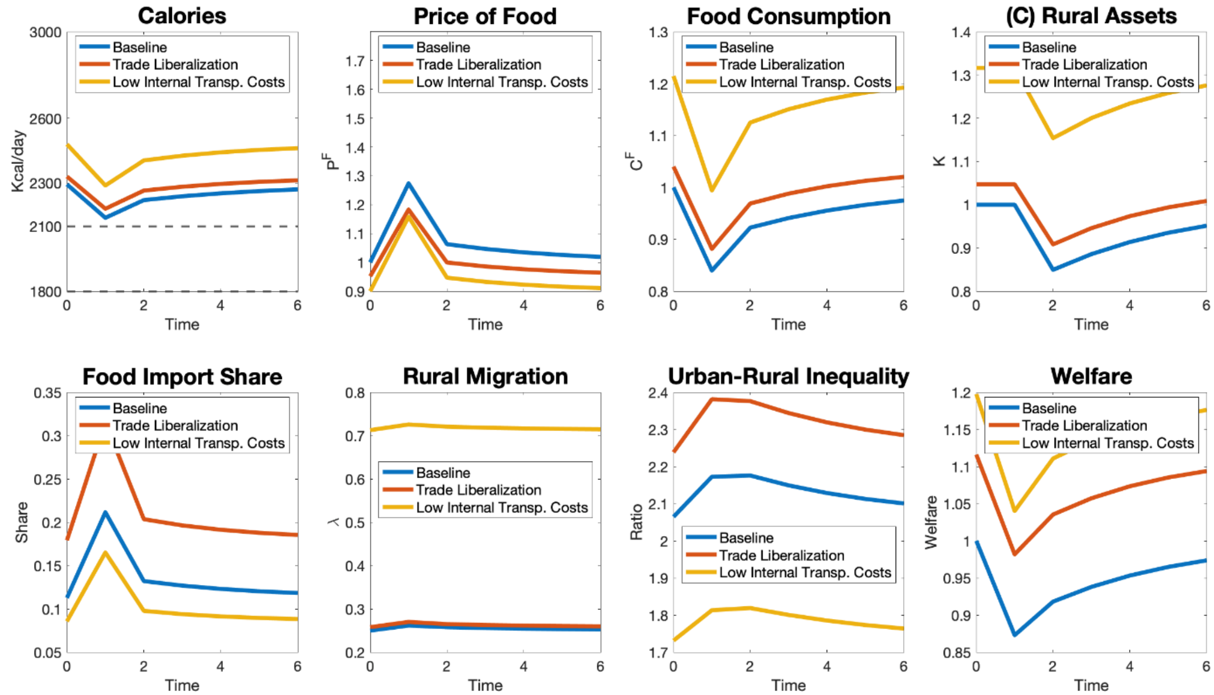


Source: IMF staff calculation

1/ Food price, food consumption, capital and welfare series are normalized, i.e., all values are expressed relative to baseline value in period 0. For simplification purpose, results are shown only for rural households.

11. Reducing mobility costs appears more effective than lowering import tariffs to mitigate the effects of climate-related food insecurity shocks on households. Figure 5 shows that the distance between total calories consumed, and the critical requirement threshold is larger in the low internal mobility cost scenario than in the trade liberalization scenario. Although the reduction in import tariffs is expected to supplement the domestic food supply by increasing food imports, its gains are not evenly distributed between urban and rural areas. Urban households benefit slightly more from this policy, as their consumption basket include a larger share of imported food. This leads to increased inequality between urban and rural areas, while in the low internal mobility cost scenario, inequality is relatively lower because farmers have access to urban areas and additional opportunities to increase their income, consumption, capital, and welfare.

Figure 5. Niger: Trade Liberalization vs Low Internal Mobility Cost[1]



Source: IMF staff calculation

1/ Food price, food consumption, capital and welfare series are normalized, i.e., all values are expressed relative to baseline value in period 0. For simplification purpose, results are shown only for rural households.

C. Policy Recommendations

12. Given the positive effects of cash transfers on welfare illustrated in the model simulations, there is an urgent need to operationalize, on a larger scale, a better coordinated national social safety net system (*See SIP #1 on Social Spending Efficiency*) . This would particularly imply:

- Strengthening the technical and financial resources of the National Mechanism for the Management and Prevention of Food Crises (DNPGCA) to improve its capacity to forecast and manage food crises and coordinate donor interventions.

- Improving safety net programs coordination through the development of a unified social registry and the establishment of common monitoring schemes to reduce fragmentation and overlaps. As a prerequisite, the government should improve the coverage and security of the existing civil registry scheme.

- Increasing safety net spending while improving the mix between long-term, predictable transfers, and shock responses. Directing three-quarters of safety net spending to long-term, predictable transfers to the chronically food insecure and/or chronically poor would help them smooth consumption, increase resilience, build human capital, and reduce the need for shock response interventions.

13. Food sales at moderate (subsidized) price and agricultural fertilizer subsidy systems should be reformed to improve their targeting, efficiency, and sustainability. Although subsidies have lower welfare gains compared to cash transfers, they could significantly decrease inequality and the price of domestically produced food as well as food imports (a key dimension of food security). Moreover, when a solid cash transfer system is not yet established, a well-designed and targeted subsidies scheme could contribute to reinforce people resilience to shocks. In this regard, the establishment of a unified social registry will pave the way for the reform of the current system of subsidized food sales, which does not target the most affected and vulnerable populations in food crisis situations. This reform should also extend to the fertilizer subsidy system (CAIMA), including its financing mechanism to ensure its sustainability by the establishment of a revolving fund replenished with sales profits.

14. Improving financial inclusion of the most vulnerable populations, including women and youth, is key to strengthen their resilience to climate shocks. Access to the formal financial system for these populations will help smooth their consumption and increase their investments to reinforce their physical and human capital and improve their resilience to shocks. Financial inclusion would play the same role as a cash transfer system in easing households budget constraints before and after shocks[5], with the difference that (i) it is not costly for urban households and (ii) could have positive long run effects. While the cost of cash transfers for urban households is permanent over time through taxation, financial inclusion could have positive effects in the long run by allowing people to self-finance their resilience to shocks through access to credit (without waiting for any assistance from the Government). In the context of Niger, key areas of reform include (SIP on Financial Inclusion in Niger):

- Improving financial literacy.
- Promoting digital financial services.
- Advancing the operationalizing the Financial Inclusion Fund.
- Re-establishing a healthy and solid microfinance sector.
- Strengthening supervision is necessary to preserve the stability of the financial system and build costumer's trust.

15. Increasing investment in road and information technology infrastructure to lower internal mobility costs and open up agricultural production areas will also reduce the impact of climate shocks on rural populations. Model simulations suggest that these investments, along

[5] See the IMF departmental paper on "*Climate Change and Chronic Food Insecurity in Sub-Saharan Africa*": https://www.imf.org/en/Publications/Departmental-Papers-Policy-Papers/Issues/2022/09/13/Climate-Change-and-Chronic-Food-Insecurity-in-Sub-Saharan-Africa-522211.

with tariff reductions on imported food staples[6] , would yield large gains by furthering integration between rural and urban areas in goods and labor markets. Moreover, these investments have the ability to facilitate rural populations access to basic social services—health, education, and social protection—needed to strengthen their human capital and thus improve their resilience to shocks. Fostering mobility will also reinforce the functioning of agricultural markets and improve competitiveness in exports to neighboring countries, while allowing rural populations to access imported food substitutes at lower price in the event of a shortage of domestic production. However, there is a trade-off between the two policies in terms of the time horizon of their gains. While the gains on investments in road infrastructure are expected to materialize in the medium term, the removal of import tariffs could be used as a short-term instrument to respond quickly to shocks.

D. A Brief Description of the Model

Overview

The economy is made up of two locations, rural (R) and urban (U), and is populated by L_U urban households and a continuum Ω of rural households of mass L_r. Both types of households consume an agricultural (F) and a non-agricultural good (M).[7] All domestic agricultural production is carried out by rural households who may then either sell their agricultural output to urban households, export it or use it for self-consumption. Households in the urban area only produce non-agricultural goods. Rural households allocate a fixed share of their labor endowment to agricultural production and use the remaining share to supply wage labor to a perfectly competitive firm in the non-farm sector. Rural households can decide to supply wage labor in the rural or urban area. Urban households, on the other hand, only supply labor to the non-farm sector firm in the urban area and are not allowed to move outside the urban area. Both agricultural and non-agricultural goods can be imported from and exported to a foreign economy denoted by the rest of the World (*ROW*).

Consumption and Saving

Households residing in location $i = 1, \dots, N$ have preferences over a final good C_t and net period savings B_{it} represented by the utility function

$$U_t = \log(C_{it} - \bar{C}) + \beta \log B_{it+1} . \qquad (1)$$

Households maximize the utility function above by choosing optimal consumption and savings subject to the per-period constraint $P_{it}C_{it} + B_{it+1} = Y_{it} + (1-\delta)B_{it}$, where Y_{it} is current household

[6] In response to this year's food crisis, the government reduced tariffs on some imported food products (e.g., vegetable oil, sugar, rice, etc.) to ease pressure on food prices.

[7] The non-agricultural good encompasses all goods produced off-farm, which includes both manufacturing and service sector goods. In our framework, the agricultural sector should be thought of as including not only the production of staple and cash crops but also livestock rearing. We equate the agricultural sector to the food sector.

income, P_{it} is the price of the final consumption good, and $(1-\delta)B_{it}$ is the net of depreciation stock of savings carried over from the previous period, with $0<\delta<1$. Y_{it} is defined as household net income which consists of gross income minus income tax paid plus cash transfers received, i.e. $Y_{it} = Y^{gross}(1 - tax_t) + cash_{it}$.

We introduce a consumption requirement $\bar{C}$ to capture the notion that households must consume a minimum amount of goods (a mix of agricultural and non-agricultural goods) to satisfy their basic needs. Importantly, the consumption requirement generates a consumption smoothing motive so that if income falls temporarily in the current period the household reacts by decreasing their savings rate, i.e. by allocating a larger share of wealth $W_{it} \equiv Y_{it} + (1 - \delta)B_{it}$ towards current consumption. The opposite happens under a temporary income windfall. Note, however, that under a permanent income increase the household reacts by increasing the savings rate. Intuitively, the higher income allows the household to move away from the consumption constraint and save at a rate closer to the "ideal" savings rate $\beta / (1+\beta)$.

The household will optimally select to spend a nominal amount Xit on goods consumption given by

$$X_{it} = \overline{P}_{it}\overline{C} + \frac{1}{1+\beta}\left(Y_{it} + (1-\delta)B_{it} - \overline{P}_{it}\overline{C}\right) ,$$

where P_{it} is the price of purchasing the minimum consumption bundle. The remaining amount of household wealth will be saved, i.e.

$$B_{it+1} = \frac{\beta}{1+\beta}\left(Y_{it} + (1-\delta)B_{it} - \overline{P}_{it}\overline{C}\right) .$$

The savings rate sav_{it} is therefore given by $sav_{it} = [\beta/(1 + \beta)](1 - P_{it}C/W_{it})$ and is increasing in wealth.

The final goods consumption bundle C_{it} is made up of agricultural and non-agricultural goods. Here, again, we introduce a subsistence requirement but this time for food consumption $\overline{C^F}$ to capture non-homothetic preferences in the final goods bundle. Note the important distinction between $\bar{C}$ and $\overline{C^F}$. The first is an upper-tier consumption requirement that introduces non-homotheticity in final goods consumption vs savings preferences, while the second is a lower-tier consumption requirement that introduces non-homotheticity for agricultural vs non-agricultural goods preferences. Thus, preferences for the final good are described by the Stone-Geary utility function

$$C_i = \left(C_i^F - \overline{C}^F\right)^{\alpha}\left(C_i^S\right)^{1-\alpha} \quad \text{, with } 0 < \alpha < 1 , \qquad (2)$$

where we omit the time subscripts for simplicity. Households take the price of the agriculture good P_i^F and non-agriculture good P_i^S as given and maximise function (2) subject to $P_i^F C_i^F + P_i^S C_i^S = P_i C_i$, where $P_i C_i$ is total household spending on goods. This problem yields optimal food (or agricultural) consumption.

$$C_i^F = \overline{C}^F + \alpha \frac{\left(P_i C_i - P_i^F \overline{C}^F\right)}{P_i^F} \tag{3}$$

Calorie consumption kcal_{it} has a constant elasticity of substitution relation with food consumption so that $kcal_{it} = a(C_{it}^{F})^{\zeta}$, where $0 < \zeta < 1$ and a is a constant.

We assume households always spend enough to satisfy the food subsistence requirement, i.e.

$P_i C_i \geq P_i^F \bar{C}^F$, for all households. For non-agriculture, optimal consumption is

$$C_i^S = (1-\alpha)\frac{\left(P_i C_i - P_i^F \overline{C}^F\right)}{P_i^S} \tag{4}$$

Optimal consumption implies the final goods consumption price index

$$P_i = \zeta (P_i^F)^{\alpha} (P_i^S)^{1-\alpha} \tag{5}$$

where $\zeta \equiv \alpha^{-\alpha}(1-\alpha)^{-(1-\alpha)}$ is a constant. We assume households derive utility from consuming different local varieties of goods and define the Armington aggregator with elasticity of substitution σ, with $\sigma > 1$

$$C_i^j = \left(c_{iR}^{j\;\frac{\sigma-1}{\sigma}} + c_{iU}^{j\;\frac{\sigma-1}{\sigma}} + c_{iROW}^{j\;\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \quad \text{, for } j = \{F,S\} \tag{6}$$

where c^F_{in} denotes food goods imported into $i = \{U,R\}$ from location $n = \{U,R,ROW\}$. The urban area produces only non-agricultural goods and so $c_{iU}^F = 0$ for all $i = \{U,R\}$. The Armington aggregator implies the CES price index:

$$P_i^j = \left(p_{iR}^{j\;\frac{\sigma-1}{\sigma}} + p_{iU}^{j\;\frac{\sigma-1}{\sigma}} + p_{iROW}^{j\;\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \tag{7}$$

where p^j_{in} is the price of sourcing goods from location n into i. Shipping goods from one location to another incurs an iceberg trade cost τ_{in} for any pair n,i with $\tau_{in} \geq 1$ and $\tau_{ii} = 1$ for all i, n. The price of importing goods from abroad, p^j_{ROW}, is exogenously determined. The net price of goods imported into i from n will equal factory gate prices in n plus a transportation cost τ_{in}, so that

$$p_{in}^j = \tau_{in}\, p_n^j \tag{8}$$

One can show that the wholesaler will optimally choose to source goods according to the import share equation:

$$\pi_{in}^{j} \equiv \frac{p_{in}^{j} c_{in}^{j}}{X_{i}^{j}} = \frac{\left(p_{n}^{j} \tau_{in}\right)^{1-\sigma}}{\sum_{n'=\{R,U,ROW\}} \left(p_{n'}^{jF} \tau_{in'}\right)^{1-\sigma}} \quad (9)$$

where π_{in}^{j} is the share of expenditures X_i^{jF} spent on purchasing goods from origin n and $\tau_{i,ROW}$ is the cost of importing goods from abroad into i. The share of expenditures from location n falls with farm-gate price $p^j{}_n$ and shipping cost τ (or $\tau_{i,ROW}$ from imports) and rises with the CES price index P_i^j. In other words, more is purchased from origin n whenever sourcing goods from there becomes relatively cheaper than the cost of final food goods bundle C_i^{jF}.

Agricultural Production

Each rural household has access to a plot of land of size h which they use to produce an agricultural good according to the production function

$$q_t^F = h\left[z_t k_t^{\gamma} f_t^{\theta}\right] \text{, with } 0 < \gamma < 1 \text{ and } 0 < \theta < 1 \quad (10)$$

where z_t is farm productivity, k_t is installed farm capital and f_t is fertilizer input. Capital should be interpreted in a broad sense so as to include a wide range of productive inputs like, seeds, tools, machinery, irrigation and livestock. All rural households supply the same fixed amount of labor to their total farm production, which we set equal to $0 < \rho < 1$. Households allocate their savings across the two productive factors so that their marginal productivity is equalized, i.e.

$$\frac{k_t(\omega)}{f_t(\omega)} = \frac{\gamma}{\theta}\frac{p^f}{p^k} \quad (11)$$

where p^f and p^k are the prices of fertilizer and capital, respectively. Households are unable to borrow and so installed capital k_t and fertilizer f_t are financed exclusively through the accumulation of household savings. Rural households employ all their savings B_{it} in the form of farm capital and fertilizer and may then decide to either carry over the net-of-depreciation capital stock to the next period or sell it off to finance current consumption. Contrarily to capital, fertilizer depreciates fully in each period. All capital goods and fertilizer are imported from the foreign economy.[8]

Non-agricultural Sector

In both the urban and rural areas there is a perfectly competitive firm that produces non-agricultural goods by hiring labor from households. In the rural area, only rural households are hired. Production is given by the linear production technology:

$$Q_{Rt}^M = z_R^M(\psi_t(1-\rho)L_{Rt} \quad (12)$$

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[8] This is a simplifying assumption we make to avoid adding a block of equilibrium conditions for capital goods. This assumption is arguably consistent with many low-income economies in which farm inputs like fertilizer, seeds and animal feed, as well as tools and machinery are largely sourced from abroad

where ψ_t is the share of rural households who decide to stay in the rural area. The remaining portion $(1 - \psi_t)$ migrates to the urban area for wage work and so production in the urban area is given by

$$Q_{Ut}^M = z_U^M [L_U^U + (1-\psi_t)(1-\rho)L_U] \tag{13}$$

where z^M is local non-agricultural TFP. Households earn wage rate w_{it}. In equilibrium, firms make zero profits or, equivalently, the marginal revenue product of labor is set equal to the wage rate

$$w_{it} = p_{it}^M z_i^M \text{ , for } i = \{R,U\} \text{ ,} \tag{14}$$

where p^S_{it} is the price of local non-agricultural goods. The foreign economy ROW has an exogenously set wage rate (and consumption price index) that households take as given.

To incorporate the wage work location choice by rural households, we assume they face the location choice problem

$$V_t(\omega) = \max_{i=\{R,U,ROW\}} \frac{D_i}{\kappa_{it}(\omega)} \frac{w_{it}}{P_{it|R}} \qquad \text{with } D_R > D_n \text{ for any } n = \{U,ROW\} \text{ ,} \tag{15}$$

where D_i is the amenity value of location i. The assumption that $D_R > D_n$ for any $n = \{U,ROW\}$ captures moving costs which make rural households more likely to supply labor in the rural area than elsewhere, holding fixed real wages $w_{it}/P_{it|n}$.[9] Term $\kappa_{it}(\omega)$ captures an idiosyncratic work location preference that follows a Frechet distribution with scale parameter 1 and dispersion parameter λ, iid across households and time. The choice of work location will depend on the household's idiosyncratic draws for the costs of temporary migration.

Households that draw a low cost of temporary migration for a given destination will be more likely to exploit spatial differentials in real wages by seeking employment in that location. For other households, the costs will be so high that they will prefer all members to remain in the residence location rather than migrate to another, higher-paying location. The dispersion parameter λ measures the degree of heterogeneity in idiosyncratic location preferences, with $\lambda \rightarrow \infty$ representing the extreme case where preferences are fully homogeneous across all households. Lower values of λ correspond to more heterogeneity in personal preferences for locations.

Note that V_t depends on a migration-adjusted real wage. The price index $P_{it|R}$ combines the price indices of rural and destination location according $P_{it|R} = P_{it}^{\phi} P_{Rt}^{1-\phi}$ with $0 < \Phi < 1$. We employ this migration-adjusted price index to account for the role of remittances.[10] We assume all members of the household pool their income and use transfers to equalize real consumption with some members of the household buying goods at the destination price index P_{it} and the remaining at the origin price index P_{nt}. Parameter Φ governs the relative consumption expenditure at the two

[9] Moving costs should be interpreted as a combination of different factors that go beyond explicit monetary costs like bus fares. They may also include other important factors such as home-bias amenity preferences and non-monetary costs of moving (e.g., searching for a job or housing)

[10] In many low-income countries one or a few members of a household (typically males) move out in search of temporary work opportunities, who then transfer some of their earnings back to the other, non-migrating, members of the household in the origin location.

locations and we set it equal to the share of migrating household members. To ensure real consumption is equalized across members of the household, migrants send remittances back to their residence location, where the other members of the household live.

Using the properties of the Frechet distribution, one can show that the probability of sending migrants to (or remaining in) location i, ξ_{it}, is given by

$$\xi_{it} = \frac{D_i\left(\frac{w_{it}}{P_{it|R}}\right)^{\lambda}}{\sum_{m=1}^{N} D_m\left(\frac{w_{mt}}{P_{mt|R}}\right)^{\lambda}} . \tag{16}$$

With the existence of a continuum of rural households, the law of large numbers implies that actual migration flows will match the probability above. This implies that $\xi_{Ut} = \psi_t$. Seen through the expression above, parameter λ controls the size of migration responses to changes in local conditions. A lower λ implies that an increase in wages in i will generate a smaller inflow of migrants into that location. λ therefore governs the elasticity of migration flows with respect to seasonal migration-adjusted real wages. In the extreme case of $\lambda \rightarrow \infty$, the elasticity of migration is infinite and indirect utility $V_t(\omega)$ must be equalized for all households. Note that real wages will not necessarily be equalized across locations due to amenity differences.

Market Clearing

In this section we close the model by providing market clearing conditions. To ensure market clearing in goods markets, we impose the condition that sales Y_i^j for $j = \{A, S\}$ must equal the sum of sales across all destinations. First, assume exports to the rest of the world $X_{ROW,n}^{jF}$ are given by a constant elasticity function of prices with elasticity $1 - \sigma$

$$X_{ROW,n}^j = \kappa^j \cdot \left(\tau_{ROW,n}\, p_n^j\right)^{1-\sigma} , \tag{17}$$

where κ^j is a constant. The market clearing condition for goods is then given by

$$Y_i^j = \sum_{n=1}^{N} \pi_{ni} X_n^j + X_{ROW,i}^j , \tag{18}$$

which pins down the vector of equilibrium farm-gate price of goods p_i^j for $i = \{R, U\}$. Since markets are perfectly competitive, sales must equal expenditures which must in turn equal total farm sales. We can then write

$$p_i^j Q_i^j = \sum_{n=1}^{N} \pi_{ni} X_n^j + X_{ROW,n}^j \tag{19}$$

This expression provides us with a system of equations that pin down equilibrium prices in the market. Given trade shares π_{ni} (which depend on the characteristics of the trade network and the relative efficiency of each location) and exports $X_{ROW,i}{}^{F}$, the equation provides the vector of equilibrium goods prices ($p^{S}{}_{U}$, $p^{F}{}_{R}$, $p^{S}{}_{R}$) that are consistent with market clearing. Finally, we assume the government budget is balanced so that tax revenues R_t must equal spending S_t on cash transfers and fertilizer subsidies

$$R_t \equiv \left(L_U Y_{U,t} + L_R Y_{R,t}\right) \cdot \text{tax}_t = L_R(f_{it}\ p^f\, sub_t + \text{cash}_t) \equiv S_t\ , \qquad (20)$$

for in all time periods t = {1, 2, ...}. Note we assume that rural households are the sole recipients of government benefits.