The Macroeconomic Impact of Agricultural Input Subsidies*

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Abstract

Governments worldwide operate agricultural input subsidy programs to stimulate local agricultural productivity and foster food security. We evaluate Malawi's Farm Input Subsidy Program using a general equilibrium model with heterogeneous households, wealth accumulation, financial frictions, occupational choice, and transaction costs introducing food security concerns. While this generous program decreases undernutrition, it also reduces welfare by exacerbating existing misallocation and redistributing resources toward the wealthier urban population. We show that halving the subsidy rate or re-channeling public spending into broader infrastructure investments can increase welfare relative to an economy without subsidy. We highlight that expanding the partial equilibrium policy evaluation by the general equilibrium effects significantly alters the quantitative conclusions drawn. Finally, we show that the microdata for Malawi and cross-country data from Sub-Saharan Africa are consistent with our model.

Keywords: Agriculture, food security, structural change, misallocation

JEL Codes: Q12, Q18, O11

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1 Introduction

Cross-country differences in agriculture performance have attracted policymakers' and academics' interest because strong agriculture may unlock robust economic growth and structural transformation.[1] Agricultural productivity dramatically improved in the last four decades of the 20th century across Asia and South America but less so in Sub-Saharan Africa (SSA). Therefore, some member states of the African Union implemented large-scale input subsidy programs (ISPs) facilitating access to modern seeds and fertilizers to produce staple crops.[2] In this paper, we study the macroeconomics of introducing ISPs at scale, focusing on food security, agricultural productivity, resource misallocation, and structural change.

The deep rural poverty in most developing regions calls for well-designed agricultural policies. ISPs introduced in SSA countries target the production of staples, which are critical for rural food security as a direct source of nutrients. Inadequate infrastructure networks, layers of intermediaries, and inefficient storage technologies generate gaps between consumer and producer prices, causing potential problems with food procurement for urban consumers and villagers with insufficient production. While this implies an efficiency-based rationale for staple-targeting ISPs, such interventions may oversubsidize food production and divert resources from cultivating cash crops, the primary local export good. Beyond their direct effects, large-scale ISPs move market prices and impact structural change, household dynamics, and inequality by affecting consumption, savings, and occupation choices.

To study the effects of large-scale agricultural subsidies on the economy, we build a model with heterogeneous households facing an occupational choice between the cultivation of staples or cash crops and wage work, with sector-specific idiosyncratic productivity shocks. A key feature of our model is that households purchasing staples on the market must pay a per-unit transaction cost as in de Janvry et al. [1991]. This feature breaks the equivalence between profit maximization and cost minimization in farming. As farmers follow the latter objective, the laissez-faire production of food is inefficiently low from the urban perspective.

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

[2] Most ISPs in SSA were introduced following the Maputo Declaration on Agriculture and Food Security in 2003, which committed resources to stimulate local agricultural sectors. For the history and details of ISPs in SSA, see Jayne et al. [2018] and Smale and Theriault [2019].

Furthermore, households' preferences are non-homothetic, incomplete financial markets limit insurance, occupational switches are costly, and the open-economy aspect of the model only partially limits the general equilibrium (GE) effects operating through market prices.

We apply the model to the case study of Malawi, one of the ten poorest countries in the world with significant food security concerns. In 2005, the Malawian government introduced the Farm Input Subsidy Program (FISP) to subsidize the cultivation of maize, the critical local staple. Until recently, the program's cost oscillated between 3%-6% of Gross Domestic Product (GDP), making it the largest ISP in the region. Our model's calibration targets the economy of Malawi in 2010, matching rural and urban income processes and the country's structural composition, the relative size of FISP, the rural-urban migration rate, the share of cash crops exported, the share of financially constrained farmers, the agricultural productivity gap (APG) across sectors and the differences between producer and consumer prices of agricultural products.

Our quantitative GE analysis accounting for transitional dynamics reveals that the large FISP in Malawi generates an average welfare loss equivalent to a 2% drop in consumption. The program significantly exacerbates existing misallocation of the labor force, increasing APG from 3.8 to 6.5. Even though some of the poorest households also benefit from FISP, there is a significant redistribution towards wealthier urban residents. Intuitively, changes in market prices induced by this extensive intervention effectively lock people in rural areas abundant in food but with reduced affordability of other goods.

To demonstrate the importance of GE effects and the difficulty of scaling up agricultural policies, we show that the partial equilibrium (PE) setting corresponding to a hypothetical small-scale FISP generates up to 10 times greater response of the economy and much higher welfare gains than the at-scale version of the policy in GE. Returning to the GE case, we show that down-scaling the large status-quo FISP by 50% turns welfare losses into welfare gains equivalent to a 3% gain in consumption on average. Analyzing an alternative use of public funds, we show that redirecting those into broadly defined infrastructural investments reducing transaction and rural-urban reallocation costs trumps effects of FISP by fostering urbanization, reducing resource misallocation and, ultimately, benefiting all households more uniformly.

We vindicate the calibrated dynamics of our framework first by showing that the household-level agricultural land allocation correlates with the input used, the harvest's value, and the self-consumed share of harvest similarly in the cross-sectional data generated by our model and in the rural sample of the 2010 Living Standards Measurement Survey (LSMS) for Malawi. Finally, we conduct a macro difference-in-difference analysis on a panel from the Food and Agriculture Organization Statistics (FAOStat) showing that introducing ISPs in SSA generated responses of staple and cash-crop yields, relative prices, and food security, that are broadly consistent with our model.

Literature review. Our paper falls 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. Herrendorf and Schoellman [2015], Lagakos and Waugh [2013] 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. Following the seminal approach of Kaboski and Townsend [2011], we contribute to the predominantly empirical literature on ISPs surveyed in Jayne et al. [2018] by showing the importance of considering the heterogeneous impacts of rural interventions for drawing policy conclusions in a structural GE framework with food security and incomplete markets. Perhaps most strikingly, we show that a positive APG may constitute a constrained efficient feature of an economy distorted by transaction costs.

McArthur and McCord [2017] build a cross-country panel dataset and show that intensified use of fertilizers, modern seeds, and agricultural irrigation significantly impacts economic growth and structural change. Similarly, in an estimated two-sector neoclassical growth model, Boppart et al. [2023] show that the cross-country gaps in the intermediate input sector productivity can explain most of the observed cross-country differences in agricultural productivity. We evaluate FISP in Malawi, which increases the intermediate input use intensity, as a candidate policy to close these productivity gaps. We show that such subsidization, which does not improve the intrinsic productivity of the intermediate inputs production, can lead to unintended increases in the gap between manufacturing and agricultural productivity. Our macroeconomic analysis yields a hump-shaped welfare response to increasing fertilizer use through subsidiziation, showing that the over-use of fertilizer may arise even in absence of environmental externalities discussed in West et al. [2014].

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], and Moll [2014] show how financial constraints reduce aggregate productivity and efficiency of intersectoral allocations. Buera et al. [2021a] study macroeconomic consequences of microcredit programs. For Indian agriculture, Donovan [2021] and Mazur [2023] investigate the relationship between incomplete consumption insurance and input adoption, productivity, and welfare. Our paper extends this class of models by the feature of transaction costs (de Janvry et al. [1991], Fafchamps [1992], Omamo [1998], Arslan and Taylor [2009], Arslan [2011], Adamopoulos [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.

Finally, our work complements the small strand of literature evaluating ISPs using quantitative models. Arndt et al. [2016] uses a static and deterministic computable general equilibrium (CGE) model to quantify the aggregate impact of FISP in Malawi. Our framework augments their approach by developing a comprehensive dynamic, stochastic general equilibrium framework accounting for household-level heterogeneity and optimizing behavior. The more recent works of Diop [2023], Bergquist et al. [2022], and Garg and Saxena [2022] develop models evaluating distributional implications of ISPs in Zambia, Uganda, and India, respectively. Relative to theirs, our framework entails interactions between household decision-making, transaction costs, incomplete asset market structure, and equilibrium price setting that render the competitive equilibrium inherently inefficient, allowing us to study the distributional consequences of ISPs and their efficiency aspects.

The rest of the paper is organized as follows. In Section 2, we outline our quantitative framework. Section 3 introduces our data, discusses the mapping between our modeling assumptions and the empirical setting in Malawi, and the calibration strategy and its evaluation. Section 4 contains the main quantitative results with empirical evidence supporting the model dynamics in Section 5. Section 6 concludes.

2 Model

A continuum of infinitely lived households (of measure one) face occupational and financial decisions in the economy while subject to idiosyncratic urban and rural productivity shocks. Households decide whether to work in urban areas for a representative manufacturing firm and earn labor income or to live in rural areas and operate their farms. These choices are frictional due to the entry and maintenance costs. Farmers can produce staple crops (such as maize) or cash crops (such as tea, tobacco, and sugar) using imported intermediate inputs (such as seeds or fertilizers). The working capital constraint may limit their 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 concerns about food security. Households can insure their consumption through saving in a risk-free asset. A government administers the FISP financed through labor taxation in urban areas or from foreign aid. GE price effects connect all decisions, with the open economy aspects limiting the responsiveness of cash crop prices.

We refer to the allocation with labor taxation financed FISP as our "baseline allocation." To ease notation, we do not include individual and time subscripts in the descriptions of the model building blocks. We define the equilibrium in Appendix B.4.

Finally, in designing our economy, we have naturally faced trade-offs between maintaining its computational feasibility and approximating the empirical environment of Malawi well enough. We discuss mapping of our model to the empirical setting in Section 3.2.

2.1 Households

Time is discrete and households live forever. In each period, they either inelastically supply a unit of labor or engage in agricultural production as farmers. 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:

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

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), and manufacturing goods (M) with $\mathbf{c}$ denoting a consumption vector of these goods. 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, which is a crucial feature for analyzing the welfare impact of FISP supporting staple production.

We normalize the producer price of staples to 1 and let p_B and p_M denote the prices of cash crops and manufacturing goods, respectively. Purchasing staples is subject to a transaction cost: acquiring q_S units of staples costs $(1+Q_S)q_S$. This feature allows for a meaningful discussion of input subsidies' impact on food security, as households do not pay transaction costs for the consumption of self-produced food.

In every period, households face uncertainty due to the time-evolving vector z of idiosyncratic rural θ^R and urban θ^U productivity. After the realization of z, households decide about their current period's occupation: working as farmers producing staples or cash crops or moving to urban areas to work as laborers. We denote this occupational decision by $e' \in \{S, B, M\}$. Whenever households decide to move from rural into urban areas and change occupations, they must pay the one-off entry cost wF_M in labor units. We assume that urban households provide 1 unit of labor inelastically and earn labor income with a competitive wage rate w per unit of skill θ^U. Whenever households decide to engage in cash crop farming, they must pay the per-period maintenance cost wFM_B, denominated in labor units. Staple farming is assumed to be a baseline activity not subject to entry or maintenance costs. Overall, there are three sources of demand for urban workers: from a competitive manufacturing sector, from cash crop farmers paying for maintenance costs, and from all rural households deciding to move to urban areas.

2.1.1 Agriculture in rural areas

Staple farmers. Households in rural areas that choose to operate as staple farmers, operate the following production technology subject to a financial constraint:

$$\pi_S(\theta^R, x_S, a) = q_S(\theta^R, x_S) - TC_S(a, x_S) \tag{2}$$

$$q_S(\theta^R, x_S) = \theta^R x_S^{\zeta} \tag{3}$$

$$TC_S(a, x_S) = (1 - \tau_S)\, p_X x_S \leq \kappa a \tag{4}$$

where x_S denotes the demanded quantity of the intermediate input purchased at a price p_X and subsidized at $\tau_S \geq 0$ rate and π_S denotes the associated profit function. Maximizing the latter will generally not be the objective function of farming households, as we explain below. Importantly, equation (4) introduces the *within-period working capital constraint* stipulating that the total purchases of agricultural inputs cannot exceed κ-times the household's total wealth.

Cash crop farmers. If households choose to produce cash crops, we allow them to cultivate both types of crops. As such, they have to decide about the allocation of both intermediate inputs $x_S,\ x_B$ and land l between the production of staples and cash crops as follows:

$$\pi_B(\theta^R, x_S, x_B, l, a) = q_S(\theta^R, x_S, l) + p_B q_B(\theta^R, x_B, l) - TC_B(a, x_B, x_S) \tag{5}$$

$$q_S(\theta^R, x_S, l) = \theta^R x_S^{\zeta}(1 - l)^{\phi} \tag{6}$$

$$q_B(\theta^R, x_B, l) = \theta^R x_B^{\zeta} l^{\phi} \tag{7}$$

$$TC_B(a, x_B, x_S) = (1 - \tau_S)\, p_X x_S + p_X x_B \leq \kappa a \tag{8}$$

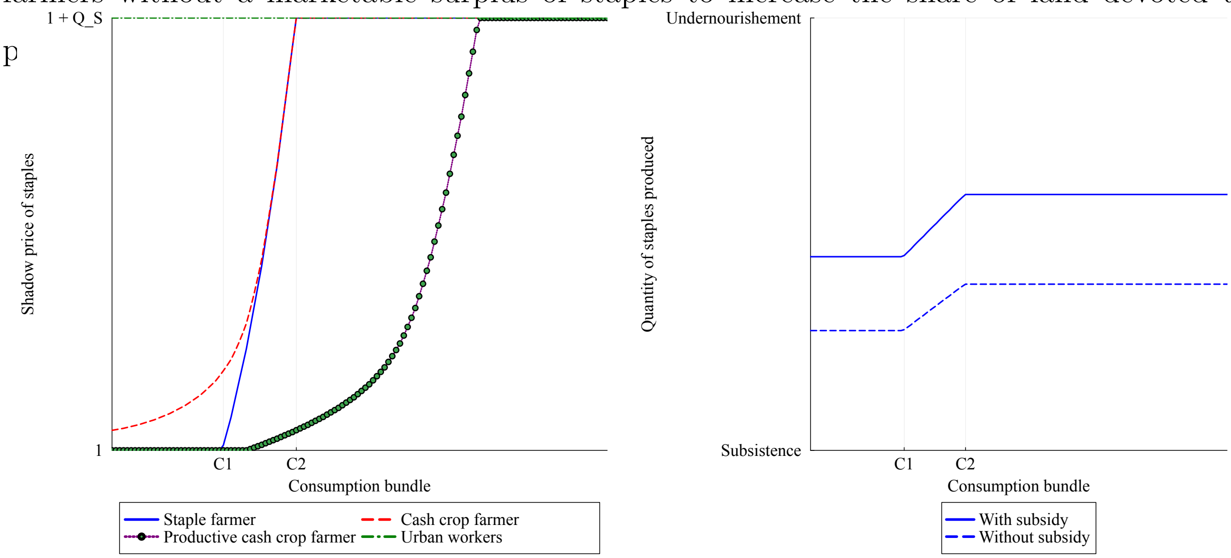
To generate positive profits from agricultural production, we assume jointly decreasing returns to scale $(\zeta, \phi) \in (0, 1)\,,\ \zeta + \phi \in (0, 1)$.

Furthermore, the optimal behavior of cash crop producers implies that:

Proposition 1. *The household-level share of land devoted to cash crops l is (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 □

This result is one manifestation of GE's importance in analyzing the impact of large-scale ISPs. In the PE, input subsidies push more resources toward the subsidized agriculture sector. However, the equilibrium forces working through the relative prices of crops can overturn these dynamics. Equally importantly, higher transaction costs push cash crop farmers without a marketable surplus of staples to increase the share of land devoted to p



(a) Shadow price of staples across household types

(b) Production impact of FISP

Figure 1: 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. "Staple farmer" and "cash crop farmer" are assumed to have the same state variables and, therefore, the same level of rural productivity. "Productive cash crop farmer" is a cash crop farmer with a higher level of rural productivity. The subsistence threshold corresponds to $\bar{c}_S$ in the model, and the undernourishment threshold is such that the baseline allocation has as many undernourished people as in 2010 Malawi, our calibration target.

2.1.2 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., $a' \geq 0$, generating precautionary behavior as households generally cannot perfectly insure their consumption against fluctuations in the idiosyncratic productivity vector z.

Finally, as we assume that $\kappa \in (0, 1)$, the working capital constraint in (6) and (7) captures both the lack of intratemporal financial intermediation for advance payments covering production costs and the relatively low investment liquidity of household wealth.

2.1.3 On inefficiency of the competitive equilibrium

First, in an economy without transaction costs ($Q_S = 0$), producers maximize profits and decide on inputs and agricultural production irrespective of their consumption bundle. Transaction costs for staples imply that the shadow (internal) valuation will differ between different types of households. For staple producers, it can lie anywhere between $\lambda \in [1, 1 + Q_S]$, depending on the household's consumption and production patterns. In contrast, the shadow price is always $1 + Q_S$ for urban households, implying that food will be generally underproduced from the perspective of the urban sector.

We show these patterns across different types of households in the left panel of Figure 1. 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, to a higher level of staple production 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 ($\lambda_S = 1 + Q_S$, $C > C_2$), their valuation of a marginal unit of staples is the same as that of urban households. As we show in the right panel of Figure 1 for the staple farmer, at this point, they do not increase the production of staples any further.

These PE production patterns interact in the GE through the incomplete asset market structure of our model economy. In particular, households cannot trade state-contingent financial claims to perfectly insure their consumption fluctuations due to idiosyncratic sector-specific productivity shocks. Occupation switching from rural to urban is inherently risky due to financial migration costs and transaction costs in food procurement. The interaction between the imperfectly insurable occupation risk and transaction cost nontrivially determines the magnitude of pecuniary externalities that render the laissez-faire competitive equilibrium inefficient.

To shed more light on this, in Appendix A, we construct a static representative agent endowment economy with occupation choice between farming and manufacturing and transaction costs for food procured by laborers. Its important feature is the risky nature of occupation choice arising due to the probability choice of becoming farmers (and, as residual, laborers). The interaction of transaction costs and uninsured occupation choice risk implies that the price system in the laissez-faire competitive equilibrium fails to coordinate actions on efficient outcomes. Intuitively, representative households choose the share of population farming at the level where the payoffs from farming and manufacturing are equalized. As food is cheaper in the farming sector and the manufacturing price is the same in both sectors, the payoff-equalization implies that farming attracts an excessive share of population. This happens precisely due to the interaction between households risk aversion and the lack of state-contingent contracts for insuring occupation risk between farmers anc laborers.[3]

In our richer quantitative model, input subsidies also allow farmers to achieve a strictly higher production of staples for a given consumption bundle and state vector. The concave nature of the utility function implies that this input support is especially valuable to households that either suffer from low productivity (in either sector, as urban can costlessly migrate to rural) or are collateral-constrained due to low asset positions. This implies that government-provided input subsidies have both a critical redistributive and insurance role. While this is also true in PE, changes in the overall food supply also alter the relative price of food in GE. Thus, a staple-targeting FISP may constitute an efficient intervention by both improving the food security of those who choose or need to engage in staple farming and by reducing the relative price of food through increases in the overall food supply. Nota bene, the latter effect indirectly incentivizes the occupational switching out from staple farming, counteracting the inefficiencies exposed in our simple model.

[3]Or the lack of a first best tax-subsidy schedule.

2.1.4 Dynamic programming

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

$$V(z,a,e) = \max_{a',e',c_S,c_B,c_M,x_S,x_B,l} \log(C) + \beta \mathbb{E} V(z',a',e') \tag{9}$$

$$s.t.: \quad C = \left(\psi_S \left(c_S - \bar{c}_S\right)^{\frac{\epsilon-1}{\epsilon}} + \psi_B c_B^{\frac{\epsilon-1}{\epsilon}} + \psi_M c_M^{\frac{\epsilon-1}{\epsilon}}\right)^{\frac{\epsilon}{\epsilon-1}} \tag{10}$$

$$X_{e'\in\{S,B,M\}} + a' = Y_{e'\in\{S,B,M\}} + (1+r)a \tag{11}$$

$$X_{e'\in\{S,B,M\}} = c_S + p_B c_B + p_M c_M + Q_S \cdot \max\{c_S - 1_{e'\in\{S,B\}} \cdot q_S(\theta^R, x_S, l, a), 0\} \tag{12}$$

$$\begin{aligned} Y_{e'\in\{S,B,M\}} = {} & 1_{e'\in\{M\}} \left(\theta^U w - 1_{e\in\{S,B\}} w F_M\right) + 1_{e'\in\{S\}} \pi_S(\theta^R, x_S, a) \\ & + 1_{e'\in\{B\}} \left(\pi_B(\theta^R, x_S, x_B, l, a) - 1_{e\in\{M,S\}} w F M_B\right) \end{aligned} \tag{13}$$

where Y denotes income and X denotes expenditures of a household with state vector (z,a,e) making occupational choice e' and choosing the optimal consumption bundle C. Unlike in most papers in the literature, the feature of transaction costs implies that the occupation choice and expenditure minimization must be solved jointly. Employing backward induction, we first jointly solve the household's static occupational and expenditure problems for a given state vector (z,a,e) and a choice of C, and then we solve the dynamic problem of choosing C, a'. Details on the solution of household problems are in Appendix B.

2.2 Urban sector

The representative firm in the urban sector produces the manufacturing good using a standard Cobb-Douglas technology $Y_M = K^\alpha (A_M L)^{1-\alpha}$ with the labor-augmenting TFP factor A_M. The factor input markets for capital and labor are competitive and centralized. All urban workers receive the same wage w per efficiency unit θ^U. The firm's problem reads:

$$\pi_M = \max_{K,L}\{p_M K^\alpha (A_M L)^{1-\alpha} - (1+\tau_w) w L - (r+\delta) K\} \tag{14}$$

where labor L is the residual of households providing urban labor net of the labor hired for covering the rural-urban entry and cash crop maintenance costs:

$$L = \int \big(\mathbf{1}_{\{e'=M\}}\theta^U - \mathbf{1}_{\{e\in\{M,S\},e'=B\}}FM_B - \mathbf{1}_{\{e\in\{S,B\},e'=M\}}F_M\big)dG \tag{15}$$

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

2.3 Government

Our baseline allocation assumes that the government finances FISP through urban labor income taxation. However, we will also consider another case where foreign aid finances the program cost.

The total expenditures X_G on the subsidy program are given by:

$$X_G = p_X \int \tau_S x_S dG_{z,a,e'=S} + p_X \int \tau_S x_S dG_{z,a,e'=B}) \tag{16}$$

Thus, the following per-period government budget constraint holds in both of the cases:

$$\text{income tax case}: X_G = \tau_w w\Big(\int dG_{z,a,e'=M} - F_M \int dG_{z,a,e'=M,e=\{S,B\}} - FM_B \int dG_{z,a,e'=B}\Big) \tag{17}$$

$$\text{foreign aid case}: X_G = FA \tag{18}$$

where FA is the amount of foreign aid used to finance the program.

2.4 Current account

The economy imports intermediate inputs at an exogenously given price p_X. The rest of the world demands cash crops according to the following export demand function:

$$c_B^F = a_D p_B^{b_D} \tag{19}$$

In the baseline allocation, we assume that the country's net foreign asset (NFA) position cannot change; hence, the current account has to equal 0. To this end, we allow foreigners to invest in the capital stock K^F, earning a net income of $(r+\delta)\cdot K^F$, such that the $NFA = 0$. Foreigners may also provide foreign aid FA to finance the subsidy or other government programs. The following equations summarize the current account's structure:

$$CA = X - M - RK^F + FA = 0 \tag{20}$$

$$X = p_B c_B^F = a_D p_B^{1+b_D} = p_B \int (q_B \mathbf{1}_{\{e'=B\}} - c_B) dG \tag{21}$$

$$M = p_X \Big(\int x_S dG_{z,a,e'=S} + \int (x_S + x_B) dG_{z,a,e'=B} \Big) \tag{22}$$

Prices and decision rules determine imports M and exports X, the foreign-supplied capital stock K^F, and foreign aid FA (if any). In all counterfactual allocations and in FISP with foreign aid, the foreign capital is fixed at the baseline allocation of FISP with labor taxation, implying that in those cases, the current account will not generally equal zero.

3 Empirical application

We apply our framework to the largest ISP in SSA deployed in Malawi. To do this, in Section 3.1, we first introduce the data sources that allow us to perform the empirical analysis. Section 3.2 discusses mapping of our model to the empirical setting of Malawi. In Sections 3.3-3.5, we develop a calibration strategy disciplining our model's parameters based on the literature, the institutional setting in Malawi, and the simulated method of moments. While Section 4 contains quantitative results of our model, we return to the use of our datasets in Section 5, where we conduct a comparative regression analysis of empirical and simulated datasets and analyze the macro-patterns upon introducing ISPs in SSA.

3.1 Data sources

Our empirical work rests on two data sources: the LSMS microdata for Malawi and the FAOStat macrodata for SSA countries. For calibration, we extensively use the FAOStat series on Malawian agricultural exports, the value and quantity of production, the quantity and price of intermediate inputs, and the agricultural land use patterns. We use this dataset again for the panel analysis of all the SSA countries in Section 5, for which we draw additional series regarding the share of the undernourished population, the share of irrigable land, the share of the rural population, total population and GDP per capita. Table 9 in Appendix C summarizes this data broken into the treated and control countries based on the assignment of the ISP treatment in the 2000s, which we use in the difference-in-difference analysis of Section 5.

Furthermore, we use the 2010 rural cross-section of Malawi LSMS data for some of the moments used in model validation (land use patterns and dispersion in average products of inputs), providing evidence on transaction costs as proxied through gaps between consumer and producer prices of staples and for regression analysis validating the model dynamics. For the last part, we use data on the annual household value of agricultural production (sold and unsold, evaluated at consumer or producer prices), the amount of fertilizer used, the share of self-consumed crops, and land use patterns.[4] For additional controls, we use the household head's characteristics such as marital status, age, education, household size, and gender.

We discipline the idiosyncratic productivity process in our model by leveraging the panel component of 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 their 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]), and in rural, we focus again on the annual value of agricultural output. We use controls as

[4]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).

in the 2010 cross-section. Table 10 in Appendix C summarizes the LSMS data.

3.2 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% percent of its population living in rural areas and being mostly engaged in small-scale, non-mechanized, and subsistence-based agriculture. Around 40% of rural households cultivate only maize. Most of the agricultural production becomes self-consumed without entering the market. Cash crops such as tobacco, sugar, tea, groundnuts, and other fruits and vegetables comprise around 80% of Malawi's total export revenue.

After the first half of the 2000s, marked by poor maize harvests and high prices of local staples, the newly elected government of Malawi decided to introduce 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, which have been later responsible for distributing voucher coupons among 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 government policy stated that FISP targets 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.[5] The feasibility of implementing effective targeting and rationing of subsidized inputs is further weakened by active secondary markets for subsidized inputs in SSA (see Diop [2023]). Because of this, we model FISP in equation (4) as linear subsidies for staple inputs available universally.

Regarding public finance, we assume in the baseline allocation that the government finances FISP entirely by taxing labor income in urban areas. We follow this approach because

[5] A recent work of Basurto et al. [2020] finds that village chiefs target FISP not so much to the poorest households but to those with higher returns to farm inputs and that links to local authorities have limited consequences for targeting otherwise.

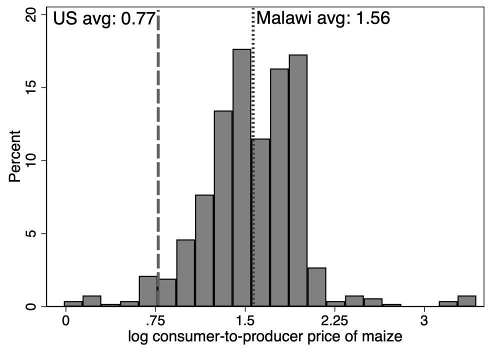
foreign donors financed only 7%-18% of the FISP costs between 2005-2010 (as discussed in Chirwa and Dorward [2013]). Moreover, Malawi's government has introduced farmers' income taxation only in 2010 and only on farmers selling cash crops (see Gourichon et al. [2017]).

Transaction costs. The central parameter of our paper is the per-unit transaction cost of purchasing staples Q_S, which drives the gap between the consumption and the producer prices of staples.[6] These gaps can be particularly large in Africa as, before reaching final consumers, agricultural products travel long distances through inadequate infrastructure (Teravaninthorn and Raballand [2009]), go through layers of intermediaries (Bergquist and Dinerstein [2020]), 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 shows a histogram of the log relative difference between the per kg price of maize faced by consumers and received by producers, constructed 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.[7] This evidence points to substantial transaction costs in the staple market of Malawi, going far beyond the efficient transaction or retail 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 is significantly associated with the presence of active local markets and the distance to district boma (administrative center), proxying variations in the quality of infrastructure and access to more liquid markets.

While we do not model per-unit transaction costs in the cash crop sector, we capture them through the per-period maintenance costs FM_B paid by cash crop farmers. We follow this approach as the cash crop expenditure share ψ_B is significantly lower than that of staples

[6] 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. In the context of Kenya, Bergquist and Dinerstein [2020] reaches different conclusions and finds evidence of significant market power among intermediaries.

[7] 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 and 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 ratios of consumer-to-producer prices of 1kg of green maize in Malawi. Panel (b) presents the regression exploring associations between consumer-to-producer price ratios and village-level characteristics. Data 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.

ψ_S, and cash crops often cannot be directly consumed as they are significantly harder to process at home than maize.[8]

Agricultural production function. We assume that each rural household has 1 unit of land available for production. Land in Malawi is usually governed under customary rules, with formal markets virtually nonexistent. As a consequence, 80% of farms are smaller than 1 hectare with an average farm size of 0.81 ha (see Chen et al. [2023]).[9] Furthermore, we assume that the agricultural production function exhibits decreasing returns to scale in intermediate inputs and land $(\zeta, \phi) \in (0, 1), \zeta + \phi < 1$, allowing farmers to generate positive profits in equilibrium. Upon paying the per-period maintenance cost FM_B, cash crop farmers enjoy increased returns on land if they produce both crops simultaneously, capturing additional gains due to crop diversification and rotation, allowing for improved income insurance, and smoothing of labor throughout the agricultural year.

We interpret the cash crop maintenance cost FM_B as representing both fixed transaction costs and all additional outlays required for production. In the case of tobacco cultivation, these can capture the costs of building curing barns and hiring additional labor during the

[8] As outlined in Appendix B, this approach also allows us to limit the model's numerical complexity.

[9] While outside of the scope of this paper, see the work of Manysheva [2022] for the analysis of land market reforms' impact on resource allocation and productivity in a framework similar to ours.

work-intensive curing stage.

Open economy. We model the key open economy aspects in detail because introducing FISP or other government programs may improve (worsen) the current account, which implies that the economy wastes resources (uses resources it does not have). The current account serves as a secondary dimension of welfare because a negative current account balance implies that additional, potentially distortionary tax measures are necessary to achieve a long-run balance.

Although Malawi has some domestic seed producers, Kachule and Chilongo [2007] show that the country imports virtually all of the fertilizer consumed.[10] 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.

Occupational choice and migration. We associate the agricultural household's decision to become a laborer 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. 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. This number reflects 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, see Narae [2016].

We denominate the urban entry and cash crop maintenance costs in terms of the urban wage rate, a standard assumption in the literature (Klenow and Li [2023]). Our interpretation of the urban entry cost covers the expenditures required for travel, housing, or finding

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

a job and the large financial commitments of rural migrants required for maintaining social links with their extended families.[11] Furthermore, although purely financial in our formulation, these costs can also be seen as a reduced-form way of capturing broader utility- or information-based barriers to migration.

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

3.3 Calibration strategy

We calibrate the model to the economy of Malawi in 2010 with FISP already in place. The assumed model periodicity is annual. We externally set the values of 15 parameters based on our estimates and the literature. Given those, we use the simulated method of moments in order to calibrate the remaining 8 parameters such that the implied model dynamics match relevant empirical facts. Tables 1 and 2 summarize the estimation procedure and parameters chosen. As part of robustness checks, we evaluate our model along non-targeted dimensions and investigate the changes in key moments as we switch off the relevant frictions. Tables 3 and 4 summarize the results of these respective exercises.

Preferences. We assume that households evaluate consumption according to the standard log utility function and are relatively impatient by setting the time preference parameter $\beta = 0.85$ (equal to the value assumed in Buera et al. [2021a]). In parameterizing the CES aggregator of consumption in (1), 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

[11] Indeed, Azam and Gubert [2006] review the related literature and evidence in SSA and conclude that migration decisions in the region 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.

Parameter	Value	Target/Source	Data	Model
Labor augmenting TFP in manuf A_M	2.85	18% urban population [LSMS2010]	18%	20%
Cash crop export demand shifter a_D	0.86	Share of 2010 cash crops exported [FAO 2010]	73%	76%
Subsidy rate for staple inputs τ_S	81%	Aggregate cost of program (% GDP) Chirwa and Dorward [2013]	3%	3%
Urban entry cost F_M	285	Rural-urban migration rate Bick et al. [2022]	1%	1%
Cash crop maintenance cost FM_B	2.2	Share of land devoted to staples [FAOStat]	70 %	68%
Working capital constraint κ	10%	Share of cash crop farmers w/ suboptimal inputs Brune et al. [2016]	70%	67%
Returns to scale in land for farming ϕ	0.74	Standard deviation of average product of farms Chen et al. [2023]	1.8	1.7
Correlation of urban/rural shocks ρ_{RU}	0.24	Agricultural productivity gap Gollin et al. [2014]	6.5	6.7

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.

consumption parameter at $\bar{c}_S = 0.02$, corresponding to the highest subsistence level possible to satisfy the poorest household (defined as a staple producer with the lowest level of assets and rural productivity and no input subsidies).[12] We define the undernourishment level $\tilde{c}_S = 0.11$ to be such that the baseline allocation has 20% of undernourished households with staple consumption below $\tilde{c}_S$, as in 2010 Malawi. Furthermore, we set the consumption share of staples $\psi_S = 0.12$, which is the approximate consumer expenditure share in the US spent on food (from the 2018-2021 data of the Bureau of Labor Statistics). Similarly, the consumption share parameter of cash crops captures preferences for clothes, alcohol, tobacco, and personal care products as reflected by approx. 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 of this part of consumption preferences over development paths, which is the standard practice in the literature.

Regarding the external demand for cash crops, we estimate demand equation (19) using the 1962-2019 data for Malawi from FAOStat by running the following regression:

$$\log(D_t) = A_D + b_D \cdot \log P_t + \epsilon_t \tag{23}$$

where D_t is Malawi's quantity of tobacco exports in year t and P_t is the export price (derived from dividing the data series of the nominal value of output by the total quantity produced). We focus on tobacco exports as this is Malawi's most important export good.

[12] Formally, we set $\bar{c}_S = \theta_{min}\left(\frac{\kappa a_{min}}{p_X}\right)^{\zeta} - a_{min}(1+\kappa)$.

Parameter	Value	Target/Source
Preferences		
Time preference β	0.85	Assumption
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
Subsistence constraint $\bar{c}_S$	0.02	Maximum level sustainable for poorest
Cash crop consumption share ψ_B	0.08	US Bureau of Labor Statistics
Export demand elasticity ϵ_D	-0.45	Our estimates from FAOStat
Production		
Transaction cost in staple sector Q_S	2.0	De Magalhaes and Santaeulalia-Llopis [2018]
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	0.4	Assumption
Capital depreciation rate δ	0.05	Assumption
Interest rate r	0.05	Assumption
Household productivity process		
Rural AR(1) persistence ρ^R	0.57	Our estimates from LSMS
Urban AR(1) persistence ρ^U	0.49	Our estimates from LSMS
Rural AR(1) standard deviation σ^R	1.11	Our estimates from LSMS
Urban AR(1) standard deviation σ^U	0.94	Our estimates from LSMS

Table 2: Externally calibrated parameters

The associated elasticity equals $b_D = -0.45$ (significant at 1% level), which is also the value we assume in our model. Finally, we set the export demand shifter in (19) to $a_D = 0.86$ such that the simulated moment of the share of cash crops exported matches its empirical counterpart of 73% from FAOStat.[13]

Production. First, we assume the transaction costs parameter of $Q_S = 2.0$ reflecting their excess in Malawi above the US level, which we take again as a frictionless benchmark. We conservatively choose a value 20% lower than the reported difference in Figure 2 as the empirical results for Malawi may be partly driven by seasonality in maize prices over the agricultural year (as explained in De Magalhaes and Santaeulalia-Llopis [2018]).

For the agricultural production functions (6) and (7), we pin down the cost share of intermediates as $\zeta = \frac{expenditures\ on\ maize\ seeds\ and\ fertilizer}{value\ of\ maize\ harvested}$. According to FAOStat data for Malawi in 2010, the average fertilizer use was 35 kgs per ha, with the average price estimated at 600 USD per tonne. Since FAOStat does not contain data on seed application rates, we

[13] 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).

assume it to be equal to the recommendation in the Malawi Country Report 2020 of 25 kgs per ha (Mabaya et al. [2021]). The same source also quotes the average price 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 the average yield of 2.2 tonnes per ha, implying the value of maize produced of 506 USD 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 $p_X = \zeta \cdot \frac{q_S}{x_S} = 0.15 \cdot \frac{230 \cdot 2.2}{35+25} = 1.26$.

We use the method of moments to pin down the value of returns to scale ϕ in cash crop land share l, the subsidy rate τ_S, the working capital constraint parameter κ, and the cash crop maintenance cost FM_B. First, we choose $\phi = 0.74$ such that the simulated standard deviation of the average farm product matches its empirical counterpart of 1.8 documented in Chen et al. [2023]. Second, we choose $\tau_S = 81\%$ such that the FISP's cost equals 3% of GDP, as was the case in 2010 Malawi (Chirwa and Dorward [2013]).[14] Third, we set $\kappa = 0.1$ targetting the share of cash crop farmers using a suboptimal amount of inputs equal to 70%, as found in the fieldwork of Brune et al. [2016]. Fourth, we set $FM_B = 2.2$ so that the share of cropland devoted to staples equals 70%, as in FAOStat.[15]

For the manufacturing production function, we assume a capital output-share of $\alpha = 40\%$ as David and Venkateswaran [2019] assumes a higher capital share for developing countries. Furthermore, we calibrate a high value of the labor-augmenting TFP factor of $A_M = 2.85$ allowing our model to replicate the low 18% share of urban population in 2010 Malawi. Importantly, our calibration implies very high entry costs from rural into urban of $F_M = 285$. We choose this parameter such that the model generates a very low migration rate of 1%, as documented in Bick et al. [2022].[16] Finally, we set the depreciation rate $\delta = 5\%$, the average between the 4% estimate for the US in Karabarbounis and Neiman [2014] and the 6% in

[14] In line with the discussion above, the institutional setup in Malawi implies no subsidies for cash crops.

[15] In the model, this moment is computed as the weighted share of land devoted to staples, with staple farmers devoting all of their lands to staples and cash crop farmers devoting 18% of it. 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.

[16] This high entry cost is equivalent to \$21,000, seven times the average urban consumption. In equilibrium, households migrate from rural to urban only when they receive the highest urban productivity shock, which allows them to overcome the entry barrier despite relatively low assets.

Midrigan and Xu [2014], with $r = 5\%$ savings rate and look for the level of foreign capital supplied to the manufacturing firm balancing the current account in the baseline calibration of 2010 Malawi.

Household productivity process. We draw on the limited 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 value (evaluated at gate prices) per ha of land cultivated on the vector of household controls, including the marital status of the head of household, their age and age^2, gender, level of education, household size 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 correction of Heckman [1979] on both regressions. We take the residuals of these two regressions as measures of our idiosyncratic productivity shocks. In order to allow for persistent shocks, we assume that both rural θ^R and urban θ^U processes follow a lognormal-AR(1): $\log(\theta^j_{i,t+1}) = \rho^j_\theta \theta^j_{i,t} + \epsilon^j_{i,t}$ with $\epsilon^j_{i,t} \sim N(0, \sigma^{j2})$ and $j \in \{R, U\}$. We find annualized persistence of rural and urban productivity shocks of 0.57 and 0.49 and standard deviations of 0.94 and 1.11, respectively. As the rural-urban productivity shock correlation is one of the important drivers of migration, we set $\rho_{RU} = 0.24$ such that the model matches the particularly large agricultural productivity gap of 6.3 in 2005 Malawi documented in Gollin et al. [2014].[17]

3.4 Non-targeted moments

In Table 3, we report 13 overidentifying moments we have not targeted in calibration. First, the implied GDP share of the agricultural sector equals 30%, just in line with the World Bank data for 2010 Malawi. Second, the share of land devoted to staples among cash crop farmers is equal to 18%, lower than the 30% found in the LSMS 2010 data for Malawi. Third, the model generates a substantial standard deviation of the average fertilizer product equal to 1.3, somewhat above the empirical one of 0.8 in the LSMS data.

[17] In our numerical implementation, we discretize the empirically estimated AR(1) process using the method of Gospodinov and Lkhagvasuren [2014].

Moment / Source	**Data**	**Model**
Agriculture output share in GDP [World Bank]	30%	30%
Production value improvement to cash grant Daidone et al. [2019]	11%	3%
Share of land devoted to staples among cash crop farmers [LSMS]	30%	18%
Standard deviation of average product of fertilizer [LSMS]	0.8	1.3
Inequality measures in De Magalhaes and Santaeulalia-Llopis [2018]:		
Urban-rural wealth ratio	3.0	2.0
Urban-rural income ratio	2.4	3.3
Urban-rural consumption ratio	2.2	2.7
Top 10% share of wealth	58%	35%
Top 10% share of income	48%	60%
Top 10% share of consumption	34%	33%
Top 1% share of wealth	25%	7%
Top 1% share of income	18%	11%
Top 1% share of consumption	8%	6%

Table 3: Non targeted moments

Note: The model counterparts are constructed in the steady state with FISP and labor taxation.

Fourth, we leverage the RCT evidence in Daidone et al. [2019], who evaluated the impact of the Social Cash Transfer (SCT) program introduced by the Malawian government in 2013-2014. The intervention injected assets worth approx. 25% of annual consumption to 3,500 poor rural households, resulting in an 11% increase in the value of their agricultural output. Upon introducing the equivalent of this RCT among the bottom 10% of rural households in our model, the value of their agricultural output increases by 3%.[18]

Finally, we implement an array of inequality indicators reported in De Magalhaes and Santaeulalia-Llopis [2018]. Our calibrated framework generates realistic gaps in mean levels of wealth, income, and consumption between the urban and rural areas. Furthermore, it implies a realistic concentration of consumption and income among the top 10% and 1% of the population, with somewhat larger deviations for the concentration of wealth.

3.5 The role of frictions

As a final part of the estimation's validation, Table 4 shows the impact of switching off the key frictions of our framework on the simulated moments targeted in the calibration

[18] The smaller size of this effect compared to findings of Daidone et al. [2019] can be because, in our framework, every cash-transfer recipient household benefits also from FISP (which is a substitute for cash transfers), which is not universally true in the empirical setting.

Variable	Data	Baseline	$\bar{c}_S = 0$	$Q_S = 0$	$\bar{c}_S = Q_S = 0$	$F_M = 0$	$FM_B = 0$	$\kappa = 10$
Urban population	18%	20%	20%	32%	31%	37%	20%	25%
Share of 2010 cash crops exported	73%	76%	74%	79%	78%	74%	75%	67%
Aggregate cost of program (% GDP)	3%	3%	3%	3%	3%	3%	3%	5%
Rural-urban migration rate	1%	1%	1%	2%	2%	24%	0.5%	1%
Share of land devoted to staples	70%	68%	67%	68%	68%	69%	80%	68%
Share of cash crop farmers w/ suboptimal inputs	70%	67%	68%	67%	67%	62%	32%	3%
Standard deviation of average product of farms	1.8	1.74	1.77	1.82	1.83	1.66	1.68	1.81
Agricultural productivity gap	6.5	6.7	6.0	2.8	2.9	3.0	6.0	6.4

Table 4: Changes in the calibration targets with relevant frictions switched off

Note: Each column reports key moments from a model with FISP and a respective change in one parameter value, with all the other parameters held constant at the baseline calibration level (including the labor income tax rate).

strategy (holding other parameters constant). The two most important drivers of our model's behavior are the transaction costs Q_S and entry costs into urban areas F_M. Both frictions are significant drivers of misallocation as evinced by large drops in APG and large increases in urbanization rate upon switching either friction off. Importantly, our model generates positive APG even without migration costs. As our simple model of risky occupation choice in Appendix A shows, with incomplete markets positive APGs arise even in the constrained efficient allocation with (i) $Q_S > 0$ and no sector-specific income risk, or (ii) with $Q_S = 0$ and a relatively higher income risk in the food sector (or a combination of both generating overfarming in the laissez faire equilibrium).

Finally, the financial friction operating through the working capital constraint is more important than usual because $\beta(1 + r)$ is significantly below 1.[19] A change in κ from 0.1 to 10 induces 5 p.p. and 9 p.p. changes in the urbanization rate and the share of exported cash crops.

4 Quantitative analysis

Having calibrated the baseline allocation to the post-reform economy of Malawi in 2010, we identify the macroeconomic impact of this large-scale policy by comparing the stationary distribution of that allocation to the one without FISP (pre-reform). We also evaluate FISP under two alternative scenarios: (i) in PE with households optimizing their decisions with

[19] Tetenyi [2019] shows that when the rest of the world owns capital in the domestic economy, financial frictions affect misallocation more than under closed capital markets.

all the prices fixed at the pre-reform level (including the zero labor income tax rate), and (ii) in GE with FISP being financed entirely through foreign aid. Table 5 contains the results of this analysis with Figure 3 showing the distributional impact of FISP.

Then, we consider two more exercises of looking for the optimal choice of τ_S and reallocating the public spending from FISP to infrastructural development investments that reduce frictions Q_S and F_M in our model. Figure 4 and Table 6 report the results of these exercises.

Throughout this section, we focus on comparisons of stationary distributions, i.e., we evaluate the long-run outcomes. Moreover, we focus on the utilitarian welfare impact of reforms by quantifying the required percentage change in consumption of every society member on average in every period of their life so that they are indifferent between the relevant cases. Finally, we consider two variants of the utilitarian welfare measure with (i) accounting for changes in the stationary distribution (our baseline welfare measure) and (ii) holding the masses of households fixed at the pre-reform level (although the stationary distribution naturally changes across the allocations).

4.1 The impact of FISP in Malawi

In the PE evaluation of FISP (column 2 in Table 5), many of the economy's margins are very sensitive to the subsidy program. Staple farming becomes much more profitable, and the share of the urban population and, consequently, the manufacturing output both drop by 45% and 60%, respectively. At the same time, the share of pure staple farmers increases by 51% together with a 150% increase in the productivity of staple farming. Farmers respond to incentives by lowering the overall output of cash crops, even though that sector's productivity increases similarly to staples due to households' optimizing behavior. As fertilizer imports increase significantly and the cash crop output and exports drop,[20] the current account collapses from an 8% surplus to a 41% deficit. The agricultural productivity gap (APG) increases by 70%, indicating a worsening misallocation in the economy as both the

[20] Notice that the share of cash crops exported in Table 5 in PE case increases by 214%. This number is high precisely due to the collapse in cash crops' output and no change in the export demand as there is no change in the cash crop price in the PE scenario.

dispersion of agricultural input's average revenue product and the number of people in the less productive rural sector increase. However, the program achieves some of its aims, as evidenced by a 38% reduction in the share of rural households with insufficient home production of staples, a 10% reduction in the share of people undernourished, and a 90% reduction in expenditures on transaction costs. While the consumption-equivalent welfare gain of the average society member seems large at 2.6%, it pales next to the unaccounted-for program cost of 17% of GDP. Once we fix the masses of households at the pre-reform level for aggregating welfare change, FISP generates gains equivalent to a 12% increase in consumption on average. Since more households are poorer and benefit much more from the reform under the "fixed distribution" scenario, the difference relative to the benchmark welfare metric reflects the large effects of FISP on wealth and occupational mobility.

In the third column of Table 5, we evaluate the GE impact of FISP accounting for changes in market prices, but without requiring the government budget clearing through labor taxation. In this case, the effects of this large-scale subsidy program feed into the broader economy through the equilibrium adjustment of prices. Food becomes cheaper as the relative prices of the cash crop p_B, manufacturing good p_M, and labor w increase by 27%, 39%, and 73%, respectively. This is the market response to the input-driven increase in productivity of the staple sector. Compared to the PE case, the reduced relative price of staples mutes the reform's impact on the output and productivity of staples with both increasing by 43% and 34%, respectively. The increased relative price of cash crops stabilizes the PE effects in the cash crop sector, so the output and productivity in this market remain almost unaffected. The import and export margins adjust so that the current account becomes essentially balanced. Similarly, the price increase of manufacturing goods and wage increase stabilizes the outflow of people from urban to rural areas, resulting in a smaller 8% drop in the urbanization rate. Interestingly, although the urbanization rate declines, the output of manufacturing increases by 9% due to increased household savings, leading to higher capital stock rented by the representative firm. Unlike the PE case, the amount of the economy's resources spent on transaction costs increases by 13%, tracking the 10% increase in aggregate consumption. After letting the market forces work, the average urban-rural gaps in consumption, income, and wealth increase by around 50%-60% due to the strong

	No FISP	FISP partial eqm.	FISP aid-financed	FISP tax-financed $\tau_W = 19\%$
Prices & Aggregates				
Cash crop, p_B	1.2	0%	+27%	+28%
Manufacturing, p_M	0.2	0%	+39%	+49%
Wages, w	0.1	0%	+73%	+63%
Consumption	3.8	-1%	+10%	-1%
Nominal output	3.9	-30%	+36%	+38%
Share of cash crops exported	86%	+214%	-8%	-12%
Transaction cost	0.3	-90%	+13%	+3%
Current account surplus % of GDP	8%	-41%	-1%	0%
Production				
Staple production	0.3	+336%	+43%	+37%
Staple productivity	0.6	+153%	+34%	+28%
Cash crop production	0.9	-68%	-2%	+1%
Cash crop productivity	3.6	+154%	+3%	+1%
Share of land devoted to staples	67%	+43%	+3%	+1%
Share of farmers without surplus	36%	-38%	-12%	-12%
Share of financially constrained farmers	67%	+49%	-2%	0%
Manufacturing production	9	-45%	+9%	+1%
Urbanization rate	24%	-60%	-8%	-15%
Agricultural productivity gap	3.8	+70%	+61%	+75%
Average agricultural ability	2.0	-5%	-4%	-5%
Average worker ability	44.6	+10%	-2%	-3%
Dispersion in ARPX	0.83	+13%	+92%	+104%
Dispersion in ARPX for cash crop farmers	0.87	-9%	-6%	-2%
Dispersion in ARPX for staple farmers	0.25	+85%	+79%	+42%
Welfare and Inequality				
Consumption equivalent welfare	-	+2.6%	+4.8%	-3.0%
Consumption equivalent welfare fixed distribution	-	+11.9%	-2.3%	-8.1%
Share of undernourished	28%	-10%	-30%	-29%
Avg urban-rural consumption ratio	1.9	-4%	+51%	+42%
Avg urban-rural income ratio	2.6	+3%	+34%	+26%
Avg urban-rural wealth ratio	1.4	+13%	+52%	+45%
Top 10% share of wealth	34%	-5%	+7%	+2%
Top 10% share of income	59%	+2%	+2%	+2%
Top 10% share of consumption	31%	-6%	+10%	+6%

Table 5: 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 eq-m" 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 that 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 in value-added 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".

equilibrium response of wage rate, which — apart from making those staying in cities richer — also renders the entry barriers into urban and cash crop sectors higher.[21] We find large differences in the welfare impact of FISP evaluated with (4.8% gain) and without (2.3% loss) accounting for distributional changes induced by the reform. This happens as GE reverses the pattern of differences relative to the PE case due to the FISP reform increasing the prices of all goods relative to staples. As we fix the masses of households at the stationary distribution of the pre-reform allocation, the net benefits of reform become negative because the adverse effects of FISP resulting in higher prices of non-staple consumption goods are not matched by the improvements in household wealth and occupational mobility. Finally, the welfare loss induced by the reform after controlling for compositional changes under this seemingly "free lunch" scenario confirms how non-trivial the interplay of the equilibrium effects present in our framework is.

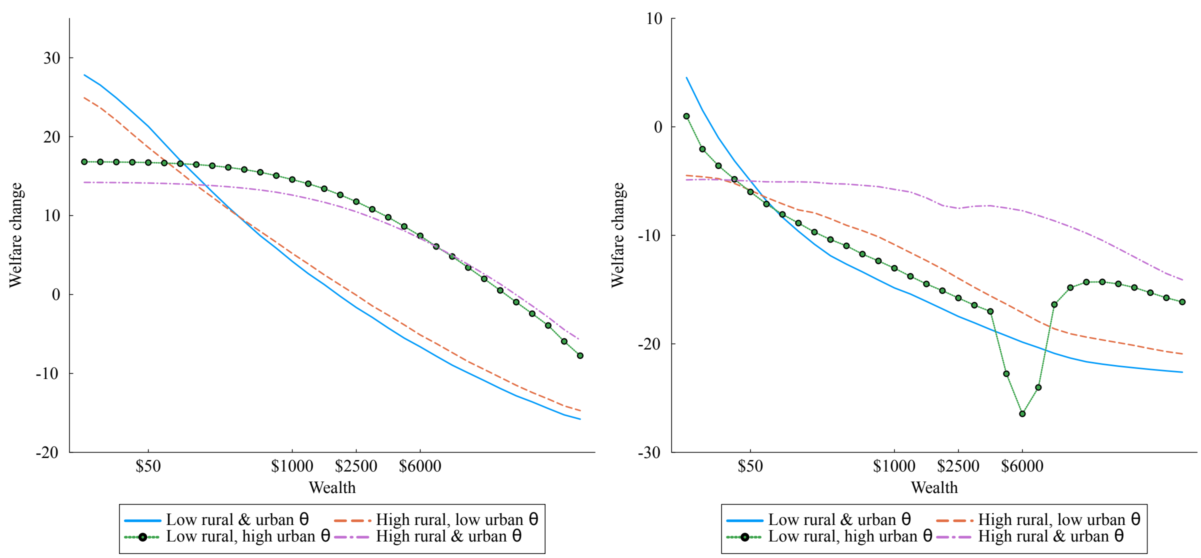
The fourth column presents the complete GE picture upon introducing the 19% urban labor income tax rate to finance the program. Relative to the foreign aid scenario, this margin of equilibrium adjustment renders living in urban areas less attractive, doubling the drop in the urbanization rate to 15%. The misallocation becomes even more extensive with APG growing by 75% and the dispersion of average revenue product of inputs doubling. The overall dispersion of ARPX in both GE cases increases by significantly more than the respective changes for staple and cash crop farmers because FISP significantly lowers the marginal costs and – by the optimizing behavior of households – also the marginal (and average) return on fertilizers for staples, without affecting the average level of ARPX for cash crops. Hence, the increased difference between marginal products of cash crops and staple producers doubles the overall dispersion.[22] The urban-rural inequalities remain similarly large as in the "foreign aid" case despite the labor income taxation. Overall, we find that in the long run, FISP generates a significant reduction in welfare, equivalent to a 3% drop in consumption on average. However, when we control for the composition changes induced by the policy by fixing the stationary distribution of agents at the pre-reform level, the reduction

[21] These effects would be qualitatively similar if we denominated entry and maintenance costs in p_B or p_M terms, as both increase with the reform, similarly as the wage rate w.

[22] In the PE case, notice that there are also fewer cash-crop farmers, hence the lower increase in the overall dispersion of ARPX.

in welfare is much more considerable and equivalent to an 8.1% drop in consumption on average. Compared to the ”foreign aid” scenario, the welfare effects in both cases are lower due to the social costs imposed by labor income taxation.

We decompose the welfare changes among rural and urban populations across different levels of asset holdings in Figure 3. The striking feature is that, upon considering all GE effects, the program, designed to benefit the rural population, redistributes virtually all welfare gains toward the urban population. On one hand, urban residents benefit from both cheaper food and higher labor income. Conversely, the rural population has more staples to consume but has to pay more for cash crops and manufacturing goods. On top of that, they find it more difficult to change occupations compared to the no subsidy equilibrium due to higher entry costs. Indeed, only a few farmers with low wealth positions below USD 50 experience some welfare gains due to the program.[23]



(a) Urban workers

(b) Farmers

Figure 3: Distributional welfare impact of FISP

Note: The figure presents the consumption equivalent welfare gains across occupations for different wealth levels for households with different rural and urban productivities. The effect on cash crop and staple farmers is the same due to no entry costs for either occupation.

[23]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.

Finally, comparing the PE and GE allocations is helpful for two reasons. First, notice that the nature of our PE allocation resembles a possible micro-evaluation of an input subsidy intervention. Because our PE allocation allows households to choose both investment and occupation optimally, the huge estimated impact of the intervention on staple and cash crop output levels partly reflects the increased share of the rural population. Regardless of the latter, however, the PE intervention implies more than doubling agricultural productivity. Relative to the GE allocation, it shows that such an approach overstates the productivity gains of staples by a factor of 5 and cash crops by a factor of 50. The impact of FISP on land reallocation decisions is also significantly overestimating the increase in the PE share of land devoted to staples. As a consequence, the positive impact of the policy on food security proxied by the share of households with sufficient staple output for own consumption is also double its actual effect under GE. Ignoring the GE effect may lead to the opposite of desired welfare consequences. This exercise demonstrates the importance of analyzing the macroeconomic effects when scaling up candidate development policies.

Our results rely on comparisons of stationary distributions, i.e., of arguably long-run outcomes. However, comparing differences in FISP's impact across the PE and GE cases is informative for gauging how different the welfare conclusions would be if we were to look at the transition dynamics. Most importantly, adjusting prices towards the new steady state would take at least several years. Households with a comparative advantage in the production of staples and low asset holdings would benefit relatively more from the productivity gains made possible by cheaper inputs, especially in the earlier periods of the reform. As this category of rural farmers would likely entail many of the economy's poorest households with a relatively high marginal utility of consumption, introducing the reform would arguably lead to better outcomes than the currently estimated welfare losses arising in the long-run comparisons.

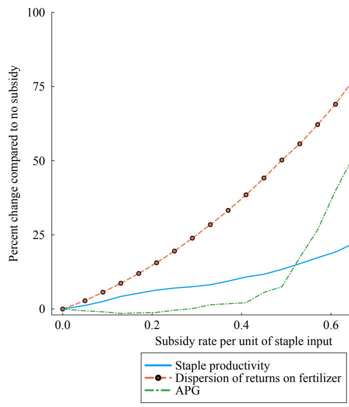
4.2 Changing the size of FISP in Malawi

We have shown that the high subsidization rate of FISP induces adverse redistribution and welfare losses in Malawi. We ask now whether it is possible to rescale the program so that the average society member can benefit from FISP.

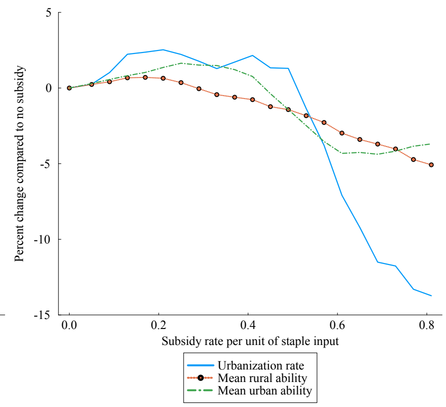
To this end, Figure 4 compares the key statistics of long-run stationary distributions associated with different levels of τ_S, holding all other parameters fixed. Panel (a) shows that while a higher subsidy rate naturally stimulates the productivity of staple farming, it also monotonically increases the dispersion of marginal returns on inputs used. The misallocation within the rural sector increases due to the increased gap between the marginal revenues of cash crops and staple farmers. The intersectoral misallocation also monotonically increases with the subsidy rate τ_S. For a small enough τ_S, APG weakly increases as the urbanization rate grows, indicating an improved overall allocation of resources in the macroeconomy. However, for a larger τ_S, fewer households decide to work in manufacturing, generating sharp increases in the value-added per worker.

Panel (b) shows that although a larger FISP monotonically increases fertilizer misallocation both within and across sectors, it can reduce overall occupation mismatch. In particular, reducing the FISP's size so that $\tau_S \in (0.25, 0.45)$ can increase the urbanization rate by up to 3% because a smaller FISP balances a higher labor income tax rate, misallocation, and the need to relax the severity of financial frictions in rural areas without excessively favoring staple farming. At the same time, the allocation of talent in the economy improves for the optimal size of FISP, with the average agricultural ability in rural areas increasing by up to 2% and the average urban ability increasing by up to 3%.

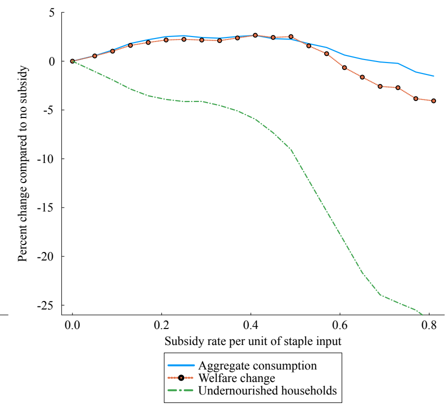
The above trade-offs induced by FISP are visible in panel (c). A smaller FISP with τ_S between 25%-45% may induce sizable welfare gains equivalent to a 3% increase in consumption on average. While a larger FISP induces welfare losses, it monotonically reduces the share of the undernourished population. Panels (d)-(f) decompose changes in consumption of staples, cash crops, and manufacturing goods across occupations. Input subsidies, especially at higher levels, disproportionately benefit urban workers as their increases in consumption of agricultural products dominate those of farmers. Moreover, while wealthier urban workers manage to increase their consumption of the manufacturing good (which has by far the highest share ψ_M in consumer preferences), the increased price of manufacturing goods implies reductions in its consumption among farmers. While staple-supporting ISPs disproportionately hurt cash crop farmers, the main trade-off induced by the program is in redistributing resources from the agricultural toward the urban sector.



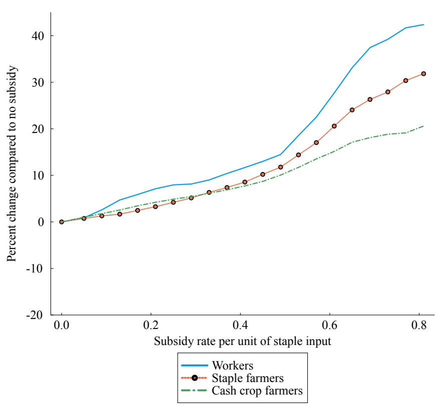
(a) Productivity



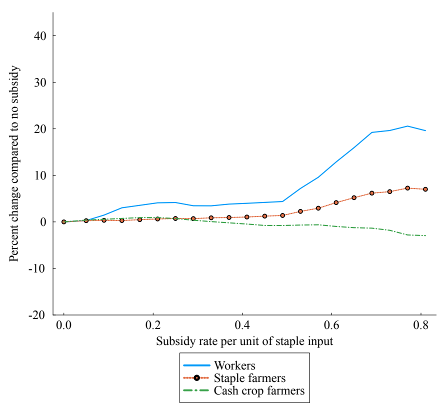
(b) Urbanization and talent allocation



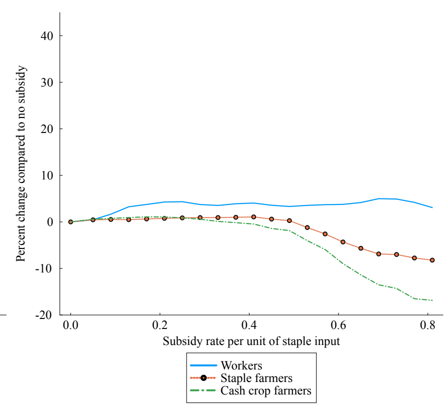
(c) Consumption and welfare



(d) Staple consumption



(e) Cash crop consumption



(f) Manufacturing good consumption

Figure 4: The impact of varying subsidy rate τ_S on Malawian economy

Note: Panels (a)-(c) show the impact of subsidy rates on key variables relative to the no subsidy equilibrium, constructed in the steady states with different subsidy rates and labor taxation that balances the government budget. Welfare change accounts for changes in stationary distribution. Panels (d)-(f) show the total consumption change of each good for each occupation relative to their consumption in the no subsidy equilibrium.

4.3 Alternative use of public funds: infrastructure investments

Nyondo et al. [2021] estimate that the average spending of the Malawian government on FISP between the years 2009 and 2019 could allow for constructing 99 (220) kilometers of the highest (lower) quality all-weather roads per year. Motivated by this, our last counterfactual exercise considers reallocating public funds from FISP into infrastructural investments such as building roads or railways and expanding fleets of vehicles or trains.

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 3% of GDP, the relative cost of FISP. 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 (Morten and Oliveira [2023]) and improves food security (Blimpo et al. [2013]). In both cases, we assume the "foreign aid" financing in order to be conservative regarding the benefits of infrastructural investment by not allowing the benefits of a larger tax base in the cities to further increase welfare gains associated with these counterfactuals.[24]

The first column of Table 6 repeats the relative changes in key statistics induced by FISP relative to the "No FISP" allocation in Table 5. The second column considers a reduction in Q_S from 2.0 to 0.7, and the third column considers the spillover scenario with additionally reduced urban entry costs F_M from 285 to 100 times the wage rate. Although the reductions in frictions are sizable, the infrastructure counterfactuals financing households' transaction cost up to 3% of GDP require 60% lower foreign aid as reducing the Q_S and F_W distortions benefits households more uniformly than the staple-targeting FISP. Although the share of people remaining in rural areas drops by up to 25%, the improved allocation of talent allows for a slight increase in output of both staples and cash crops and also a large increase of up to 59% in the manufacturing output. The economy's overall allocation of key resources becomes more efficient with APG and the urban-rural inequalities dropping by up to approx. 30%. All non-food goods become relatively cheaper, and (the precautionary) savings decrease.

[24] Arguably, infrastructural investments may have broader implications in our model, e.g., they may also reduce prices of intermediate inputs p_X or cash crop maintenance costs FM_B.

	FISP foreign aid	Infrastructure $Q_S = 0.7$	Infrastructure w/ spillovers $Q_S = 0.7$ & $F_M = 100$
Prices and Aggregates			
Cash crop price, p_B	+27%	0%	-1%
Manufacturing price, p_M	+39%	-5%	-32%
Wage rate, w	+73%	-8%	−47%
Consumption	+10%	+6%	+49%
Nominal output	+36%	-1%	+5%
Share of cash crops exported	-8%	+1%	-4%
Transaction cost	+13%	-38%	-41%
Current account surplus % of GDP	-1%	+8%	+7%
Production			
Staple production	+43%	-2%	+8%
Staple productivity	+34%	0%	+20%
Cash crop production	-2%	-1%	+5%
Cash crop productivity	+3%	+1%	+8%
Share of land devoted to staples	+3%	-1%	-3%
Share of farmers without surplus	-12%	+3%	+13%
Share of financially constrained farmers	-2%	0%	-8%
Manufacturing production	+9%	+4%	+59%
Urbanization rate	-8%	+7%	+25%
Agricultural productivity gap	+61%	-11%	-30%
Average agricultural ability	-4%	+1%	+11%
Average worker ability	-2%	0%	+69%
Dispersion in ARPX	+92%	-20%	-30%
Dispersion in ARPX for cash crop farmers	-6%	-1%	-18%
Dispersion in ARPX for staple farmers	+79%	-64%	-66%
Welfare and Inequality			
Cons.-equiv. welfare	+4.8%	+6.8%	+43.6%
Cons.-equiv. welfare w/ fixed distribution	-2.3%	+5.7%	+49.9%
Share of undernourished	-30%	-26%	-47%
Avg urban-rural consumption ratio	+51%	-9%	-33%
Avg urban-rural income ratio	+34%	-9%	-20%
Avg urban-rural wealth ratio	+52%	-12%	-30%
Top 10% share of wealth	+7%	+5%	-19%
Top 10% share of income	+2%	-1%	-28%
Top 10% share of consumption	+10%	-2%	-19%

Table 6: Quantitative results of FISP and infrastructure investment

Note: All changes reported in columns 1-3 are relative to the "No FISP" allocation presented in Table 5. The "infrastructure" allocation in column 2 considers a 65% reduction in Q_S such that the aggregate household spending on transaction costs declines by 3% of GDP, the equivalent of the FISP's cost. In the "infrastructure w/ spillovers" allocation in column 3, we assume that both Q_S and F_M decline by 65%. All allocations assume "foreign aid" financing.

All of this allows for an increase in total consumption of up to 49%. The infrastructural investments induce welfare gains of up to 44%-50% in the "spillover" case, trumping any positive effects of FISP.

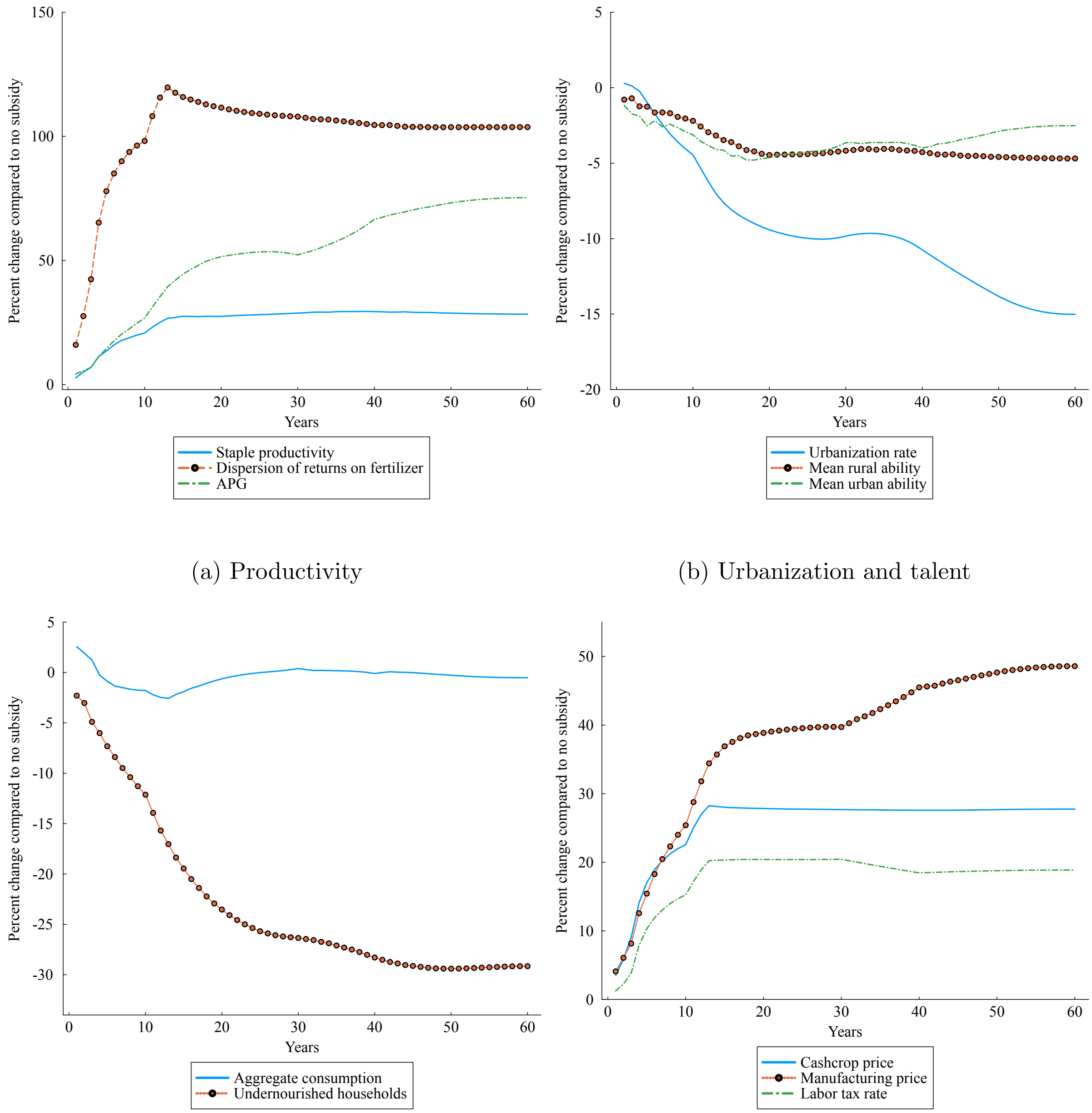
4.4 Transition dynamics

We are focusing on the transition of the Malawian economy from the pre- to post-reform, which augments the comparison of long-term steady states. The dynamics of the economy's adjustment starting from $\tau_S = 0.0$ to $\tau_S = 0.81$ - our baseline FISP calibration in 2010 Malawi, increasing τ_S gradually in 5 periods following the evidence on actual implementation in Malawi as discussed in Benson et al. [2024]. Figure 5 shows the results of this exercise under the balanced government budget case.

The adjustment process of the Malawian economy is sluggish not only due to the gradual implementation of FISP but also because scaling up individual agriculture production and moving from the rural to the urban sector requires the accumulation of savings. Because of this, staple productivity increases relatively slowly, similar to the urbanization rate and the APG. These slow-moving adjustments go hand-in-hand with gradual increases in the cash crop and manufacturing prices and the labor tax rates. Most of the margins converge to the new steady state in 20 years.

Regarding the impact on the FISP's welfare evaluation, we find that accounting for transition induces a smaller average welfare cost equivalent to a permanent 2% loss in consumption (as opposed to the estimated 3% loss in our baseline comparison of stationary equilibria).[25] The main reason for this is that depopulation of urban areas takes decades, allowing government to finance the program initially with a lower labor tax rate.

[25]Our consumption-equivalent welfare evaluations in this exercise are similarly based on a utilitarian social welfare function but account for the immediate impact of a policy change on the whole population and discount later periods with the discount factor β. Aid financed subsidy program delivers a 2.4% welfare increase when the transition is accounted for; see Appendix D.



(a) Productivity

(b) Urbanization and talent

(c) Consumption

(d) Prices

Figure 5: Transitional dynamics after introducing $\tau_S = 0.81$ in Malawian economy

Note: The figure shows transitional dynamics induced by a gradual introduction of FISP in equal increments during the first five periods starting from $\tau_S = 0.0$ to $\tau_S = 0.81$. Every period is financed from concurrent taxes on urban wages.

5 Empirical validation

In this section, we show that the model-generated dynamics are in line with the data. In Table 7, we compare cross-sectional regressions run on data from the model in steady state with FISP against the corresponding ones on the 2010 rural sample of the LSMS data for Malawi. Then, in Figure 6 and Table 8, we conduct a "macro diff-in-diff" analysis of SSA countries implementing large-scale ISPs in the 2000s and compare those with predictions of our model.

5.1 Micro-evidence from Malawi: model vs data

Table 7 assesses the model's predictions on non-targeted moments from the Malawian cross-sectional LSMS data in 2010. 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 we acknowledge that the causal relationships between our outcome and independent 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 to leverage the power of indirect inference 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 sample size. We purge the empirical regressions of factors not modeled in our framework 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. Finally, we ensure comparability of the estimates across regressions by normalizing all variables by their respective means.

First, there is a strong negative association between the land allocation decisions and the amount of inputs used ($\hat{\beta}^{model} = -0.82$ vs $\hat{\beta}^{data} = -0.46$). This relationship demonstrates that the direct effect of allocating more land to staples and benefiting more from FISP is

	Inputs used		Value of harvest		Share self-consumed	
	Model	Data	Model	Data	Model	Data
Share land w/ maize	-0.82^{***}	-0.46^{***}	-1.87^{***}	-1.12^{***}	0.88^{***}	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 7: 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.

relatively weak compared to the indirect effect of asset-poor (i.e., collateral-constrained) farmers' selecting staple farming.

Second, both the empirical and simulated data confirm that the cultivation of staples is not a revenue-maximizing choice. However, the large estimates of the negative association between the share of land devoted to maize and gross value of harvest ($\hat{\beta}^{model} = -1.87$ vs $\hat{\beta}^{data} = -1.12$) reflect not only the latter but also the selection into staple production of asset-poor farmers with a lower fertilizer use intensity.

Finally, cultivating maize is a critical source of food for disadvantaged households. While somewhat overestimated in the model ($\hat{\beta}^{model} = 0.88$ vs. $\hat{\beta}^{data} = 0.18$), we find a robust positive relationship between the share of land devoted to maize and the share of total harvest self-consumed, presumably as an attempt of rural households to reduce their exposure to transaction costs.

5.2 Cross-Country Evidence

Results from our quantitative model show the importance of considering price effects in evaluating the impacts of large-scale agricultural interventions such as FISP. In PE, FISP generates substantial increases in agricultural productivity and pushes farmers to increase the share of land devoted to staples. However, the GE forces working through increased relative market price of cash crops significantly weaken these effects. Similarly, our framework shows that FISP reduces undernourishment and affects migration choices and structural transformation, with the exact sign of effects depending on the program's size.

We evaluate these predictions in the event study of SSA countries that introduced large-scale ISPs around the 2000s. Because the timing of introducing ISPs in the region was heterogeneous, we use the Callaway and Sant'Anna [2021] estimator with the control group of never-treated countries.[26] Table 9 in Appendix C summarizes the 1980-2020 FAOStat data used together with the treatment classification of countries.

Figure 6 presents event study plots quantifying the impact of ISPs on fertilizer use, agricultural yields, market prices, land allocation, the share of the population undernourished, and the share of the rural population. We find that such interventions increase fertilizer use by 5kg per ha (or 37%) and significantly increase yields of staples by 20% without affecting much of those of cash crops. As the share of land devoted to staples does not change on the impact of ISPs, increases in the supply of staples significantly drive up the relative price of cash crops by 24%. Validating one of ISPs' aims, we find that the share of undernourished populations drops by 23%. Interestingly, we also find evidence that the urban-rural migration decisions may indeed be responsive to the macroeconomic effects induced by ISPs, and more so in the long run.

In Table 8, we contrast the event study results with predictions of our model under both the baseline subsidy rate of $\tau_S = 0.81$, and the optimally scaled-down FISP with $\tau_S = 0.41$. Comparing results from these two parameterizations is important not only because of the non-linearities produced by our framework but more so because the Malawian FISP has been particularly large compared to the rest of treated SSA countries (see, e.g., Jayne et al. [2018]). The simulated responses of input use (at least under the optimally rescaled FISP), staple yields, relative prices, land allocation, and the impact on undernourishment are particularly well-aligned with the data. The lack of effects on farmers' land allocation decisions in SSA is consistent with strong price effects unleashed by ISPs. The ability of our framework to generate a hump-shaped response of the urbanization rate to FISP can also plausibly

[26] Our identifying assumption is that the 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 per capita.

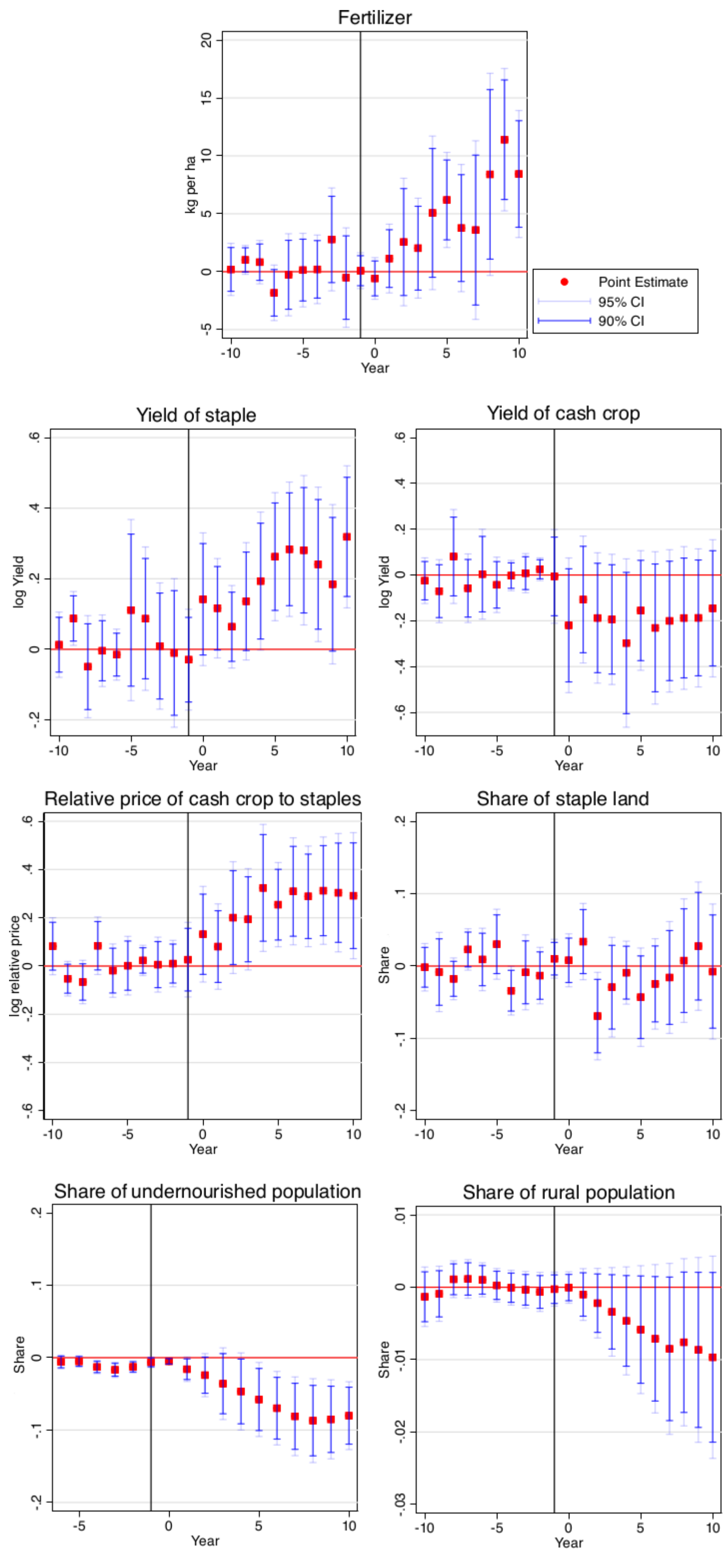


Figure 6: Empirical investigation of ISPs' economic impact in SSA

Note: The figure presents the Callaway and Sant'Anna [2021] event study of introducing ISPs in SSA. All data from FAOStat, see details of it in Table 9 in Appendix C. Yields and relative prices are log terms, and fertilizer is expressed in kilograms used per hectare.

	Input use	Staple yield	Cash crop yield	Relative price	% staple land	% undernourished	% rural pop.
Diff-in-diff	+37%**	+20%***	-19%	+24%**	-2%	-23%***	-1%
Model $\tau_S = 0.41$	+39%	+11%	+11%	+9%	+1%	-6%	+2%
Model $\tau_S = 0.81$	+194%	+27%	+26%	+26%	+2%	-27%	-14%

Table 8: Impact of ISP in the model and cross-country data

Note: The impact of ISP is relative to the no-subsidy equilibrium in the model and to the mean level of respective variables among treated countries before the treatment in the data. Significance at 0.01, 0.05, and 0.1 levels for empirical moments is denoted by ***, **, and *, respectively.

rationalize the sluggish increase in the urbanization rate in the data.

6 Conclusion

Government policy aims to raise living standards, and especially in developing countries, agricultural policy is a popular candidate to increase welfare. Many SSA countries have implemented large-scale input subsidies supporting access to modern seeds and fertilizers to cultivate staples. 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 fundamental belief in market forces in the 1970s and 80s (times of "Washington Consensus") to, starting at the end of 1990s, a gradual acknowledgment of powerful frictions in developing countries that may seriously inhibit the power of markets and so render agriculture subsidies efficient.

We develop a holistic framework that integrates the main concerns regarding agricultural subsidy programs in a frictional GE market economy with heterogeneous households facing an occupational choice between working in cities or rural areas. A key feature of our model is that households purchasing staples on the market must pay a per-unit transaction cost, incentivizing the home production of staples. Applying the model to Malawi shows that while the current large size of the local agricultural ISP is detrimental to welfare, halving the subsidy rate can generate significant welfare improvements relative to the complete elimination of the program. We also provide indicative quantitative evidence that the opportunity cost of such interventions is considerable: a similarly-sized investment into a broadly defined infrastructure reducing the transaction and rural-urban migration costs trumps any positive effects of FISP. Finally, we show that the key predictions of our framework are borne out both in the micro-data from Malawi and the cross-country macro-panel from SSA.

Our work highlights several fruitful directions for future research. Although we have focused on comparing long-run allocations, our framework can easily account for the impact of FISP along transition paths. Furthermore, an exciting extension of our framework would lie in studying the optimal design of ISPs upon introducing targeting with capacity constraints on the subsidized amount of inputs awarded and active secondary markets, allowing households to overcome these institutional constraints. Likewise, one could also use our framework to study the consequences of ISPs on the market power of agricultural intermediaries.

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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), describe the datasets used for the empirical analysis (Appendix C) and additional results in the quantitative model (Appendix D).

A Simple model

Ex ante homogeneous agent choosing prob of being farmer χ or worker:

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

Preferences over two goods of food and manufacturing:

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

Conditional on becoming worker, they receive $A(1-\gamma)$ with $p = 0.5$ and $A(1+\gamma)$ with $p = 0.5$ units of manufacturing good priced at p. Similarly, conditional on becoming farmer they receive $(1-\sigma)$ with $p = 0.5$ and $(1+\sigma)$ with $p = 0.5$ units of manufacturing good. We denote by $i \in \{H, L\}$ type of agent with high or low endowment realization of respective good. Purchase of food by workers is subject to per unit transaction costs Q.

The resource constraints for two goods read:

$$\chi 0.5\left(f^{F,H} + f^{F,L}\right) + (1-\chi)(1+Q)0.5\left(f^{W,H} + f^{W,L}\right) = \chi\ \ [= \chi 0.5(1-\sigma+1+\sigma)] \tag{2}$$

$$\chi 0.5\left(m^{F,H} + m^{F,L}\right) + (1-\chi)0.5\left(m^{W,H} + m^{W,L}\right) = (1-\chi)A \tag{3}$$

Worker i chooses utility max basket condition to the following budget constraint:

$$(1+Q)\, f^{W,i} + p\cdot m^{W,i} \leq p(1 \pm \gamma)A \tag{4}$$

FOC of such worker reads:

$$\frac{f^W}{m^W} = \frac{p}{1+Q} \tag{5}$$

Farmer i chooses utility max basket and effort condition to the following budget constraint:

$$f^{F,i} + p \cdot m^{F,i} \leq (1 \pm \sigma) \tag{6}$$

And FOCs of farmer reads:

$$\frac{f^F}{m^F} = p \tag{7}$$

Putting together FOCs (5) and (7) we get:

$$\frac{f^{W,i}}{m^{W,i}} = \frac{1}{1+Q}\frac{f^{F,i}}{m^{F,i}} \tag{8}$$

Lets combine now farmer FOC (7) and farmer's b.c. (6):

$$\begin{aligned} pm^{F,i} \cdot 2 &= (1 \pm \sigma) \\ \Rightarrow m^{F,i} &= \frac{1}{p}\frac{(1 \pm \sigma)}{2} \end{aligned} \tag{9}$$

Lets combine now worker FOC (5) and worker's b.c. (4):

$$\begin{aligned} 2 \cdot pm^{Wi} &= p(1 \pm \gamma)A \\ \Rightarrow m^{W,i} &= A\frac{(1 \pm \gamma)}{2} \end{aligned} \tag{10}$$

Use (9) and (10) in resource constraint (3) for manuf good to get p:

$$0.5\chi\left\{0.5\frac{1}{p}(1-\sigma+1+\sigma)\right\}+0.5(1-\chi)\left\{0.5\frac{1}{p}\left[p(1-\gamma)A+p(1+\gamma)A\right]\right\}=(1-\chi)A$$

$$\Rightarrow p=\frac{1}{A}\frac{\chi}{1-\chi} \quad (11)$$

Now use derived price in (11) to solve for consumption of manufacturing good by farmers:

$$m^{F,i}=A\frac{(1\pm\sigma)}{2}\frac{1-\chi}{\chi} \quad (12)$$

Now we can solve for optimal χ from solving the condition given by taking FOC wrt χ of objective function (1), after using the knowledge about m's and f's:

$$0.5\log\left(\frac{f^{FH}f^{FL}}{f^{WH}f^{WL}}\frac{m^{FH}m^{FL}}{m^{WH}m^{WL}}\right)=0$$

$$\Longleftrightarrow$$

$$f^{FH}f^{FL}m^{FH}m^{FL}=f^{WH}f^{WL}m^{WH}m^{WL}$$

$$\Longleftrightarrow$$

$$p^2\left(m^{FH}\right)^2\left(m^{FL}\right)^2=\frac{p^2}{(1+Q)^2}\left(m^{WH}\right)^2\left(m^{WH}\right)^2$$

$$\Longleftrightarrow$$

$$(1-\sigma)(1+\sigma)\left(\frac{1-\chi}{\chi}\right)^2(1+Q)=(1-\gamma)(1+\gamma) \quad (13)$$

$$\Longleftrightarrow$$

$$\chi^{comp.eqm.}=\frac{1}{1+\sqrt{\frac{(1-\gamma)(1+\gamma)}{(1-\sigma)(1+\sigma)(1+Q)}}} \quad (14)$$

Comparative statics seem to make sense, the share of farmers intuitively grows in Q, and increases if the relative riskiness in manuf to farming increases. This summarizes the competive eqm:

$$
\begin{aligned}
m^{Fi} &= \frac{(1+-\sigma)}{2}A\frac{1-\chi}{\chi},\ i \in \{H, L\} \\
m^{Wi} &= \frac{(1+-\gamma)}{2}A \\
f^{Fi} &= pm^{Fi} \\
f^{Wi} &= \frac{p}{1+Q}m^{Wi} \\
p &= \frac{1}{A}\frac{\chi}{1-\chi} \\
\chi^{comp.eqm.} &= \frac{1}{1+\sqrt{\frac{(1-\gamma)(1+\gamma)}{(1-\sigma)(1+\sigma)(1+Q)}}}
\end{aligned}
$$

Lets rewrite the welfare function (1) using what we found about consumption quantities in :

$$
\begin{aligned}
W &= \chi 0.5(V^{F,H} + V^{FL}) + (1-\chi)0.5(V^{WH} + V^{WL}) \\
&= \chi \log\left(p^2\left(m^{FH}\right)^2\left(m^{FL}\right)^2\right) + (1-\chi)\log\left(\frac{p^2}{(1+Q)^2}\left(m^{WH}\right)^2\left(m^{WH}\right)^2\right)
\end{aligned}
$$

Consider now a marginal deviation's of χ impact on W:

$$
\begin{aligned}
\frac{\partial W}{\partial \chi} = &\log\left(p^2\left(m^{FH}\right)^2\left(m^{FL}\right)^2\right) + \chi\frac{1}{p^2\left(m^{FH}\right)^2\left(m^{FL}\right)^2}\frac{\partial(p^2\left(m^{FH}\right)^2\left(m^{FL}\right)^2)}{\partial \chi} \\
&- \log\left(\frac{p^2}{(1+Q)^2}\left(m^{WH}\right)^2\left(m^{WH}\right)^2\right) + (1-\chi)\frac{1}{\frac{p^2}{(1+Q)^2}\left(m^{WH}\right)^2\left(m^{WH}\right)^2}\frac{\partial(\frac{p^2}{(1+Q)^2}\left(m^{WH}\right)^2\left(m^{WH}\right)^2)}{\partial \chi}
\end{aligned}
$$

Notice that $\log\left(p^2\left(m^{FH}\right)^2\left(m^{FL}\right)^2\right) = \log\left(\frac{p^2}{(1+Q)^2}\left(m^{WH}\right)^2\left(m^{WH}\right)^2\right)$ by condition (13) from optimal private choice of χ. Then, we have that:

$$\frac{\partial(p^2\left(m^{FH}\right)^2\left(m^{FL}\right)^2)}{\partial\chi} = 2p\frac{\partial p}{\partial\chi}\left(m^{FH}\right)^2\left(m^{FL}\right)^2 + p^2 2m^{FH}\frac{\partial m^{FH}}{\partial\chi}\left(m^{FL}\right) + p^2\left(m^{FH}\right)^2 2m^{FL}\frac{\partial m^{FL}}{\partial\chi}$$

$$where:$$

$$\frac{\partial m^{FH}}{\partial\chi} = \frac{1+\sigma}{2}A\left(-\frac{1}{\chi}\right)\left(1+\frac{1-\chi}{\chi}\right)$$

$$\frac{\partial m^{FL}}{\partial\chi} = \frac{1-\sigma}{2}A\left(-\frac{1}{\chi}\right)\left(1+\frac{1-\chi}{\chi}\right)$$

$$\frac{\partial(\frac{p^2}{(1+Q)^2}\left(m^{WH}\right)^2\left(m^{WH}\right)^2)}{\partial\chi} = 2p\frac{\partial p}{\partial\chi}\frac{1}{1+Q}\left(m^{WH}\right)^2\left(m^{WL}\right)^2$$

This implies that we can rewrite $\frac{\partial W}{\partial\chi}$ around $\chi = \chi^{comp.eqm.}$ as:

$$\frac{\partial W}{\partial\chi}_{|\chi=\chi^{comp.eqm.}} = \chi\left[\frac{2}{p}\frac{\partial p}{\partial\chi} + \frac{2}{m^{FH}}\frac{\partial m^{FH}}{\partial\chi} + \frac{2}{m^{FL}}\frac{\partial m^{FL}}{\partial\chi}\right] + (1-\chi)\left[\frac{2(1+Q)}{p}\frac{\partial p}{\partial\chi}\right]$$
$$= 2\left[\frac{-1}{1-\chi} + (1+Q)\frac{1}{\chi}\right]_{|\chi=\chi^{comp.eqm.}}$$

Thus, $\frac{\partial W}{\partial\chi}_{|\chi=\chi^{comp.eqm.}} > 0$ iff $\chi^{comp.eqm.} < \frac{1}{2}$. Since we have that $\chi^{comp.eqm.} = \frac{1}{1+\sqrt{\frac{(1-\gamma)(1+\gamma)}{(1-\sigma)(1+\sigma)(1+Q)}}}$, the main result follows:

Proposition 2. *If $Q > 0$ and $\sigma = \gamma = 0$, the laissez faire competitive equilibrium is inefficient and characterized by over-farming relative to the constrained efficient benchmark.*

Figure 7 shows the results of solving the constrained efficient and competitive equilibrium for different values of Q under $\sigma = \gamma = 0$. Apart from confirming the above result, it also shows that the relative inefficiency due to overfarming increases as Q grows.

Finally, the APG in simple model is defined as $APG = \frac{A\cdot\chi}{1-\chi}$, which is the same as the equilibrium manufacturing price p. Proposition above immediately implies that:

Proposition 3. *The Agricultural Productivity Gap and manufacturing price are larger than 1 with $Q > 0$ and are larger in the competitive equilibrium than in the constrained efficient allocation.*

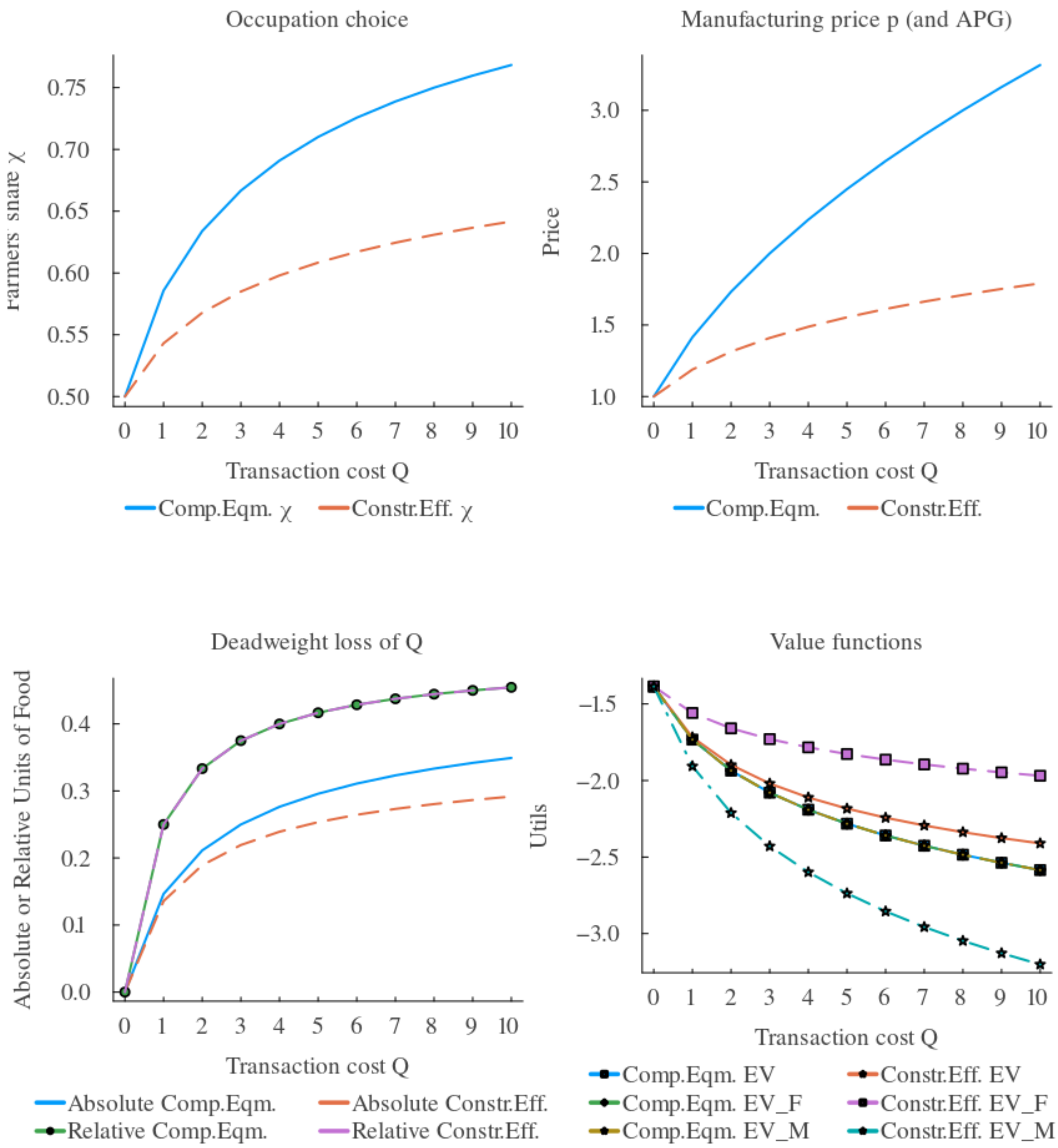


Figure 7: Competitive equilibrium and constrained efficient allocations in simple model

Note: Model is solved under assumptions of $\sigma = \gamma = 0$.

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.

$$V(z,a,e) = \max_{C,a',e'} u(C) + \beta \mathbb{E} V(z',a',e') \tag{15}$$

$$st.: Y(z,e,C) + a' = (1+r)a \tag{16}$$

$$Y(z,e,C) \in \{Y_S(z,e,C), Y_B(z,e,C), Y_M(z,e,C)\}_{e' \in \{S,B,M\}} \tag{17}$$

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 (3) as follows:

$$\begin{aligned} Y(z,e,C) = & \min_{e' \in \{S,B,M\}, c_S, c_B, c_M} c_S + p_B c_B + p_M c_M + Q_S \cdot \max((c_S - q_S), 0) \\ & - 1_{e' \in \{M\}} (\theta^U w - 1_{e \in \{S,B\}} F_M w) - 1_{e' \in \{S\}} \pi_S \\ & - 1_{e' \in \{B\}} (\pi_B - 1_{e \in \{M,S\}} FM_B w) \end{aligned} \tag{18}$$

$$st.: C = \left(\psi_S \left(c_S - \bar{c}_S \right)^{\frac{\epsilon-1}{\epsilon}} + \psi_B c_B^{\frac{\epsilon-1}{\epsilon}} + \psi_M c_M^{\frac{\epsilon-1}{\epsilon}} \right)^{\frac{\epsilon}{\epsilon-1}} \tag{19}$$

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 (4) 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.[27] Then, we approximate these decisions and outcomes for each possible value of C. Using all of those, we solve the dynamic problem (1) for optimal C, a', e'.

[27] 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.

In what follows, we show in detail how we solve each case of occupational choice.

B.1 Workers

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

$$\min_{c_S,c_B,c_M} (1+Q_S)c_S + p_B c_B + p_M c_M - w \tag{20}$$

$$+\lambda(C- \left(\psi_S \left(c_S - \bar{c}_S\right)^{\frac{\epsilon-1}{\epsilon}} + \psi_B c_B^{\frac{\epsilon-1}{\epsilon}} + \psi_M c_M^{\frac{\epsilon-1}{\epsilon}}\right)^{\frac{\epsilon}{\epsilon-1}}) \tag{21}$$

FOCs read:

$$1+Q_S = \lambda \psi_S \left(c_S - \bar{c}_S\right)^{-\frac{1}{\epsilon}} C^{\frac{1}{\epsilon}} \tag{22}$$

$$p_B = \psi_B c_B^{-\frac{1}{\epsilon}} \lambda C^{\frac{1}{\epsilon}} \tag{23}$$

$$p_M = \psi_M c_M^{-\frac{1}{\epsilon}} \lambda C^{\frac{1}{\epsilon}} \tag{24}$$

Therefore:

$$c_S - \bar{c}_S = (1+Q_S)^{-\epsilon} \lambda^{\epsilon} \psi_S^{\epsilon} C \tag{25}$$

$$c_B = p_B^{-\epsilon} \psi_B^{\epsilon} C \lambda^{\epsilon} \tag{26}$$

$$c_M = p_M^{-\epsilon} \psi_M^{\epsilon} C \lambda^{\epsilon} \tag{27}$$

The objective function (6) thus becomes:

$$Y_W = (1+Q_S)c_S + p_B c_B + p_M c_M - w = \lambda^{\epsilon} C((1+Q_S)^{1-\epsilon} \psi_S^{\epsilon} + p_B^{1-\epsilon} \psi_B^{\epsilon} + p_M^{1-\epsilon} \psi_M^{\epsilon}) + (1+Q_S)\bar{c}_S - w \tag{28}$$

Plugging back (11), (12) & (13) into definition of C in (5), 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 (14) ultimately becomes:

$$(1+Q_S)\bar{c}_S + PC - w \tag{29}$$

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. The content of C changes though, in this case:

$$c_S - \bar{c}_S = (1+Q_S)^{-\epsilon} C P_W^{\epsilon} \psi_S^{\epsilon} \tag{30}$$

$$c_B = p_B^{-\epsilon} \psi_B^{\epsilon} C P_W^{\epsilon} \tag{31}$$

$$c_M = p_M^{-\epsilon} \psi_M^{\epsilon} C P_W^{\epsilon} \tag{32}$$

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:

$$q_S = \theta x_S^{\zeta} \tag{33}$$

$$TC_S = (1-\tau_S)\, p_X x_S \tag{34}$$

$$TC_S \leq \kappa a \tag{35}$$

B.2.1 Case 1: farmer produces strictly more staples than consumes $q_S > c_S$

$$x_S = \left(\frac{\zeta\theta}{(1+\lambda_S)(1-\tau_S)p_X}\right)^{\frac{1}{1-\zeta}} \tag{36}$$

$$\bar{x}_S = \left(\frac{\zeta\theta}{(1-\tau_S)p_X}\right)^{\frac{1}{1-\zeta}} \tag{37}$$

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

$$x_S = \frac{\kappa a}{(1-\tau_S)p_X} \tag{38}$$

$$\lambda_S = \frac{\zeta\theta}{(\kappa a)^{1-\zeta}(p_X(1-\tau_S))^{\zeta}} - 1 \tag{39}$$

and

$$\pi_S = \{\theta x_S^{\zeta} - (1-\tau_S)\, p_X x_S\} \tag{40}$$

$$P_S = (\psi_S^{\epsilon} + p_B^{1-\epsilon}\psi_B^{\epsilon} + p_M^{1-\epsilon}\psi_M^{\epsilon})^{\frac{1}{1-\epsilon}} \tag{41}$$

$$c_S = \bar{c}_S + P_S^{\epsilon}\psi_S^{\epsilon}C \tag{42}$$

$$c_B = p_B^{-\epsilon}\psi_B^{\epsilon}CP_S^{\epsilon} \tag{43}$$

$$c_M = p_M^{-\epsilon}\psi_M^{\epsilon}CP_S^{\epsilon} \tag{44}$$

$$Y_S = c_S + p_B c_B + p_M c_M - \pi_S \tag{45}$$

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 decision 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 $q_S \leq c_S$

As in this case the staple producer is only selling staples, this case necessarily implies negative net savings. The problem to solve reads:

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

$$+\lambda_1(C - \left(\psi_S\,(c_S - \bar{c}_S)^{\frac{\epsilon-1}{\epsilon}} + \psi_B c_B^{\frac{\epsilon-1}{\epsilon}} + (1-\psi_S-\psi_B)\, c_M^{\frac{\epsilon-1}{\epsilon}}\right)^{\frac{\epsilon}{\epsilon-1}}) \tag{46}$$

$$+\lambda_2(q_S - \theta x_S^{\zeta}) \tag{47}$$

$$+\lambda_3(q_S - c_S) \tag{48}$$

$$+\lambda_S((1-\tau_S)p_X x_S - \kappa a)) \tag{49}$$

There is an interplay here between transaction costs and the working capital constraint. The household would like to overproduce to avoid paying transaction cost, but this might be prevented because of the working capital constraint. Both $\lambda_1 \& \lambda_2$, must be positive. That is, the presence of transaction costs changes the shadow value of production.

Taking FOCs:

$$1 + Q_S = \lambda_1 \psi_S \left(c_S - \bar{c}_S\right)^{-\frac{1}{\epsilon}} C^{\frac{1}{\epsilon}} + \lambda_3 \tag{50}$$

$$p_B = \psi_B c_B^{-\frac{1}{\epsilon}} \lambda_1 C^{\frac{1}{\epsilon}} \tag{51}$$

$$p_M = \psi_M c_M^{-\frac{1}{\epsilon}} \lambda_1 C^{\frac{1}{\epsilon}} \tag{52}$$

$$\left(1 + \lambda_S\right)\left(1 - \tau_S\right) p_X = \lambda_2 \zeta \theta x_S^{\zeta - 1} \tag{53}$$

$$\left(1 + Q_S\right) = \lambda_2 + \lambda_3 \tag{54}$$

Reordering:

$$\lambda_2 = \lambda_1 \psi_S \left(c_S - \bar{c}_S\right)^{-\frac{1}{\epsilon}} C^{\frac{1}{\epsilon}} \tag{55}$$

$$c_S - \bar{c}_S = \lambda_2^{-\epsilon} \psi_S^{\epsilon} \lambda_1^{\epsilon} C \tag{56}$$

$$c_B = p_B^{-\epsilon} \psi_B^{\epsilon} \lambda_1^{\epsilon} C \tag{57}$$

$$c_M = p_M^{-\epsilon} \psi_M^{\epsilon} \lambda_1^{\epsilon} C \tag{58}$$

By plugging in consumption levels (42), (43) and (44) into the definition of C in (32) we get:

$$P_S = \lambda_1 = \left(\psi_S^{\epsilon} \lambda_2^{1-\epsilon} + \psi_B^{\epsilon} p_B^{1-\epsilon} + \psi_M^{\epsilon} p_M^{1-\epsilon}\right)^{\frac{1}{1-\epsilon}} \tag{59}$$

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

$$\lambda_2 = \left(1 + Q_S\right) \tag{60}$$

$$1 + Q_S = \lambda_1 \psi_S \left(c_S - \bar{c}_S\right)^{-\frac{1}{\epsilon}} C^{\frac{1}{\epsilon}} \tag{61}$$

and it follows from Equation (59) 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 (25)

$$x_S = \left(\frac{(1 + Q_S)\zeta\theta}{(1 + \lambda_S)(1 - \tau_S) p_X}\right)^{\frac{1}{1-\zeta}} \tag{62}$$

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 (47) and (46), and then plugging the latter into (39), and then exploiting that from the production of the household we have $x_S = \left(\frac{c_S}{\theta}\right)^{\frac{1}{\zeta}}$ yields:

$$(1+\lambda_S)(1-\tau_S)\,p_X = \lambda_1\psi_S\,(c_S-\bar{c}_S)^{-\frac{1}{\epsilon}}\,C^{\frac{1}{\epsilon}}\zeta\theta x_S^{\zeta-1} \tag{63}$$

$$(1+\lambda_S)(1-\tau_S)\,p_X = \lambda_1\psi_S\,(c_S-\bar{c}_S)^{-\frac{1}{\epsilon}}\,C^{\frac{1}{\epsilon}}\zeta\theta\Big(\frac{c_S}{\theta}\Big)^{\frac{\zeta-1}{\zeta}} \tag{64}$$

$$(1+\lambda_S)(1-\tau_S)\,p_X = \lambda_1\psi_S\,(c_S-\bar{c}_S)^{-\frac{1}{\epsilon}}\,C^{\frac{1}{\epsilon}}\zeta\theta^{\frac{1}{\zeta}}c_S^{\frac{\zeta-1}{\zeta}} \tag{65}$$

$$\frac{(1+\lambda_S)(1-\tau_S)\,p_X}{\zeta\theta^{\frac{1}{\zeta}}} = \lambda_1\psi_S\,(c_S-\bar{c}_S)^{-\frac{1}{\epsilon}}\,C^{\frac{1}{\epsilon}}c_S^{\frac{\zeta-1}{\zeta}} \tag{66}$$

$$\Big(\frac{(1+\lambda_S)(1-\tau_S)\,p_X}{\zeta\theta^{\frac{1}{\zeta}}}\Big)^{\epsilon} = \lambda_1^{\epsilon}\psi_S^{\epsilon}\,(c_S-\bar{c}_S)^{-1}\,Cc_S^{\frac{\epsilon(\zeta-1)}{\zeta}} \tag{67}$$

$$(c_S-\bar{c}_S) = c_S^{\frac{\epsilon(\zeta-1)}{\zeta}}\lambda_1^{\epsilon}\psi_S^{\epsilon}C\Big(\frac{\zeta\theta^{\frac{1}{\zeta}}}{(1+\lambda_S)(1-\tau_S)\,p_X}\Big)^{\epsilon} \tag{68}$$

$$c_B = p_B^{-\epsilon}\psi_B^{\epsilon}C\lambda_1^{\epsilon} \tag{69}$$

$$c_M = p_M^{-\epsilon}\psi_M^{\epsilon}C\lambda_1^{\epsilon} \tag{70}$$

Note that the problem is the c_S on the RHS of (54). For now ignore it, and just plug it back to the definition of C in (32):

$$C^{\frac{\epsilon-1}{\epsilon}} = c_S^{\frac{(\epsilon-1)(\zeta-1)}{\zeta}}\lambda_1^{\epsilon-1}\psi_S^{\epsilon}C^{\frac{\epsilon-1}{\epsilon}}\Big(\frac{\zeta\theta^{\frac{1}{\zeta}}}{(1+\lambda_S)(1-\tau_S)\,p_X}\Big)^{\epsilon-1} \tag{71}$$

$$+\,p_B^{1-\epsilon}\psi_B^{\epsilon}C^{\frac{\epsilon-1}{\epsilon}}\lambda_1^{\epsilon-1} \tag{72}$$

$$+\,p_M^{1-\epsilon}\psi_M^{\epsilon}C^{\frac{\epsilon-1}{\epsilon}}\lambda_1^{\epsilon-1} \tag{73}$$

Implying that:

$$\lambda_1 = \Big(\psi_S^{\epsilon}\Big(\frac{\zeta(\theta c_S^{\zeta-1})^{\frac{1}{\zeta}}}{(1+\lambda_S)\,(1-\tau_S)\,p_X}\Big)^{\epsilon-1} + p_B^{1-\epsilon}\psi_B^{\epsilon} + p_M^{1-\epsilon}\psi_M^{\epsilon}\Big)^{\frac{1}{1-\epsilon}} \tag{74}$$

Plugging (60) back into (54) allows us to arrive at expression that can be used for solving for c_S:

$$\psi_S^{\epsilon-1}C^{\frac{\epsilon-1}{\epsilon}}\left(c_S-\bar{c}_S\right)^{\frac{1-\epsilon}{\epsilon}} = \psi_S^{\epsilon} + c_S^{\frac{(1-\zeta)(\epsilon-1)}{\zeta}}\Big(\frac{\zeta(\theta)^{\frac{1}{\zeta}}}{(1+\lambda_S)\,(1-\tau_S)\,p_X}\Big)^{1-\epsilon}(p_B^{1-\epsilon}\psi_B^{\epsilon} + p_M^{1-\epsilon}\psi_M^{\epsilon}) \tag{75}$$

We first find the numerical solution to (61) 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 (61) to obtain λ_S:

$$\lambda_S = \Big[\frac{(c_S-\bar{c_S})^{\frac{1-\epsilon}{\epsilon}}\psi_S^{\epsilon-1}C^{\frac{\epsilon-1}{\epsilon}} - \psi_S^{\epsilon}}{(p_B^{1-\epsilon}\psi_B^{\epsilon} + p_M^{1-\epsilon}\psi_M^{\epsilon})((1-\tau_S)p_X)^{\epsilon-1}} c_S^{\frac{(1-\zeta)(1-\epsilon)}{\zeta}}\Big]^{\frac{1}{\epsilon-1}}\zeta(\theta)^{\frac{1}{\zeta}} - 1 \tag{76}$$

and then (60) 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:

$$(1+Q_S)c_S + p_B c_B + p_M c_M - (1+Q_S)q_S + (1-\tau_S)\,p_X x_S \tag{77}$$

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:

$$\min_{c_S,c_B,c_M,x_S,q_S,x_B,q_B,l} c_S + Q_S \max(c_S - q_S, 0) + p_B c_B + p_M c_M - q_S - p_B q_B$$

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

$$+\lambda_1 (C - \left(\psi_S \left(c_S - \bar{c}_S\right)^{\frac{\epsilon-1}{\epsilon}} + \psi_B c_B^{\frac{\epsilon-1}{\epsilon}} + (1-\psi_S-\psi_B)\, c_M^{\frac{\epsilon-1}{\epsilon}}\right)^{\frac{\epsilon}{\epsilon-1}}) \tag{78}$$

$$+\lambda_2 (q_S - \theta(1-l)^{\phi} x_S^{\zeta}) \tag{79}$$

$$+\lambda_3 (q_B - \theta l^{\phi} (x_B)^{\zeta}) \tag{80}$$

$$-\lambda_B (\kappa a - (1-\tau_B)\, p_X x_B + (1-\tau_S)\, p_X x_S) \tag{81}$$

B.3.1 Case 1: farmer produces strictly more staples than consumes $q_S > c_S$

It follows that no transaction cost is paid. Thus, the problem is equivalent to:

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

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

$$+\lambda_1 (C - \left(\psi_S \left(c_S - \bar{c}_S\right)^{\frac{\epsilon-1}{\epsilon}} + \psi_B c_B^{\frac{\epsilon-1}{\epsilon}} + (1-\psi_S-\psi_B)\, c_M^{\frac{\epsilon-1}{\epsilon}}\right)^{\frac{\epsilon}{\epsilon-1}}) \tag{82}$$

$$+\lambda_2 (q_S - \theta(1-l)^{\phi} x_S^{\zeta}) \tag{83}$$

$$+\lambda_3 (q_B - \theta l^{\phi} (x_B)^{\zeta}) \tag{84}$$

$$-\lambda_B (\kappa a - (1-\tau_B)\, p_X x_B + (1-\tau_S)\, p_X x_S) \tag{85}$$

FOCs read:

$$\lambda_2\zeta\theta(1-l)^{\phi}x_S^{\zeta-1} = (1+\lambda_B)(1-\tau_S)p_X \tag{86}$$

$$\lambda_3\zeta\theta l^{\phi}x_B^{\zeta-1} = (1+\lambda_B)(1-\tau_B)p_X \tag{87}$$

$$\lambda_2 = 1 \tag{88}$$

$$\lambda_3 = p_B \tag{89}$$

$$\lambda_3\phi\theta l^{\phi-1}x_B^{\zeta} = \lambda_2\phi\theta(1-l)^{\phi-1}x_S^{\zeta} \tag{90}$$

$$1 = \lambda_1\psi_S\left(c_S-\bar{c}_S\right)^{-\frac{1}{\epsilon}}C^{\frac{1}{\epsilon}} \tag{91}$$

$$p_B = \psi_B c_B^{-\frac{1}{\epsilon}}\lambda_1 C^{\frac{1}{\epsilon}} \tag{92}$$

$$p_M = \psi_M c_M^{-\frac{1}{\epsilon}}\lambda_1 C^{\frac{1}{\epsilon}} \tag{93}$$

The consumption problem can be separated from the production problem in this subcase, hence by substituting out shadow producer prices λ_2 from (76) and λ_3 from (77), equations (74), (75) and (76) give us the following system of equations:

$$\zeta\theta(1-l)^{\phi-1}x_S^{\zeta} = (1+\lambda_B)(1-\tau_S)\frac{p_X x_S}{(1-l)} \tag{94}$$

$$\zeta p_B\theta l^{\phi-1}x_B^{\zeta} = (1+\lambda_B)(1-\tau_B)\frac{p_X x_B}{l} \tag{95}$$

$$p_B l^{\phi-1}x_B^{\zeta} = (1-l)^{\phi-1}x_S^{\zeta} \tag{96}$$

which can be rearranged to get:

$$x_B = \frac{l}{1-l}\frac{1-\tau_S}{1-\tau_B}x_S \tag{97}$$

$$x_S = \Big[\frac{\zeta\theta(1-l)^{\phi}}{(1-\tau_S)p_X(1+\lambda_B)}\Big]^{\frac{1}{1-\zeta}} \tag{98}$$

$$x_B = \Big[\frac{\zeta\theta p_B l^{\phi}}{(1-\tau_B)p_X(1+\lambda_B)}\Big]^{\frac{1}{1-\zeta}} \tag{99}$$

This system gives us expression for land allocated l:

$$\Big[\frac{\zeta\theta p_B l^{\phi}}{(1-\tau_B)p_X(1+\lambda_B)}\Big]^{\frac{1}{1-\zeta}} = \frac{l}{1-l}\frac{1-\tau_S}{1-\tau_B}\Big[\frac{\zeta\theta(1-l)^{\phi}}{(1-\tau_S)p_X(1+\lambda_B)}\Big]^{\frac{1}{1-\zeta}} \tag{100}$$

$$\Big[\frac{\zeta\theta p_B l^{\phi}}{(1-\tau_B)p_X(1+\lambda_B)}\Big] = \frac{l^{1-\zeta}}{(1-l)^{1-\zeta}}\frac{(1-\tau_S)^{1-\zeta}}{(1-\tau_B)^{1-\zeta}}\Big[\frac{\zeta\theta(1-l)^{\phi}}{(1-\tau_S)p_X(1+\lambda_B)}\Big] \tag{101}$$

$$\frac{p_B(1-\tau_S)^{\zeta}}{(1-\tau_B)^{\zeta}} = \Big[\frac{l}{1-l}\Big]^{1-\phi-\zeta} \tag{102}$$

$$l\Big[(1-\tau_B)^{\zeta}\Big]^{\frac{1}{1-\phi-\zeta}} = (1-l)\Big[p_B(1-\tau_S)^{\zeta}\Big]^{\frac{1}{1-\phi-\zeta}} \tag{103}$$

$$l = \frac{\big[p_B(1-\tau_S)^{\zeta}\big]^{\frac{1}{1-\phi-\zeta}}}{\big[p_B(1-\tau_S)^{\zeta}\big]^{\frac{1}{1-\phi-\zeta}} + \big[(1-\tau_B)^{\zeta}\big]^{\frac{1}{1-\phi-\zeta}}} \tag{104}$$

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:

$$x_S = \Big[\frac{\zeta\theta}{(1-\tau_S)p_X(1+\lambda_B)}\Big]^{\frac{1}{1-\zeta}} \frac{\big[(1-\tau_B)^{\zeta}\big]^{\frac{\phi}{(1-\zeta)(1-\phi-\zeta)}}}{\Big[\big[p_B(1-\tau_S)^{\zeta}\big]^{\frac{1}{1-\phi-\zeta}} + \big[(1-\tau_B)^{\zeta}\big]^{\frac{1}{1-\phi-\zeta}}\Big]^{\frac{\phi}{1-\zeta}}} \tag{105}$$

$$x_B = \Big[\frac{\zeta\theta p_B}{(1-\tau_B)p_X(1+\lambda_B)}\Big]^{\frac{1}{1-\zeta}} \frac{\big[p_B(1-\tau_S)^{\zeta}\big]^{\frac{\phi}{(1-\zeta)(1-\phi-\zeta)}}}{\Big[\big[p_B(1-\tau_S)^{\zeta}\big]^{\frac{1}{1-\phi-\zeta}} + \big[(1-\tau_B)^{\zeta}\big]^{\frac{1}{1-\phi-\zeta}}\Big]^{\frac{\phi}{1-\zeta}}} \tag{106}$$

$$\begin{aligned}
TC_B &= \Big[\frac{\zeta\theta}{(1+\lambda_B)}\Big]^{\frac{1}{1-\zeta}} \frac{p_X^{-\frac{\zeta}{(1-\zeta)}}}{\Big[\big[p_B(1-\tau_S)^{\zeta}\big]^{\frac{1}{1-\phi-\zeta}} + \big[(1-\tau_B)^{\zeta}\big]^{\frac{1}{1-\phi-\zeta}}\Big]^{\frac{\phi}{1-\zeta}}} \\
&\quad \cdot\Big((1-\tau_B)^{\frac{\phi\zeta}{(1-\zeta)(1-\phi-\zeta)}}(1-\tau_S)^{-\frac{\zeta}{1-\zeta}} + (p_B)^{\frac{1}{(1-\phi-\zeta)}}(1-\tau_S)^{\frac{\phi\zeta}{(1-\zeta)(1-\phi-\zeta)}}(1-\tau_B)^{-\frac{\zeta}{1-\zeta}}\Big) && (107)\\
&= \Big[\frac{\zeta\theta}{(1+\lambda_B)}\Big]^{\frac{1}{1-\zeta}} \frac{(p_X(1-\tau_B)(1-\tau_S))^{-\frac{\zeta}{(1-\zeta)}}}{\Big[\big[p_B(1-\tau_S)^{\zeta}\big]^{\frac{1}{1-\phi-\zeta}} + \big[(1-\tau_B)^{\zeta}\big]^{\frac{1}{1-\phi-\zeta}}\Big]^{\frac{\phi-1+\zeta}{1-\zeta}}} && (108)\\
&= \Big[\frac{\zeta\theta}{(1+\lambda_B)}\Big]^{\frac{1}{1-\zeta}} \frac{\Big[\big[p_B(1-\tau_S)^{\zeta}\big]^{\frac{1}{1-\phi-\zeta}} + \big[(1-\tau_B)^{\zeta}\big]^{\frac{1}{1-\phi-\zeta}}\Big]^{\frac{1-\phi-\zeta}{1-\zeta}}}{(p_X(1-\tau_B)(1-\tau_S))^{\frac{\zeta}{(1-\zeta)}}} && (109)
\end{aligned}$$

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:

$$\lambda_B = \Big[\frac{\zeta\theta}{(\kappa a)^{1-\zeta}}\Big]\frac{\Big[\big[p_B(1-\tau_S)^\zeta\big]^{\frac{1}{1-\phi-\zeta}} + \big[(1-\tau_B)^\zeta\big]^{\frac{1}{1-\phi-\zeta}}\Big]^{1-\phi-\zeta}}{(p_X(1-\tau_B)(1-\tau_S))^\zeta} - 1 \tag{110}$$

$$TC_B = \Big[\frac{\zeta\theta}{(1+\lambda_B)}\Big]^{\frac{1}{1-\zeta}}\frac{\Big[\big[p_B(1-\tau_S)^\zeta\big]^{\frac{1}{1-\phi-\zeta}} + \big[(1-\tau_B)^\zeta\big]^{\frac{1}{1-\phi-\zeta}}\Big]^{\frac{1-\phi-\zeta}{1-\zeta}}}{(p_X(1-\tau_B)(1-\tau_S))^{\frac{\zeta}{(1-\zeta)}}} \tag{111}$$

$$l = \frac{\big[p_B(1-\tau_S)^\zeta\big]^{\frac{1}{1-\phi-\zeta}}}{\big[p_B(1-\tau_S)^\zeta\big]^{\frac{1}{1-\phi-\zeta}} + \big[(1-\tau_B)^\zeta\big]^{\frac{1}{1-\phi-\zeta}}} \tag{112}$$

$$x_S = \Big[\frac{\zeta\theta}{(1-\tau_S)p_X(1+\lambda_B)}\Big]^{\frac{1}{1-\zeta}}\frac{\big[(1-\tau_B)^\zeta\big]^{\frac{\phi}{(1-\zeta)(1-\phi-\zeta)}}}{\Big[\big[p_B(1-\tau_S)^\zeta\big]^{\frac{1}{1-\phi-\zeta}} + \big[(1-\tau_B)^\zeta\big]^{\frac{1}{1-\phi-\zeta}}\Big]^{\frac{\phi}{1-\zeta}}} \tag{113}$$

$$x_B = \Big[\frac{\zeta\theta p_B}{(1-\tau_B)p_X(1+\lambda_B)}\Big]^{\frac{1}{1-\zeta}}\frac{\big[p_B(1-\tau_S)^\zeta\big]^{\frac{\phi}{(1-\zeta)(1-\phi-\zeta)}}}{\Big[\big[p_B(1-\tau_S)^\zeta\big]^{\frac{1}{1-\phi-\zeta}} + \big[(1-\tau_B)^\zeta\big]^{\frac{1}{1-\phi-\zeta}}\Big]^{\frac{\phi}{1-\zeta}}} \tag{114}$$

$$q_S = \theta(1-l)^\phi x_S^\zeta \tag{115}$$

$$q_B = \theta l^\phi x_B^\zeta \tag{116}$$

$$\pi_B = q_S + p_B q_B - TC_B \tag{117}$$

$$P_B = (\psi_S^\epsilon + p_B^{1-\epsilon}\psi_B^\epsilon + p_M^{1-\epsilon}\psi_M^\epsilon)^{\frac{1}{1-\epsilon}} \tag{118}$$

$$c_S = \bar{c}_S + P_B^\epsilon \psi_B^\epsilon C \tag{119}$$

$$c_B = p_B^{-\epsilon}\psi_B^\epsilon C P_B^\epsilon \tag{120}$$

$$c_M = p_M^{-\epsilon}\psi_M^\epsilon C P_B^\epsilon \tag{121}$$

$$Y_B = c_S + p_B c_B + p_M c_M - \pi_B \tag{122}$$

B.3.2 Case 2: farmer produces weakly less staples than consumes $q_S \leq c_S$

Here the problem reads:

$$\min_{c_S,c_B,c_M,x_S,q_S,x_B,q_B,l} (1+Q_S)c_S + p_B c_B + p_M c_M - (1+Q_S)q_S - p_B q_B$$
$$+ (1-\tau_B)\, p_X x_B + (1-\tau_S)\, p_X x_S$$
$$+\lambda_1 (C - \left(\psi_S \left(c_S - \bar{c}_S\right)^{\frac{\epsilon-1}{\epsilon}} + \psi_B c_B^{\frac{\epsilon-1}{\epsilon}} + (1-\psi_S-\psi_B)\, c_M^{\frac{\epsilon-1}{\epsilon}}\right)^{\frac{\epsilon}{\epsilon-1}}) \quad (123)$$
$$+\lambda_2 (q_S - \theta(1-l)^{\phi} x_S^{\zeta}) \quad (124)$$
$$+\lambda_3 (q_B - \theta l^{\phi} (x_B)^{\zeta}) \quad (125)$$
$$-\lambda_4 (c_S - q_S) \quad (126)$$
$$-\lambda_B (\kappa a - (1-\tau_B)\, p_X x_B + (1-\tau_S)\, p_X x_S) \quad (127)$$

We get the following FOCs:

$$\lambda_2 \zeta \theta (1-l)^{\phi} x_S^{\zeta-1} = (1+\lambda_B)(1-\tau_S) p_X \quad (128)$$
$$\lambda_3 \zeta \theta l^{\phi} x_B^{\zeta-1} = (1+\lambda_B)(1-\tau_B) p_X \quad (129)$$
$$\lambda_2 = 1 + Q_S - \lambda_4 \quad (130)$$
$$\lambda_3 = p_B \quad (131)$$
$$\lambda_3 \phi \theta l^{\phi-1} x_B^{\zeta} = \lambda_2 \phi \theta (1-l)^{\phi-1} x_S^{\zeta} \quad (132)$$
$$1 + Q_S - \lambda_4 = \lambda_1 \psi_S \left(c_S - \bar{c}_S\right)^{-\frac{1}{\epsilon}} C^{\frac{1}{\epsilon}} \quad (133)$$
$$p_B = \psi_B c_B^{-\frac{1}{\epsilon}} \lambda_1 C^{\frac{1}{\epsilon}} \quad (134)$$
$$p_M = \psi_M c_M^{-\frac{1}{\epsilon}} \lambda_1 C^{\frac{1}{\epsilon}} \quad (135)$$

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):

$$\lambda_B = \Big[\frac{\zeta\theta}{(\kappa a)^{1-\zeta}}\Big]\frac{\Big[\big[p_B(1-\tau_S)^\zeta\big]^{\frac{1}{1-\phi-\zeta}} + \big[(1+Q_S)(1-\tau_B)^\zeta\big]^{\frac{1}{1-\phi-\zeta}}\Big]^{1-\phi-\zeta}}{(p_X(1-\tau_B)(1-\tau_S))^\zeta} - 1 \tag{136}$$

$$TC_B = \Big[\frac{\zeta\theta}{(1+\lambda_B)}\Big]^{\frac{1}{1-\zeta}}\frac{\Big[\big[p_B(1-\tau_S)^\zeta\big]^{\frac{1}{1-\phi-\zeta}} + \big[(1+Q_S)(1-\tau_B)^\zeta\big]^{\frac{1}{1-\phi-\zeta}}\Big]^{\frac{1-\phi-\zeta}{1-\zeta}}}{(p_X(1-\tau_B)(1-\tau_S))^{\frac{\zeta}{(1-\zeta)}}} \tag{137}$$

$$l = \frac{\big[p_B(1-\tau_S)^\zeta\big]^{\frac{1}{1-\phi-\zeta}}}{\big[p_B(1-\tau_S)^\zeta\big]^{\frac{1}{1-\phi-\zeta}} + \big[(1+Q_S)(1-\tau_B)^\zeta\big]^{\frac{1}{1-\phi-\zeta}}} \tag{138}$$

$$x_S = \Big[\frac{\zeta\theta(1+Q_S)}{(1-\tau_S)p_X(1+\lambda_B)}\Big]^{\frac{1}{1-\zeta}}\frac{\big[(1+Q_S)(1-\tau_B)^\zeta\big]^{\frac{\phi}{(1-\zeta)(1-\phi-\zeta)}}}{\Big[\big[p_B(1-\tau_S)^\zeta\big]^{\frac{1}{1-\phi-\zeta}} + \big[(1+Q_S)(1-\tau_B)^\zeta\big]^{\frac{1}{1-\phi-\zeta}}\Big]^{\frac{\phi}{1-\zeta}}} \tag{139}$$

$$x_B = \Big[\frac{\zeta\theta p_B}{(1-\tau_B)p_X(1+\lambda_B)}\Big]^{\frac{1}{1-\zeta}}\frac{\big[p_B(1-\tau_S)^\zeta\big]^{\frac{\phi}{(1-\zeta)(1-\phi-\zeta)}}}{\Big[\big[p_B(1-\tau_S)^\zeta\big]^{\frac{1}{1-\phi-\zeta}} + \big[(1+Q_S)(1-\tau_B)^\zeta\big]^{\frac{1}{1-\phi-\zeta}}\Big]^{\frac{\phi}{1-\zeta}}} \tag{140}$$

$$q_S = \theta(1-l)^\phi x_S^\zeta \tag{141}$$

$$q_B = \theta l^\phi x_B^\zeta \tag{142}$$

$$\pi_B = p_B q_B - TC_B \tag{143}$$

$$P_B = ((1+Q_S)^{1-\epsilon}\psi_S^\epsilon + p_B^{1-\epsilon}\psi_B^\epsilon + p_M^{1-\epsilon}\psi_M^\epsilon)^{\frac{1}{1-\epsilon}} \tag{144}$$

$$c_S = \bar{c}_S + (1+Q_S)^{-\epsilon}P_B^\epsilon\psi_S^\epsilon C \tag{145}$$

$$c_B = p_B^{-\epsilon}\psi_B^\epsilon C P_B^\epsilon \tag{146}$$

$$c_M = p_M^{-\epsilon}\psi_M^\epsilon C P_B^\epsilon \tag{147}$$

$$Y_B = (1+Q_S)(c_S - q_S) + p_B c_B + p_M c_M - \pi_B \tag{148}$$

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 (114), (115) and (118) by keeping λ_2:

$$\lambda_2 \zeta \theta (1-l)^{\phi-1} x_S^{\zeta} = (1+\lambda_B)(1-\tau_S) \frac{p_X x_S}{(1-l)} \tag{149}$$

$$\zeta p_B \theta l^{\phi-1} x_B^{\zeta} = (1+\lambda_B)(1-\tau_B) \frac{p_X x_B}{l} \tag{150}$$

$$p_B l^{\phi-1} x_B^{\zeta} = \lambda_2 (1-l)^{\phi-1} x_S^{\zeta} \tag{151}$$

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:

$$\lambda_B = \Big[\frac{\zeta\theta}{(\kappa a)^{1-\zeta}}\Big] \frac{\Big[\big[p_B(1-\tau_S)^{\zeta}\big]^{\frac{1}{1-\phi-\zeta}} + \big[\lambda_2(1-\tau_B)^{\zeta}\big]^{\frac{1}{1-\phi-\zeta}}\Big]^{1-\phi-\zeta}}{(p_X(1-\tau_B)(1-\tau_S))^{\zeta}} - 1 \tag{152}$$

$$TC_B = \Big[\frac{\zeta\theta}{(1+\lambda_B)}\Big]^{\frac{1}{1-\zeta}} \frac{\Big[\big[p_B(1-\tau_S)^{\zeta}\big]^{\frac{1}{1-\phi-\zeta}} + \big[\lambda_2(1-\tau_B)^{\zeta}\big]^{\frac{1}{1-\phi-\zeta}}\Big]^{\frac{1-\phi-\zeta}{1-\zeta}}}{(p_X(1-\tau_B)(1-\tau_S))^{\frac{\zeta}{(1-\zeta)}}} \tag{153}$$

$$l = \frac{\big[p_B(1-\tau_S)^{\zeta}\big]^{\frac{1}{1-\phi-\zeta}}}{\big[p_B(1-\tau_S)^{\zeta}\big]^{\frac{1}{1-\phi-\zeta}} + \big[\lambda_2(1-\tau_B)^{\zeta}\big]^{\frac{1}{1-\phi-\zeta}}} \tag{154}$$

$$x_S = \Big[\frac{\zeta\theta\lambda_2}{(1-\tau_S)p_X(1+\lambda_B)}\Big]^{\frac{1}{1-\zeta}} \frac{\big[\lambda_2(1-\tau_B)^{\zeta}\big]^{\frac{\phi}{(1-\zeta)(1-\phi-\zeta)}}}{\Big[\big[p_B(1-\tau_S)^{\zeta}\big]^{\frac{1}{1-\phi-\zeta}} + \big[\lambda_2(1-\tau_B)^{\zeta}\big]^{\frac{1}{1-\phi-\zeta}}\Big]^{\frac{\phi}{1-\zeta}}} \tag{155}$$

$$x_B = \Big[\frac{\zeta\theta p_B}{(1-\tau_B)p_X(1+\lambda_B)}\Big]^{\frac{1}{1-\zeta}} \frac{\big[p_B(1-\tau_S)^{\zeta}\big]^{\frac{\phi}{(1-\zeta)(1-\phi-\zeta)}}}{\Big[\big[p_B(1-\tau_S)^{\zeta}\big]^{\frac{1}{1-\phi-\zeta}} + \big[\lambda_2(1-\tau_B)^{\zeta}\big]^{\frac{1}{1-\phi-\zeta}}\Big]^{\frac{\phi}{1-\zeta}}} \tag{156}$$

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

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

Using equations (140) and (141) in (143), we get the following expression for q_S:

$$q_S = \theta \frac{\left[\left[\lambda_2(1-\tau_B)^\zeta\right]^{\frac{\phi}{1-\phi-\zeta}}\right.}{\left[\left[p_B(1-\tau_S)^\zeta\right]^{\frac{1}{1-\phi-\zeta}} + \left[\lambda_2(1-\tau_B)^\zeta\right]^{\frac{1}{1-\phi-\zeta}}\right]^\phi}\left[\frac{\zeta\theta\lambda_2}{(1-\tau_S)p_X(1+\lambda_B)}\right]^{\frac{\zeta}{1-\zeta}} \tag{159}$$

$$\cdot \frac{\left[\lambda_2(1-\tau_B)^\zeta\right]^{\frac{\zeta\phi}{(1-\zeta)(1-\phi-\zeta)}}}{\left[\left[p_B(1-\tau_S)^\zeta\right]^{\frac{1}{1-\phi-\zeta}} + \left[\lambda_2(1-\tau_B)^\zeta\right]^{\frac{1}{1-\phi-\zeta}}\right]^{\frac{\zeta\phi}{1-\zeta}}} \tag{160}$$

$$= \theta \cdot \frac{\left[\lambda_2(1-\tau_B)^\zeta\right]^{\frac{\phi}{(1-\zeta)(1-\phi-\zeta)}}}{\left[\left[p_B(1-\tau_S)^\zeta\right]^{\frac{1}{1-\phi-\zeta}} + \left[\lambda_2(1-\tau_B)^\zeta\right]^{\frac{1}{1-\phi-\zeta}}\right]^{\frac{\phi}{1-\zeta}}}\left[\frac{\zeta\theta\lambda_2}{(1-\tau_S)p_X(1+\lambda_B)}\right]^{\frac{\zeta}{1-\zeta}} \tag{161}$$

$$= \left[\frac{\zeta}{(1-\tau_S)p_X(1+\lambda_B)}\right]^{\frac{\zeta}{1-\zeta}} \frac{\lambda_2^{\frac{\phi-\zeta\phi+\zeta-\zeta^2}{(1-\zeta)(1-\zeta-\phi)}}\theta^{\frac{1}{1-\zeta}}(1-\tau_B)^{\frac{\zeta\phi}{(1-\zeta)(1-\phi-\zeta)}}}{\left[\left[p_B(1-\tau_S)^\zeta\right]^{\frac{1}{1-\phi-\zeta}} + \left[\lambda_2(1-\tau_B)^\zeta\right]^{\frac{1}{1-\phi-\zeta}}\right]^{\frac{\phi}{1-\zeta}}} \tag{162}$$

From the price index equation (130) adjusted for the shadow price of staples, and the staple consumption FOC (119) combined with (116) we get:

$$P_B = (\lambda_2^{1-\epsilon}\psi_S^\epsilon + p_B^{1-\epsilon}\psi_B^\epsilon + p_M^{1-\epsilon}\psi_M^\epsilon)^{\frac{1}{1-\epsilon}} \tag{163}$$

$$c_S = \bar{c}_S + \lambda_2^{-\epsilon}P_B^\epsilon\psi_S^\epsilon C \tag{164}$$

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

$$\bar{c}_S + \lambda_2^{-\epsilon}(\lambda_2^{1-\epsilon}\psi_S^\epsilon + p_B^{1-\epsilon}\psi_B^\epsilon + p_M^{1-\epsilon}\psi_M^\epsilon)^{\frac{\epsilon}{1-\epsilon}}\psi_S^\epsilon C =$$
$$\left[\frac{\zeta}{(1-\tau_S)p_X(1+\lambda_B)}\right]^{\frac{\zeta}{1-\zeta}} \frac{\lambda_2^{\frac{\phi-\zeta\phi+\zeta-\zeta^2}{(1-\zeta)(1-\zeta-\phi)}}\theta^{\frac{1}{1-\zeta}}(1-\tau_B)^{\frac{\zeta\phi}{(1-\zeta)(1-\phi-\zeta)}}}{\left[\left[p_B(1-\tau_S)^\zeta\right]^{\frac{1}{1-\phi-\zeta}} + \left[\lambda_2(1-\tau_B)^\zeta\right]^{\frac{1}{1-\phi-\zeta}}\right]^{\frac{\phi}{1-\zeta}}} \tag{165}$$

In equation (151), 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 (151) for solving for λ_2. Do this for each θ value, and interpolate for all possible C. Let us call this approximation $c_{S,UC}^B(C)$. 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 (138) to get an expression for λ_B:

$$\lambda_B = \Big[\frac{\zeta\theta}{(\kappa a)^{1-\zeta}}\Big] \frac{\Big[\big[p_B(1-\tau_S)^\zeta\big]^{\frac{1}{1-\phi-\zeta}} + \big[\lambda_2(1-\tau_B)^\zeta\big]^{\frac{1}{1-\phi-\zeta}}\Big]^{1-\phi-\zeta}}{(p_X(1-\tau_B)(1-\tau_S))^\zeta} - 1 \tag{166}$$

and after plugging it back to equation (151), we get:

$$\begin{aligned}\bar{c}_S + \lambda_2^{-\epsilon}(\lambda_2^{1-\epsilon}\psi_S^\epsilon + p_B^{1-\epsilon}\psi_B^\epsilon + p_M^{1-\epsilon}\psi_M^\epsilon)^{\frac{\epsilon}{1-\epsilon}}\psi_S^\epsilon C = \\ \Big[\frac{\zeta}{(1-\tau_S)p_X}\Big]^{\frac{\zeta}{1-\zeta}} \frac{\lambda_2^{\frac{\phi-\zeta\phi+\zeta-\zeta^2}{(1-\zeta)(1-\zeta-\phi)}}\theta^{\frac{1}{1-\zeta}}(1-\tau_B)^{\frac{\zeta\phi}{(1-\zeta)(1-\phi-\zeta)}}}{\Big[\big[p_B(1-\tau_S)^\zeta\big]^{\frac{1}{1-\phi-\zeta}} + \big[\lambda_2(1-\tau_B)^\zeta\big]^{\frac{1}{1-\phi-\zeta}}\Big]^{\frac{\phi}{1-\zeta}}} \\ \cdot\Big[\frac{(\kappa a)^\zeta}{(\zeta\theta)^{\frac{\zeta}{(1-\zeta)}}}\Big] \frac{(p_X(1-\tau_B)(1-\tau_S))^{\frac{\zeta^2}{1-\zeta}}}{\Big[\big[p_B(1-\tau_S)^\zeta\big]^{\frac{1}{1-\phi-\zeta}} + \big[\lambda_2(1-\tau_B)^\zeta\big]^{\frac{1}{1-\phi-\zeta}}\Big]^{\frac{(1-\phi-\zeta)\zeta}{1-\zeta}}}\end{aligned} \tag{167}$$

- 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.

B.4 Recursive competitive equilibrium

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

$$\{G_t(z, a, e), Q_t(z, a, e, a', z', e')\}_{t=0}^{\infty} \tag{168}$$

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

$$\{C_t, c_S^t, c_B^t, c_M^t, a_{t+1}, e_{t+1}, x_S^t, q_S^t, x_S^t, q_B^t, x_B^t, l^t\}_{t=0}^{\infty} \tag{169}$$

the aggregate allocations $\{K_t, L_t\}_{t=0}^{\infty}$, current account variables $\{K_t^F, FA_t\}_{t=0}^{\infty}$, the prices: $\{p_B^t, p_M^t, W_t, r_t\}_{t=0}^{\infty}$ and the subsidies $\{\tau_S^t, \tau_B^t, \tau_w^t\}_{t=0}^{\infty}$ constitute an equilibrium if:

- given prices, the household allocations solve the household's dynamic consumption-saving-occupation choice problem in equation (15)
- The aggregate allocations solve the manufacturing firm's problem in equation (14)
- the labor market clears:

$$L_t = \int \big(\mathbf{1}_{\{e_{t+1}=M\}}\theta^U - \mathbf{1}_{\{e_t\in\{M,S\},e_{t+1}=B\}}F_B - \mathbf{1}_{\{e_t\in\{S,B\},e_{t+1}=M\}}F_M\big)dG_t \tag{170}$$

- the capital market clears:

$$K_t = \int a_t dG_t + K_t^F \tag{171}$$

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

$$\int (c_S^t - q_S^t(\mathbf{1}_{\{e_{t+1}=S\}} + \mathbf{1}_{\{e_{t+1}=B\}}))(1 + Q_S \mathbf{1}_{c_S - q_S < 0}) dG_t = 0 \tag{172}$$

$$\int (c_B^t - q_B^t \mathbf{1}_{\{e_{t+1}=B\}}) dG_t - a_D p_B^{b_D} = 0 \tag{173}$$

$$\int c_M^t dG_t - A K_t^{\alpha} L_t^{1-\alpha} = 0 \tag{174}$$

- Government budget constraint holds, either as Equation (18) or as in Equation (17).

- Distribution evolves:

$$G_{t+1} = \int Q_t(z, a, e, a', z', e') dG_t \tag{175}$$

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

$$Q_t(\mathcal{S}, (a', z', e')) = \mathbf{1}_{a' \in a_{t+1}(\mathcal{S})} \pi_z(\mathcal{Z}, z_{t+1}) \mathbf{1}_{e' \in e_t(\mathcal{S})} \tag{176}$$

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

- In addition, if the system of equations (20)-(22) regarding the current account clears either because K_t^F adjusts, we refer to the equilibrium as balanced current account equilibrium

B.5 Numerical implementation

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.

C Data sources

	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%)

Table 9: FAO 1980-2020 panel data summary

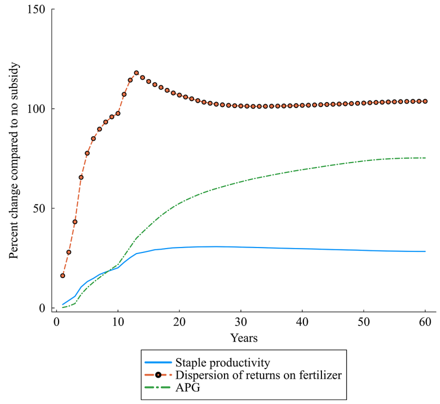
Note: Treated group is made of 10 SSA countries that implemented ISPs, as described in Jayne et al. [2018]. We split them into 3 groups according to the time of ISP implementation. Early group with implementation around 2000 includes Nigeria and Zambia. Malawi is on its own with implementation in 2005. Late group with implementation around 2008 includes Burkina Faso, Ethiopia, Ghana, Kenya, Mali, Senegal and Tanzania. Control countries include all the other SSA states. Staples are composed of beans, cassava, fonio, maize, millet, rice, sorghum, plantains and wheat. Cash crops are composed of 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 (in 2014-2016 constant prices) and quantity produced. The quantities harvested for each crop provide country-year-specific weights for average 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.

	Rural cross-sec		Rural panel		Urban panel	
	Mean	(St.Dev.)	Mean	(St.Dev.)	Mean	(St.Dev.)
Number of observations	8,753	–	2,173	–	1,950	–
Share male	74%	–	78%	–	62%	–
Real annual income	306	(1,391)	280	(1,337)	1,011	(3,246)
Labour hours	–	–	–	–	1,515	(1,207)
Land size	2.1	(24.8)	2.1	(6.6)	–	–
Age	43.2	(16.5)	45.4	(16.3)	35.5	(11.3)
Years of education	4.9	(4.0)	5.4	(4.1)	9.4	(4.2)
Number of adults in household	2.4	(1.2)	2.8	(1.4)	3.1	(1.6)

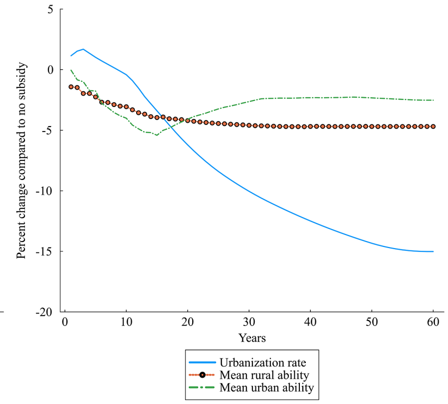
Table 10: Malawi LSMS 2010 cross-sectional & 2010-2013 panel data summary

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.

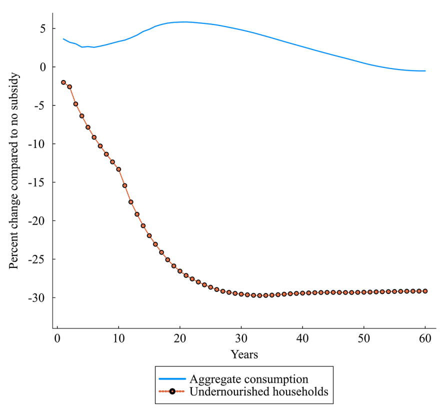
D Additional results



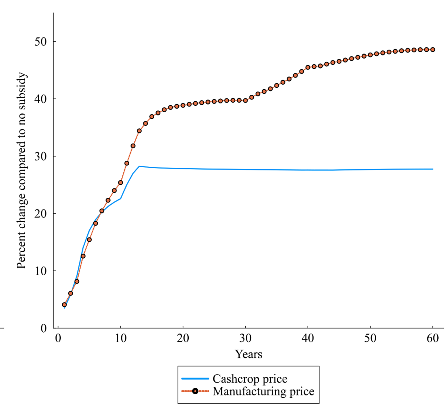
(a) Productivity



(b) Urbanization and talent



(c) Consumption



(d) Prices

Figure 8: Transitional dynamics after introducing $\tau_S = 0.81$ in Malawian economy

Note: The figure shows transitional dynamics induced by a gradual introduction of FISP in equal increments during the first five periods starting from $\tau_S = 0.0$ to $\tau_S = 0.81$. Every period is financed by international aid.