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The Macroeconomic Impact of Agricultural Input Subsidies

Karol Mazur
Peking University

Laszlo Tetenyi
Bank of Portugal & Católica Lisbon School of Business and Economics

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Keywords: agriculture, food security, structural change, misallocation
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Peking University HSBC Business School
University Town, Nanshan District
Shenzhen 518055, China

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Governments intervene in agriculture worldwide, a sector particularly susceptible to efficiency losses due to transaction costs. Upon introducing advantageous home production of food into a general equilibrium model with heterogeneous agents and incomplete markets, we show that agricultural input subsidy programs generate consumption-equivalent welfare gains of up to 3.8%. We demonstrate that Malawi's large program benefits society by mitigating the impact of transaction costs, redistributing resources to the poor, and providing insurance, thereby stimulating occupational mobility. We validate the model dynamics using an event study on the staggered introduction of input subsidy programs across Sub-Saharan Africa.

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†Peking University HSBC Business School, contact: kmazur@phbs.pku.edu.cn

‡Bank of Portugal & Católica Lisbon School of Business and Economics, contact: ltetenyi@bportugal.pt

1 Introduction

The theoretical justification for government intervention stems from the need to correct market failures through resource redistribution and enhancing efficiency. The Coase [1960] theorem shows that a necessary condition for markets to achieve efficient outcomes in the presence of externalities is absence of transaction costs. While transaction costs permeate all markets (Coase [1937]), agriculture is especially susceptible due to the high perishability of its products, its reliance on quality infrastructure, and an efficient network of intermediaries.

Most governments worldwide operate programs to support their local agriculture and to foster growth and structural transformation.[1] In the 2000s, several countries in Sub-Saharan Africa (SSA) implemented large-scale input subsidy programs (ISPs), facilitating access to modern seeds and fertilizers to produce staple crops, the direct source of critical nutrients. Malawi, one of the poorest countries in SSA, has implemented one of the largest ISPs. At the same time, it also suffers from large gaps between consumer and producer prices of food, indicating potentially large transaction costs that drive a wedge between the incentives of farmers for production and urban demand, impacting local access to food. While ISPs improve food security, they may divert resources from cultivating cash crops, leading to reduced export revenues and potentially inhibiting structural change. This paper studies the trade-offs associated with ISPs and their broader dynamic implications for inequality and resource misallocation.

We begin by constructing a one-shot economy with incomplete markets in which risk-averse households face risky occupation choices between rural farming and urban manufacturing. We demonstrate that transaction costs associated with food procurement by urban residents, combined with the lack of formal insurance, lead to *overfarming* in the laissez-faire competitive equilibrium. By choosing an inefficiently high probability of becoming a farmer, which results in higher prices for manufacturing goods, precautionary households achieve perfect consumption insurance. While this model cannot rationalize agricultural subsidies, a simple extension that incorporates production under collateral constraints does so. However, the impact of ISPs in the presence of transaction costs may extend beyond these static

[1] See Caselli [2005], Gollin et al. [2014] and Suri and Udry [2022].

effects by providing additional social insurance against idiosyncratic shocks or redistributing resources across groups.

Therefore, in the second step, we develop a quantitative model that allows for the dynamic and distributional effects of ISPs. Heterogeneous households face an occupational choice between cultivating staples, cash crops, and wage work, all of which are subject to sector-specific, idiosyncratic productivity shocks. As in canonical models of entrepreneurship [Buera et al., 2015], farmers are subject to a collateral constraint that limits their input use. Staples play a central role because every farmer who consumes more staples than they produce must also pay a per-unit transaction cost on the difference. Together with the non-homothetic nature of preferences due to food subsistence constraints, this structure implies that most rural households forgo pure profit maximization in favor of maintaining their food security. Switching from rural farming to urban labor is risky because it involves substantial entry costs and eliminates the option of home-produced food. Households can smooth their consumption directly only through a single non-contingent bond. The government finances the subsidies for imported agricultural inputs by taxing urban laborers. Finally, we carefully account for the ISP's impact on structural change patterns by opening our economy to external trade, limiting the strength of general equilibrium (GE) effects operating through market prices (Johnston and Mellor [1961], Matsuyama [1992]).

In the third step, we apply the model to the case of Malawi by using a simulated method of moments matching both micro- and macro-level evidence. Our quantitative GE analysis, which accounts for transitional dynamics, reveals that the large FISP in Malawi generates a substantial average welfare gain equivalent to a permanent 3.5% increase in consumption. Due to the relaxation of financing constraints, coupled with equilibrium price adjustments, the program primarily benefits asset-poor households by improving redistribution and providing insurance, stimulating occupational mobility.

FISP generates a disproportional increase in food production not only due to the direct effect of reducing the price of inputs and relaxing collateral constraints but also due to the realignment of farmers' incentives to produce with the value of food for urban residents. Moreover, the increase in the price of cash crops relative to staples prompts farmers to allocate a higher share of their land to cash crops, resulting in higher export revenues that enable further imports of both agricultural inputs and manufacturing goods. By switching off individual elements of the model, we demonstrate that the single key parameter driving the framework's welfare predictions is the transaction cost in the food sector, followed by the standard friction of costly occupational switching. We also demonstrate that a partial equilibrium (PE) analysis, which ignores equilibrium price adjustments, overestimates the actual welfare gains of the program by a factor of two, as well as the evolution of key economic variables. By varying the subsidy rate, we show that Malawi's program design is close to optimal.

We conclude the paper by empirically revisiting the introductions of ISPs among SSA countries in the 2000s and contrasting them with transition dynamics induced by our model. To this end, we leverage the wealth of data in the Food and Agriculture Organization Statistics (FAOStat) to construct a panel of macro-agricultural outcomes in SSA countries and compare the ISP-adopters against non-adopters. Although entirely non-targeted, fertilizer use, staple and cash-crop yields, relative prices, land allocation, and food security measures respond consistently with our model.

Literature review. Our paper fits within the recent macro-development literature reviewed by Buera et al. [2021b]. Caselli [2005], Restuccia et al. [2008], Vollrath [2009], and Gollin et al. [2014] document that the difference between the productivity of agricultural (rural) and manufacturing (urban) sectors is much larger in developing countries than in developed countries. Lagakos and Waugh [2013], Herrendorf and Schoellman [2015] or Chen et al. [2023] focus on the reasons behind these productivity gaps. In contrast, de Janvry et al. [2015], Chen et al. [2022], Adamopoulos et al. [2022], or Lagakos et al. [2023] discuss policy interventions that can alleviate the underlying causes. We contribute to this line of work by quantitatively analyzing agricultural input subsidies. As such, we also contribute to the predominantly empirical literature on ISPs surveyed in Jayne et al. [2018] by, similarly to Kaboski and Townsend [2011], considering the heterogeneous impacts of rural interventions within a structural GE framework with an endogenous Agricultural Productivity Gap (APG) due to transaction costs.

McArthur and McCord [2017] show in a panel of countries that intensified use of fertilizers, modern seeds, and agricultural irrigation significantly impacts economic growth and structural change. Stressing the importance of transaction costs in the food sector, we show that a purely subsidy-induced input intensification can not only increase agricultural productivity, as argued by Boppart et al. [2023], but also welfare, even in the absence of shocks to the import costs of food or fertilizer (as in Adamopoulos and Leibovici [2024] or Donovan and Brooks [2025]).

Our approach builds on a workhorse GE model with heterogeneous agents and incomplete markets following the tradition of Bewley [1986], Imrohoroğlu [1989], Huggett [1993], and Aiyagari [1994]. Buera et al. [2011], Midrigan and Xu [2014], Moll [2014], and Tetenyi [2019] show how financial constraints reduce aggregate productivity and efficiency of intersectoral allocations. Itskhoki and Moll [2019] analyze government interventions capable of reducing factor misallocation and Buera et al. [2021a] study macroeconomic consequences of microcredit programs. Donovan [2021] and Mazur [2023] study the interactions between incomplete consumption insurance and input adoption in Indian agriculture. Our paper extends this class of models by the feature of transaction costs (de Janvry et al. [1991], Omamo [1998], Arslan and Taylor [2009], Arslan [2011] and Gollin and Rogerson [2014]), an important determinant of agricultural and occupational choices that invalidates the usual profit maximization paradigm due to food security concerns. Chakraborty et al. [2025] is another application of this class of models to analyzing agricultural policies in India, albeit without the key feature of transaction costs.

Finally, our work complements the strand of literature evaluating ISPs using quantitative models. Arndt et al. [2016] use a static and deterministic computable general equilibrium model to quantify the aggregate impact of FISP in Malawi. Bergquist et al. [2022] and Garg and Saxena [2022] develop static spatial trade models to evaluate the distributional implications of ISPs in Uganda and India, respectively. Our framework is characterized by inefficient competitive equilibrium, allowing us to discuss not only distributional, but also efficiency consequences of ISPs.

2 A theory of transaction costs & incomplete markets

We highlight the core equilibrium effects of transaction costs, occupational choice, and market incompleteness in a simple one-shot model. Consider a measure one of ex-ante homogeneous households who are tasked with choosing the probability χ of becoming a farmer $(j = F)$ vs. becoming a worker $(j = W)$. A household solves the following problem:

$$\max_{\chi \in [0,1]} \chi V^F + (1 - \chi) V^W \tag{1}$$

Conditional on occupational realization j, the agent's value is derived from standard $\log - \log$ preferences over consumption of food (f) vs manufacturing goods (m):

$$V^j = \log(f^j) + \log(m^j), \ j \in \{F, W\} \tag{2}$$

As a worker, the agent receives an endowment of A units of manufacturing goods. Similarly, as a farmer, she receives an endowment of 1 unit of food. Our key assumption is that food consumption by workers is subject to a per-unit transaction cost Q, i.e., that a 1 unit of food consumed by workers requires a transfer of $1 + Q$ units, with Q units of food being lost. We further assume that consumption of manufacturing goods is not subject to any such transaction costs.

We define a laissez-faire competitive equilibrium as a collection of decisions $\{\chi, f^F, m^F, f^W, m^W\}$ and relative price p of manufacturing goods such that:

1. households maximize their expected utility (1) taking p as given,

2. budget constraints of agents $j \in \{F, W\}$ hold:

$$\begin{aligned} f^j + p \cdot m^j &\leq 1, \quad && \text{if } j = F \\ (1 + Q)\, f^j + p \cdot m^j &\leq pA, && \text{if } j = W \end{aligned} \tag{3}$$

3. food and manufacturing markets clear:

$$\begin{aligned} \chi f^F + (1-\chi)(1+Q)f^W &= \chi \\ \chi m^F + (1-\chi)m^W &= (1-\chi)A \end{aligned} \tag{4}$$

To characterize the implications of transaction costs, we compare the laissez-faire equilibrium with the constrained efficient and first-best planner solutions. Informally,[2] the constrained efficient allocation assumes that the planner can directly dictate choices of χ subject to respecting individual budget constraints (and not being able to redistribute across types directly). The first-best planner similarly makes all decisions for households and can directly resources across types due to being constrained only by the resource constraints. Importantly, while the economy is an endowment economy from the household's perspective, it is a production economy from the planner's. With this, we find the following:

Theorem 1. *If $Q = 0$, the laissez-faire competitive equilibrium (LF) coincides with both the first best (FB) and constrained efficient (CE) allocations. If $Q > 0$, LF is characterized by an inefficiently high share of farming relative to both FB and CE. In particular, it holds that: $\chi^{LF} > \chi^{FB} > \chi^{CE}$.*

Proof. See Appendix A. □

By defining the Agricultural Productivity Gap as the ratio of manufacturing output's value per worker to that of farming per farmer, i.e. APG $= \frac{p \cdot A \cdot \chi}{1-\chi}$, Theorem 1 implies that:

Corollary 1. *If $Q > 0$, the APG in LF exceeds that in CE: $APG^{LF} > APG^{CE}$*

The inefficiency of LF relative to FB arises due to the planner's optimal plan prescribing equalization of manufacturing good consumption across all households and, due to the technological advantage of farmers in food *consumption*, allocating $(1+Q)$-proportionally more food to farmers. As such, farmers are efficiently favored over workers by the planner, which creates profitable deviations for households in choosing higher χ in a decentralized economy.

[2] We define these objects formally in Appendix A.

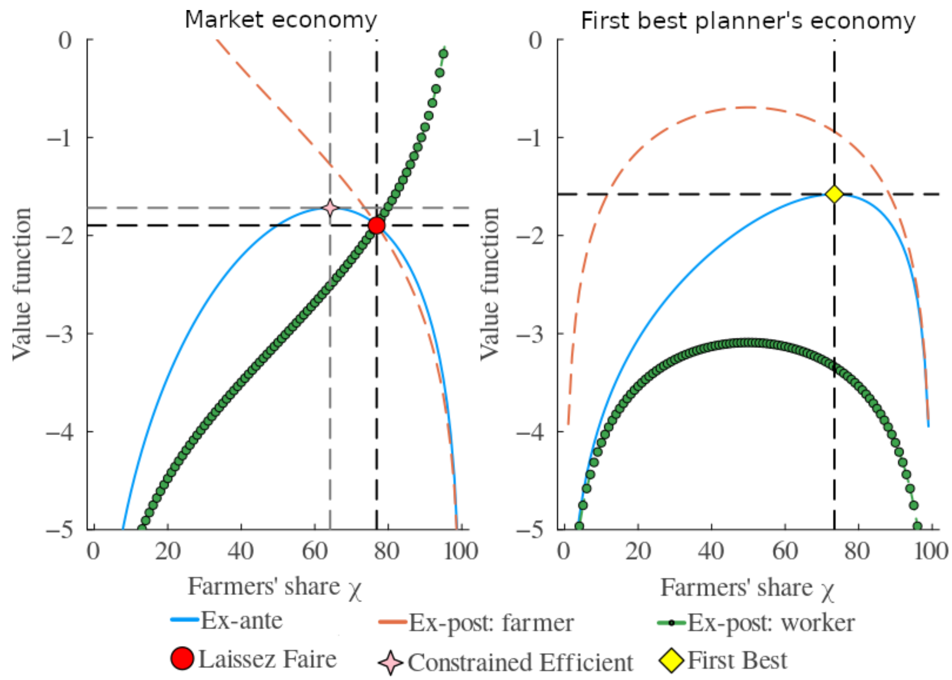


Figure 1: Welfare properties of different equilibria in the simple model

Note: Parameters assumed $A = 2$ and $Q = 10$.

Through the lens of the Coase [1960] theorem, the inefficiency of laissez-faire arises only with positive transaction costs, $Q > 0$, even though pecuniary externalities are always present. Transaction costs render the budget constraints (3) of the two occupations asymmetric. Although markets are incomplete, the risk-averse households achieve perfect consumption insurance against occupational risks through excessive selection into farming. This can be seen from the first order condition (FOC) for the occupational decision χ in the competitive equilibrium: $V^F = V^W$. Thus, perfect insurance comes at the cost of inefficient reduction in the value of farming to the benefit of the worker's value.

We explain the rest of Theorem 1 with the numerical example in Figure 1 mapping the properties of the market (left panel) and planner's (right panel) allocations across the values of occupational choice χ. Firstly, in the left panel, the difference between the laissez-faire and constrained efficient allocations confirms that a constrained planner can improve the ex-ante welfare of households. By coordinated reduction in χ, the planner increases the relative supply of manufacturing goods and makes the more numerous group of farmers better off. Doing so implements *constrained efficient inequality*. In the market economy, the value of being a farmer (worker) is strictly increasing (decreasing) in χ as food becomes more abundant relative to the manufacturing good. However, in the first-best allocation, the planner can directly redistribute resources across the two groups, allowing for both the increase in the number of workers and the increase in farmers' consumption. The constrained efficient allocation attains a higher urbanization rate $1 - \chi$ than the first-best, due to the technological constraints on redistribution in the form of two independent budget constraints.

As a consequence, subsidizing farming (in the spirit of FISP) cannot decentralize either the constrained efficient or the first-best allocations. To this end, in Appendix A, we extend the above model by agricultural production technology that is subject to collateral constraints. Although we lose analytical tractability, simulations in Figure A.2 demonstrate that with a binding collateral constraint, increases in subsidies *reduce* the equilibrium share of farmers χ through increases in food supply, reducing the value of being a farmer. Furthermore, we demonstrate that the Ramsey planner optimally subsidizes farmers' inputs if financial frictions are severe enough, even for very high values of Q. We also show that the optimal choice of the subsidy level is *increasing* in the level of transaction costs if there are equilibrium spillovers of Q to tightening the collateral constraint. An additional implication of $\chi^{FB} > \chi^{CE}$ in Theorem 1 is that a policy reducing the urbanization rate can be welfare improving if it also optimally redistributes from workers to farmers.

Overall, the results from the two simple models in this section indicate that while transaction costs lead to overfarming on the extensive margin, financial frictions result in underfarming on the intensive margin, creating room for optimal input subsidization. In the next section, we develop a model that can capture further dynamic and distributional effects of FISP.

3 Quantitative model

A continuum of infinitely lived households of measure one populate the economy. Households face occupational, production, and financial decisions in the presence of idiosyncratic shocks to urban and rural productivity. The occupation choice is also a migration decision, as the household either works in urban areas for a representative manufacturing firm and earns labor income, or lives in rural areas and operates their farms. The occupation choice is frictional due to the associated entry and maintenance costs. Farmers can produce staple crops or cash crops using imported intermediate inputs. The working capital constraint may limit a farmer's input choice. While households consume staples, cash crops, and manufacturing goods, there is also external demand for cash crop exports. Stone-Geary preferences and transaction costs for staples introduce food security considerations. Households can imperfectly insure their consumption by saving in a non-state contingent asset. The government finances FISP through urban labor taxation or foreign aid. GE price effects connect all decisions, with the open economy aspects limiting the responsiveness of cash crop prices.

To ease notation, we omit individual and time subscripts. We show how to solve the household's problem with transaction costs in Appendix B. In Appendix C, we formally define the equilibrium and outline the numerical algorithm for solving it.

Finally, in designing our economy, we have naturally faced trade-offs between maintaining its computational feasibility and approximating the empirical environment in Malawi. We map our model to the empirical setting in Section 4.2.

3.1 Households

Time is discrete, and households live forever. In each period, they inelastically provide one unit of labor as urban workers or rural farmers on a unit of non-tradable[3] land that is not usable outside of agriculture. They discount the future at the rate of β and maximize the expected lifetime utility $U(\mathbf{c}) = \mathbb{E}\left[\sum_{t=0}^{\infty} \beta^t u(\mathbf{c}_t)\right]$, with the following constant elasticity of substitution (CES) per-period utility function:

$$u(\mathbf{c}) = \frac{1}{1-\sigma}\left(\psi_S (c_S - \bar{c}_S)^{\frac{\epsilon-1}{\epsilon}} + \psi_B c_B^{\frac{\epsilon-1}{\epsilon}} + (1-\psi_S-\psi_B)\, c_M^{\frac{\epsilon-1}{\epsilon}}\right)^{\frac{(1-\sigma)(\epsilon-1)}{\epsilon}} \tag{5}$$

where σ is the coefficient of relative risk aversion, ϵ is the intratemporal elasticity of substitution, and ψ_S, ψ_B, ψ_M control the share of expenditure of staples (S), cash crops (B, price p_B), and manufacturing goods (M, price p_M) with $\mathbf{c}$ denoting a consumption vector of these goods. We normalize the producer price of staples to 1.

[3] Appendix E considers a relaxation of this assumption.

The preferences are non-homothetic due to $\bar{c}_S$ introducing the food subsistence constraint, implying that poorer households have a higher expenditure share on staples. Furthermore, purchasing staples is subject to a transaction cost: acquiring q_S units of staples costs $(1 + Q_S)q_S$. Non-homotheticity and transaction costs introduce food security concerns, as food consumption becomes more important for poorer households, and self-produced food allows households to avoid paying transaction costs.

In every period, households face uncertainty due to the time-evolving vector $z = \left(\theta^R, \theta^U\right)$ of idiosyncratic rural θ^R and urban θ^U productivities. After observing z, households decide on their occupation for the current period: working as farmers producing staples or cash crops in agriculture, or as urban laborers in manufacturing. We denote this occupational decision by $e' \in \{A, M\}$. Upon moving from rural into urban areas and changing occupations, households must pay the one-off, labor-denominated entry cost wF_M. We assume that urban households earn labor income with a competitive wage rate w per unit of skill θ^U. When living in urban areas, households need to pay a per-period maintenance cost wFM_M. Whenever rural households engage in cash crop farming, they must pay the per-period maintenance cost of wFM_B. Staple farming is assumed to be a baseline activity that is not subject to entry or maintenance costs. Overall, there are four sources of demand for urban workers: from the competitive manufacturing sector, from cash crop farmers and urban households paying maintenance, and from rural households that decide to move to urban areas.

3.1.1 Agriculture in rural areas

Households in rural areas operate as agricultural producers, generating profits π_A by optimally choosing the allocation of land between staples $(1 - l)$ and cash crops l, as well as intermediate inputs for staples and cash crops x_S, x_B, subject to a collateral constraint.

Their profits are generated according to the following technology:

$$\pi_A(x_S, x_B, l; a, \theta^R) = q_S(x_S, l; \theta^R) + p_B q_B(x_B, l; \theta^R) - TC_A(x_S, x_B; a) - \mathbf{1}_{\{l>0\}} wFM_B \quad (6)$$

subject to:

$$q_S(x_S, l; \theta^R) = \theta^R x_S^{\zeta}(1-l)^{\phi} \quad (7)$$

$$q_B(x_B, l; \theta^R) = \theta^R x_B^{\zeta} l^{\phi} \quad (8)$$

$$TC_A(x_S, x_B; a) = (1-\tau_S)\, p_X x_S + p_X x_B \leq \kappa a \quad (9)$$

In what follows, we refer to farmers who choose $l > 0$ and pay the maintenance cost FM_B as cash crop farmers, whereas farmers with $l = 0$ are referred to as staple farmers, even though cash crop farmers may also produce staples.

The total input cost $TC_A(x_S, x_B, l; a)$ depends on the (exogenously given) price p_X and the staple-inputs subsidy rate $\tau_S \geq 0$. Crucially, agricultural producers are subject to the *within-period working capital constraint* (9), ensuring that the total expenditures on agricultural inputs do not exceed κ-times their total wealth a.

To ensure positive profits from agricultural production, we assume jointly decreasing returns to scale $(\zeta, \phi) \in (0,1)$ and $\zeta + \phi \in (0,1)$, with ϕ driving the benefits of multiproduct farming. The optimal behavior of farmers implies three observations:

Proposition 1. *The household-level share of land devoted to cash crops l is ceteris paribus (i) decreasing in the staple-input subsidy rate τ_S, (ii) increasing in the relative price of cash crops p_B, and (iii) decreasing in Q_S if $c_S \geq q_S$ and is unaffected by Q_S if $c_S < q_S$.*

Proof. See Appendix B. □

The proposition highlights that while higher staple subsidies directly decrease the land allocated to cash crops, there are two indirect, opposing effects. First, increases in the relative supply of staples result in higher prices for cash crops. Second, as a consequence of (iii), increasing the subsidy rate τ_S with $Q_S > 0$ increases the share of land devoted to cash crops for cash crop farmers who move from the region of state space satisfying $c_S < q_s$ to $c_S \geq q_S$.

3.1.2 Financial market structure

Households can save using a risk-free asset a', denominated in staple consumption good, at the interest rate r. This asset is pooled by a competitive financial sector, lending intertemporally to the manufacturing sector at the rate $r + \delta$, where r is the deposit rate and δ is the capital depreciation rate. We further assume households cannot borrow across periods, i.e., $a' \geq 0$.

Finally, as we assume that $\kappa \in (0, 1)$, the working capital constraint (9) captures both the lack of intratemporal financial intermediation for advance payments covering production costs and the relatively low investment liquidity of household wealth.

3.1.3 Dynamic programming

The household's problem can be summarized recursively as a joint occupation choice and expenditure minimization problem:

$$V(z,a,e) = \max_{a',e',c_S,c_B,c_M,x_S,x_B,l} \log(C) + \beta \mathbb{E} V(z',a',e') \tag{10}$$

$$s.t.: \quad C = \left(\psi_S \left(c_S - \bar{c}_S\right)^{\frac{\epsilon-1}{\epsilon}} + \psi_B c_B^{\frac{\epsilon-1}{\epsilon}} + \psi_M c_M^{\frac{\epsilon-1}{\epsilon}}\right)^{\frac{\epsilon}{\epsilon-1}} \tag{11}$$

$$X_{e' \in \{A,M\}} + a' = Y_{e' \in \{A,M\}} + (1+r)a \tag{12}$$

$$X_{e' \in \{A,M\}} = c_S + p_B c_B + p_M c_M + Q_S \cdot \hat{c}_S \tag{13}$$

$$\hat{c}_S = \max\{c_S - \mathbf{1}_{\{e'=A\}} \cdot q_S(x_S, l; a, \theta^R), 0\} \tag{14}$$

$$\begin{aligned} Y_{e' \in \{A,M\}} = {} & \mathbf{1}_{\{e'=M\}} \left(\theta^U w - wFM_M - \mathbf{1}_{\{e=A\}} wF_M\right) \\ & + \mathbf{1}_{\{e'=A\}} \pi_A(x_S, x_B, l; a, \theta^R) \end{aligned} \tag{15}$$

where X and Y denote the expenditures and income of a household with state vector (z, a, e) making occupational choice e' and choosing the optimal consumption bundle C. Unlike in standard models of occupation choice and entrepreneurship (Buera et al. [2015]), transaction costs imply that the occupation choice and expenditure minimization must be solved jointly. We first jointly solve the household's occupational and expenditure problems, including the decision to purchase $\hat{c}_S$ quantity of staples on the market, given a specific state vector (z, a, e) and a choice of C. Then we solve the dynamic problem of choosing C, a'.

3.2 Urban sector

The representative firm in the urban sector produces the manufacturing good using a standard Cobb-Douglas technology $Y_M = K^\alpha L^{1-\alpha}$. The markets for capital and labor are competitive and centralized. All urban workers receive the same wage w per efficiency unit θ^U. The firm solves:

$$\pi_M = \max_{K,L}\{p_M K^\alpha L^{1-\alpha} - (1+\tau_w)wL - (r+\delta)K\} \tag{16}$$

where K denotes physical capital sourced from households' savings. Furthermore, labor L is the residual of households providing urban labor, net of the labor hired for covering the cash crop maintenance, urban entry, and urban maintenance costs:

$$L = \int \big(\mathbf{1}_{\{e'=M\}}\theta^U - \mathbf{1}_{\{e'=A,l>0\}}FM_B - \mathbf{1}_{\{e=A,e'=M\}}F_M - \mathbf{1}_{\{e'=M\}}FM_M\big)dG \tag{17}$$

with G denoting the joint distribution of productivity z, assets a, and past occupation e. For numerical simplicity, τ_w is the labor income tax rate imposed by the government only on the manufacturing firm; that is, urban workers providing services for entry and maintenance costs are not subject to this tax.

3.3 Government

The total expenditures of government X_G are given by:

$$X_G = p_X \tau_S \int x_S dG_{z,a,e'=A} \tag{18}$$

Our baseline assumption is financing of the subsidy program with labor taxes. Thus, we assume that the following per-period government budget constraint holds in every period:

$$\begin{aligned} X_G = \tau_w w\Big(\int dG_{z,a,e'=M} - F_M \int dG_{z,a,e=A,e'=M} - FM_M \int dG_{z,a,e'=M} \\ - FM_B \int dG_{z,a,e'=A,l>0}\Big) \end{aligned} \tag{19}$$

We also consider a scenario of foreign aid financing where the amount FA fully covers the expenditures on the program. In this case, expenditures are given by $X_G = FA$.

3.4 Current account

The rest of the world demands cash crops according to the following export demand function:

$$c_B^F = a_D {p_B}^{b_{D_p}} y^{b_{D_y}} \tag{20}$$

which, implied by our empirical evidence below, depends negatively on prices ($b_{D_p} < 0$) and positively on the economy's output ($b_{D_y} > 0$). The output component of this demand function is a reduced form for the idea common in Armington [1969] class of models that more productive economies produce higher quality goods that are more demanded (as supported by empirical evidence, e.g. in Hallak [2006]).

Importantly, we assume that the economy's current account (CA) is balanced[4] in every period, and its structure looks as follows:

$$CA = X - (M^M + M^X) \overset{!}{=} 0 \tag{21}$$

$$X = p_B c_B^F = a_D {p_B}^{1+b_{D_p}} y^{b_{D_y}} = p_B \int (q_B \mathbf{1}_{\{e'=A\}} - c_B) dG_{z,a,e'} \tag{22}$$

$$M^M = p_M \Big(\int c_M dG_{z,a,e'} - Y_M \Big) \tag{23}$$

$$M^X = p_X \Big(\int (x_S + x_B) dG_{z,a,e'=A} \Big) \tag{24}$$

The value of imports $M^M + M^X$ and exports X is determined in equilibrium by prices and the aggregation of individual decision rules.[5] As the interest rate is fixed and we impose capital market clearing in equilibrium, the net exports of the manufacturing firm and the associated price adjust such that the current account clears in equilibrium.

[4]In the case of foreign aid financing, the amount FA enters into the current account equation (21).
[5]We implicitly assume that manufacturing goods can be imported or exported at the prevailing domestic price p_M.

3.5 Equilibrium & welfare measurement

We formally define the recursive competitive equilibrium along the transition path in Appendix C. Our welfare measurement is based on a utilitarian social welfare function with welfare changes expressed in consumption equivalent terms, that is, the population-weighted averages of the permanent percentage changes in consumption making each society member indifferent between the pre-subsidy steady state and a transition induced by an unexpected reform, assuming perfect foresight over the evolution of the post-reform economy. We also utilize a long-run welfare metric reporting the average, across all members of the society, of the permanent percentage changes in consumption based on the indifference between the pre- and post-reform steady-state allocations constructed using the pre-reform stationary distribution.

4 Empirical application

We apply our framework to the case of Malawi, the country with the largest ISP in SSA. In Section 4.1, we introduce the relevant data sources. Section 4.2 discusses mapping the model to the empirical setting. In Sections 4.3-4.4, we develop a calibration strategy disciplining our model's parameters based on the literature, the institutional setting, and the simulated method of moments.

4.1 Data sources

Our empirical work is based on two data sources: the LSMS microdata for Malawi and the FAOStat macrodata for SSA countries. For calibration, we extensively rely on the FAOStat series on agricultural exports, including the value and quantity of production, the quantity and price of intermediate inputs, and agricultural land use patterns. We utilize this dataset again for the panel analysis of all SSA countries in Section 6, for which we draw additional series on the share of the undernourished population, the share of irrigable land, the share of rural population, total population, and GDP per capita.[6]

[6] Table A.5 in Appendix D summarizes this data separately for treated and control countries based on the assignment of the ISP treatment in the 2000s, which we rely on in the analysis of Section 6.

Furthermore, we utilize the 2010 rural cross-section of Malawi LSMS data. Most importantly, we proxy transaction costs through the gaps between consumer and producer prices of staples for which we utilize household-level data on the value of agricultural production.

We discipline the idiosyncratic productivity process by leveraging the panel component of the Malawi LSMS for 2010 and 2013. As we estimate this process separately for rural and urban households, we restrict the sample to households that do not change residence between the two waves. For urban households, our measure of income is the total annual earnings from wage labor, ganyu, and self-employment (following Bick et al. [2022]). In agriculture, we focus again on the annual value of output. We use controls similar to those in the 2010 cross-section. Table A.6 in Appendix D summarizes the LSMS data.

4.2 Mapping the model to the empirical setting

Institutional environment. As of 2023, Malawi is one of the ten poorest countries in the world, with 20% of the population undernourished, 40% of its children stunted, and a life expectancy of only 65 years. The country relies heavily on agriculture, with 80% of its population living in rural areas and primarily engaged in small-scale, non-mechanized, and subsistence-based agriculture. Around 40% of rural households cultivate only maize. Most of the agricultural production is self-consumed and does not enter the market. Cash crops such as tobacco, sugar, tea, groundnuts, and other fruits and vegetables comprise around 80% of Malawi's total export revenue.

Following the first half of the 2000s, marked by poor harvests and high maize prices, the newly elected government of Malawi introduced a large-scale FISP in 2005 to stimulate food security and boost agricultural productivity. The central government has made FISP-supported inputs available to more than half of Malawi's farmers by distributing the procured inputs to local authorities responsible for distributing voucher coupons to local populations. A typical coupon entitled its recipient to purchase at a symbolic price one bag of improved maize seeds, one 50kg bag of basal maize fertilizer, and one 50kg bag of urea for top dressing. While the official policy stated targeting of households needing help to afford inputs independently, a large body of empirical works reviewed in Jayne et al. [2018]

found mixed evidence on following these guidelines in practice.[7] The feasibility of effective targeting and rationing of subsidized inputs is further weakened by active secondary markets for subsidized inputs in SSA (Diop [2023]).

Therefore, we model FISP in equation (9) as linear subsidies for staple inputs that are universally available with the subsidy rate targeting the relative size of the program. Furthermore, we assume in the baseline allocation that the government finances FISP entirely by taxing labor income in urban areas.[8] We conservatively follow this approach because foreign donors financed only 7%-18% of the FISP costs between 2005 and 2010 (as discussed in Chirwa and Dorward [2013]).

Transaction costs. The central parameter of our paper is the per-unit, exogenous[9] transaction cost of purchasing staples Q_S, which drives the gap between the consumption and the producer prices of staples. These gaps can be particularly large in Africa, as agricultural products often travel long distances through inadequate infrastructure (Teravaninthorn and Raballand [2009]), pass through multiple layers of intermediaries (Bergquist and Dinerstein [2020]), and are stored using inefficient technologies (Sheahan and Barrett [2017]). Furthermore, farmers, traders, and final customers may lack information about the locations of markets offering the best prices (Jensen [2007]).

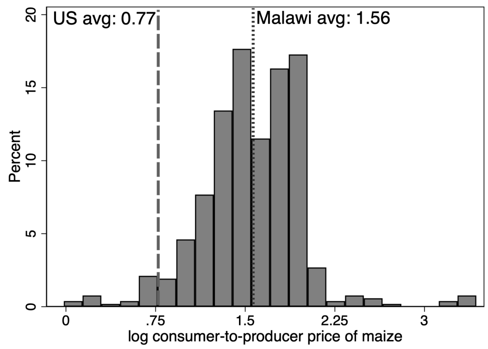
The left panel of Figure 2 displays a histogram of the log relative difference between the per kilogram price of maize faced by consumers and received by producers, derived from the 2010 LSMS data for Malawi. The mean value of 4.75 is significantly larger than 2.16 estimated for the case of wheat in the US.[10] This evidence points to substantial transaction costs in the staple market of Malawi, going far beyond the efficient transaction or retail

[7] Basurto et al. [2020] find that village chiefs target FISP not so much to the poorest households but to those with higher returns to inputs with limited consequences of links to local authorities otherwise.

[8] Malawi's government introduced farmers' income taxation only in 2010 and initially only for farmers selling cash crops, see (Gourichon et al. [2017]).

[9] Exogenous per-unit transaction costs implicitly assume perfect competition among intermediaries of that sector, consistent with the study of agricultural intermediaries in Malawi by Fafchamps and Gabre-Madhin [2006] documenting the existence of many small traders operating under constant returns to scale technology, with an inability to exploit any increasing returns to scale due to inefficient monitoring technologies, underdeveloped infrastructure, and incomplete legal systems. For Kenya, Bergquist and Dinerstein [2020] find evidence of significant market power among intermediaries.

[10] Wheat is by far the most important staple in the US. We estimate its relative price using the USDA Wheat Yearbook Tables for 2015-2020 by comparing the wholesale price of wheat flour and edible byproducts to the price received by farmers for wheat grain.



(a) Histogram of relative prices

	$\log \frac{Consumer\ price}{Producer\ price}$
Daily market in village	-0.082**
	(0.038)
Log dist. to district admin center	0.081**
	(0.036)
District FE	Yes
Observations	521
R^2	0.34

(b) Regression analysis of determinants

Figure 2: Distribution and determinants of consumer-to-producer maize prices in rural Malawi

Note: Panel (a) presents the histogram of consumer-to-producer price ratios for one kg of green maize in Malawi. Panel (b) presents the regression exploring associations between consumer-to-producer price ratios and village-level characteristics. The data is for Malawi from the 2010 wave of LSMS. The average relative price of wheat for the US is from the USDA Wheat Yearbook Tables 2015-2020.

costs incurred in the relatively frictionless US economy. The right panel of Figure 2 provides additional evidence that the across-village variation in average relative prices correlates negatively with the presence of active local markets and positively with the distance to administrative centers (so-called "bomas"), which serve as proxies for market frictions arising from a variety of reasons.

We capture potential differences between producer and consumer prices of cash crops by assuming that cultivation of cash crops is associated with a per-period fixed maintenance cost FM_B (instead of a per-unit cost). We follow this approach because the empirical cash crop expenditure share ψ_B is significantly lower than that of staples ψ_S, and cash crops often do not constitute a good source of nutrients or are relatively difficult to process at home.

Agricultural production function. Land in Malawi is usually governed by customary rules, with virtually no formal markets. As a consequence, 80% of farms are smaller than 1 hectare with an average farm size of 0.81 ha (Chen et al. [2023]). For these reasons, we abstract from land markets in the model and assume that if the land owner moves into the urban area, the land is not reused or resold, and vice versa, when a household moves to the rural area, they use their potentially long unused land without incurring any cost (open frontier assumption). We account for the heterogeneous quality and quantity of land through a time-varying (but persistent) agricultural productivity process. In Appendix E.3, we investigate the robustness of our results upon relaxing the open land frontier assumption.[11]

In addition to representing fixed transaction costs, the cash crop maintenance cost, FM_B, also captures additional outlays required for production such as, in the case of tobacco, the costs of building curing barns or hiring additional labor during the work-intensive curing stage. Maintenance costs FM_B allow farmers to increase their total revenue by producing both crops simultaneously, capturing improved income smoothing and insurance due to crop rotation and diversification throughout the agricultural year.

Open economy. We model the key aspects of the open economy in detail because introducing FISP increases total imports of fertilizers, which implies that the economy either has to increase exports or reduce imports of other goods, with potentially non-trivial welfare consequences.

Although Malawi has some domestic seed producers, Kachule and Chilongo [2007] show that the country imports virtually all of the fertilizer.[12] According to FAOStat, Malawi exported the vast majority of its cash crop output, with the associated revenue accounting for almost all of the country's export revenue in 2005-2011. Motivated by these observations, our model economy imports all the demanded agricultural inputs at an exogenous price and exports cash crops in quantity and at a price determined in equilibrium by the interaction of external and internal demand forces. As the rest of imports are overwhelmingly[13] non-agricultural goods, the model economy, apart from fertilizer, imports (and in some counterfactuals potentially exports) manufacturing goods.

Occupational choice and migration. We associate the agricultural household's decision to become an urban worker with migrating from rural to urban areas. Using data from Malawi's 2008 Population Census and 2013 Labor Force Survey, Narae [2016] finds that only 15% of the urban population is engaged in agriculture (primarily cultivation of maize), and around a third of the rural population is engaged in non-agricultural activities.[14]

[11] See Manysheva [2022] for analysis of the land market reforms' impact on resource allocation and productivity in a framework similar to ours.

[12] World Bank data shows that in 2009, Malawi used almost 60,000% of the fertilizer produced in the country. Patterns for most other SSA countries are similar.

[13] 73.5% of all imports were manufacturing goods in 2010. Source: WITS

[14] Adjognon et al. [2017] confirm the latter in the 2010 and 2013 waves of LSMS data and show that these occupations in rural areas are of secondary importance as they generate only 16% of income.

These findings reflect the fact that rural jobs concentrate on relatively low value-added jobs in manufacturing (e.g., maize milling) or services (trade or restaurants), as opposed to the relatively higher share of urban jobs concentrated in the clothing, chemicals, and furniture industries, or the business and finance sectors, and public administration (Narae [2016]).

We denominate the maintenance and entry costs in terms of the urban wage rate, a standard assumption (Klenow and Li [2023]). Our interpretation of the urban entry cost encompasses the expenditures required for travel or job search. The urban maintenance cost corresponds to typical periodic expenses on housing and utilities, or the large financial commitments required by rural migrants to maintain social links with their extended families.[15] Furthermore, although purely financial in our formulation, these costs capture broader utility- or information-based barriers to migration (Lagakos et al. [2020]).

Financial frictions. We assume household assets are relatively illiquid to finance the within-period purchases of agricultural inputs, i.e., $\kappa \in (0, 1)$. This illiquidity aligns with the findings of Fafchamps et al. [1998] showing that rural households in Burkina Faso rarely sell livestock during adverse times. Furthermore, Daidone et al. [2019], Ambler et al. [2020], and Aggarwal et al. [2022] show that giving randomized cash grants to Malawian farmers generates positive investment responses, suggesting that farmers may face financial constraints.

4.3 Calibration strategy

We calibrate the steady state of the model to the Malawian economy in 2010, with FISP already in place. The assumed model periodicity is annual. We externally set the values of 16 parameters based on our estimates and the literature. We use the simulated method of moments to calibrate the remaining 10 parameters, ensuring that the model's implied moments align with relevant empirical moments. Tables 1 and 2 summarize the estimation procedure and parameters chosen. As robustness checks, Figure 3 evaluates the performance of our model in matching non-targeted evidence on inequality in Malawi.

Preferences. We assume that households evaluate their consumption bundle with a

[15] Azam and Gubert [2006] review evidence on migration in SSA and conclude that migration decisions are usually a collective decision made by the extended family, or even the whole village, that comes with expectations about future remittances and insurance transfers.

log utility function and are relatively impatient by setting the time preference parameter $\beta = 0.75$. The latter number is calibrated such that the simulated ratio of within-period borrowing to GDP $\frac{p_X \int [(1-\tau_S)x_S + x_B] dG}{Y}$ matches the evidence in Agar et al. [2012] of agriculture's 1.1% share in total lending in 2010 Malawi's banking sector. In parameterizing the CES aggregator of consumption in (5), we assume that the elasticity of substitution across the three goods of our economy is $\epsilon = 0.95$, which is well between the values of 0.85 suggested in Herrendorf et al. [2013] and of 1 assumed in Buera et al. [2011]. We set the subsistence consumption parameter[16] at $\bar{c}_S = 0.05$ such that the simulated moment of the share of agriculture in GDP equals 30%.[17] We define the undernourishment level $\tilde{c}_S = 0.145$ so that the baseline allocation has $\bar{u} = 22\%$ of undernourished households with staple consumption below $\tilde{c}_S$, as reported in the 2010 Global Hunger Index for Malawi.

We set the consumption share of staples $\psi_S = 0.12$, which is the approximate consumer expenditure share in the US spent on food (based on the 2018-2021 data of the Bureau of Labor Statistics). Similarly, the consumption share parameter of cash crops captures preferences for clothing, alcohol, tobacco, and personal care products, as reflected in an approximately 6% expenditure share in the US. We assume a slightly higher value of $\psi_B = 0.08$ as some of the food in Malawi also comes from cash crops (e.g., groundnuts). The implied manufacturing share is $\psi_M = 0.80$. By taking the US economy as a frictionless benchmark for expenditure shares, our approach assumes stability in consumption preferences across the development path.

Regarding the external demand for cash crops (20), we estimate the relevant price and output elasticities through a two-way fixed effects regression using the unbalanced panel of 39 SSA countries covering the period 1970-2020 from FAOStat:

$$\log(D_{i,t}) = a_D + \underbrace{b_{D_p}}_{=-0.1^*} \cdot \log P_{i,t} + \underbrace{b_{D_y}}_{=0.75^{***}} \cdot \log Y_{i,t} + \gamma_i + \gamma_t + \epsilon_t \tag{25}$$

where $D_{i,t}$ is country i's quantity of tobacco exports in year t, $Y_{i,t}$ denotes the GDP per

[16] In the model, given $\bar{c}_S$, we find the minimum level of sector-neutral TFP ensuring that the least productive and asset-poor staple farmer (which is the always feasible outside option for other occupations) can afford the minimum level of consumption and input investment.

[17] Source: World Bank

Parameter	Value	Target	Data	Model
Discount factor β	0.75	Share of lending to agriculture in GDP Agar et al. [2012]	1%	2%
Urban entry cost F_M	28	Rural-urban migration rate Bick et al. [2022]	1%	1%
Urban maintenance cost FM_M	0.65	Share of urban population [LSMS2010]	18%	19%
Stone-Geary parameter $\bar{c}_S$	0.05	Agriculture output share in GDP [WB 2010]	30%	29%
Cash crop export demand shifter a_D	0.28	Share of cash crops exported [FAO 2010]	73%	70%
Subsidy rate for staple inputs τ_S	72%	Aggregate cost of program (% GDP) Chirwa and Dorward [2013]	3%	2%
Cash crop maintenance cost FM_B	0.07	Share of land devoted to staples [FAOStat]	70%	72%
Working capital constraint κ	10%	Cash crop farmers share w/ suboptimal inputs Brune et al. [2016]	73%	72%
Returns to scale in farming land ϕ	0.6	Standard deviation of average product of farms Chen et al. [2023]	1.8	1.7
Urban-rural shock correlation ρ_{RU}	0.23	Agricultural productivity gap Gollin et al. [2014]	6.5	6.3

Table 1: Internally calibrated parameters

Note: Data moments come from the literature cited, LSMS, and FAOStat. Simulated moments come from the steady state with tax-financed FISP.

capita[18] and $P_{i,t}$ is the export price (derived from dividing the data series on the nominal value of output by the total quantity produced). We focus on tobacco exports as this is Malawi's most important export good. We assume the values of estimated elasticities directly in our model. Finally, we set the export demand shifter in (20) to $a_D = 0.28$ such that the simulated moment of the share of cash crops exported matches its empirical counterpart of 73% from FAOStat.[19]

Production. We assume that the transaction cost parameter of $Q_S = 2.0$ reflects the excess consumer-to-producer price ratio in Malawi above the US level, which we take as a frictionless benchmark. We conservatively choose a value 20% lower than the gap reported in Figure 2 to account for the seasonality in maize prices over the agricultural year (De Magalhaes and Santaeulalia-Llopis [2018]).

For the agricultural production function (6), we pin down the cost share of intermediates as $\zeta = \frac{\text{expenditures on maize seeds and fertilizer}}{\text{value of maize harvested}}$. According to FAOStat data for Malawi in 2010, the average fertilizer use was 35 kilograms per hectare, with an estimated average pre-subsidy price of 600 USD per ton. Since FAOStat does not contain data on seed application rates, we assume it to be equal to the recommendation of 25 kgs per ha in the Malawi Country Report by Mabaya et al. [2021]. The same source also quotes the average pre-subsidy price

[18]Computationally, this feature makes the export demand less rigid, allowing for clearing in the cash crop market. We implement this demand function using wage rate as a proxy for output (and therefore the economy's productivity and export goods quality), which allows us to reduce the already high dimensionality of the fixed point problem solved.

[19]This ratio is estimated as the value-weighted export share of Malawi's top 4 export items' tonnes in 2010 (tobacco, sugar from beet or cane, tea leaves, and cotton).

Parameter	Value	Target/Source
Preferences		
Risk aversion σ	1	Assumption
Elasticity of substitution ϵ	0.95	Herrendorf et al. [2013] & Buera et al. [2011]
Staple consumption share ψ_S	0.12	US Bureau of Labor Statistics
Cash crop consumption share ψ_B	0.08	US Bureau of Labor Statistics
Price elasticity of export demand ϵ_{D_p}	-0.1	Our estimates from FAOStat
Output elasticity of export demand ϵ_{D_y}	0.75	Our estimates from FAOStat
Production		
Transaction cost in staple sector Q_S	2.0	Our estimates from Figure 2
Price of intermediate input p_X	1.26	Our estimates from FAOStat
Cost share of intermediate inputs ζ	0.15	Our estimates from FAOStat & Mabaya et al. [2021]
Capital share in manufacturing α	0.33	Assumption
Capital depreciation rate δ	0.05	Assumption
Interest rate r	0.05	Assumption
Household productivity process		
Rural AR(1) persistence ρ^R	0.62	Our estimates from LSMS
Urban AR(1) persistence ρ^U	0.49	Our estimates from LSMS
Rural AR(1) standard deviation σ^R	0.87	Our estimates from LSMS
Urban AR(1) standard deviation σ^U	1.12	Our estimates from LSMS

Table 2: Externally calibrated parameters

of modern maize seeds at 11.42 USD per 5kg bag, implying total expenditures of 78.1 USD per ha. According to FAOStat, the average producer price of maize was 230 USD per tonne, with an average yield of 2.2 tonnes per ha, implying a value of 506 USD for maize produced per ha. We arrive at $\zeta = 0.15$, consistent with estimates in Boppart et al. [2023] for the least developed countries. Using the same data, we estimate the input price using the FOC governing optimal input use of staple producers $p_X = \zeta \cdot \frac{q_S}{x_S} = 0.15 \cdot \frac{230 \cdot 2.2}{35+25} = 1.26$.

For the manufacturing production function, we set a standard value of the capital output-share $\alpha = 33\%$. We fix the interest rate on savings at $r = 5\%$. Likewise, we set the depreciation rate $\delta = 5\%$, which is the average of the 4% estimate for the US in Karabarbounis and Neiman [2014] and the 6% estimate in Midrigan and Xu [2014].

For other production parameters, we jointly target the model equivalents of empirical moments. With $\phi = 0.6$, the model matches the standard deviation of the average farm revenue product of 1.8 documented in Chen et al. [2023]. By targeting the variations in the average farm revenue product, we ensure that θ^R also captures differences in land quality and quantity across Malawian households. With $\tau_S = 72\%$, the FISP's fiscal cost equals approx.

3% of the GDP program cost, as reported in Chirwa and Dorward [2013] for Malawi in 2010.[20] Brune et al. [2016] find that 70% of cash crop farmers use a suboptimal amount of inputs, which requires $\kappa = 0.1$. Data from FAOStat shows that cropland devoted to staples equals 70%, implying $FM_B = 0.07$.[21] Matching the very low migration rate of 1% documented in Bick et al. [2022] requires a high entry cost from rural to urban of $F_M = 28$.[22] Furthermore, we calibrate a low urban maintenance cost of $FM_M = 0.65$,[23] helping to replicate the 18% urban population share in Malawi in 2010.

Household productivity process. We draw on the panel dimension of the Malawi LSMS dataset for 2010 and 2013 to parameterize the idiosyncratic productivity processes. In the case of rural households, we regress the log of household-level agricultural output per ha of land cultivated (evaluated at gate prices) on the vector of household controls, including the marital status of the head of household, their age and age^2, gender, schooling years, number of adults in the household and total kgs of fertilizer used. In the case of urban households, we regress the log of earnings per hour of work on a similar vector of controls (without fertilizer use). Since the empirical sample suffers from endogenous selection, we apply the Heckman [1979] correction on both regressions. We take the residuals of these two regressions $\theta^j_{i,t}$ as measures of our idiosyncratic productivity shocks. Allowing for persistent shocks, we assume that both rural θ^R and urban θ^U follow first order autoregressive (AR(1)) processes with lognormal innovations: $\log(\theta^j_{i,t+1}) = \rho^j_\theta \theta^j_{i,t} + \epsilon^j_{i,t}$ with $\epsilon^j_{i,t} \sim N(0, \sigma^{j2})$ and $j \in \{R, U\}$. Our results indicate that working in the urban sector is relatively riskier, as the annualized persistence of rural and urban productivity shocks is 0.57 and 0.49, with standard deviations of 0.94 and 1.11, respectively.[24] As the rural-urban productivity shock correlation is one of the important drivers of migration, $\rho_{RU} = 0.24$ enables the model to match the large agricultural productivity gap of 6.3 in 2005 Malawi documented in Gollin

[20] In line with the Malawi's institutional setup discussed above, we assume no subsidies for cash crops.

[21] In the data, we compute this moment as a share of Malawi's key staples (maize, wheat, millet, sorghum, plantain, rice, potatoes, cassava, and soybeans) in the total land devoted to primary crops. Evaluated at the equilibrium wage rate, this maintenance cost is equivalent to \$72.

[22] Evaluated at the equilibrium wage rate, this entry cost is equivalent to \$29,365. In equilibrium, households migrate from rural to urban areas only when they receive the highest urban productivity shock, which allows them to overcome the entry barrier despite having relatively low assets.

[23] Evaluated at the equilibrium wage rate, this maintenance cost is equivalent to \$694.

[24] Appendix D contains the productivity estimation results. We discretize the empirically estimated AR(1) process using the method of Gospodinov and Lkhagvasuren [2014].

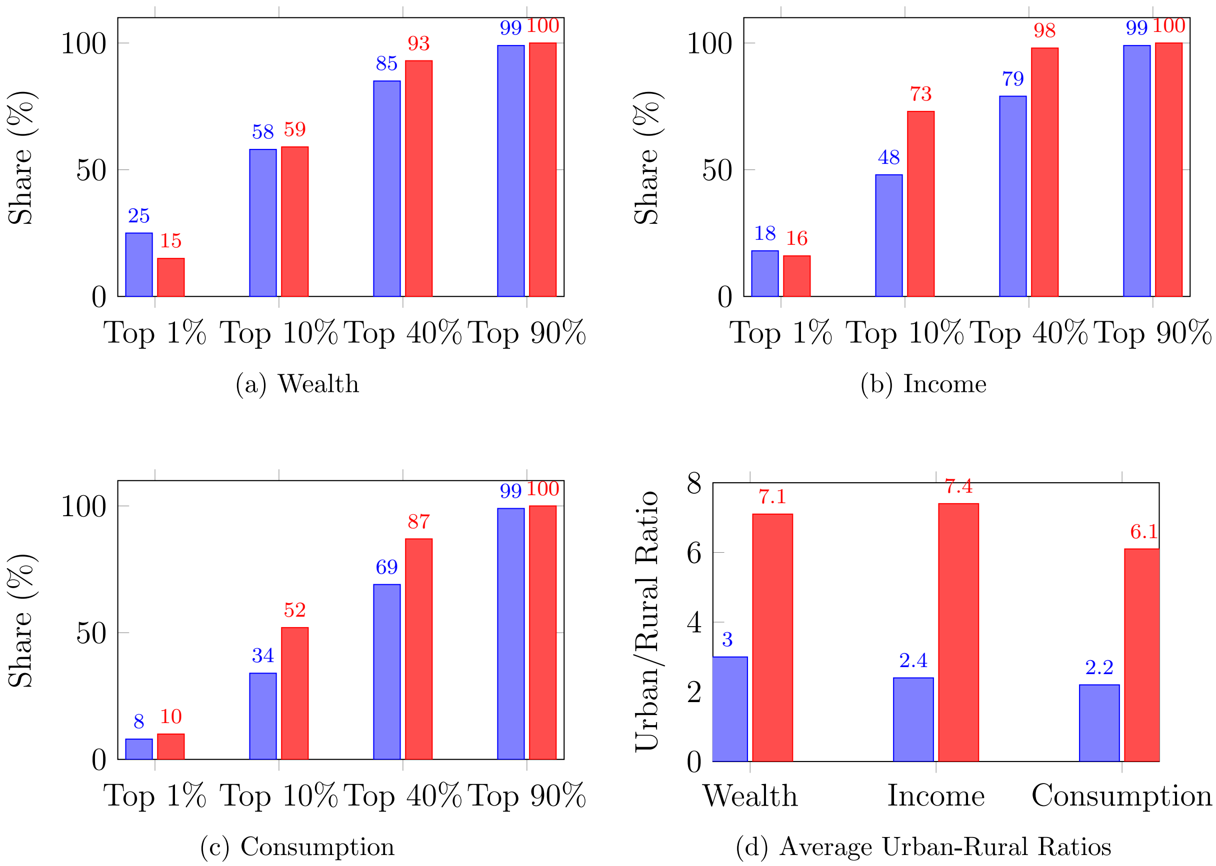


Figure 3: Non-targeted inequality measures: Data vs. Model.

Note: The figure shows top percentile shares in wealth, income and consumption and average urban-rural ratios, from De Magalhaes and Santaeulalia-Llopis [2018] and our baseline calibration.

et al. [2014]. Intuitively, with a positive correlation, the household is more likely to receive high or low draws in both sectors. As we estimate a higher variance in urban productivity, a higher value of ρ_{RU} also implies that most highly productive households will reside in urban areas, driving up the APG.

4.4 Non-targeted moments

In terms of non-targeted moments, our model predicts a 28% share of land devoted to staples among cash crop farmers, close to the 30% we find in the LSMS 2010 data for Malawi. Second, we leverage the RCT evidence in Aggarwal et al. [2022] on randomized cash transfers worth 193% of the 2010 average annual rural income, disbursed among all households living in 150

Malawian villages between 2019 and 2020 (less than 1% of the population). The intervention targeted relatively small villages with relatively high poverty levels and populations of fewer than 100 households. Aggarwal et al. [2022] found a 22% increase in the total value of harvest due to the impact of this cash grant. We implement this RCT in our model as a cash grant worth 193% of the average rural income disbursed in PE among the bottom 50% of rural households (in terms of consumption). Upon impact, the agricultural output of the treated households increases by 15% on average.

Finally, Figure 3 compares an array of inequality indicators reported in De Magalhaes and Santaeulalia-Llopis [2018] with corresponding moments from our baseline calibration. Our model successfully generates a realistic concentration of wealth, income, and consumption. Although the bottom right panel indicates that our framework overpredicts the average gaps between rural and urban areas, it also highlights the success of transaction costs in sustaining these gaps concurrently with the low urbanization rate.

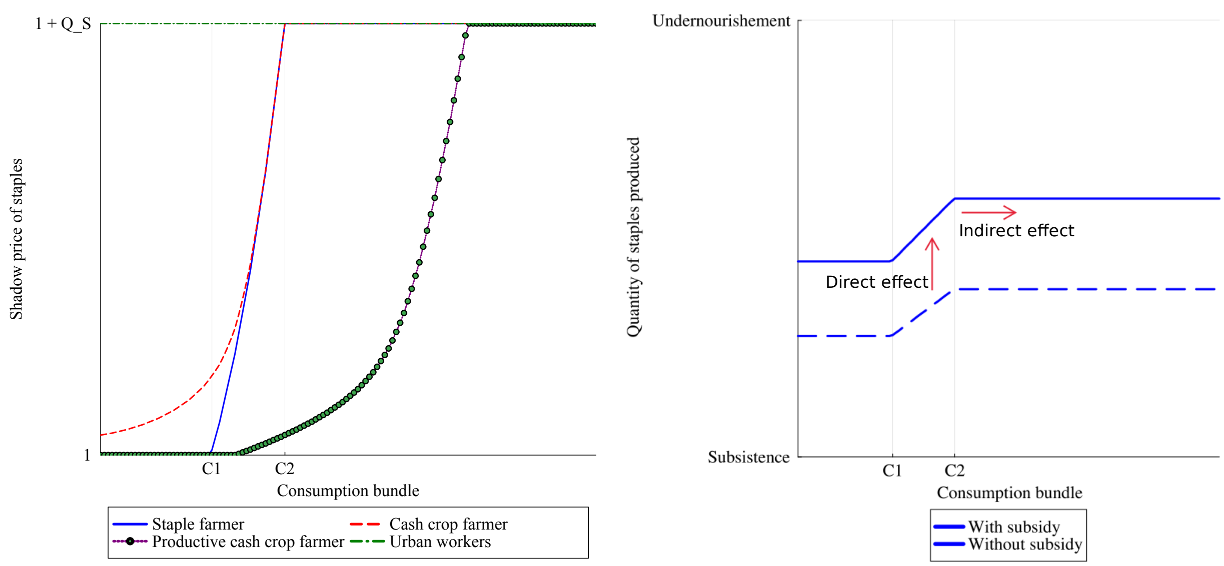
5 Quantitative analysis

We proceed with the analysis of Malawi's large-scale agricultural input subsidy program in several steps. In Section 5.1, we first explain the household-level effects of the program by analyzing the relationship between food production and valuation of food, and by looking at simulation paths of urban and rural households (Figures 4 and 5). In Section 5.2, we identify the aggregate-level effects by comparing the stationary equilibria of calibrated post-reform allocation to the pre-reform one without FISP (Table 3). In doing so, we also decompose the effects of FISP into the GE and PE effects, as well as those due to individual model features (transaction costs, subsistence constraint, urban entry barriers, collateral constraint, and export demand). Then, in Section 5.3 we discuss the importance of transition dynamics for welfare calculations and conduct the distributional analysis of the winners and losers (Figure 6). In Section 5.4, we conclude the analysis by varying the FISP's size (Figure 7).

5.1 The micro-impact of FISP in Malawi

Static implications

In our dynamic economy without transaction costs ($Q_S = 0$), households choose the income-maximizing occupation irrespective of their consumption bundle. On the other hand, positive transaction costs for staples imply that their shadow (internal) valuation, represented by the Lagrange multiplier on constraint (14), varies across the household distribution. For farmers, it can lie anywhere between $\lambda_S \in [1, 1 + Q_S]$, depending on the household's consumption and production patterns. In contrast, the shadow price is always equal to the market price $1 + Q_S$ for urban households, implying that food will be generally under-produced from the perspective of the urban sector.



(a) Shadow price of staples across household types

(b) Production impact of FISP

Figure 4: Internal valuation of food and the impact of FISP on produced quantities

Note: The feasibility of consumption bundle choice depends on the household's total income and assets and is not represented in these figures. The shadow price of food is the Lagrange multiplier on equation (14). "Staple farmer" and "cash crop farmer" refer to households with the same (relatively low, as indicated by their amount of self-produced staples being lower than the undernourishment level) productivity and assets. "Productive cash crop farmer" is a cash crop farmer with a higher level of rural productivity. The subsistence threshold corresponds to $\bar{c}_S$, and undernourishment threshold to $\tilde{c}_S$ (Section 4.3 explains its construction).

We show these patterns across different types of households in the left panel of Figure 4. As the desired consumption bundle C increases, farmers switch from consuming only self-produced staples ($\lambda_S = 1$, $C < C_1$), in which case they disregard the transaction cost in their production and maximize profits, to a higher level of the staple output where the farmers' valuation becomes closer to that of urban households ($\lambda_S \in (1, 1 + Q_S)$, $C \in [C_1, C_2]$). If farmers decide to consume even more, their valuation of a marginal unit of staples is the same as that of urban households ($\lambda_S = 1 + Q_S$, $C > C_2$).

As we show in the right panel of Figure 4, staple farmers consuming beyond level C_2 do not increase the production of staples any further as their internal valuation equates that of the market price. Furthermore, input subsidies will generally induce two effects: the direct one, pushing farmers' production away from the subsistence level, and the indirect one, moving farmers to a higher level of consumption. The indirect effect (weakly) increases the quantity of food produced due as the producers' food valuation converges to that of the market $1 + Q_S$.

Dynamic implications

The static effects of the input subsidies are similar to those of the simple model from Section 2 extended by production with collateral constraints (Appendix A). In the quantitative model, the combination of urban migration risk (arising through the interaction of stochastic urban labor productivity and entry costs) and transaction costs similarly result in excessive selection into farming. However, this mechanism further interacts with the uninsurable nature of occupation-specific productivity fluctuations and incomplete market structure giving rise to typical precautionary savings distorting market prices, as studied, e.g., in Davila et al. [2012].

As preferences are non-homothetic and self-produced food is cheaper than that purchased on the market, households are more sensitive to food consumption risk and therefore view working in the agricultural sector as an occupation that provides valuable consumption insurance. Staple-targeting ISPs reduce precautionary distortions by providing insurance to asset-poor or unproductive households through subsidized inputs and a reduced food price, resulting from increased aggregate food supply. Because of these insurance effects, FISP enhances occupational mobility.

We illustrate this point in Figure 5 using two scenarios of productivity paths for rural and urban agents, along with their associated optimal decisions, in economies with and without

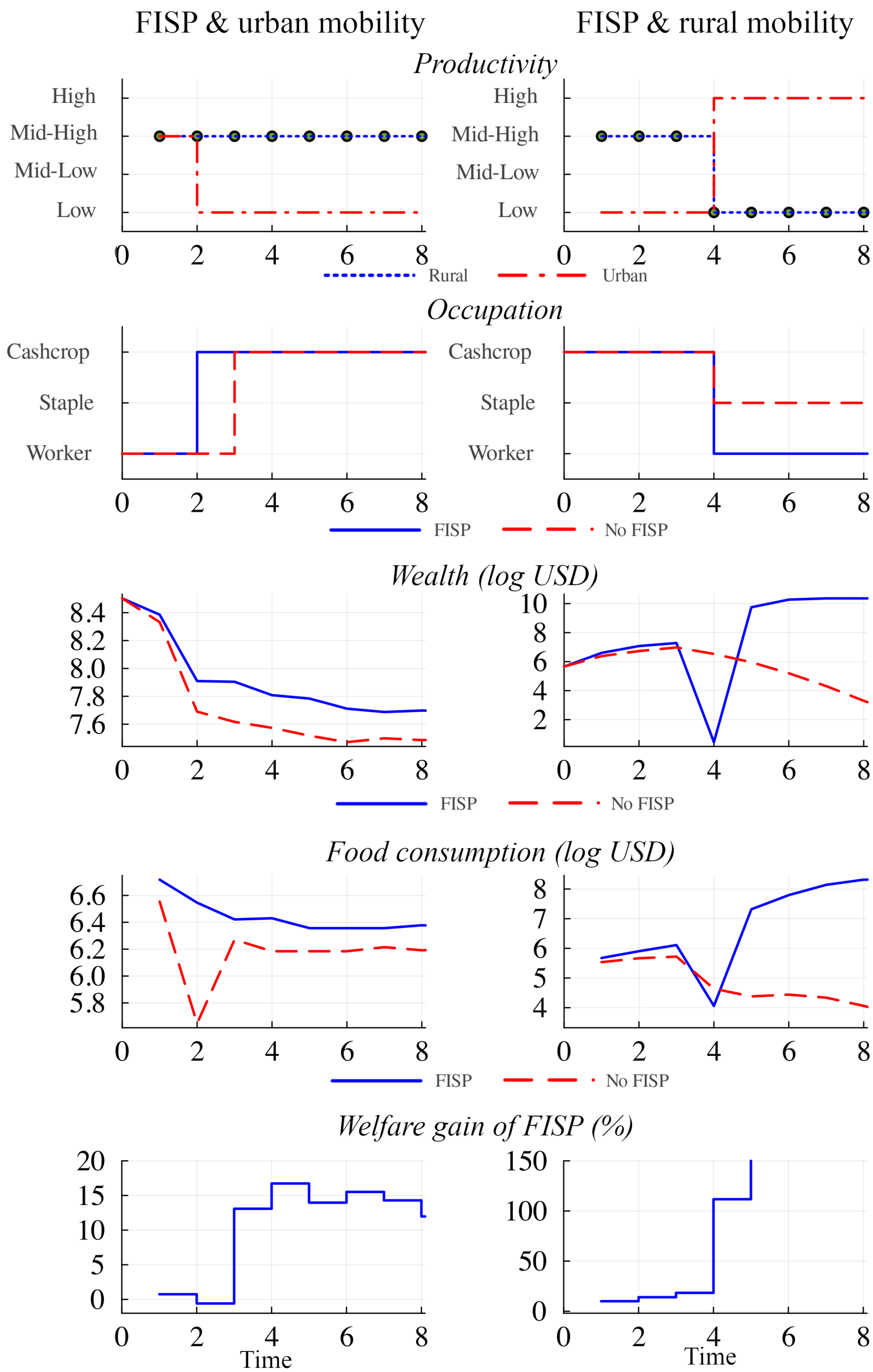


Figure 5: Mobility-insurance effects of FISP in two simulation paths

Note: The left panels show the simulation path of a worker moving to rural and the right panels show corresponding simulation for a rural farmer moving to urban sector. "Cash crop" occupation denotes a household paying maintenance cost FM_B and choosing optimal staple-cash crop mix. "Welfare" is expressed in consumption equivalent terms and compares value functions of the agent at a specific point in simulation between the "FISP" and "No FISP" economies.

FISP. The left panels show a household starting as an urban worker with medium-high productivity in both sectors. In period 2, however, the agent experiences a negative shock to urban productivity. On impact, the same household living in the "FISP economy" switches to producing staples and cash crops. In the economy without FISP, the same household waits for one more period before doing so in expectation of the shock reversal in period 3, which would allow the household to benefit from the urban location, which is hard to re-enter due to entry costs. However, this scenario does not materialize in our simulation, and the household maintains low urban and mid-high rural productivity for the remaining periods. In the face of this, the household in "no FISP economy" changes occupation with a delay leading to significant divergence in wealth positions and food consumption between the two economies. The welfare panel shows that although having FISP is not valued immediately in the second period when productivity changes, the value of FISP is equivalent to approximately 15% from period 3 onward, i.e., starting from the period when the adverse scenario materializes and the "no FISP economy" household changes occupation with a delay.

The right panels of Figure 5 show a household building up assets as a relatively productive cash crop producer. In period 4, their agricultural productivity collapses, while urban productivity reaches its highest level. In the "FISP economy", the household seizes the opportunity immediately, while in the "no FISP economy", she stays in rural areas, becoming an impoverished staple producer. Notice that migration to urban areas is risky due to the large entry fixed cost and the positive probability that urban productivity may drop already in period 5. Hence, FISP encourages migration through the insurance effects discussed in the previous example. Overall, FISP generates large welfare gains to the household in every period of simulation, reaching up to 110% already in period 4 and increasing further as the households' histories diverge.

5.2 The macro-impact of FISP

Table 3 reports the aggregate effects of FISP by analyzing its impact on the key moments targeted in our calibration strategy in various versions of the model.[25] The first column

[25]Further moments from the no subsidy, FISP in GE and PE, and FISP financed with foreign aid are relegated to Table A.9 in Appendix D.

Variable	Data	No Subsidy	Baseline	PE	$Q_S = 0$	$\bar{c}_S = 0$	$F_M = 0$	$\kappa = 10$	$c_B^F = 0$
Aggregate cost of program (% GDP)	3%	0%	2%	4%	2%	2%	3%	5%	2%
Share of cash crop f. w/ subopt. inputs	70%	93%	72%	95%	61%	70%	47%	32%	93%
Share lending to agr. in GDP	1%	1.2%	2.0%	2.2%	2.0%	2.0%	2.0%	5.0%	1%
Share of cash crops exported	73%	67%	70%	87%	67%	70%	38%	72%	0%
Share of land devoted to staples	70%	79%	72%	86%	66%	68%	66%	83%	83%
Rural-urban migration rate	1%	1%	1%	1%	1%	1%	26%	1%	1%
Urban population	18%	20%	19%	16%	23%	19%	52%	18%	23%
Agr. output share in GDP	30%	29%	29%	33%	28%	30%	19%	26%	15%
Std. dev. of average product of farms	1.8	1.6	1.7	1.6	1.7	1.7	1.6	1.8	1.5
Agricultural Productivity Gap	6.5	6.2	6.3	6.4	6.2	5.3	2.6	8.0	11.7
Long-run welfare impact of FISP	-	-	5.0%	10.1%	0.1%	3.9%	0.9%	3.5%	2.1%

Table 3: The decomposition of FISP's macroeconomic impact on Malawian economy

Note: Column 1 reports the empirical moments used in our calibration. Columns 2 and 3 report the moments from the model without FISP ($\tau_S = 72\%$) and with FISP in GE. Column 4 presents the results from the model with FISP in PE (with all prices at "No Subsidy" level). Columns 5-8 show respective changes in the moments of the model on impact of switching off key features of the model: transaction costs, urban entry costs, collateral constraint, positive export demand. The last row shows the welfare impact of FISP in respective allocations measured in consumption equivalent long-run changes in value functions, fixing the stationary distribution at the pre-reform (no subsidy) level.

repeats the empirical moments targeted. A comparison between columns 2 and 3 reveals the GE impact of FISP in Malawi. Column 4 reports the same moments generated in the PE model with FISP, with prices assumed at the "no subsidy" level (including no labor income tax). To highlight the mechanism, columns 5-9 decompose the effects of FISP in counterfactuals with the key features of our model switched off.

As FISP heavily reduces input prices for staple production, it doubles the agriculture lending share relative to GDP and reduces by 23% the share of collateral-constrained cash crop farmers. The program increases the share of cash crops produced for export by 5% and reduces the share of land devoted to staples by 9%. These adjustments reflect forces discussed in Proposition 1: the intensification of fertilizer use for staple production reduces the relative price of food, releasing more resources for cash crop production. Despite the program's large size and direct targeting of the rural population, the urbanization rate drops by only 5%.

All these effects are accompanied by modest increases in within-agriculture and across-sector misallocation, as reflected by the 6% increase in the standard deviation of average farm products and the 2% increase in the APG. However, the program still generates large welfare gains equivalent to a 5.0% long-run increase in average consumption.

The GE welfare gains are half of the welfare gains predicted by the PE model. Without equilibrium price adjustments, many of the model's margins become overly sensitive, leading to potentially qualitatively wrong conclusions. For instance, without accounting for the large changes in the food's relative price, the drop in urbanization rate would be four times larger, and the share of collateral-constrained cash crop farmers would slightly increase. As such, this exercise confirms the importance of equilibrium adjustments for at-scale evaluations of micro-developmental policies.

Columns 5-9 decompose the welfare benefits of FISP in GE by switching off the key features of our framework, holding other parameters constant. Moreover, it reports the welfare impact of introducing FISP in corresponding counterfactual economies as a proxy for the importance of individual frictions in driving the positive effects of FISP uncovered above.

The most critical driver of FISP's welfare gains is transaction costs Q_S. Switching off this feature of the model removes virtually all the gains of the program. Confirming the dynamics of our simple model, transaction costs increase the rural population share by 5% and the APG by 2%. For similar reasons, the share of land devoted to staples increases by 9%.

The second most important feature is the urban entry costs. Setting $F_M = 0$ reduces welfare gains of the program by 92%. The urban population share increases by 173% and the APG drops by 59%. Overall, with either $Q_S = 0$ or $F_M = 0$, FISP does not generate any insurance effects, as neither idiosyncratic risks nor occupation choices affect individual food security, or occupational choice becomes effectively riskless. Switching off subsistence constraints generates comparatively minor changes relative to the baseline allocation (column 6).

Notably, removing either of the two major frictions still allows for positive, albeit small, benefits of the program to be attained due to the relaxation of the collateral constraint. This financial friction is more important than usual because our calibration assumes that $\beta(1 + r)$ is significantly below 1. Column 8 reports results from increasing κ by a factor of 100. Upon doing so, the share of financially constrained farmers drops by 56% and the aggregate program cost doubles. Since the positive welfare impact of FISP in this allocation is reduced by only 30%, it further confirms the importance of insurance effects induced by

FISP, particularly in the presence of positive transaction costs and risky occupational choice.

In the last column, we test the importance of the open economy aspects in determining the benefits of FISP. We do so by setting $a_D = 0$ in the export demand function (20). This implies that all agricultural input imports must be financed with exports of the manufacturing good, reducing the amount available for the within-country consumption. In this case, the welfare gains of FISP decline by 58%, suggesting that allowing for cash crop exports is important, albeit less so than transaction costs or entry barriers.

5.3 Transition dynamics and redistribution

In this part, we dissect the distributional welfare impact of FISP by comparing household welfare gains across occupation status. In order to account for the time and investments required for convergence to new steady states, we compute the associated transition path dynamics. Figure A.3 in Appendix D shows an example of transition path dynamics induced by a change from $\tau_S = 0.0$ to $\tau_S = 0.72$ under the balanced government budget, our baseline calibration for 2010 Malawi. We increase τ_S gradually in 5 periods following the evidence from actual implementation in Malawi (Benson et al. [2024]).[26]

The adjustment process of most variables in the economy takes around 20 years, as scaling up individual agriculture production and reallocating the labor force from the rural to the urban sector requires the accumulation of savings. Staple productivity and the APG increase monotonically. These slow-moving adjustments gradually increase cash crop and manufacturing prices, as well as labor tax rates. Interestingly, the response of the urbanization rate is U-shaped. Immediately following the introduction, the urbanization rate drops by up to 6%. However, as food becomes relatively more abundant and cheaper, incentives for working in the rural sector diminish, and the urbanization rate slightly recovers.

	All population		Rural		Urban	
	Long-run	Transition	Long-run	Transition	Long-run	Transition
Welfare impact of FISP	+5.0%	+3.5%	+6.3%	+4.4%	-0.2%	+0.1%

Table 4: The welfare impact of FISP: long-run vs transition

Table 4 shows that upon accounting for transitional dynamics, the average long-run

[26] See Appendix C for a detailed algorithm description.

welfare gain induced by FISP of 5.0% reduces to 3.5%. The program is pro-rural, with welfare gains of farmers at the time of policy introduction amounting to 6.3% in the long run and 4.4% after accounting for transition. The transition-adjusted welfare gains are lower due to the increased consumption costs associated with accumulating savings along the transition path. On the other hand, the urban population, on average, experiences small welfare losses equivalent to 0.2% of consumption in the long run, but benefits with a slight 0.1% welfare gain after accounting for the transition. The average welfare impact of FISP on urban workers changes sign as labor tax distortions are lower along the transition than in the final steady state due to a slow depopulation of urban areas.

Figure 6 decomposes the welfare changes among rural and urban populations across different asset and productivity levels, and time horizons. In rural areas, the program benefits most those with low assets and (i) low productivity in both occupations, who need cheap inputs and food; and (ii) low productivity in farming but high productivity in labor, who benefit from subsidies to build up their savings for funding migration and, ultimately once they move, from the mobility-insurance. In urban areas, the highest gains accrue to asset-poor workers with low urban productivity and either low or high productivity in farming, i.e., those who need inexpensive food or agricultural inputs once they switch sectors.

Households with higher productivity or assets tend to lose out, as non-homothetic preferences imply that they spend relatively less on food, yet still incur the costs of the policy through labor taxation or a lower price of food produced. As there are relatively few urban workers with lower asset positions, FISP effectively favors poorer rural households.[27]

5.4 Varying the size of FISP

We next map the evolution of macroeconomic outcomes along the size of FISP's subsidy rate (relative to the no-subsidy equilibrium).[28] We show that the program's welfare benefits

[27]The irregular shape of the welfare gains of farmers with low rural and high urban productivity is because this group would have migrated to urban areas without FISP, but the introduction of the policy renders the entry barriers higher due to increased wages.

[28]We limit our analysis to $\tau_S \in [0, 0.8]$ as, due to the food subsistence constraint $\bar{c}_S$, the input imports and food production increase exponentially in the level of τ_S. Subsidy rates exceeding 80% lead to exponential increases in manufacturing and cash crop prices, implying problems with the solution due to the non-homothetic structure of preferences and the poorest households unable to afford a minimum amount of consumption.

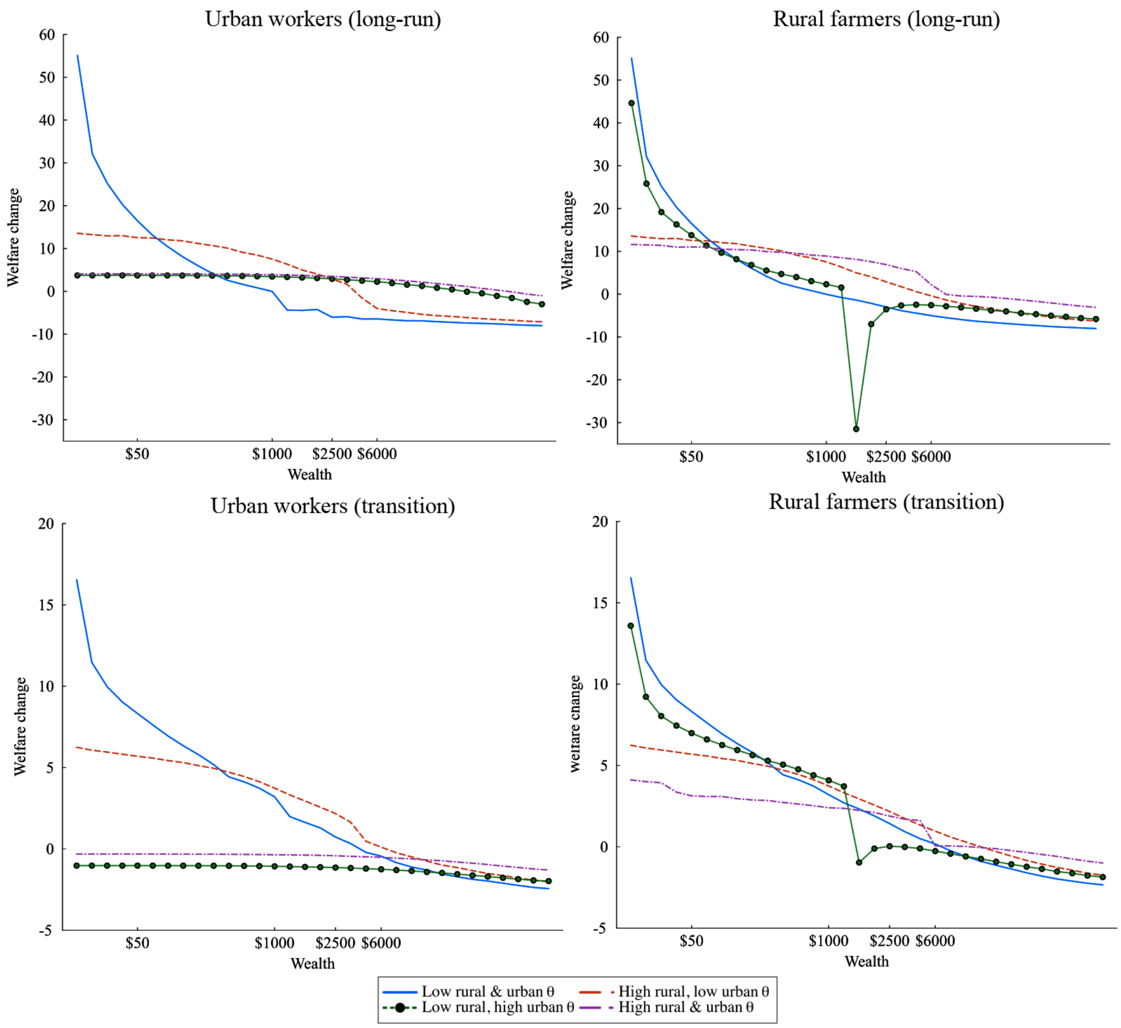


Figure 6: Distributional welfare impact of FISP

Note: The figure presents the consumption-equivalent welfare gains across occupations for different wealth levels and rural and urban productivity. "Long run" figures do not account for the transition induced by the introduction of FISP.

increase in its size. Apart from the food insurance mechanism discussed before, we highlight the importance of interactions between transaction costs and international trade. Figure 7 summarizes these comparative statics.

First, a higher subsidy rate stimulates the productivity of staple farming through relaxation of collateral constraints.[29] Expanded food production drives down the price of staples, improves food affordability, generates savings on internal transaction costs, and shifts rel-

[29]While the upper-right panel of Figure 7 shows that the share of collateral-constrained pure staple farmers increases in τ_S, this happens due to input intensification on impact of lowered input prices combined with composition effects.

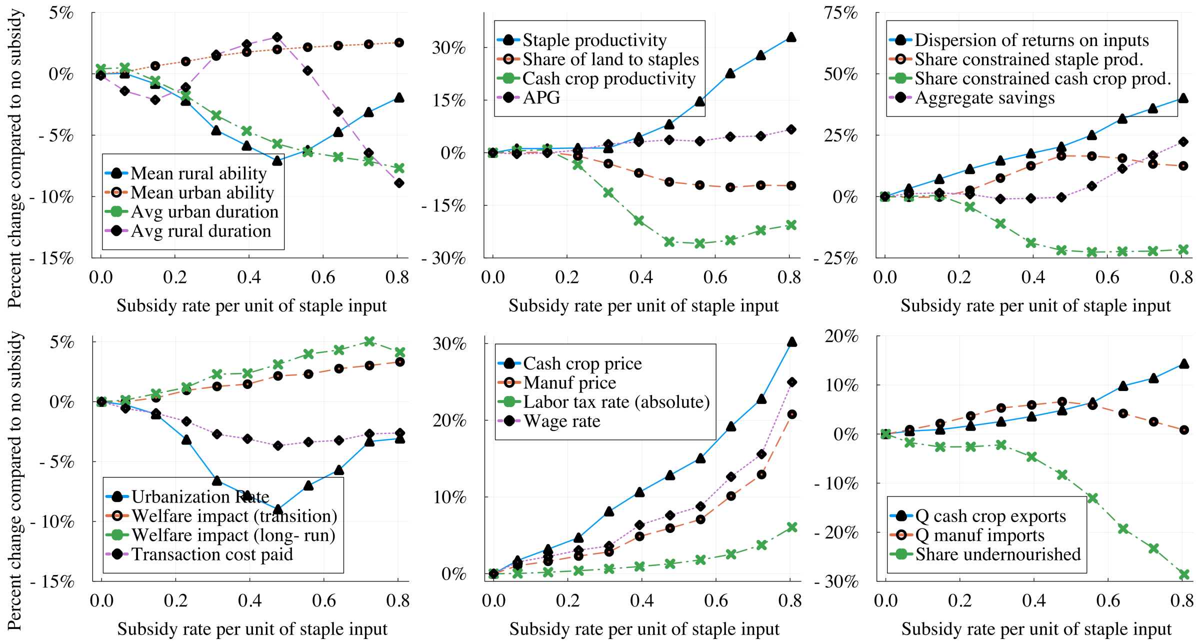


Figure 7: The impact of FISP in Malawi under different subsidy rates τ_S

Note: Panels show the impact of different levels of τ_S on key variables relative to the no subsidy equilibrium, constructed in the steady-states with labor taxation balancing the government budget.

ative profitability toward export-oriented cash crops. While the staple fertilizer subsidy crowds out input use on cash crops, farmers allocate more land to cash crop production once their staple needs are met. The result is higher cash crop export revenue, which finances greater imports of fertilizers and manufacturing goods. Since imported agricultural inputs and manufacturing goods are not subject to transaction costs, the economy generates further savings, and the trade feedback loop amplifies the welfare gains from FISP. In other words, a larger FISP partially "pays for itself" by enabling more exports and thus more affordable imports, instead of simply draining resources abroad. Without the export channel, a surge in fertilizer imports would deteriorate the current account and reduce the positive welfare impact of FISP by 58% (as demonstrated in Table 3).

Second, as τ_S grows large, subsidizing staples initially encourages more households to remain in or switch to farming. However, beyond $\tau_S > 0.45$, urbanization begins to recover towards the no-subsidy level. These dynamics reflect the interplay between the direct effect of making farming more beneficial and the indirect ones working against it, through the reduced relative price of food and the increase in the wage rate due to the labor-pulling effects from the manufacturing sector.

Third, FISP increases food availability and lowers the incidence of undernourishment. Therefore, the program disproportionately benefits the poorest, reaffirming that FISP provides efficient insurance by raising the minimum food production level. With FISP making food cheaper and more abundant, households can accumulate more savings. Consequently, enhanced food security and higher savings enable households with high urban productivity to take on the risk of urban migration, as indicated by increases in the mean urban ability or reductions in the average rural duration.[30] In the rural sector, as the subsidy policy becomes more generous, and the only factor of production becomes cheaper, factor misallocation[31] increases, similar to the mechanism in Tetenyi [2019]. Nonetheless, the urban-rural misallocation, proxied by APG, increases only weakly in τ_S.

In summary, despite adverse allocational effects, FISP consistently helps the poorest households and provides valuable food insurance.[32] With the fiscal cost of the program not exceeding 7% of the wage rate, the welfare gains increase in τ_S reflecting the accumulation of positive micro- and macroeconomic effects described above. However, the long-run welfare gains begin to decline at the levels of τ_S beyond 72% as the labor tax distortions are more immediate in the steady state comparisons.[33]

6 Event study validation of model dynamics

The quantitative evaluation of the FISP shows that the program generates substantial shifts in the economic landscape, including a reduction in the undernourishment rate and increases in the productivity of staples and the relative price of cash crops. We compare the predic-

[30] These effects also contribute to the rebound in urbanization at higher levels of τ_S.

[31] Proxied by the dispersion of marginal returns on inputs used.

[32] Figure A.4 in Appendix D provides a decomposition of average welfare gains across the two sectors as τ_S changes. It confirms that the reform is pro-rural, with average urban residents experiencing a minimal welfare impact.

[33] As we have shown in Figure A.3 of Appendix D with an example of transition dynamics, the labor tax adjustments are gradual and the fiscal costs are lower in the short-run. Furthermore, the right panel of Figure A.4 with long-run sectoral decomposition of welfare gains along τ_S shows that the hump-shaped welfare impact of FISP is present for both rural and urban residents. While urban laborers are directly affected by tax rate hikes required for financing FISP, rural farmers also bear the costs of excessive FISP as the gross wage rate required to attract workers starts increasing sharply, increasing all the wage-denominated entry and maintenance costs in the economy.

tions of our model against the non-targeted evidence from the event study of SSA countries that introduced large-scale ISPs around the 2000s. Using the Callaway and Sant'Anna [2021] estimator, we identify the effects of ISPs exploiting the heterogeneous timing of ISP introductions among 10 SSA countries, with the control group of never-treated countries.[34] Table A.5 in Appendix D summarizes the 1980-2020 FAOStat data used together with the treatment classification of countries.

Figure 8 shows evidence on the ISP's impact on fertilizer use, agricultural yields, market prices, land allocation, and the shares of cash crops exported, of population undernourished, and of population living in rural areas. Although non-targeted, the transition dynamics induced by subsidies in the model match most of the signs and magnitudes. For all the variables analyzed, the assumption of parallel trends holds well, lending credence to our identification strategy.

We find that African ISPs' have increased application rates of fertilizer by up to 15kg per ha, effectively doubling the average use of these modern inputs in the region. Due to the staple-targeting nature of regional ISPs, the programs have increased staple yields by up to 25% with similarly sized reductions in cash crop yields.[35] Consequently, ISPs induced a 25% increase in the relative price of cash crops. Responding to the price incentives and intensified cultivation of staples, farmers reduced the share of land devoted to staples by up to 8 percentage points, approximately 16% three years after the introduction of the subsidy. The share of cash crops exported increased slightly, consistent with a net increase in overall production and substitution between crops in within-country consumption. Validating one of ISPs' main goals, the share of undernourished population dropped by 8 p.p. (approx. 35%). Finally, despite small negative point estimates, the empirical impact of ISPs on the population share living in rural areas is mostly statistically insignificant. In this sense, these empirical estimates are not far off from our model's prediction of a modest up to 1 p.p. increase in the share of rural population, which converges to 0.5 p.p. in the long-run (as shown in the analysis of transition paths in Figure A.3 of Appendix D).

[34] Formally, our identifying assumption is that the decision and timing of introducing ISPs in SSA countries is as good as random conditional on country-year specific controls of the share of land irrigable (proxying modernization of agriculture), total population and GDP.

[35] Empirical results in Diop [2023] provide evidence of similar increases in yields of staples upon introducing agricultural input subsidies in Zambia.

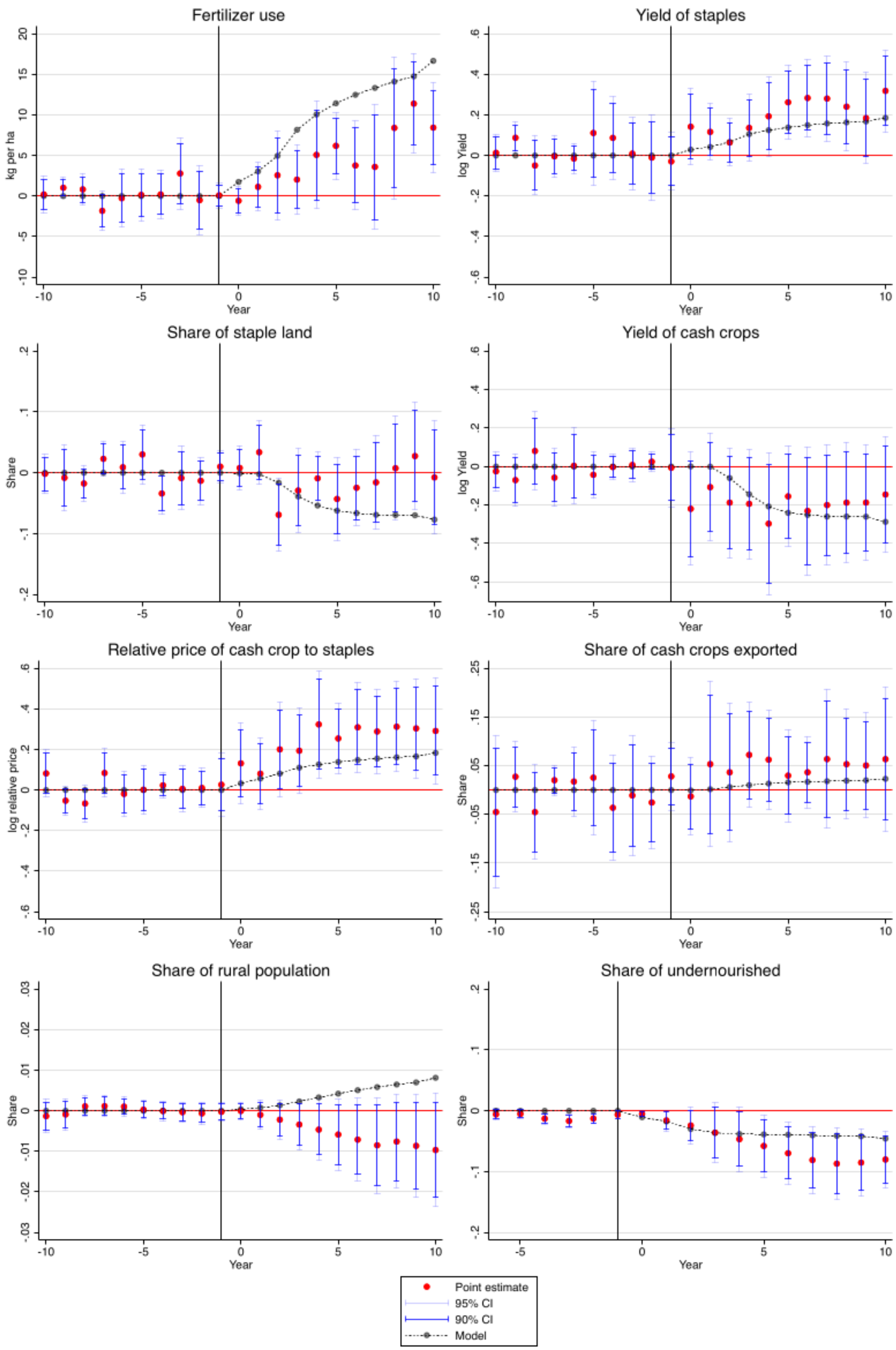


Figure 8: Event study of ISPs' impact in empirical and simulated data

Note: The figure shows the Callaway and Sant'Anna [2021] event study of introducing ISPs in SSA, with the control group of countries that did not implement ISPs. 95% and 90% confidence intervals are marked with light and dark blue, respectively. Standard errors are clustered at the country level. Model refers to the transition path following the introduction of FISP in the calibrated Malawian economy. See Table A.5 in Appendix D for details on the sample used.

7 Robustness and further analyses

Infrastructure investments. Nyondo et al. [2021] estimate that the government spending on FISP between the years 2009 and 2019 could allow for constructing 99 kilometers of high-quality all-weather roads per year. In Appendix E.1, we compare the macroeconomic impact of FISP against redirecting public funds into broadly defined infrastructural investments, bringing reductions in transaction cost parameter Q_S and rural-urban reallocation costs F_M. We demonstrate that such investments, particularly when leading to reductions in both frictions simultaneously, can trump the effects of FISP by promoting mobility, urbanization, and reducing resource misallocation — effects akin to those discussed in Murphy et al. [1989]. In contrast with the effects of ISPs, infrastructure investments increase the relative price of food, consistent with some evidence on historical development paths of industrializing nations [Alvarez-Cuadrado and Poschke, 2011].

Undernourishment productivity externalities. Strauss [1986] showed that the productivity of farmer households in Sierra Leone is negatively affected by cuts in calorie intake, with especially strong effects present among the poorest. Such considerations are likely at play also in the very poor rural areas of Malawi. In Appendix E.2, we probe the robustness of our welfare estimates to assuming that the agriculture and manufacturing productivity of all households is decreasing in the mass of people with food consumption falling below the level of undernourishment $\tilde{c}_S$. We show that the welfare gains of FISP double for a plausible elasticity argued for in Strauss [1986].

Inelastic land supply. With about 236 people living per square kilometer, Malawi is one of the most densely populated countries in the SSA. Furthermore, around 81% of Malawi's population resides in rural areas and derives most of their income from agriculture. Appendix E.3 relaxes the open land frontier assumption[36] by assuming that the productivity of farming is decreasing in the number of farmers, proxying effects of land scarcity discussed in Ricker-Gilbert et al. [2014]. Because an increase in τ_S increases the number of farmers, the welfare effects of FISP can become negative when land is sufficiently inelastic.

[36] While our model assumes perfectly elastic land frontier with each rural household being endowed with 1 unit of land, our calibration strategy captures the differences in land quality and, more importantly, quantity among Malawian households (as we argued in Section 4.3).

Cross-sectional validation of household dynamics. In Appendix E.4, we conduct further model validation comparing cross-sectional household-level regressions using the 2010 LSMS data for Malawi and the simulated data. Our model qualitatively matches the correlations of the amount of inputs used, the value of harvest produced, and the share of staples self-consumed with the land allocation decisions.

8 Conclusion

A secure food supply is critically important everywhere, especially in countries where food shortages occur periodically, storage and transportation technologies are inefficient, information flows are imperfect, and – as a consequence – market transactions are subject to large transaction costs. Large-scale agricultural input subsidy programs are often a popular candidate for addressing these issues and raising living standards. As summarized in Harrigan [2003], the approach of policymakers and international development agencies to this particular policy has fluctuated over the past decades from a strong opposition due to a fundamental belief in market forces in the 1970s and 80s to, starting at the end of 1990s, a gradual acknowledgment of severe frictions in developing countries that may inhibit the power of market forces and so render agriculture subsidies efficient.

We develop a holistic framework that integrates the main concerns regarding agricultural subsidy programs. Our incomplete market model introduces a novel channel of inefficiencies by assuming that households purchasing staples on the market must pay a per-unit transaction cost, incentivizing the home production of food. Application of the model to Malawi shows that the large local ISP significantly increases welfare, operating through multiple channels. First, it allows asset-poor farmers to escape undernourishment. Second, it reduces the price of food in urban areas. Third, it enhances occupational mobility by reducing the risk of occupational switching through lowering the cost of self-produced food in the outside option-occupation. These effects imply that the policy effectively benefits more the asset-poor and misallocated individuals with the highest marginal propensities to consume. Finally, we validate the key predictions of our framework through the event study analysis on a cross-country panel from SSA.

Our work highlights several fruitful directions for future research, such as studying ISPs with capacity constraints on the subsidized amount of inputs awarded in the presence of active secondary markets allowing households to overcome these institutional constraints. One could also use our framework to study the consequences of endogenous transaction costs, such as those arising from agricultural intermediaries with market power.

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Appendices

In this Appendix for online publication only, we provide the simple model with the derivation of the laissez-faire competitive equilibrium inefficiency result (Appendix A), additional details regarding solving the model (Appendix B), the definition of the competitive equilibrium (Appendix C), description of the datasets used for the empirical analysis and additional results from the quantitative model (Appendix D).

A Simple model appendix

First best equilibrium: Defined as a collection of allocations $\chi, \{f^j, m^j\}_{j=F,W}$ that maximize ex ante, utilitarian social welfare (1) subject to the resource constraints (2) & (3):

$$W = \chi(\log(f^F) + \log(m^F)) + (1-\chi)(\log(f^W) + \log(m^W)) \tag{1}$$

$$\text{s.t.: } \chi f^F + (1-\chi)(1+Q)f^W = \chi \tag{2}$$

$$\chi m^F + (1-\chi)m^W = (1-\chi)A \tag{3}$$

Constrained efficient equilibrium: Defined as a collection of allocations $\chi, \{f^j, m^j\}_{j=F,W}$, household ex-post utilities $\{V^j\}_{j=F,W}$ and price p such that:

1. allocations $\{f^j, m^j\}_{j=F,W}$ and household utilities $\{V^j\}_{j=F,W}$ solve (taking p as given):

$$\begin{aligned} V^F = & \max_{f^F, m^F} \log(f^F) + \log(m^F) \\ \text{s.t.: } & f^F + p \cdot m^F \leq 1 \end{aligned} \tag{4}$$

$$\begin{aligned} V^W = & \max_{f^W, m^W} \log(f^W) + \log(m^W) \\ \text{s.t.: } & f^W + p \cdot m^W \leq p \cdot A \end{aligned} \tag{5}$$

2. χ solves the maximization of social welfare, taking the household problem in equations 4 & 5 into account:

$$W = \chi V^F + (1-\chi)V^W \tag{6}$$

3. resource constraints in equations 2 & 3 hold.

In this appendix, we first prove the main result of the simple model. Then, we present the associated comparative statics with respect to transaction cost Q. Finally, we introduce numerical results from the model's extension allowing for agricultural production and collateral constraints.

Theorem 1. *If $Q = 0$, the laissez-faire competitive equilibrium (LF) coincides with both the first best (FB) and constrained efficient (CE) allocations. If $Q > 0$, LF is inefficient* *relative to both FB and CE. Furthermore, LF is characterized by over-farming and excessive Agricultural Productivity Gap relative to CE:* $\chi^{LF} > \chi^{CE}$ *and* $APG^{LF} > APG^{CE}$*.*

Proof. Let us start with the competitive equilibrium. Given the objective function, occupation-specific budget constraints, the FOC of worker reads:

$$\frac{f^W}{m^W} = \frac{p}{1+Q} \tag{7}$$

And the FOC of farmer reads:

$$\frac{f^F}{m^F} = p \tag{8}$$

Putting together these FOCs, we get:

$$\frac{f^W}{m^W} = \frac{1}{1+Q}\frac{f^F}{m^F} \tag{9}$$

Let us combine now farmer's FOC and farmer's budget constraint to get the farmer's demand for manufacturing goods:

$$\begin{aligned} pm^F \cdot 2 &= 1 \\ \Rightarrow m^F &= \frac{1}{p}\frac{1}{2} \end{aligned} \tag{10}$$

Lets combine now worker's FOC and worker's budget constraints to get worker's demand for manufacturing goods:

$$\begin{aligned} 2 \cdot pm^W &= pA \\ \Rightarrow m^W &= A\frac{1}{2} \end{aligned} \tag{11}$$

Use both demand functions in the resource constraint for manufacturing goods to get price p:

$$\begin{aligned} \chi\frac{1}{2p} + (1-\chi)\frac{A}{2} &= (1-\chi)A \\ \Rightarrow p &= \frac{1}{A}\frac{\chi}{1-\chi} \end{aligned} \tag{12}$$

Use the derived price to solve for consumption of manufacturing goods by farmers:

$$m^F = \frac{A}{2}\frac{1-\chi}{\chi} \tag{13}$$

Using derived m's and f's, we can solve for optimal χ in laissez-faire allocation from the

FOC wrt χ of objective function, taking p as given:

$$\log\left(\frac{f^F}{f^W}\frac{m^F}{m^W}\right) = 0$$

$$\iff$$

$$f^F m^F = f^W m^W$$

$$\iff$$

$$\left(m^F\right)^2 = \frac{1}{1+Q}\left(m^W\right)^2$$

$$\iff$$

$$\left(\frac{1-\chi}{\chi}\right)^2 (1+Q) = 1 \tag{14}$$

$$\iff$$

$$\chi^{LF} = \frac{1}{1+\sqrt{\frac{1}{1+Q}}} \tag{15}$$

This shows that the share of farmers grows in Q, with farmer share at 0.5 with $Q = 0$.

In order to prove that LF is characterized by over-farming relative to the constrained efficient benchmark, let us rewrite the ex-ante welfare function using the LF-optimal consumption levels:

$$\begin{aligned} W^{LF} &= \chi V^F + (1-\chi)V^W \\ &= \chi \log\left(\frac{1}{4p}\right) + (1-\chi)\log\left(\frac{pA^2}{4(1+Q)}\right) \end{aligned}$$

With this, i.e. accounting for price changes due to χ, the constrained efficient level of χ solves:

$$\begin{aligned} \frac{\partial W}{\partial \chi} = {} & \log\left(\frac{1}{4p}\right) - \log\left(\frac{pA^2}{4(1+Q)}\right) \\ & - \frac{\chi}{pA(1-\chi)^2} + \frac{1}{pA(1-\chi)} \end{aligned} \tag{16}$$

While equation (16) can be used for solving the level of constrained efficient farming (combined with the expression for p in (12), that leads to), notice that by the optimal private choice of χ in the competitive equilibrium: $\log\left(p^2\left(m^F\right)^2\right) = \log\left(\frac{p^2}{(1+Q)^2}\left(m^W\right)^2\right)$, implying $\log\left(\frac{1}{4p}\right) = \log\left(\frac{pA^2}{4(1+Q)}\right)$. Thus, $\frac{\partial W}{\partial \chi}$ evaluated at $\chi = \chi^{LF}$ gives:

$$\frac{\partial W}{\partial \chi}_{|\chi=\chi^{LF}} = -\frac{2\chi^{LF}-1}{\chi^{LF}(1-\chi^{LF})}$$

Since under $Q > 0$ we have that $\chi^{LF} = \frac{1}{1+\sqrt{\frac{1}{1+Q}}} > \frac{1}{2}$, it follows that $\frac{\partial W}{\partial \chi}_{|\chi=\chi^{LF}} < 0$ meaning that agents can increase their ex-ante welfare by reducing the choice of χ below the LF level, implying that $\chi^{LF} \geq \chi^{CE}$.

Using expression for p from (12), the APG is given by $\frac{pA/(1-\chi)}{1/\chi} = \left(\frac{\chi}{1-\chi}\right)^2$. Given that we showed $\chi^{LF} > \chi^{CE}$, the conclusion about excessive APG follows (Corollary 1).

Moving on to the first best allocation, the planner maximizes the same objective function subject to the following resource constraints:

$$\chi f^F + (1-\chi) f^W (1+Q) = \chi$$
$$\chi m^F + (1-\chi) m^W = A(1-\chi)$$

Following similar FOC approach, we find the following first best consumption sharing rules:

$$\frac{f^F}{f^W} = (1+Q)$$
$$\frac{m^F}{m^W} = 1$$

Upon using those in the χ-FOC we get a quadratic equation:

$$\ln(1+Q)x^2 + [2 - \ln(1+Q)]x - 1 = 0$$

Given the requirement that $\chi \in (0,1)$, this quadratic equation delivers the first best solution for farmer share under the case $Q > 0$:

$$\chi^{FB} = \frac{1}{2} - \frac{1}{\ln(1+Q)} + \frac{\sqrt{4 + (\ln(1+Q))^2}}{2\ln(1+Q)} \tag{17}$$

which is clearly different than χ^{LF}. With $Q = 0$, $\chi^{FB} = 0.5$, as in LF and CE.

Similarly, and assuming $Q > 0$, plugging in $\chi = \chi^{FB}$ into the constrained efficient equilibrium social welfare (and replacing p with equation (12)) yields:

$$\frac{\partial W}{\partial \chi}_{|\chi=\chi^{FB}} = \ln(1+Q) - \frac{2\chi - 1}{\chi(1-\chi)}_{|\chi=\chi^{FB}} - 2\ln\frac{\chi}{1-\chi}_{|\chi=\chi^{FB}} \tag{18}$$

$$= \ln(1+Q) - \frac{2(\frac{1}{2} - \frac{1}{\ln(1+Q)} + \frac{\sqrt{4+(\ln(1+Q))^2}}{2\ln(1+Q)}) - 1}{(\frac{1}{2} + \frac{1}{\ln(1+Q)} - \frac{\sqrt{4+(\ln(1+Q))^2}}{2\ln(1+Q)})(\frac{1}{2} - \frac{1}{\ln(1+Q)} + \frac{\sqrt{4+(\ln(1+Q))^2}}{2\ln(1+Q)})} - 2\ln\frac{\chi}{1-\chi}_{|\chi=\chi^{FB}} \tag{19}$$

$$= \ln(1+Q) - \frac{4ln(1+Q)(-2+\sqrt{4+(\ln(1+Q))^2}))}{(\ln(1+Q)+2-\sqrt{4+(\ln(1+Q))^2})(\ln(1+Q)-2+\sqrt{4+(\ln(1+Q))^2})} - 2\ln \tag{20}$$

$$= \ln(1+Q) - \frac{4\ln(1+Q)(-2+\sqrt{4+(\ln(1+Q))^2}))}{(\ln(1+Q))^2 - (2-\sqrt{4+(\ln(1+Q))^2})^2)} - 2\ln\frac{\chi}{1-\chi}_{|\chi=\chi^{FB}} \tag{21}$$

$$= \ln(1+Q) - \frac{4\ln(1+Q)(-2+\sqrt{4+(\ln(1+Q))^2}))}{(\ln(1+Q))^2 - (4-4\sqrt{4+(\ln(1+Q))^2}+4+(\ln(1+Q))^2))} - 2\ln\frac{\chi}{1-\chi}_{|\chi=\chi^{FB}} \tag{22}$$

$$= \ln(1+Q) - \frac{4\ln(1+Q)(-2+\sqrt{4+(\ln(1+Q))^2}))}{-8+4\sqrt{4+(\ln(1+Q))^2}} - 2\ln\frac{\chi}{1-\chi}_{|\chi=\chi^{FB}} \tag{23}$$

$$= \ln(1+Q) - \ln(1+Q) - 2\ln\frac{\chi}{1-\chi}_{|\chi=\chi^{FB}} \tag{24}$$

$$= -2\ln\frac{\chi}{1-\chi}_{|\chi=\chi^{FB}} < 0 \tag{25}$$

with last inequality following from the fact that $1-\chi^{FB} < \frac{1}{2} < \chi^{FB}$ and therefore $\frac{\chi}{1-\chi}_{|\chi=\chi^{FB}} > 1$ due to equation (17) for $Q > 0$. Therefore $\frac{\partial W}{\partial \chi}_{|\chi=\chi^{FB}} < 0$ and $\chi^{CE} < \chi^{FB}$.

To prove that $\chi^{FB} < \chi^{LF}$, we need to prove that for all $Q > 0$,

$$\frac{\ln(1+Q) - 2 + \sqrt{4+(\ln(1+Q))^2}}{2\ln(1+Q)} < \frac{1}{1+\frac{1}{\sqrt{1+Q}}}.$$

Substitute $y = \sqrt{1+Q}$. Since $Q > 0$, we have $y > 1$. Then,

$$\ln(1+Q) = \ln(y^2) = 2\ln y.$$

Set $z = \ln y$, so $z > 0$ (as $y > 1$). The left-hand side becomes

$$f(z) = \frac{2z - 2 + \sqrt{4+(2z)^2}}{4z} = \frac{z - 1 + \sqrt{1+z^2}}{2z} = \frac{1}{\sqrt{1+z^2} - z + 1}.$$

The right-hand side becomes

$$g(z) = \frac{1}{1 + \frac{1}{y}} = \frac{1}{1 + e^{-z}} = \frac{e^z}{e^z + 1}.$$

We need to show $f(z) < g(z)$ for all $z > 0$. The inequality $f(z) < g(z)$ is equivalent to

$$\frac{1}{\sqrt{1 + z^2} - z + 1} < \frac{e^z}{e^z + 1}.$$

Which is equivalent to:

$$\sqrt{1 + z^2} - z + 1 > 1 + e^{-z} \iff \sqrt{1 + z^2} - z > e^{-z}.$$

Define $k(z) = \sqrt{1 + z^2} - z - e^{-z}$. We will now show that $k(z) > 0$ for $z > 0$.

At $z = 0$:

$$k(0) = \sqrt{1 + 0} - 0 - e^0 = 1 - 1 = 0.$$

The first derivative evaluated at 0 is:

$$k'(z)_{|z=0} = \left(\frac{z}{\sqrt{1 + z^2}} - 1 + e^{-z}\right)_{|z=0} = \frac{0}{1} - 1 + e^0 = -1 + 1 = 0$$

The second derivative is

$$k''(z) = \frac{1}{(1 + z^2)^{3/2}} + e^{-z}.$$

Since $(1 + z^2)^{3/2} > 0$ and $e^{-z} > 0$ for all z, we have $k''(z) > 0$ for all z. Thus, $k'(z)$ is strictly increasing. Since $k'(0) = 0$, it follows that $k'(z) > 0$ for $z > 0$. Therefore, $k(z)$ is strictly increasing for $z > 0$. Given $k(0) = 0$, we have $k(z) > 0$ for $z > 0$.

Thus, $\sqrt{1 + z^2} - z > e^{-z}$ for all $z > 0$, implying $f(z) < g(z)$ for all $z > 0$. Reverting to Q, the original inequality holds for all $Q > 0$.

Therefore, we have shown that $\chi^{LF} \geq \chi^{FB} \geq \chi^{CE}$ and that equality only holds when $Q = 0$. □

Figure A.1 shows comparative statics of the simple model with respect to the level of transaction costs. Unsurprisingly, the equilibrium farmers' share χ increases in all allocations with laissez-faire share being higher than first best's, and the latter being higher than constrained efficient one. The ranking of ex-ante welfare is reverse of the χ patterns. Interestingly, the APG grows at a much higher rate in the laissez-faire equilibrium than in the constrained efficient allocation. The fact that it is still growing in the latter, confirms our claims that positive APGs may be an efficient characteristic of real world developing economies.

Moving forward, we extend our simple model above by the features of agricultural production and collateral constraints. In particular, we consider the following problem of a Ramsey planner choosing input subsidies τ and lump-sum taxes for workers T with the goal of maximizing the ex-ante welfare of households, taking into account their best responses to

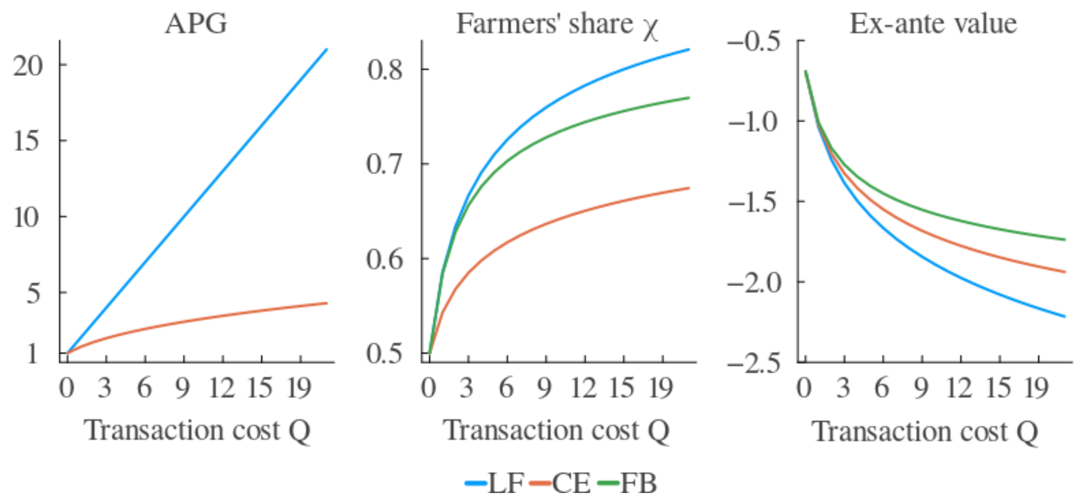


Figure A.1: Comparative statics of simple model with respect to Q

Note: Model is solved under assumption of $A = 2$.

fiscal policies:[37]

$$\max \quad \chi(\log f^F + \log m^F) + (1-\chi)(\log f^W + \log m^W) \tag{26}$$

$$\text{subject to:} \quad f^F + pm^F + pe(1-\tau) = e^\alpha \tag{27}$$

$$f^W(1+Q) + pm^W = pA - T \tag{28}$$

$$\chi\tau pe = (1-\chi)T \tag{29}$$

$$(1-\tau)e \leq \overline{e}(1+Q)^{-\gamma} \tag{30}$$

Equations (27) and (28) are the budget constraints of two occupations. We assume that agricultural input is sourced from the manufacturing sector and is subsidized at rate τ. The production technology in agriculture exhibits decreasing returns to scale with $\alpha \in (0, 1)$. Input subsidies are financed with lump sum taxation T of workers. Equation (29) ensures that the government's budget constraint holds.

Importantly, the collateral constraint (30) potentially restricts input use if $\overline{e}$ is low enough and τ relaxes it. The term $(1 + Q)^{-\gamma}$ with $\gamma \geq 0$ is a reduced-form for equilibrium effects of transaction costs that may operate in a richer dynamic framework. Our primary interpretation of it are GE price effects of Q increasing number of households choosing agricultural sector, making food more abundant and therefore the real price of inputs relatively higher, thereby leading to tightening of the collateral constraint.

Figure A.2 presents numerical results of this model. A general, and perhaps unsurprising, conclusion flowing from it is that a binding collateral constraint rationalizes positive input subsidies. What is less obvious, is the equilibrium impact of subsidies on occupational choice and the interaction with transaction costs.

Let us start with the model with an inelastic collateral constraint. Notice that the value

[37] Derivations of the model are available upon request.

of $\overline{e}$ is chosen deliberately low and implies that the collateral constraint stops binding from the level of $\tau \approx 60\%$ onward (for $Q = 10$; see the middle panel of first row). In this model, there is a negative interaction between Q and τ: higher transaction costs imply lower optimal subsidy rate. This is so as higher transaction costs still push up the equilibrium share of farmers, increasing the amount of food in the system and thereby reducing the need for subsidization in spite of binding collateral constraints. Interestingly, as long as collateral constraints bind, the share of farmers *declines* in τ as higher food supply reduces the value of farming.

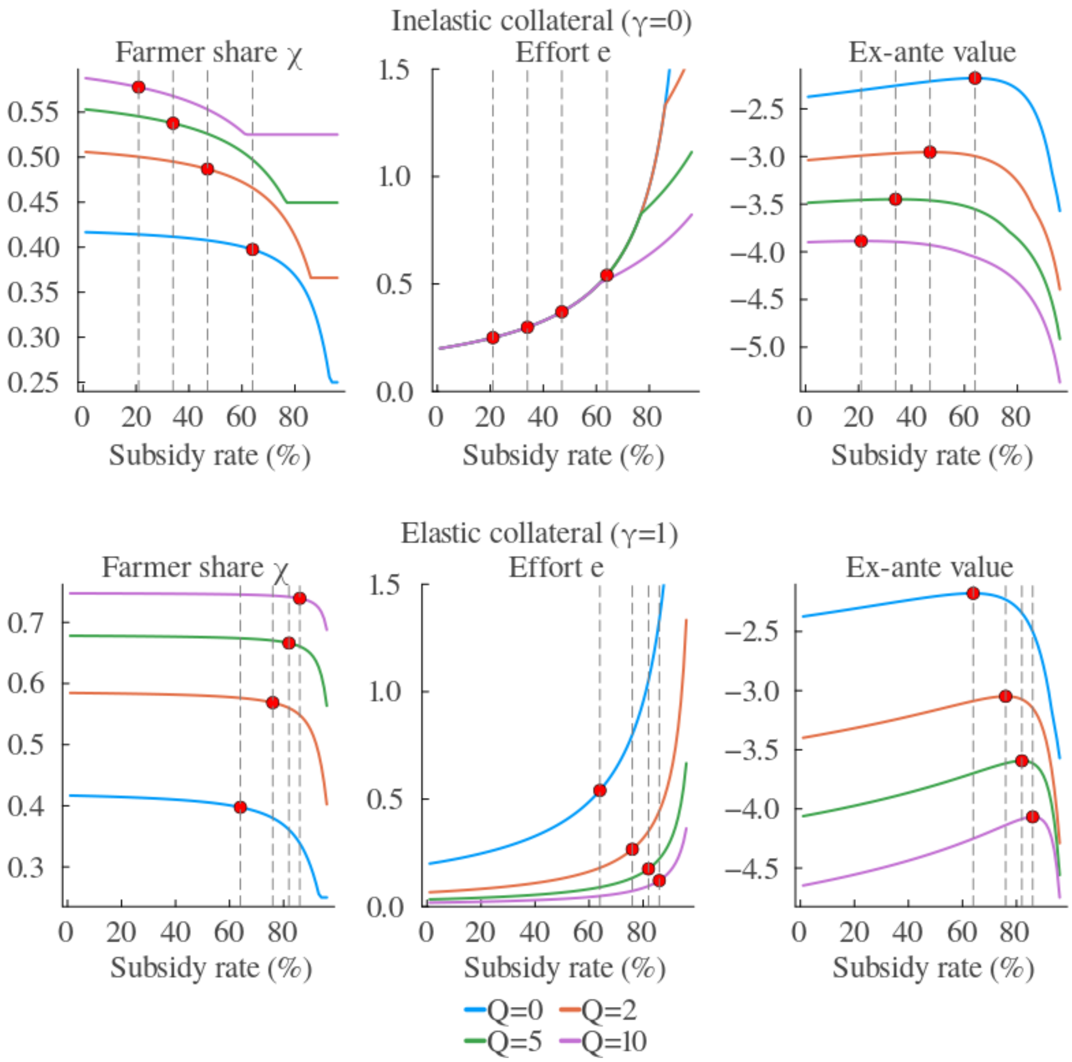


Figure A.2: Comparative statics and optimal policy in simple model with agricultural production and collateral constraints

Note: Model is solved under assumption of $A = 1$, $\overline{e} = 0.2$, $\alpha = 0.5$ and $\gamma = 0$ (first row) or $\gamma = 1$ (second row). Red markers indicate Ramsey-optimal subsidy rates.

Things work out somewhat differently in the model with an elastic collateral constraint. In this case, as Q increases, the constraint becomes tighter (proxying GE effects mentioned above). As the right panel of second row confirms, this implies that with binding collateral constraints, the optimal level of subsidies τ can be *increasing* in transaction costs Q in spite of them generating a higher equilibrium share of farmers. While the farmers' share χ still declines in τ, the absolute gradient of this decline is much lower.

B Solving the household problem

We show how the household dynamic programming problem is solved. We use the analytical expressions derived here in our numerical implementation of the quantitative model.

$$V(z,a,e) = \max_{C,a',e'} u(C) + \beta \mathbb{E} V(z',a',e') \tag{31}$$

$$st.: Y(z,e,C) + a' = (1+r)a \tag{32}$$

$$Y(z,e,C) \in \{Y_S(z,e,C), Y_B(z,e,C), Y_M(z,e,C)\}_{e' \in \{A,M\}} \tag{33}$$

where $Y(z,e,C)$ with $z = (\theta^R, \theta^U)$ denotes the net expenditures of a household. Positive net expenditure implies that wealth is decreasing because income is below the sum of consumption and input investments i.e. the net expenditures are positive. We can expand the occupation choice problem in (31) as follows:

$$\begin{aligned} Y(z,e,C) = & \min_{e' \in \{A,M\}, c_S, c_B, c_M} c_S + p_B c_B + p_M c_M + Q_S \cdot \max((c_S - \mathbf{1}_{e'=A} \cdot q_S), 0) \\ & - \mathbf{1}_{e' \in \{M\}} (\theta^U w - \mathbf{1}_{e \in \{A\}} F_M w) - \mathbf{1}_{e' \in \{S\}} \pi_S \\ & - \mathbf{1}_{e' \in \{B\}} (\pi_B - FM_B w) \end{aligned} \tag{34}$$

$$st.: C = \left(\psi_S \left(c_S - \bar{c}_S \right)^{\frac{\epsilon-1}{\epsilon}} + \psi_B c_B^{\frac{\epsilon-1}{\epsilon}} + \psi_M c_M^{\frac{\epsilon-1}{\epsilon}} \right)^{\frac{\epsilon}{\epsilon-1}} \tag{35}$$

where π denotes agricultural profits and q_S denotes staple output.

Our strategy to solve the household's problem is to proceed by backward induction. First, we solve the above problem (34) for each occupation choice e' without entry and maintenance costs F_M, FM_B as a cost minimization problem for a given productivity state vector z and aggregate consumption basket C.[38] Then, we approximate these decisions and outcomes for each possible value of C. Using all of those, we solve the dynamic problem (31) for optimal C, a', e'.

In what follows, we represent the shadow price of staples λ_S discussed in Section 3 by the sum of λ_2 and λ_3 for the staple farmer and of λ_2 and λ_4 for the cash crop farmer (see details below). We now show how we solve each case of occupational choice.

[38]We can ignore the entry and maintenance costs in this solution as we assume that the within-period borrowing can be done only for the purpose of intermediate input purchases, and not for financing of any other costs.

B.1 Workers

Workers do not produce food, so they always pay the transaction cost:

$$\min_{c_S,c_B,c_M} (1+Q_S)c_S + p_Bc_B + p_Mc_M - w \tag{36}$$

$$+\lambda(C- \left(\psi_S\left(c_S-\bar{c}_S\right)^{\frac{\epsilon-1}{\epsilon}} + \psi_B c_B^{\frac{\epsilon-1}{\epsilon}} + \psi_M c_M^{\frac{\epsilon-1}{\epsilon}}\right)^{\frac{\epsilon}{\epsilon-1}}) \tag{37}$$

FOCs read:

$$1+Q_S = \lambda\psi_S\left(c_S-\bar{c}_S\right)^{-\frac{1}{\epsilon}} C^{\frac{1}{\epsilon}} \tag{38}$$

$$p_B = \psi_B c_B^{-\frac{1}{\epsilon}} \lambda C^{\frac{1}{\epsilon}} \tag{39}$$

$$p_M = \psi_M c_M^{-\frac{1}{\epsilon}} \lambda C^{\frac{1}{\epsilon}} \tag{40}$$

Therefore:

$$c_S - \bar{c}_S = (1+Q_S)^{-\epsilon}\lambda^\epsilon\psi_S^\epsilon C \tag{41}$$

$$c_B = p_B^{-\epsilon}\psi_B^\epsilon C\lambda^\epsilon \tag{42}$$

$$c_M = p_M^{-\epsilon}\psi_M^\epsilon C\lambda^\epsilon \tag{43}$$

The objective function (37) thus becomes:

$$Y_W = (1+Q_S)c_S + p_Bc_B + p_Mc_M - w = \lambda^\epsilon C((1+Q_S)^{1-\epsilon}\psi_S^\epsilon + p_B^{1-\epsilon}\psi_B^\epsilon + p_M^{1-\epsilon}\psi_M^\epsilon) + (1+Q_S)\bar{c}_S - w \tag{44}$$

Plugging back (41), (42) & (43) into definition of C in (35), gives $\lambda = (\psi_S^\epsilon(1+Q_S)^{1-\epsilon} + \psi_B^\epsilon p_B^{1-\epsilon} + \psi_M^\epsilon p_M^{1-\epsilon})^{\frac{1}{1-\epsilon}}$. Therefore the objective function Y_W in (44) ultimately becomes:

$$(1+Q_S)\bar{c}_S + PC - w \tag{45}$$

with $P = ((1+Q_S)^{1-\epsilon}\psi_S^\epsilon + p_B^{1-\epsilon}\psi_B^\epsilon + p_M^{1-\epsilon}\psi_M^\epsilon)^{\frac{1}{1-\epsilon}}$ being the optimal price index. In effect, the price index is adjusted by the transaction cost. Ultimately, to compare occupations, we have to compare expenditure Y for the same consumption basket, since the agent makes the dynamic decision about C at a different stage (as explained in Appendix C). The content of C changes though, in this case:

$$c_S - \bar{c}_S = (1+Q_S)^{-\epsilon} C P_W^\epsilon \psi_S^\epsilon \tag{46}$$

$$c_B = p_B^{-\epsilon}\psi_B^\epsilon C P_W^\epsilon \tag{47}$$

$$c_M = p_M^{-\epsilon}\psi_M^\epsilon C P_W^\epsilon \tag{48}$$

B.2 Agriculture: staple farmer

Things are more complicated for agricultural households as they may lower their internal household price index by (over)producing staples so that they can avoid paying (at least partially) transaction costs. We start with the simpler case of pure staple farmer:

$$q_S = \theta x_S^{\zeta} \tag{49}$$
$$TC_S = (1 - \tau_S)\, p_X x_S \tag{50}$$
$$TC_S \leq \kappa a \tag{51}$$

B.2.1 Case 1: farmer produces strictly more staples than consumes

This case requires that $q_S > c_S$:

$$x_S = \left(\frac{\zeta\theta}{(1+\lambda_S)(1-\tau_S)p_X}\right)^{\frac{1}{1-\zeta}} \tag{52}$$
$$\bar{x}_S = \left(\frac{\zeta\theta}{(1-\tau_S)p_X}\right)^{\frac{1}{1-\zeta}} \tag{53}$$

and if $\bar{x}_S > \frac{\kappa a}{(1-\tau_S)p_X}$ then:

$$x_S = \frac{\kappa a}{(1-\tau_S)p_X} \tag{54}$$
$$\lambda_S = \frac{\zeta\theta}{(\kappa a)^{1-\zeta}(p_X(1-\tau_S))^{\zeta}} - 1 \tag{55}$$

and

$$\pi_S = \{\theta x_S^{\zeta} - (1-\tau_S)\, p_X x_S\} \tag{56}$$
$$P_S = (\psi_S^{\epsilon} + p_B^{1-\epsilon}\psi_B^{\epsilon} + p_M^{1-\epsilon}\psi_M^{\epsilon})^{\frac{1}{1-\epsilon}} \tag{57}$$
$$c_S = \bar{c}_S + P_S^{\epsilon}\psi_S^{\epsilon} C \tag{58}$$
$$c_B = p_B^{-\epsilon}\psi_B^{\epsilon} C P_S^{\epsilon} \tag{59}$$
$$c_M = p_M^{-\epsilon}\psi_M^{\epsilon} C P_S^{\epsilon} \tag{60}$$
$$Y_S = c_S + p_B c_B + p_M c_M - \pi_S \tag{61}$$

If the solution to this problem violates $q_S > c_S$, the household might still not be paying transaction cost, diverting from profit maximization and *overproducing* staples so that $q_S = c_S$. Yet if the condition is fulfilled, then the production and consumption decisions can be separated. If it is violated, then we need to consider the case of $q_S \leq c_S$, as described below.

B.2.2 Case 2: farmer produces weakly less staples than consumes

As $q_S \leq c_S$, the staple producer is only selling staples, this case necessarily implies negative net savings. The problem to solve reads:

$$\min_{c_S,c_B,c_M,x_S,q_S} c_S + Q_S(c_S - q_S) + p_B c_B + p_M c_M - q_S + (1-\tau_S)\, p_X x_S$$

$$+\lambda_1 (C - \left(\psi_S\,(c_S - \bar{c}_S)^{\frac{\epsilon-1}{\epsilon}} + \psi_B c_B^{\frac{\epsilon-1}{\epsilon}} + (1-\psi_S-\psi_B)\, c_M^{\frac{\epsilon-1}{\epsilon}}\right)^{\frac{\epsilon}{\epsilon-1}}) \tag{62}$$

$$+\lambda_2 (q_S - \theta x_S^{\zeta}) \tag{63}$$

$$+\lambda_3 (q_S - c_S) \tag{64}$$

$$+\lambda_S ((1-\tau_S) p_X x_S - \kappa a)) \tag{65}$$

There is an interplay here between transaction costs and the working capital constraint. The household would like to overproduce to avoid paying transaction costs, but this might be prevented because of the working capital constraint. Both λ_1 and λ_2, must be positive.

Taking FOCs:

$$1 + Q_S = \lambda_1 \psi_S\,(c_S - \bar{c}_S)^{-\frac{1}{\epsilon}}\, C^{\frac{1}{\epsilon}} + \lambda_3 \tag{66}$$

$$p_B = \psi_B c_B^{-\frac{1}{\epsilon}} \lambda_1 C^{\frac{1}{\epsilon}} \tag{67}$$

$$p_M = \psi_M c_M^{-\frac{1}{\epsilon}} \lambda_1 C^{\frac{1}{\epsilon}} \tag{68}$$

$$(1+\lambda_S)\,(1-\tau_S)\, p_X = \lambda_2 \zeta \theta x_S^{\zeta-1} \tag{69}$$

$$(1 + Q_S) = \lambda_2 + \lambda_3 \tag{70}$$

Reordering:

$$\lambda_2 = \lambda_1 \psi_S\,(c_S - \bar{c}_S)^{-\frac{1}{\epsilon}}\, C^{\frac{1}{\epsilon}} \tag{71}$$

$$c_S - \bar{c}_S = \lambda_2^{-\epsilon} \psi_S^{\epsilon} \lambda_1^{\epsilon} C \tag{72}$$

$$c_B = p_B^{-\epsilon} \psi_B^{\epsilon} \lambda_1^{\epsilon} C \tag{73}$$

$$c_M = p_M^{-\epsilon} \psi_M^{\epsilon} \lambda_1^{\epsilon} C \tag{74}$$

By plugging in consumption levels (72), (73) and (74) into the definition of C in (62) we get:

$$P_S = \lambda_1 = (\psi_S^{\epsilon} \lambda_2^{1-\epsilon} + \psi_B^{\epsilon} p_B^{1-\epsilon} + \psi_M^{\epsilon} p_M^{1-\epsilon})^{\frac{1}{1-\epsilon}} \tag{75}$$

Consider next the sub-case of $\lambda_3 = 0$, that is, $q_S < c_S$:

$$\lambda_2 = (1 + Q_S) \tag{76}$$

$$1 + Q_S = \lambda_1 \psi_S\,(c_S - \bar{c}_S)^{-\frac{1}{\epsilon}}\, C^{\frac{1}{\epsilon}} \tag{77}$$

and it follows from equation (75) that $P_S = (\psi_S^{\epsilon}(1+Q_S)^{1-\epsilon} + \psi_B^{\epsilon} p_B^{1-\epsilon} + \psi_M^{\epsilon} p_M^{1-\epsilon})^{\frac{1}{1-\epsilon}}$. Production decision takes into account this higher internal price for staples and hence similar to equation

(55):

$$x_S = \Big(\frac{(1+Q_S)\zeta\theta}{(1+\lambda_S)(1-\tau_S)p_X}\Big)^{\frac{1}{1-\zeta}} \tag{78}$$

As $q_S < c_S$, the household is not producing enough to satisfy its staple consumption and therefore faces the marginal staple price of $1+Q_S$. The transaction cost shifts the production quantity up relative to the model with $Q_S = 0$ as an attempt of the household to lower its average internal price of staples.

The next case is when $\lambda_3 > 0$ and therefore $c_S = q_S$:

Combining (76) and (77), and then plugging the latter into (69), and then exploiting that from the production of the household we have $x_S = \left(\frac{c_S}{\theta}\right)^{\frac{1}{\zeta}}$ yields:

$$(1+\lambda_S)(1-\tau_S)\,p_X = \lambda_1\psi_S\,(c_S-\bar{c}_S)^{-\frac{1}{\epsilon}}\,C^{\frac{1}{\epsilon}}\zeta\theta x_S^{\zeta-1} \tag{79}$$

$$(1+\lambda_S)(1-\tau_S)\,p_X = \lambda_1\psi_S\,(c_S-\bar{c}_S)^{-\frac{1}{\epsilon}}\,C^{\frac{1}{\epsilon}}\zeta\theta\Big(\frac{c_S}{\theta}\Big)^{\frac{\zeta-1}{\zeta}} \tag{80}$$

$$(1+\lambda_S)(1-\tau_S)\,p_X = \lambda_1\psi_S\,(c_S-\bar{c}_S)^{-\frac{1}{\epsilon}}\,C^{\frac{1}{\epsilon}}\zeta\theta^{\frac{1}{\zeta}}c_S^{\frac{\zeta-1}{\zeta}} \tag{81}$$

$$\frac{(1+\lambda_S)(1-\tau_S)\,p_X}{\zeta\theta^{\frac{1}{\zeta}}} = \lambda_1\psi_S\,(c_S-\bar{c}_S)^{-\frac{1}{\epsilon}}\,C^{\frac{1}{\epsilon}}c_S^{\frac{\zeta-1}{\zeta}} \tag{82}$$

$$\Big(\frac{(1+\lambda_S)(1-\tau_S)\,p_X}{\zeta\theta^{\frac{1}{\zeta}}}\Big)^{\epsilon} = \lambda_1^{\epsilon}\psi_S^{\epsilon}\,(c_S-\bar{c}_S)^{-1}\,Cc_S^{\frac{\epsilon(\zeta-1)}{\zeta}} \tag{83}$$

$$(c_S-\bar{c}_S) = c_S^{\frac{\epsilon(\zeta-1)}{\zeta}}\lambda_1^{\epsilon}\psi_S^{\epsilon}C\Big(\frac{\zeta\theta^{\frac{1}{\zeta}}}{(1+\lambda_S)(1-\tau_S)\,p_X}\Big)^{\epsilon} \tag{84}$$

$$c_B = p_B^{-\epsilon}\psi_B^{\epsilon}C\lambda_1^{\epsilon} \tag{85}$$

$$c_M = p_M^{-\epsilon}\psi_M^{\epsilon}C\lambda_1^{\epsilon} \tag{86}$$

Note that the problem is the c_S on the RHS of (84). For now ignore it, and just plug it back to the definition of C in (62):

$$C^{\frac{\epsilon-1}{\epsilon}} = c_S^{\frac{(\epsilon-1)(\zeta-1)}{\zeta}}\lambda_1^{\epsilon-1}\psi_S^{\epsilon}C^{\frac{\epsilon-1}{\epsilon}}\Big(\frac{\zeta\theta^{\frac{1}{\zeta}}}{(1+\lambda_S)(1-\tau_S)\,p_X}\Big)^{\epsilon-1} \tag{87}$$

$$+\,p_B^{1-\epsilon}\psi_B^{\epsilon}C^{\frac{\epsilon-1}{\epsilon}}\lambda_1^{\epsilon-1} \tag{88}$$

$$+\,p_M^{1-\epsilon}\psi_M^{\epsilon}C^{\frac{\epsilon-1}{\epsilon}}\lambda_1^{\epsilon-1} \tag{89}$$

Implying that:

$$\lambda_1 = \Big(\psi_S^{\epsilon}\Big(\frac{\zeta(\theta c_S^{\zeta-1})^{\frac{1}{\zeta}}}{(1+\lambda_S)(1-\tau_S)\,p_X}\Big)^{\epsilon-1} + p_B^{1-\epsilon}\psi_B^{\epsilon} + p_M^{1-\epsilon}\psi_M^{\epsilon}\Big)^{\frac{1}{1-\epsilon}} \tag{90}$$

Plugging (90) back into (84) allows us to arrive at the expression that can be used for solving for c_S:

$$\psi_S^{\epsilon-1} C^{\frac{\epsilon-1}{\epsilon}} \left(c_S - \bar{c}_S\right)^{\frac{1-\epsilon}{\epsilon}} = \psi_S^{\epsilon} + c_S^{\frac{(1-\zeta)(\epsilon-1)}{\zeta}} \Big(\frac{\zeta(\theta)^{\frac{1}{\zeta}}}{(1+\lambda_S)\left(1-\tau_S\right) p_X}\Big)^{1-\epsilon} (p_B^{1-\epsilon}\psi_B^{\epsilon} + p_M^{1-\epsilon}\psi_M^{\epsilon}) \quad (91)$$

We first find the numerical solution to (91) by assuming that the working capital constraint is not binding (setting $\lambda_S = 0$). After that, we calculate $\bar{x}_S = \left(\frac{c_S}{\theta}\right)^{\frac{1}{\zeta}}$ and if $\bar{x_S} > \frac{\kappa a}{(1-\tau_S)p_X}$ then we set $x_S = \frac{\kappa a}{(1-\tau_S)p_X}$ and $c_S = \theta x_S^{\zeta}$, else we set $x_S = \bar{x}_S$. If we are constrained by the working capital constraint, use (91) to obtain λ_S:

$$\lambda_S = \Big[\frac{(c_S - \bar{c_S})^{\frac{1-\epsilon}{\epsilon}} \psi_S^{\epsilon-1} C^{\frac{\epsilon-1}{\epsilon}} - \psi_S^{\epsilon}}{(p_B^{1-\epsilon}\psi_B^{\epsilon} + p_M^{1-\epsilon}\psi_M^{\epsilon})((1-\tau_S)p_X)^{\epsilon-1}} c_S^{\frac{(1-\zeta)(1-\epsilon)}{\zeta}}\Big]^{\frac{1}{\epsilon-1}} \zeta(\theta)^{\frac{1}{\zeta}} - 1 \quad (92)$$

and then (90) to obtain λ_1. Finally, verify (irrespective of λ_S) which case of λ_3 produces lower net expenditure. Recall, net expenditure in these cases is equal to:

$$(1 + Q_S)c_S + p_B c_B + p_M c_M - (1 + Q_S)q_S + (1 - \tau_S)\, p_X x_S \quad (93)$$

and we choose between the cases of $q_S > c_S$, $q_S = c_S$, $q_S < c_S$ the one that yields the lowest expenditure.

B.3 Agriculture: cash crop farmer

In this case, the problem to solve reads:

$$\begin{aligned}
\min_{c_S,c_B,c_M,x_S,q_S,x_B,q_B,l}\; & c_S + Q_S \max(c_S - q_S, 0) + p_B c_B + p_M c_M - q_S - p_B q_B \\
& + (1-\tau_B)\, p_X x_B + (1-\tau_S)\, p_X x_S \\
& +\lambda_1 (C - \left(\psi_S \left(c_S - \bar{c}_S\right)^{\frac{\epsilon-1}{\epsilon}} + \psi_B c_B^{\frac{\epsilon-1}{\epsilon}} + \left(1-\psi_S-\psi_B\right) c_M^{\frac{\epsilon-1}{\epsilon}}\right)^{\frac{\epsilon}{\epsilon-1}}) && (94)\\
& +\lambda_2 (q_S - \theta(1-l)^{\phi} x_S^{\zeta}) && (95)\\
& +\lambda_3 (q_B - \theta l^{\phi} (x_B)^{\zeta}) && (96)\\
& -\lambda_B (\kappa a - (1-\tau_B)\, p_X x_B + (1-\tau_S)\, p_X x_S) && (97)
\end{aligned}$$

B.3.1 Case 1: farmer produces strictly more staples than consumes

If $q_S > c_S$ then no transaction cost is paid. Thus, the problem is equivalent to:

$$\min_{c_S, c_B, c_M, x_S, q_S, x_B, q_B, l} c_S + p_B c_B + p_M c_M - q_S - p_B q_B$$

$$+ (1 - \tau_B) p_X x_B + (1 - \tau_S) p_X x_S$$

$$+\lambda_1 (C - \left(\psi_S (c_S - \bar{c}_S)^{\frac{\epsilon-1}{\epsilon}} + \psi_B c_B^{\frac{\epsilon-1}{\epsilon}} + (1 - \psi_S - \psi_B) c_M^{\frac{\epsilon-1}{\epsilon}} \right)^{\frac{\epsilon}{\epsilon-1}}) \quad (98)$$

$$+\lambda_2 (q_S - \theta(1-l)^{\phi} x_S^{\zeta}) \quad (99)$$

$$+\lambda_3 (q_B - \theta l^{\phi} (x_B)^{\zeta}) \quad (100)$$

$$-\lambda_B (\kappa a - (1 - \tau_B) p_X x_B + (1 - \tau_S) p_X x_S) \quad (101)$$

FOCs read:

$$\lambda_2 \zeta \theta (1-l)^{\phi} x_S^{\zeta-1} = (1 + \lambda_B)(1 - \tau_S) p_X \quad (102)$$

$$\lambda_3 \zeta \theta l^{\phi} x_B^{\zeta-1} = (1 + \lambda_B)(1 - \tau_B) p_X \quad (103)$$

$$\lambda_2 = 1 \quad (104)$$

$$\lambda_3 = p_B \quad (105)$$

$$\lambda_3 \phi \theta l^{\phi-1} x_B^{\zeta} = \lambda_2 \phi \theta (1-l)^{\phi-1} x_S^{\zeta} \quad (106)$$

$$1 = \lambda_1 \psi_S (c_S - \bar{c}_S)^{-\frac{1}{\epsilon}} C^{\frac{1}{\epsilon}} \quad (107)$$

$$p_B = \psi_B c_B^{-\frac{1}{\epsilon}} \lambda_1 C^{\frac{1}{\epsilon}} \quad (108)$$

$$p_M = \psi_M c_M^{-\frac{1}{\epsilon}} \lambda_1 C^{\frac{1}{\epsilon}} \quad (109)$$

The consumption problem can be separated from the production problem in this subcase, hence by substituting out shadow producer prices λ_2 from (104) and λ_3 from (105), equations (101), (102), (103) and (106) give us the following system of equations:

$$\zeta \theta (1-l)^{\phi-1} x_S^{\zeta} = (1 + \lambda_B)(1 - \tau_S) \frac{p_X x_S}{(1-l)} \quad (110)$$

$$\zeta p_B \theta l^{\phi-1} x_B^{\zeta} = (1 + \lambda_B)(1 - \tau_B) \frac{p_X x_B}{l} \quad (111)$$

$$p_B l^{\phi-1} x_B^{\zeta} = (1-l)^{\phi-1} x_S^{\zeta} \quad (112)$$

which can be rearranged to get:

$$x_B = \frac{l}{1-l} \frac{1-\tau_S}{1-\tau_B} x_S \quad (113)$$

$$x_S = \left[\frac{\zeta \theta (1-l)^{\phi}}{(1-\tau_S) p_X (1 + \lambda_B)} \right]^{\frac{1}{1-\zeta}} \quad (114)$$

$$x_B = \left[\frac{\zeta \theta p_B l^{\phi}}{(1-\tau_B) p_X (1 + \lambda_B)} \right]^{\frac{1}{1-\zeta}} \quad (115)$$

This system gives us expression for land allocated l:

$$\left[\frac{\zeta\theta p_B l^\phi}{(1-\tau_B)p_X(1+\lambda_B)}\right]^{\frac{1}{1-\zeta}} = \frac{l}{1-l}\frac{1-\tau_S}{1-\tau_B}\left[\frac{\zeta\theta(1-l)^\phi}{(1-\tau_S)p_X(1+\lambda_B)}\right]^{\frac{1}{1-\zeta}} \tag{116}$$

$$\left[\frac{\zeta\theta p_B l^\phi}{(1-\tau_B)p_X(1+\lambda_B)}\right] = \frac{l^{1-\zeta}}{(1-l)^{1-\zeta}}\frac{(1-\tau_S)^{1-\zeta}}{(1-\tau_B)^{1-\zeta}}\left[\frac{\zeta\theta(1-l)^\phi}{(1-\tau_S)p_X(1+\lambda_B)}\right] \tag{117}$$

$$\frac{p_B(1-\tau_S)^\zeta}{(1-\tau_B)^\zeta} = \left[\frac{l}{1-l}\right]^{1-\phi-\zeta} \tag{118}$$

$$l\Big[(1-\tau_B)^\zeta\Big]^{\frac{1}{1-\phi-\zeta}} = (1-l)\Big[p_B(1-\tau_S)^\zeta\Big]^{\frac{1}{1-\phi-\zeta}} \tag{119}$$

$$l = \frac{\big[p_B(1-\tau_S)^\zeta\big]^{\frac{1}{1-\phi-\zeta}}}{\big[p_B(1-\tau_S)^\zeta\big]^{\frac{1}{1-\phi-\zeta}} + \big[(1-\tau_B)^\zeta\big]^{\frac{1}{1-\phi-\zeta}}} \tag{120}$$

Note that optimal land allocation to cash crop production is independent of λ_B, increases with cash crop price or subsidies for cash crop inputs (Proposition 1).

Given the solution for l, we obtain the following quantities:

$$x_S = \left[\frac{\zeta\theta}{(1-\tau_S)p_X(1+\lambda_B)}\right]^{\frac{1}{1-\zeta}} \frac{\big[(1-\tau_B)^\zeta\big]^{\frac{\phi}{(1-\zeta)(1-\phi-\zeta)}}}{\Big[\big[p_B(1-\tau_S)^\zeta\big]^{\frac{1}{1-\phi-\zeta}} + \big[(1-\tau_B)^\zeta\big]^{\frac{1}{1-\phi-\zeta}}\Big]^{\frac{\phi}{1-\zeta}}} \tag{121}$$

$$x_B = \left[\frac{\zeta\theta p_B}{(1-\tau_B)p_X(1+\lambda_B)}\right]^{\frac{1}{1-\zeta}} \frac{\big[p_B(1-\tau_S)^\zeta\big]^{\frac{\phi}{(1-\zeta)(1-\phi-\zeta)}}}{\Big[\big[p_B(1-\tau_S)^\zeta\big]^{\frac{1}{1-\phi-\zeta}} + \big[(1-\tau_B)^\zeta\big]^{\frac{1}{1-\phi-\zeta}}\Big]^{\frac{\phi}{1-\zeta}}} \tag{122}$$

$$\begin{aligned} TC_B = {} & \left[\frac{\zeta\theta}{(1+\lambda_B)}\right]^{\frac{1}{1-\zeta}} \frac{p_X^{-\frac{\zeta}{(1-\zeta)}}}{\Big[\big[p_B(1-\tau_S)^\zeta\big]^{\frac{1}{1-\phi-\zeta}} + \big[(1-\tau_B)^\zeta\big]^{\frac{1}{1-\phi-\zeta}}\Big]^{\frac{\phi}{1-\zeta}}} \\ & \cdot\Big((1-\tau_B)^{\frac{\phi\zeta}{(1-\zeta)(1-\phi-\zeta)}}(1-\tau_S)^{-\frac{\zeta}{1-\zeta}} + (p_B)^{\frac{1}{(1-\phi-\zeta)}}(1-\tau_S)^{\frac{\phi\zeta}{(1-\zeta)(1-\phi-\zeta)}}(1-\tau_B)^{-\frac{\zeta}{1-\zeta}}\Big) \qquad (123) \\ = {} & \left[\frac{\zeta\theta}{(1+\lambda_B)}\right]^{\frac{1}{1-\zeta}} \frac{(p_X(1-\tau_B)(1-\tau_S))^{-\frac{\zeta}{(1-\zeta)}}}{\Big[\big[p_B(1-\tau_S)^\zeta\big]^{\frac{1}{1-\phi-\zeta}} + \big[(1-\tau_B)^\zeta\big]^{\frac{1}{1-\phi-\zeta}}\Big]^{\frac{\phi-1+\zeta}{1-\zeta}}} \qquad (124) \\ = {} & \left[\frac{\zeta\theta}{(1+\lambda_B)}\right]^{\frac{1}{1-\zeta}} \frac{\Big[\big[p_B(1-\tau_S)^\zeta\big]^{\frac{1}{1-\phi-\zeta}} + \big[(1-\tau_B)^\zeta\big]^{\frac{1}{1-\phi-\zeta}}\Big]^{\frac{1-\phi-\zeta}{1-\zeta}}}{(p_X(1-\tau_B)(1-\tau_S))^{\frac{\zeta}{(1-\zeta)}}} \qquad (125) \end{aligned}$$

We obtain closed form solutions for the case when the working capital constraint is not binding by plugging in $\lambda_B = 0$ in the above. For the case when this constraint is binding, we set $TC_B = \kappa a$. Overall, the solution to this case can be summarized as follows:

$$\lambda_B = \Big[\frac{\zeta\theta}{(\kappa a)^{1-\zeta}}\Big]\frac{\Big[\big[p_B(1-\tau_S)^\zeta\big]^{\frac{1}{1-\phi-\zeta}} + \big[(1-\tau_B)^\zeta\big]^{\frac{1}{1-\phi-\zeta}}\Big]^{1-\phi-\zeta}}{(p_X(1-\tau_B)(1-\tau_S))^\zeta} - 1 \tag{126}$$

$$TC_B = \Big[\frac{\zeta\theta}{(1+\lambda_B)}\Big]^{\frac{1}{1-\zeta}}\frac{\Big[\big[p_B(1-\tau_S)^\zeta\big]^{\frac{1}{1-\phi-\zeta}} + \big[(1-\tau_B)^\zeta\big]^{\frac{1}{1-\phi-\zeta}}\Big]^{\frac{1-\phi-\zeta}{1-\zeta}}}{(p_X(1-\tau_B)(1-\tau_S))^{\frac{\zeta}{(1-\zeta)}}} \tag{127}$$

$$l = \frac{\big[p_B(1-\tau_S)^\zeta\big]^{\frac{1}{1-\phi-\zeta}}}{\big[p_B(1-\tau_S)^\zeta\big]^{\frac{1}{1-\phi-\zeta}} + \big[(1-\tau_B)^\zeta\big]^{\frac{1}{1-\phi-\zeta}}} \tag{128}$$

$$x_S = \Big[\frac{\zeta\theta}{(1-\tau_S)p_X(1+\lambda_B)}\Big]^{\frac{1}{1-\zeta}}\frac{\big[(1-\tau_B)^\zeta\big]^{\frac{\phi}{(1-\zeta)(1-\phi-\zeta)}}}{\Big[\big[p_B(1-\tau_S)^\zeta\big]^{\frac{1}{1-\phi-\zeta}} + \big[(1-\tau_B)^\zeta\big]^{\frac{1}{1-\phi-\zeta}}\Big]^{\frac{\phi}{1-\zeta}}} \tag{129}$$

$$x_B = \Big[\frac{\zeta\theta p_B}{(1-\tau_B)p_X(1+\lambda_B)}\Big]^{\frac{1}{1-\zeta}}\frac{\big[p_B(1-\tau_S)^\zeta\big]^{\frac{\phi}{(1-\zeta)(1-\phi-\zeta)}}}{\Big[\big[p_B(1-\tau_S)^\zeta\big]^{\frac{1}{1-\phi-\zeta}} + \big[(1-\tau_B)^\zeta\big]^{\frac{1}{1-\phi-\zeta}}\Big]^{\frac{\phi}{1-\zeta}}} \tag{130}$$

$$q_S = \theta(1-l)^\phi x_S^\zeta \tag{131}$$

$$q_B = \theta l^\phi x_B^\zeta \tag{132}$$

$$\pi_B = q_S + p_B q_B - TC_B \tag{133}$$

$$P_B = (\psi_S^\epsilon + p_B^{1-\epsilon}\psi_B^\epsilon + p_M^{1-\epsilon}\psi_M^\epsilon)^{\frac{1}{1-\epsilon}} \tag{134}$$

$$c_S = \bar{c}_S + P_B^\epsilon \psi_B^\epsilon C \tag{135}$$

$$c_B = p_B^{-\epsilon}\psi_B^\epsilon C P_B^\epsilon \tag{136}$$

$$c_M = p_M^{-\epsilon}\psi_M^\epsilon C P_B^\epsilon \tag{137}$$

$$Y_B = c_S + p_B c_B + p_M c_M - \pi_B \tag{138}$$

B.3.2 Case 2: farmer produces weakly less staples than consumes

With $q_S \leq c_S$ the problem reads:

$$\min_{c_S,c_B,c_M,x_S,q_S,x_B,q_B,l} (1+Q_S)c_S + p_B c_B + p_M c_M - (1+Q_S)q_S - p_B q_B$$

$$+ (1-\tau_B)\,p_X x_B + (1-\tau_S)\,p_X x_S$$

$$+\lambda_1(C - \Big(\psi_S\,(c_S - \bar{c}_S)^{\frac{\epsilon-1}{\epsilon}} + \psi_B c_B^{\frac{\epsilon-1}{\epsilon}} + (1-\psi_S-\psi_B)\,c_M^{\frac{\epsilon-1}{\epsilon}}\Big)^{\frac{\epsilon}{\epsilon-1}}) \tag{139}$$

$$+\lambda_2(q_S - \theta(1-l)^\phi x_S^\zeta) \tag{140}$$

$$+\lambda_3(q_B - \theta l^\phi (x_B)^\zeta) \tag{141}$$

$$-\lambda_4(c_S - q_S) \tag{142}$$

$$-\lambda_B(\kappa a - (1-\tau_B)\,p_X x_B + (1-\tau_S)\,p_X x_S) \tag{143}$$

We get the following FOCs:

$$\lambda_2 \zeta \theta (1-l)^{\phi} x_S^{\zeta-1} = (1+\lambda_B)(1-\tau_S) p_X \tag{144}$$

$$\lambda_3 \zeta \theta l^{\phi} x_B^{\zeta-1} = (1+\lambda_B)(1-\tau_B) p_X \tag{145}$$

$$\lambda_2 = 1 + Q_S - \lambda_4 \tag{146}$$

$$\lambda_3 = p_B \tag{147}$$

$$\lambda_3 \phi \theta l^{\phi-1} x_B^{\zeta} = \lambda_2 \phi \theta (1-l)^{\phi-1} x_S^{\zeta} \tag{148}$$

$$1 + Q_S - \lambda_4 = \lambda_1 \psi_S \left(c_S - \bar{c}_S\right)^{-\frac{1}{\epsilon}} C^{\frac{1}{\epsilon}} \tag{149}$$

$$p_B = \psi_B c_B^{-\frac{1}{\epsilon}} \lambda_1 C^{\frac{1}{\epsilon}} \tag{150}$$

$$p_M = \psi_M c_M^{-\frac{1}{\epsilon}} \lambda_1 C^{\frac{1}{\epsilon}} \tag{151}$$

Consider first the case of $c_S > q_S$. This implies $\lambda_4 = 0$. In this case, the shadow price of staples is $1 + Q_S$ and we can get our solution based on the case solved just above (where we set λ_B=0 if the working capital constraint is not binding, and set $TC_B = \kappa a$ otherwise):

$$\lambda_B = \left[\frac{\zeta\theta}{(\kappa a)^{1-\zeta}}\right]\frac{\left[\left[p_B(1-\tau_S)^\zeta\right]^{\frac{1}{1-\phi-\zeta}} + \left[(1+Q_S)(1-\tau_B)^\zeta\right]^{\frac{1}{1-\phi-\zeta}}\right]^{1-\phi-\zeta}}{(p_X(1-\tau_B)(1-\tau_S))^\zeta} - 1 \tag{152}$$

$$TC_B = \left[\frac{\zeta\theta}{(1+\lambda_B)}\right]^{\frac{1}{1-\zeta}}\frac{\left[\left[p_B(1-\tau_S)^\zeta\right]^{\frac{1}{1-\phi-\zeta}} + \left[(1+Q_S)(1-\tau_B)^\zeta\right]^{\frac{1}{1-\phi-\zeta}}\right]^{\frac{1-\phi-\zeta}{1-\zeta}}}{(p_X(1-\tau_B)(1-\tau_S))^{\frac{\zeta}{(1-\zeta)}}} \tag{153}$$

$$l = \frac{\left[p_B(1-\tau_S)^\zeta\right]^{\frac{1}{1-\phi-\zeta}}}{\left[p_B(1-\tau_S)^\zeta\right]^{\frac{1}{1-\phi-\zeta}} + \left[(1+Q_S)(1-\tau_B)^\zeta\right]^{\frac{1}{1-\phi-\zeta}}} \tag{154}$$

$$x_S = \left[\frac{\zeta\theta(1+Q_S)}{(1-\tau_S)p_X(1+\lambda_B)}\right]^{\frac{1}{1-\zeta}}\frac{\left[(1+Q_S)(1-\tau_B)^\zeta\right]^{\frac{\phi}{(1-\zeta)(1-\phi-\zeta)}}}{\left[\left[p_B(1-\tau_S)^\zeta\right]^{\frac{1}{1-\phi-\zeta}} + \left[(1+Q_S)(1-\tau_B)^\zeta\right]^{\frac{1}{1-\phi-\zeta}}\right]^{\frac{\phi}{1-\zeta}}} \tag{155}$$

$$x_B = \left[\frac{\zeta\theta p_B}{(1-\tau_B)p_X(1+\lambda_B)}\right]^{\frac{1}{1-\zeta}}\frac{\left[p_B(1-\tau_S)^\zeta\right]^{\frac{\phi}{(1-\zeta)(1-\phi-\zeta)}}}{\left[\left[p_B(1-\tau_S)^\zeta\right]^{\frac{1}{1-\phi-\zeta}} + \left[(1+Q_S)(1-\tau_B)^\zeta\right]^{\frac{1}{1-\phi-\zeta}}\right]^{\frac{\phi}{1-\zeta}}} \tag{156}$$

$$q_S = \theta(1-l)^\phi x_S^\zeta \tag{157}$$

$$q_B = \theta l^\phi x_B^\zeta \tag{158}$$

$$\pi_B = p_B q_B - TC_B \tag{159}$$

$$P_B = ((1+Q_S)^{1-\epsilon}\psi_S^\epsilon + p_B^{1-\epsilon}\psi_B^\epsilon + p_M^{1-\epsilon}\psi_M^\epsilon)^{\frac{1}{1-\epsilon}} \tag{160}$$

$$c_S = \bar{c}_S + (1+Q_S)^{-\epsilon}P_B^\epsilon\psi_S^\epsilon C \tag{161}$$

$$c_B = p_B^{-\epsilon}\psi_B^\epsilon C P_B^\epsilon \tag{162}$$

$$c_M = p_M^{-\epsilon}\psi_M^\epsilon C P_B^\epsilon \tag{163}$$

$$Y_B = (1+Q_S)(c_S - q_S) + p_B c_B + p_M c_M - \pi_B \tag{164}$$

Now, to the more complicated case when $q_S = c_S$. Here, we have $\lambda_4 \geq 0$. First, let us work with the production FOCs (144), (145) and (148) by keeping λ_2:

$$\lambda_2\zeta\theta(1-l)^{\phi-1}x_S^\zeta = (1+\lambda_B)(1-\tau_S)\frac{p_X x_S}{(1-l)} \tag{165}$$

$$\zeta p_B\theta l^{\phi-1}x_B^\zeta = (1+\lambda_B)(1-\tau_B)\frac{p_X x_B}{l} \tag{166}$$

$$p_B l^{\phi-1}x_B^\zeta = \lambda_2(1-l)^{\phi-1}x_S^\zeta \tag{167}$$

and hence we end up with equations similar to the case above, but with the staples shadow price, λ_2 showing up on the RHS:

$$\lambda_B = \left[\frac{\zeta\theta}{(\kappa a)^{1-\zeta}}\right]\frac{\left[\left[p_B(1-\tau_S)^\zeta\right]^{\frac{1}{1-\phi-\zeta}}+\left[\lambda_2(1-\tau_B)^\zeta\right]^{\frac{1}{1-\phi-\zeta}}\right]^{1-\phi-\zeta}}{(p_X(1-\tau_B)(1-\tau_S))^\zeta}-1 \tag{168}$$

$$TC_B = \left[\frac{\zeta\theta}{(1+\lambda_B)}\right]^{\frac{1}{1-\zeta}}\frac{\left[\left[p_B(1-\tau_S)^\zeta\right]^{\frac{1}{1-\phi-\zeta}}+\left[\lambda_2(1-\tau_B)^\zeta\right]^{\frac{1}{1-\phi-\zeta}}\right]^{\frac{1-\phi-\zeta}{1-\zeta}}}{(p_X(1-\tau_B)(1-\tau_S))^{\frac{\zeta}{(1-\zeta)}}} \tag{169}$$

$$l = \frac{\left[p_B(1-\tau_S)^\zeta\right]^{\frac{1}{1-\phi-\zeta}}}{\left[p_B(1-\tau_S)^\zeta\right]^{\frac{1}{1-\phi-\zeta}}+\left[\lambda_2(1-\tau_B)^\zeta\right]^{\frac{1}{1-\phi-\zeta}}} \tag{170}$$

$$x_S = \left[\frac{\zeta\theta\lambda_2}{(1-\tau_S)p_X(1+\lambda_B)}\right]^{\frac{1}{1-\zeta}}\frac{\left[\lambda_2(1-\tau_B)^\zeta\right]^{\frac{\phi}{(1-\zeta)(1-\phi-\zeta)}}}{\left[\left[p_B(1-\tau_S)^\zeta\right]^{\frac{1}{1-\phi-\zeta}}+\left[\lambda_2(1-\tau_B)^\zeta\right]^{\frac{1}{1-\phi-\zeta}}\right]^{\frac{\phi}{1-\zeta}}} \tag{171}$$

$$x_B = \left[\frac{\zeta\theta p_B}{(1-\tau_B)p_X(1+\lambda_B)}\right]^{\frac{1}{1-\zeta}}\frac{\left[p_B(1-\tau_S)^\zeta\right]^{\frac{\phi}{(1-\zeta)(1-\phi-\zeta)}}}{\left[\left[p_B(1-\tau_S)^\zeta\right]^{\frac{1}{1-\phi-\zeta}}+\left[\lambda_2(1-\tau_B)^\zeta\right]^{\frac{1}{1-\phi-\zeta}}\right]^{\frac{\phi}{1-\zeta}}} \tag{172}$$

$$q_S = \theta(1-l)^\phi x_S^\zeta \tag{173}$$

$$q_B = \theta l^\phi x_B^\zeta \tag{174}$$

Using equations (170) and (171) in (173), we get the following expression for q_S:

$$q_S = \theta\frac{\left[\left[\lambda_2(1-\tau_B)^\zeta\right]^{\frac{\phi}{1-\phi-\zeta}}\right.}{\left[\left[p_B(1-\tau_S)^\zeta\right]^{\frac{1}{1-\phi-\zeta}}+\left[\lambda_2(1-\tau_B)^\zeta\right]^{\frac{1}{1-\phi-\zeta}}\right]^\phi}\left[\frac{\zeta\theta\lambda_2}{(1-\tau_S)p_X(1+\lambda_B)}\right]^{\frac{\zeta}{1-\zeta}} \tag{175}$$

$$\cdot\frac{\left[\lambda_2(1-\tau_B)^\zeta\right]^{\frac{\zeta\phi}{(1-\zeta)(1-\phi-\zeta)}}}{\left[\left[p_B(1-\tau_S)^\zeta\right]^{\frac{1}{1-\phi-\zeta}}+\left[\lambda_2(1-\tau_B)^\zeta\right]^{\frac{1}{1-\phi-\zeta}}\right]^{\frac{\zeta\phi}{1-\zeta}}} \tag{176}$$

$$= \theta\cdot\frac{\left[\lambda_2(1-\tau_B)^\zeta\right]^{\frac{\phi}{(1-\zeta)(1-\phi-\zeta)}}}{\left[\left[p_B(1-\tau_S)^\zeta\right]^{\frac{1}{1-\phi-\zeta}}+\left[\lambda_2(1-\tau_B)^\zeta\right]^{\frac{1}{1-\phi-\zeta}}\right]^{\frac{\phi}{1-\zeta}}}\left[\frac{\zeta\theta\lambda_2}{(1-\tau_S)p_X(1+\lambda_B)}\right]^{\frac{\zeta}{1-\zeta}} \tag{177}$$

$$= \left[\frac{\zeta}{(1-\tau_S)p_X(1+\lambda_B)}\right]^{\frac{\zeta}{1-\zeta}}\frac{\lambda_2^{\frac{\phi-\zeta\phi+\zeta-\zeta^2}{(1-\zeta)(1-\zeta-\phi)}}\theta^{\frac{1}{1-\zeta}}(1-\tau_B)^{\frac{\zeta\phi}{(1-\zeta)(1-\phi-\zeta)}}}{\left[\left[p_B(1-\tau_S)^\zeta\right]^{\frac{1}{1-\phi-\zeta}}+\left[\lambda_2(1-\tau_B)^\zeta\right]^{\frac{1}{1-\phi-\zeta}}\right]^{\frac{\phi}{1-\zeta}}} \tag{178}$$

From the price index equation (160) adjusted for the shadow price of staples, and the staple consumption FOC (149) combined with (146) we get:

$$P_B = (\lambda_2^{1-\epsilon}\psi_S^\epsilon + p_B^{1-\epsilon}\psi_B^\epsilon + p_M^{1-\epsilon}\psi_M^\epsilon)^{\frac{1}{1-\epsilon}} \tag{179}$$

$$c_S = \bar{c}_S + \lambda_2^{-\epsilon}P_B^\epsilon\psi_S^\epsilon C \tag{180}$$

Combining the two equations above with $c_S = q_S$ yields:

$$\bar{c}_S + \lambda_2^{-\epsilon}(\lambda_2^{1-\epsilon}\psi_S^{\epsilon} + p_B^{1-\epsilon}\psi_B^{\epsilon} + p_M^{1-\epsilon}\psi_M^{\epsilon})^{\frac{\epsilon}{1-\epsilon}}\psi_S^{\epsilon}C =$$
$$\left[\frac{\zeta}{(1-\tau_S)p_X(1+\lambda_B)}\right]^{\frac{\zeta}{1-\zeta}} \frac{\lambda_2^{\frac{\phi-\zeta\phi+\zeta-\zeta^2}{(1-\zeta)(1-\zeta-\phi)}}\theta^{\frac{1}{1-\zeta}}(1-\tau_B)^{\frac{\zeta\phi}{(1-\zeta)(1-\phi-\zeta)}}}{\left[\left[p_B(1-\tau_S)^{\zeta}\right]^{\frac{1}{1-\phi-\zeta}} + \left[\lambda_2(1-\tau_B)^{\zeta}\right]^{\frac{1}{1-\phi-\zeta}}\right]^{\frac{\phi}{1-\zeta}}} \tag{181}$$

In equation (181), there are two unknowns: λ_B and λ_2. The numerical algorithm we implement is as follows:

- First assume that the working capital constraint is not binding and so set $\lambda_B = 0$. Use (181) for solving for λ_2. Do this for each θ value, and interpolate for all possible consumption values C. Let us call this approximation $c_{S,UC}^B(C)$ (as consumption bundle coefficients in an approximation, not related to cash crop). We do this for each case corresponding to whether q_S is greater or smaller than c_S, we calculate TC_B and check if the working capital constraint is satisfied and $\lambda_2 \in [1, 1+Q_S]$, otherwise we set expenditures to $Y_B = \infty$.

- Then we create a second function $\lambda_{2,WCC}(C)$, for each productivity θ and wealth a, assuming that the working capital constraint is binding, i.e. that $\lambda_B > 0$. Here, we use equation (168) to get an expression for λ_B:

$$\lambda_B = \left[\frac{\zeta\theta}{(\kappa a)^{1-\zeta}}\right] \frac{\left[\left[p_B(1-\tau_S)^{\zeta}\right]^{\frac{1}{1-\phi-\zeta}} + \left[\lambda_2(1-\tau_B)^{\zeta}\right]^{\frac{1}{1-\phi-\zeta}}\right]^{1-\phi-\zeta}}{(p_X(1-\tau_B)(1-\tau_S))^{\zeta}} - 1 \tag{182}$$

  and after plugging it back to equation (181), we get:

$$\bar{c}_S + \lambda_2^{-\epsilon}(\lambda_2^{1-\epsilon}\psi_S^{\epsilon} + p_B^{1-\epsilon}\psi_B^{\epsilon} + p_M^{1-\epsilon}\psi_M^{\epsilon})^{\frac{\epsilon}{1-\epsilon}}\psi_S^{\epsilon}C =$$
$$\left[\frac{\zeta}{(1-\tau_S)p_X}\right]^{\frac{\zeta}{1-\zeta}} \frac{\lambda_2^{\frac{\phi-\zeta\phi+\zeta-\zeta^2}{(1-\zeta)(1-\zeta-\phi)}}\theta^{\frac{1}{1-\zeta}}(1-\tau_B)^{\frac{\zeta\phi}{(1-\zeta)(1-\phi-\zeta)}}}{\left[\left[p_B(1-\tau_S)^{\zeta}\right]^{\frac{1}{1-\phi-\zeta}} + \left[\lambda_2(1-\tau_B)^{\zeta}\right]^{\frac{1}{1-\phi-\zeta}}\right]^{\frac{\phi}{1-\zeta}}}$$
$$\cdot\left[\frac{(\kappa a)^{\zeta}}{(\zeta\theta)^{\frac{\zeta}{(1-\zeta)}}}\right] \frac{(p_X(1-\tau_B)(1-\tau_S))^{\frac{\zeta^2}{1-\zeta}}}{\left[\left[p_B(1-\tau_S)^{\zeta}\right]^{\frac{1}{1-\phi-\zeta}} + \left[\lambda_2(1-\tau_B)^{\zeta}\right]^{\frac{1}{1-\phi-\zeta}}\right]^{\frac{(1-\phi-\zeta)\zeta}{1-\zeta}}} \tag{183}$$

- This equation characterizes the λ_2 of the working capital constrained problem. For this to be feasible, we need the following conditions to hold:

  - $\lambda_2 \in [1, 1+Q_S]$
  - $TC_B < TC_B^{\lambda_B=0}$

  Otherwise we set $TC_B = \infty$.

This algorithm covers all occupation choice cases possible. As already said at the beginning, for a given state vector z, a, e we choose the feasible occupation decision that minimizes expenditures.

C Recursive competitive equilibrium

C.1 Equilibrium definition

We define the equilibrium along the transition path to allow the option of studying the macroeconomic adjustment following the introduction of ISP. Let $G_t(z, a, e)$ be the cumulative density function for the joint distribution of households, and let $Q_t(z, a, e, a', z', e')$ be the transition function. a denotes the wealth, z the joint labor and agricultural productivity and e the past employment of households. Then, the distribution of households and its transition function:

$$\{G_t(z, a, e), Q_t(z, a, e, a', z', e')\}_{t=0}^{\infty} \tag{184}$$

and the household allocations (as functions of the state variables (z, a, e)):

$$\{C_t, c_{S,t}, c_{B,t}, c_{M,t}, a_{t+1}, e_{t+1}, x_{S,t}, q_{S,t}, x_{B,t}, q_{B,t}, l_t\}_{t=0}^{\infty} \tag{185}$$

and the aggregate allocations $\{K_t, L_t\}_{t=0}^{\infty}$, trade $\{X_t, M_t^M, M_t^X\}_{t=0}^{\infty}$, foreign aid $\{FA_t\}_{t=0}^{\infty}$, the prices: $\{p_{B,t}, p_{M,t}, w_t\}_{t=0}^{\infty}$ and the subsidies and taxes $\{\tau_{S,t}, \tau_{w,t}\}_{t=0}^{\infty}$ constitute an equilibrium if:

- given prices, the household allocations solve the household's dynamic consumption-saving-occupation choice problem in equation (10)
- The aggregate allocations solve the manufacturing firm's problem in equation (16)
- the current account clears:

$$CA_t = X_t - (M_t^X + M_t^M) + FA_t \tag{186}$$

- the labor market clears:

$$L_t = \int \left(\mathbf{1}_{\{e_{t+1}=M\}}\theta^U - \mathbf{1}_{\{e_{t+1}=A, l>0\}}FM_B - \mathbf{1}_{\{e_t=A, e_{t+1}=M\}}F_M - \mathbf{1}_{\{e_{t+1}=M\}}FM_M\right)dG \tag{187}$$

- the capital market clears:

$$K_t = \int a_t dG_t \tag{188}$$

- the staple, the cash crop, and the manufacturing goods markets clear:

$$\int (c_{S,t} - q_{S,t}\mathbf{1}_{\{e_{t+1}=A\}})(1 + Q_S\mathbf{1}_{\{c_{S,t}-q_{S,t}<0\}})dG_t = 0 \tag{189}$$

$$\int (c_{B,t} - q_{B,t}\mathbf{1}_{\{e_{t+1}=B\}})dG_t - X_t = 0 \tag{190}$$

$$\int c_{M,t}dG_t - AK_t^{\alpha}L_t^{1-\alpha} - M_t^M = 0 \tag{191}$$

- Government budget constraint holds, either due to Equation (18) financed by labor taxes defined in Equation (19) or by foreign aid.

- Distribution evolves:

$$G_{t+1} = \int Q_t(z, a, e, a', z', e')dG_t \tag{192}$$

- $\forall\ \mathcal{S} = \{\mathcal{A}, \mathcal{Z}, \mathcal{X}\}$ measurable subset of the power set of the state space, the transition function becomes

$$Q_t(\mathcal{S}, (a', z', e')) = \mathbf{1}_{a'\in a_{t+1}(\mathcal{S})}\pi_z(\mathcal{Z}, z_{t+1})\mathbf{1}_{e'\in e_t(\mathcal{S})} \tag{193}$$

  where the joint (agriculture and urban) productivity process of the households defines π_z.

C.2 Numerical implementation

This section describes the method of computing an equilibrium. We first describe how we compute the stationary equilibrium:

1. We create a grid of assets and urban + rural productivities. Our other endogenous state variable is past occupational choice (staple, cash crop, laborer).

2. We start with a vector of guessed prices p_B, p_M, τ_w (and assumed R). In the externality allocation, this vector also includes the guess on the share of undernourished $\bar{u}$. Given those, we can compute wage rate from the profit maximization problem of the firm.

3. Given these variables, solve individuals' decision problems. This step consists of sub-steps:

   (a) We compute income of households at each state-grid point.

   (b) Using the budget constraints, we derive feasible aggregate consumption C choices for each state. Conditional on the price index P, we derive optimal consumption bundles of staples manufacturing and cash crops, as derived in Appendix B, for each possible occupation in the entire state space.

(c) We conduct value function iteration (with Newton iteration to speed up the computations) to look for optimal occupational, saving, input, and aggregate consumption choices of households given the current price guess.

4. Given solved-for individual decisions, we compute the stationary distribution of households over the state space and check implied market clearings for staple goods, manufacturing goods, cash crop goods, and government budget constraints (and cttilde in the externality allocation).

5. We update price-guess until the maximum market clearing error is low enough.

For computing the transition, we consider an unexpected and permanent reform introduction in period 1. Our reform introduction is gradual, with equally-sized increments of the reform variable over 5 periods (i.e., changes in tau_S for FISP allocations or in Q_S and F_M for infrastructure allocations). We begin by fixing a large value of the convergence period T and approximate equilibrium that converges in T as follows:

1. Using the algorithm described above, we compute initial (pre-reform) and final (post-reform) stationary competitive equilibria with associated optimal decisions.

2. We start by feeding in an initial guess of a sequence of price vectors such that these prices are equal to pre- and post-reform prices at the first and last periods of transition.

3. Then at each price guess iteration, we proceed according to a standard shooting algorithm as follows:

   (a) Given the price guess at each period of transition, we solve for household's value functions at each state grid point going backward, i.e. starting in the last period of transition where the solved for value functions in period t serve as input in period $t-1$. The key difference relative to the standard algorithm is that we have to save the consumption decisions for the entire state space.

   (b) Using the current price guess, the stored value functions, and consumption decisions from the previous step, we compute stationary distributions at every period of the transition going forward, i.e., using the period's $t-1$ stationary distribution as input past distribution for period t. When doing this, we compute all market clearings in every period t going forward.

   (c) We stop the algorithm if the maximum market clearing error across all markets and transition periods is small enough. Otherwise, we update the guess price vector as a convex combination between the old guess and a residual-rescaled version of it (i.e. made by increasing or decreasing the old price guess according to the sign of residual in the corresponding market clearing condition). If errors do not decrease, we increase T.

The online appendix at Laszlo Tetenyi's github repository contains the Julia code necessary to obtain the results of the model. Upon request, we can provide all Stata do files required for data construction and empirical analysis.

	Treated		Control	
	Mean	(St.Dev.)	Mean	(St.Dev.)
Number of observations*	397	–	1,229	–
Annual fertilizer use (kgs/ha)	16	(13)	18	(51)
Yields of staples (tonnes/ha)	44.1	(38.9)	43.5	(28.6)
Yields of cash crops (tonnes/ha)	58.9	(35.5)	30.3	(28.2)
Relative price of cash crops to staples	1.2	(0.7)	1.6	(2.0)
Share of land with staples	54%	(16%)	42%	(21%)
Share of population in rural areas	71%	(12%)	63%	(17%)
Share of population undernourished	19%	(12%)	22%	(12%)
Gross domestic product (USD million)	43,335	(88,093)	16,706	(45,912)
Population size (million)	34.5	(40.3)	10.7	(13.9)
Share of land irrigable	1%	(1%)	1%	(2%)

Table A.5: FAO 1980-2020 panel data summary

Note: Treated group is made of 10 SSA countries that implemented ISPs, as described in Jayne et al. [2018]. We split them into 3 groups according to the time of ISP implementation. Early group with implementation around 2000 includes Nigeria and Zambia. Malawi is on its own with implementation in 2005. Late group with implementation around 2008 includes Burkina Faso, Ethiopia, Ghana, Kenya, Mali, Senegal and Tanzania. Control countries include all the other SSA states. The basket of staples is composed of beans, cassava, fonio, maize, millet, rice, sorghum, plantains and wheat. Cash crops basket includes cocoa, coffee, cotton, palm oil fruit, pineapples, rubber, sisal, sugar cane, tea, tobacco and vanilla. Price series for each crop is derived from dividing each crop's value of agricultural production and quantity produced. All monetary variables are in 2014-2016 constant USD. The quantities harvested for each crop provide country-year-specific weights for yield and price of each crop basket. The share of the undernourished is only recorded starting in 2001, hence the number of observations is 566 for control and 200 for treated.

D Data sources and additional results

	Rural cross-sec		Rural panel		Urban panel	
	Mean	(St.Dev.)	Mean	(St.Dev.)	Mean	(St.Dev.)
Number of observations	8,753	–	2,673	–	1,950	–
Share male	74%	–	76%	–	62%	–
Real annual income	306	(1,391)	212	(443)	1,011	(3,246)
Labour hours	–	–	–	–	1,515	(1,207)
Land size	2.1	(24.8)	1.9	(8.3)	–	–
Age	43.2	(16.5)	44.5	(16.8)	35.5	(11.3)
Years of education	4.9	(4.0)	5.1	(3.9)	9.4	(4.2)
Number of adults in household	2.4	(1.2)	2.6	(1.3)	3.1	(1.6)

Table A.6: Malawi LSMS 2010 cross-sectional & 2010-2013 panel data summary

Note: Observations in rural samples are recorded at the household head level and in urban samples at the individual laborer level. The rural sample's annual income is the total household-level value of sold and unsold agricultural output evaluated at producer prices. The urban sample represents individual annual labor earnings generated from self-employment, labor work, and ganyu. Real income values in USD are computed ate 2010 Malawi price level. Land size reported in acres. For constructing the agricultural output's value and derivation of the consumer and producer prices, we follow the methodology of De Magalhaes and Santaeulalia-Llopis [2018]. In particular, we derive producer prices from the data on the quantities sold and the associated revenue. Similarly, we use the data on consumption expenditures to estimate consumer prices. In both cases, we approximate prices at the lowest possible level given available data (household, village, district, region, or country).

	$\log(income_{i,t}^{Urban})$	$\log(income_{i,t}^{Rural})$
Married	0.15***	-0.028
	(0.019)	(0.088)
Age	0.35***	-0.001
	(0.024)	(0.007)
Age^2	-0.004***	-0.00004
	(0.0002)	(0.00007)
Female	0.510***	-0.077
	(0.086)	(0.082)
Schooling years	1.098***	0.063***
	(0.068)	(0.013)
No. of adults in HH	0.303***	0.013
	(0.027)	(0.019)
Fertilizer kgs used	-	0.001***
	-	(0.0002)
Inverse Mills Ratio	9.537***	-0.582**
	(0.697)	(0.234)
R^2	0.27	0.10
N	1,950	2,673

Table A.7: Heckman-corrected determinants of earnings in urban and rural panels

	Urban	Rural
ρ_θ	0.12^{***}	0.24^{***}
	(0.031)	(0.035)
σ	1.28	1.08

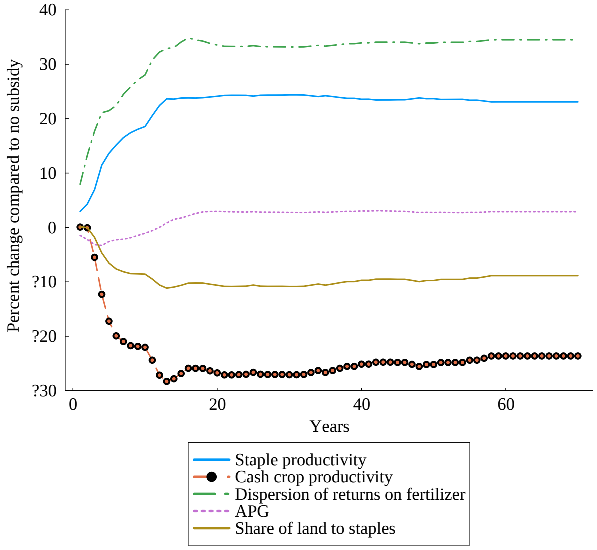
Table A.8: AR1 estimates of productivity processes

Note: Table reports persistence of $\theta^j_{i,t}$ (taken as residuals in regressions of Table A.7) and standard deviation of residuals $\epsilon^j_{i,t}$ in $\log(\theta^j_{i,t+1}) = \rho^j_\theta \theta^j_{i,t} + \epsilon^j_{i,t}$ with $\epsilon^j_{i,t} \sim N(0, \sigma^{j2})$ and $j \in \{R, U\}$. For our calibration, we annualize these coefficients by inverting how an AR(1) would unconditionally be observed at a tri-annual frequency. That is, we assume that $\rho_1 = \rho_3^{\frac{1}{3}}$ and $\sigma_1 = \frac{\sigma_3}{\sqrt{1+\rho_1^2+\rho_1^4}}$, with index 3 corresponding to the empirical estimates and 1 to the annualized parameters.

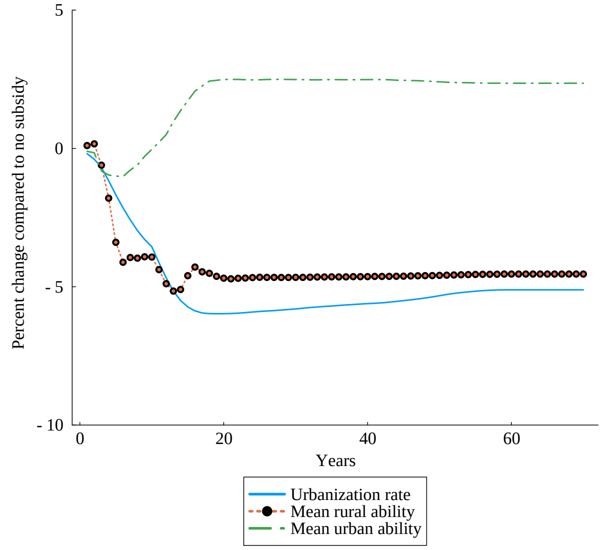
	No FISP	FISP partial eqm.	FISP aid-funded	FISP tax-funded $\tau_W = 6\%$
Prices & Aggregates				
Cash crop, p_B	1.3	0%	+23%	+23%
Manufacturing, p_M	2.5	0%	+10%	+13%
Wages, w	4.6	0%	+16%	+16%
Consumption	1.5	-11%	+4%	+2%
Savings	7.8	-16%	+11%	+11%
Nominal output	6.4	-15%	+11%	+13%
Share of cash crop exported	67	+29%	+5%	+4%
Transaction cost	0.4	-50%	-4%	-4%
Current account surplus % of GDP	0%	-4%	0%	0%
Production				
Staple production	0.9	+56%	+13%	+13%
Staple productivity	1.5	+37%	+22%	+23%
Cash crop production	1.3	-23%	+4%	+5%
Cash crop productivity	7.8	+8%	-24%	-24%
Share of land devoted to staples	79%	+9%	-9%	-9%
Share of farmers without surplus	15%	-20%	+11%	+19%
Share of staple farmers constrained	60%	+2%	+14%	+14%
Share of cash crop farmers constrained	93%	+2%	-23%	-23%
Manufacturing production	2	-21%	-1%	+0%
Urbanization rate	20%	-19%	-5%	-5%
Average duration in occupation	51.6	+19.8%	-1.0%	-1.8%
Agricultural productivity gap	6.2	+4%	+1%	+3%
Average agricultural ability	1.4	-7%	-5%	-5%
Average worker ability	6.7	+0%	+2%	+2%
Dispersion in ARPX	1.74	+22%	+35%	+34%
Dispersion in ARPX for cash crop farmers	1.98	2%	+22%	+21%
Dispersion in ARPX for staple farmers	0.57	+21%	+45%	+45%
Welfare and Inequality				
Consumption equivalent welfare	-	+10.1%	+4.1%	+3.5%
Consumption equivalent long-run welfare	-	+10.1%	+7.0%	+5.0%
Share of undernourished	28%	-7%	-18%	-18%
Avg urban-rural consumption ratio	7.0	-5%	-2%	-3%
Avg urban-rural income ratio	7.7	-6%	-4%	-4%
Avg urban-rural wealth ratio	7.1	+1%	+0%	-1%

Table A.9: The impact of introducing FISP in Malawi under various scenarios

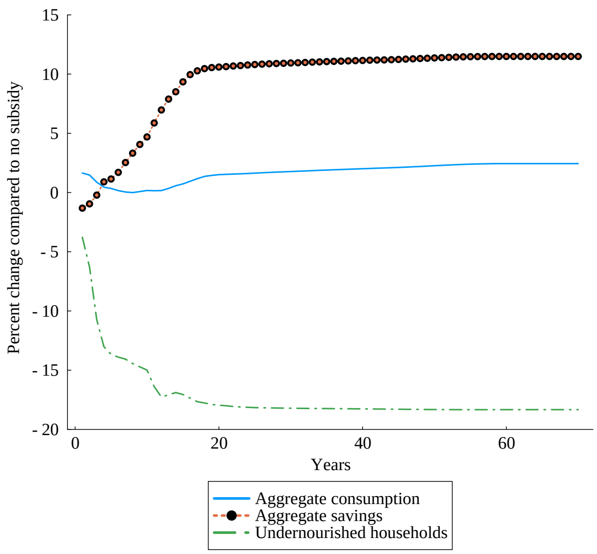
Note: All changes reported in columns 2-4 are relative to the "No FISP" allocation. "Partial eqm." refers to the case of introducing FISP without changes in market prices. "Foreign aid" refers to the case of introducing FISP with changes in all market prices but without introducing τ_w for financing government spending. "Labor tax" adds equilibrium adjustment in τ_w to the latter scenario and is also the equilibrium we calibrate to the Malawi data. "Dispersion in ARPX" denotes the standard deviation of the log average revenue product of inputs. We define the agricultural productivity gap as the ratio of the "nominal value of manufacturing output net of spending on entry costs per urban worker" to the "nominal value of agricultural output net of spending on maintenance costs and inputs per farmer" in value-added terms. The consumption-equivalent measure of welfare change accounts for transitional dynamics.



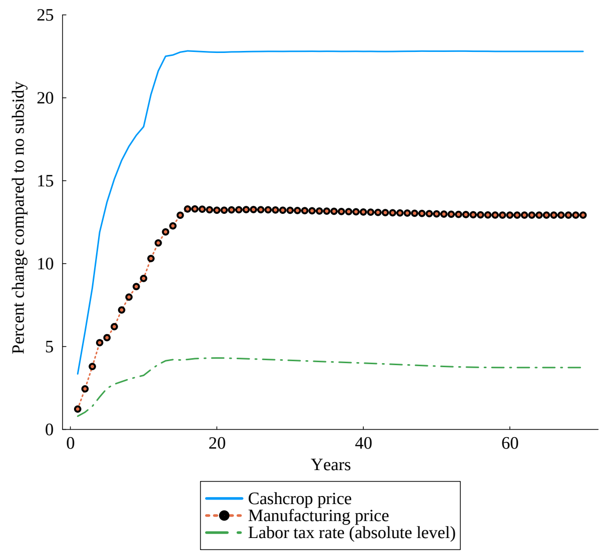
(a) Productivity



(b) Urbanization and talent



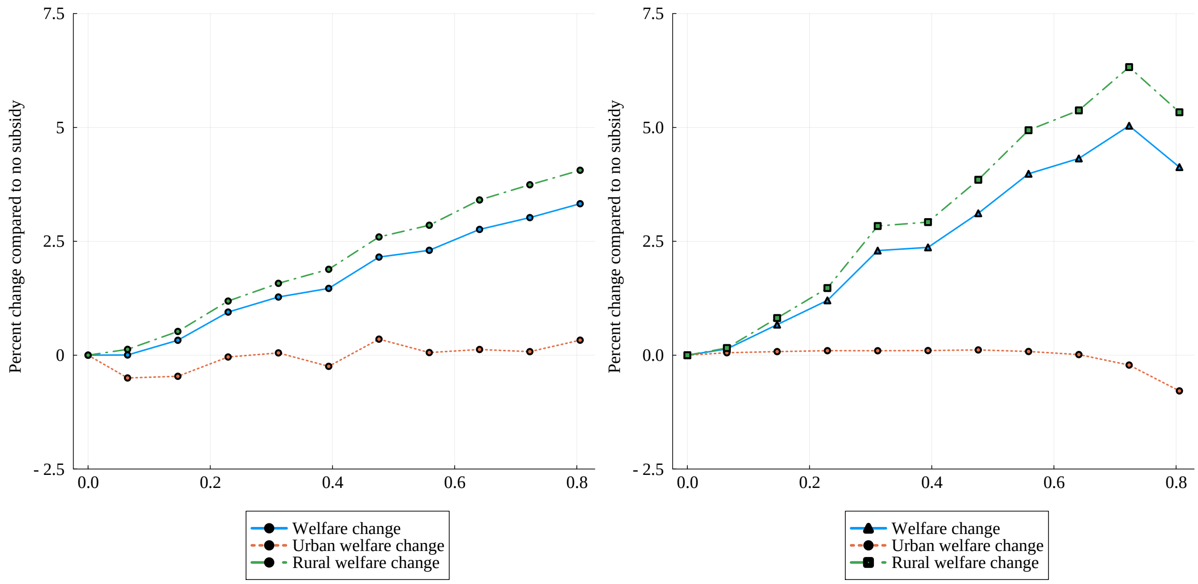
(c) Consumption and savings



(d) Prices

Figure A.3: Transitional dynamics after introducing $\tau_S = 0.72$ in Malawian economy financed through taxation

Note: FISP is introduced gradually in equal increments during the first five periods starting from $\tau_S = 0.0$ to $\tau_S = 0.72$. Every period is financed from concurrent taxes on urban wages.



(a) Transition

(b) Long-run

Figure A.4: The welfare impact of FISP in Malawi under different subsidy rates for urban and rural households

Note: Panel (a) shows the impact of subsidy rates on welfare gains relative to the no subsidy equilibrium, accounting for transition paths induced by reforms; panel (b) ignores the transition paths and only compares the steady-state to steady-state welfare gains.

E Robustness and further analyses

E.1 Alternative use of public funds: infrastructure investments

The key ingredient of this exercise is how to measure the costs and benefits of building such infrastructure. We take a simple approach of setting $\tau_S = 0$ and reducing Q_S to the level where the aggregate expenditures saved on staple transaction costs equal 2.4% of GDP, the relative cost of FISP in our baseline calibration. We also consider an allocation where reducing Q_S comes with a spillover of an equally-sized relative reduction in F_M. These assumptions are consistent with the literature showing that infrastructure development promotes internal migration (Asher and Novosad [2020], Morten and Oliveira [2023]) and improves food security (Blimpo et al. [2013], Gollin and Rogerson [2014]). In both cases, we assume that the reductions in frictions are aid-financed so that the benefits of infrastructural investments are conservative in the sense of not allowing for the welfare gains of this counterfactual to arise due to a larger tax base in the cities.

The first column of Table A.10 repeats the relative changes in key statistics induced by the aid-financed FISP in Table A.9. The second column considers a reduction in Q_S from 2.0 to 1.43 (28% relative reduction), and the third column considers the spillover scenario with additionally reduced urban entry costs F_M of the same relative magnitude, from 27.5 to 20 times the wage rate. All columns report statistics relative to the "No FISP" allocation in Table A.9.

The economy reacts quite differently to infrastructure investment than to FISP. Although the share of rural population drops by up to 21%, the improved allocation of talent does not lead to a collapse in the quantity of staples and cash crops produced. Furthermore, infrastructure intervention generates a large increase of up to 62% in the manufacturing output. The economy's overall allocation of key resources becomes both more equitable and efficient as average urban-rural inequality ratios drop by up to 60% and the APG drops by up to 43%. Non-food goods become relatively cheaper while the undernourished share of the population declines by up to 31%, accompanied by an up to a 47% increase in total consumption. While the allocation reducing only Q_S induces transitional welfare gains half of of those induced by FISP, the case with spillovers into reducing F_M yields up to 43% welfare gains. In terms of their redistributional impact, infrastructural investments benefit the urban sector relatively more than FISP. Overall, our results suggest that infrastructure investments may constitute a more cost-effective use of public funds than FISP.

E.2 FISP in the presence of undernourishment externalities

Given that FISP increases the food supply at both micro and macro levels, we now stipulate that both the productivity of farming technology and the labor productivity of workers are negatively affected by increases in the incidence of undernourishment $\bar{u}$ above the baseline level of 20% in 2010 Malawi:

$$\text{Farming: } y(\theta^R, l, x_S, x_B, \bar{u}) = \exp\{-\gamma \cdot (\bar{u} - 0.2)\}\theta^R \Big((1-l)^\phi x_S^\zeta + l^\phi x_B^\zeta\Big) \tag{194}$$

$$\text{Manufacturing: } Y(K, L, \bar{u}) = K^\alpha \left(\exp\{-\gamma \cdot (\bar{u} - 0.2)\} L\right)^{1-\alpha} \tag{195}$$

	FISP foreign aid	Infrastructure $Q_S = 1.43$	Infrastructure w/ spillovers $Q_S = 1.43$ & $F_M = 20$
Prices and Aggregates			
Cash crop price, p_B	+23%	-4%	-15%
Manufacturing price, p_M	+10%	-14%	-34%
Wage rate, w	+16%	-20%	-46%
Consumption	+4%	+10%	+47%
Savings	+11%	-6%	-13%
Nominal output	+11%	-5%	-2%
Share of cash crop exported	+5%	-7%	-23%
Transaction cost	-4%	-10%	-6%
Production			
Staple production	+13%	-3%	+5%
Staple productivity	+22%	+9%	+50%
Cash crop production	+4%	-9%	-17%
Cash crop productivity	-24%	-18%	-28%
Share of land devoted to staples	-9%	-5%	-11%
Share of farmers without surplus	+11%	-1%	+49%
Share of staple farmers constrained	+14%	+12%	+19%
Share of cash crop farmers constrained	-23%	-20%	-33%
Manufacturing production	-1%	+13%	+62%
Urbanization rate	-5%	+25%	+84%
Average duration in occupation	-1%	-35%	-90%
Agricultural productivity gap	+1%	-20%	-43%
Average agricultural ability	-5%	+0%	+6%
Average worker ability	2%	0%	+37%
Dispersion in ARPX	+35%	-2%	-23%
Dispersion in ARPX for cash crop farmers	+22%	+16%	-24%
Dispersion in ARPX for staple farmers	+45%	+7%	+31%
Welfare and Inequality			
Consumption equivalent welfare	+4.1%	+1.2%	+43.0%
Consumption equivalent long-run welfare	+7.0%	+10.0%	+72.7%
Consumption equivalent long-run welfare - urban	+1.7%	+3.1%	+10.1%
Consumption equivalent long-run welfare - rural	8.3%	+11.7%	+88.1%
Share of undernourished	-18%	-4%	-31%
Avg urban-rural consumption ratio	-2%	-18%	-50%
Avg urban-rural income ratio	-4%	-18%	-37%
Avg urban-rural wealth ratio	+0%	-17%	-60%

Table A.10: The impact of introducing FISP vs infrastructural investments

Note: All changes reported in columns 1-3 are relative to the "No FISP" allocation presented in Table A.9. The "infrastructure" allocation in column 2 considers a 28% reduction in Q_S such that the aggregate household spending on transaction costs declines by 2.4% of GDP, the equivalent of the FISP's cost in our baseline calibration. In the "infrastructure w/ spillovers" allocation in column 3, we assume that both Q_S and F_M decline by 28%. All allocations assume "foreign aid" financing.

The green plot in Figure A.5 shows how much stronger are the social benefits of FISP upon allowing for such negative externalities arising through undernourishment. FISP can generate up to a 40% welfare gain (in long-run) if the productivity elasticity γ equals 0.5 (as opposed to a 5% welfare gain in our baseline model with $\gamma = 0$). The empirically relevant elasticity of around 0.12 from Strauss [1986] suggests that the large input subsidy program in Malawi can generate even more benefits, if we allow for such undernourishment externalities.[39]

E.3 FISP without the open land frontier assumption

Our baseline model effectively assumes an "open land frontier", or perfect elasticity of land supply, as changes in the share of rural population do not have any impact on productivity or land availability of each farming household. To this end, we examine the sensitivity of our welfare estimates by relaxing the "open land frontier" assumption. We sidestep the computational complexity of modeling explicitly land markets by assuming that increases in the rural population share above the baseline level of 81% reduce agricultural TFP. In particular, we assume the following production function for farmers:

$$y(\theta^R, l, x_S, x_B, \bar{r}) = \exp\{-\gamma \cdot \frac{(\bar{r} - 0.81)}{0.81}\}\theta^R\Big((1-l)^\phi x_S^\zeta + l^\phi x_B^\zeta\Big)$$

The blue plot in Figure A.5 shows that allowing for inelastic land supply lowers the benefits of FISP. The long-run welfare gains can even become slightly negative for values of γ above 0.4. The reduction in welfare gains grows in γ as a higher rural population share induced by FISP reduces the agricultural TFP more, proxying the idea of the land frontier becoming more binding.

E.4 Model validation: micro-evidence from Malawi

Table A.11 assesses the model's predictions on the cross-sectional distribution of households in the equilibrium with subsidies, contrasted with non-targeted moments from the 2010 Malawian cross-sectional LSMS data. Motivated by Proposition 1 showing that transaction costs drive land allocation choices, we investigate the relationships between the choice of household's share of land devoted to staples and outcome variables such as the amount of fertilizer used, the gross value of harvest and the share of harvest self-consumed (unsold). While the causal relationships between our outcome and control variables run in both directions, this is so in the empirical and model-simulated datasets. As such, our aim is not to find unbiased coefficients of interest but rather to provide further evidence that our calibrated framework generates empirically plausible behavior.

To this end, we simulate half a million households in the FISP stationary equilibrium and compute standard errors by bootstrapping 1000 sample populations equal to the LSMS

[39] While the estimate in Strauss [1986] of 0.33 captures the household-level caloric intake elasticity of productivity, our parameter γ captures the macro-level undernourishment elasticity of productivity. For the sake of comparability, we convert the household level estimate to a macro elasticity as $0.33 \cdot 0.35$, where 0.35 is the relative difference between the calories consumed by the undernourished bottom 20% and the average amount of calories consumed in 2010 Malawi, as reported in Aberman et al. [2015].

	Inputs used		Value of harvest		Share self-consumed	
	Model	Data	Model	Data	Model	Data
Share land w/ maize	-1.08^{***}	-0.46^{***}	-2.24^{***}	-1.12^{***}	0.79^{***}	0.18^{***}
		(0.09)		(0.13)		(0.01)
Household controls	n.a.	Yes	n.a.	Yes	n.a.	Yes
Village FEs	n.a.	Yes	n.a.	Yes	n.a.	Yes
Observations	n.a.	8,753	n.a.	8,753	n.a.	8,753
R^2	0.22	0.13	0.42	0.10	0.54	0.36

Table A.11: Comparison of rural households' behavior in the model and data

Note: Share land w/ maize is the share of a household's land devoted to maize. *Inputs used* is the total amount of fertilizer used. *Value of harvest* represents the gross total (sold and unsold) household value of crop harvested evaluated at producer prices. $Share\ self-consumed$ is the share of harvest unsold. The data is from the rural sample of Malawi LSMS 2010. Significance at 0.01, 0.05, and 0.1 levels is denoted by ***, **, and *, respectively. The model standard errors are bootstrapped using 1000 samples of 8,753 individuals. For comparability, we normalize all variables by sample means.

sample size. We remove factors not modeled in our framework from the empirical regressions by including village fixed effects and a vector of household controls such as sex, age, marital status, religion, language, schooling years of the head of household, household size, and farm size. We ensure the comparability of the estimates across regressions by normalizing all variables by their respective means.

First, there is a strong negative association between allocating more land to staples and inputs used ($\hat{\beta}^{model} = -1.01$ vs. $\hat{\beta}^{data} = -0.46$), implying that the static effect of benefiting more from FISP due to higher fertilizer use and therefore allocating more land to staples is relatively weak compared to the dynamic effect of collateral constrained or low productivity households selecting into staple farming.

Second, negative associations between the share of land devoted to maize and gross value of harvest ($\hat{\beta}^{model} = -2.27$ vs. $\hat{\beta}^{data} = -1.12$) indicate that the cultivation of staples is not a revenue-maximizing choice, in line with the existence of credit market frictions lowering fertilizer use among the poorer staple farmers and the presence of transaction costs that lead to a shift in the crop choice.

Finally, we find a robust positive relationship between the share of land devoted to maize and the share of harvest self-consumed. Although somewhat overestimated in the model ($\hat{\beta}^{model} = 0.79$ vs. $\hat{\beta}^{data} = 0.18$), this shows that cultivating maize is a critical source of food for disadvantaged households that attempt to reduce their exposure to transaction costs.

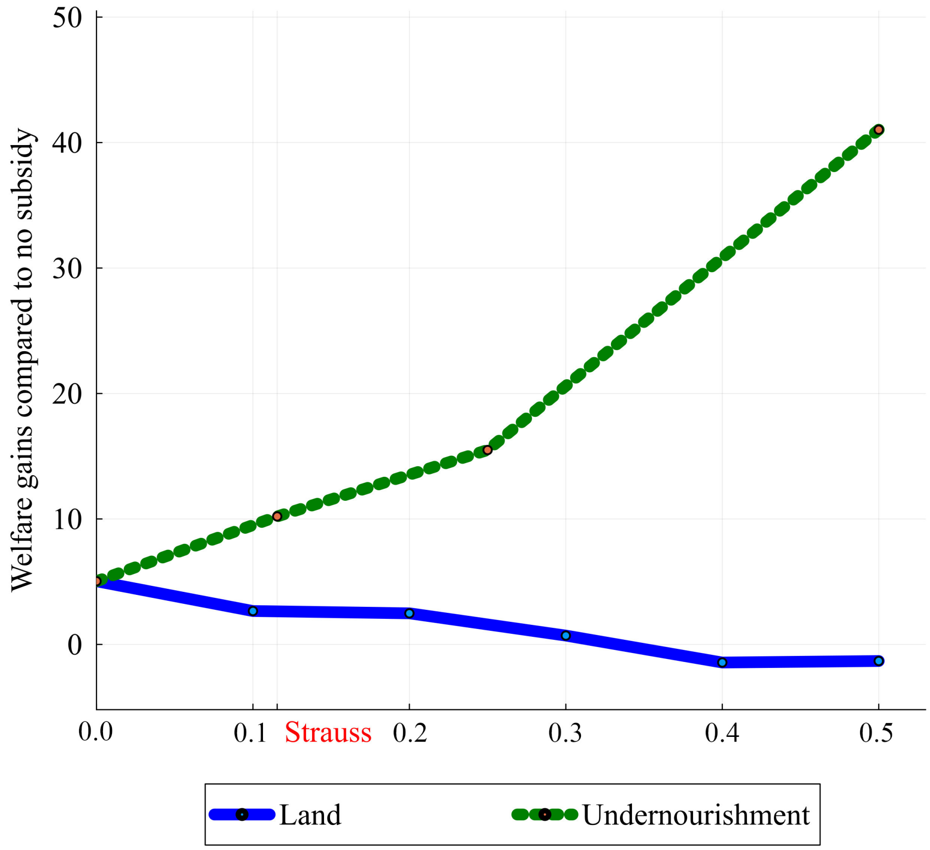


Figure A.5: Welfare impact of FISP and the sensitivity of productivity to land supply and undernourishment

Note: The figure shows the welfare impact of introducing FISP with $\tau_S = 0.72$ and labor tax financing under undernourishment externalities (Appendix E.2) and inelastic land frontier (Appendix E.3). The green plot shows results under different values of parameter γ in equations (194) and (195) (relative to the no subsidy equilibrium). The blue line shows results under different values of parameter γ in equation (**??**) (relative to the no subsidy equilibrium). The elasticity marked in red "Strauss" corresponds to the empirical estimate of undernourishment elasticity in Strauss [1986] of 0.12.