The Macroeconomic Impact of Agricultural Input Subsidies*

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October 7, 2024

Abstract

Governments operate agricultural input subsidy programs worldwide. Using a general equilibrium heterogeneous agent model featuring transaction costs, we quantitatively evaluate the macroeconomic consequences of such policies. Focusing on Malawi's Farm Input Subsidy Program, we find that while this large program decreases undernutrition, it reduces welfare by exacerbating misallocation and benefiting the wealthier urban population. We show that partial equilibrium analysis leads to contrary conclusions and that halving the subsidy rate or investing in infrastructure improves outcomes. Finally, we demonstrate that the microdata from Malawi and cross-country data from Sub-Saharan Africa are consistent with the predictions of our model.

Keywords: Agriculture, food security, structural change, misallocation

JEL Codes: Q12, Q18, O11

*Our thanks for valuable input are due to Arpad Abraham, Jason Agar, Zsofia Barany, Leandro De Magalhaes, Douglas Gollin, Federico Huneeus, Alexander Karaivanov, David Lagakos, and Albert Rodriguez-Sala. We are grateful to Karthik Sridhar and Rongli Xue for their valuable research assistance. We also thank conference and seminar participants at the Econometric Society Meetings (Abidjan, Barcelona, Milan, Nairobi, and New Orleans), NUS, Oxford, Peking HSBC, St. Gallen, the Spanish Macro Network (ESADE), STEG (NYU Abu Dhabi), Vienna Macro Workshop, Y-RISE and 100 Years of Economic Development (Cornell). Karol gratefully acknowledges financial support from the British Academy under the Leverhulme Small Research Grant 2021/210492. The views expressed in this article are the authors' and do not necessarily represent those of Banco de Portugal or the Eurosystem. All remaining errors are our own.

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1 Introduction

Strong agriculture may unlock robust economic growth and structural transformation, and governments all across the globe finance subsidy programs for agriculture to foster economic development.[1] While agricultural productivity dramatically improved in the last four decades of the 20th century across Asia and South America, it improved considerably less in Sub-Saharan Africa (SSA). To address this issue, 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.

ISPs introduced in SSA countries target the production of staples, which are critical for 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 usual primary local export good. Beyond their direct effects, large-scale ISPs move market prices and impact structural change, household dynamics, and inequality.

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, all subject to sector-specific idiosyncratic productivity shocks. Staples play a central role in our framework as not only are they a necessity good due to the subsistence constraint making preferences non-homothetic, but every household purchasing staples on the market must also pay a per-unit transaction cost. As staple production allows for avoiding transaction costs, this feature breaks the equivalence between profit maximization and cost minimization in farming. With farmers following the latter

[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].

objective, the laissez-faire allocation has inefficiently many households opting into farming with an inefficiently low quantity of food produced from the urban perspective. Furthermore, 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, Malawi introduced the Farm Input Subsidy Program (FISP) with spending totaling up to 6% of the Gross Domestic Product (GDP). Our model's calibration to Malawi in 2010 matches the empirical rural and urban income processes, 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. The key parameters driving the model dynamics are the migration and transaction costs and the tightness of the collateral constraint.

Our quantitative GE analysis accounting for transitional dynamics reveals that the large FISP in Malawi generates an average welfare loss equivalent to a 1% 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 in the long run, magnifying the urban-rural divide. Intuitively, changes in market prices induced by this extensive intervention effectively lock people in rural areas that are abundant in food but with reduced affordability of other goods. We also demonstrate the importance of accounting for responses to market prices through a comparative evaluation of FISP in the partial equilibrium (PE). In contrast to the GE case, it predicts large welfare gains and overly sensitive key macroeconomic margins.

Proceeding with comparative statics analysis, we find that a rescaled staple-targeting FISP can properly address the underlying inefficiencies by increasing the total food supply in the economy and driving its relative price down. In particular, we find a hump-shaped welfare impact of FISP in the subsidy rate: reducing the status-quo 81% subsidy rate down

to 45% turns welfare losses into welfare gains equivalent to a 0.4% gain in consumption. 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 the effects of FISP by fostering urbanization, reducing resource misallocation, and, ultimately, benefiting all households more uniformly. Finally, we consider a model extension with negative productivity externalities of undernourishment. We show that these externalities must be implausibly strong for the large status-quo FISP to be justifiable in the utilitarian welfare sense.

We validate 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 fertilizer use, staple and cash-crop yields, relative prices, and food security that are broadly consistent with the transition dynamics of 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. Lagakos and Waugh [2013], Herrendorf and Schoellman [2015] or Chen et al. [2023] focus on the reasons behind these productivity gaps. In contrast, de Janvry et al. [2015], Chen et al. [2022], Adamopoulos et al. [2022] or Lagakos et al. [2023] discuss policy interventions that can alleviate the underlying causes. We contribute to this line of work by quantitatively analyzing agricultural input subsidies. As such, we also contribute to the predominantly empirical literature on ISPs surveyed in Jayne et al. [2018] by, similarly to Kaboski and Townsend [2011], 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. We show that a positive APG is a feature of an economy distorted by transaction costs, even in the constrained-efficient allocation.

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. FISP in Malawi increases the intermediate input use intensity; therefore, it is 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 increase the APG. Our macroeconomic analysis yields a hump-shaped welfare response to increasing fertilizer use through subsidization, showing that the over-use of fertilizer may arise even without 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. Donovan [2021] shows that incomplete consumption insurance significantly reduces risky input adoption in Indian agriculture.[3] 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 strand of literature evaluating ISPs using quantitative models. Arndt et al. [2016] use a static and deterministic computable general equilibrium model to quantify the aggregate impact of FISP in Malawi. 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 static

[3]Also focusing on Indian agriculture, Mazur [2023] studies interactions between risk sharing and investment in irrigation in the presence of limited commitment constraints.

spatial models evaluating distributional implications of ISPs in Zambia, Uganda, and India, respectively. Relative to theirs, our dynamic 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 by saving in the 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 show how to solve the household's problem with transaction costs in Appendix B, formally define the equilibrium, and outline the numerical algorithm

for solving it in Appendix C.

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 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 their unit endowment 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. 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.

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

In every period, households face uncertainty due to the time-evolving vector z of idiosyncratic rural θ^R and urban θ^U productivities. 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, labor-denominated entry cost wF_M. 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 engage in cash crop farming, they must pay the per-period maintenance cost of wFM_B. Staple farming is assumed to be a baseline activity that is not subject to entry or maintenance costs. Overall, there are 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 generate profits π_S by applying intermediate inputs on 1 unit of land using the following production technology subject to a collateral 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. Note that maximizing profits will generally not be the objective function of farming households. 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, they generate profits π_B from the following production function by deciding about the allocation of both the intermediate inputs $x_S,\ x_B$ and the share of land $1 - l$ allocated to cash crops:

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

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

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

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

To generate positive profits from agricultural production, we assume jointly decreasing returns to scale $(\zeta, \phi) \in (0,1)\,,\ \zeta + \phi \in (0,1)$. The optimal behavior of cash crop producers implies three important observations summarized in Proposition 1.

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 crop. However, the equilibrium forces working through the relative prices of crops can overturn or mitigate 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 producing food.

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., $a' \geq 0$.

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 Dynamic programming

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

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

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

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

$$X_{e' \in \{S,B,M\}} = c_S + p_B c_B + p_M c_M + Q_S \cdot \hat{c}_S \tag{12}$$

$$\hat{c}_S = \max\{c_S - 1_{e' \in \{S,B\}} \cdot q_S(\theta^R, x_S, l, a), 0\} \tag{13}$$

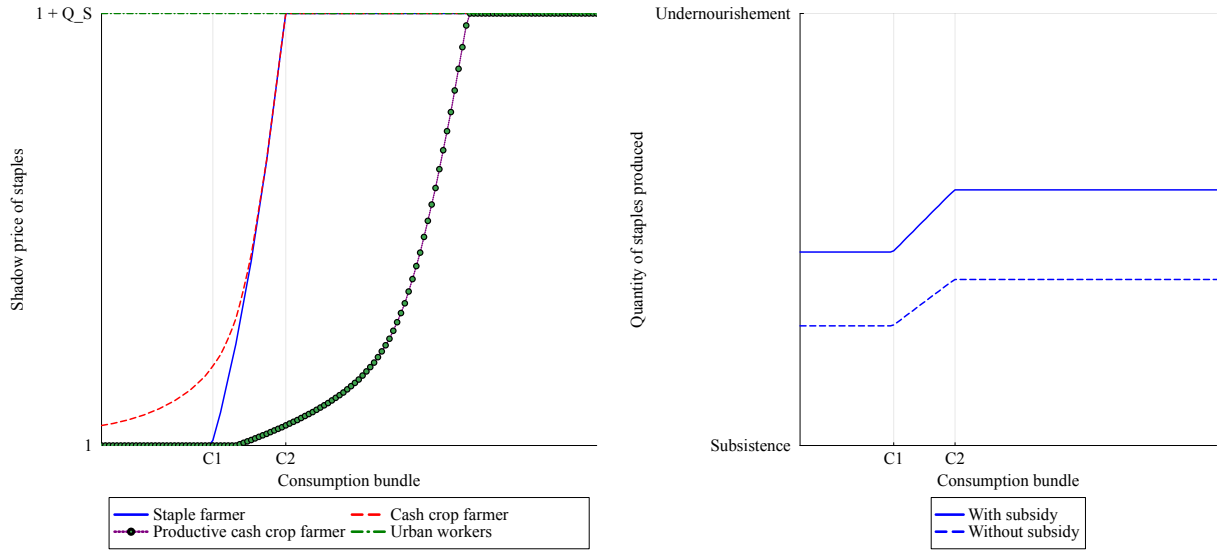
$$\begin{aligned} Y_{e' \in \{S,B,M\}} = {} & 1_{e' \in \{M\}} \left(\theta^U w - 1_{e \in \{S,B\}} w F_M\right) + 1_{e' \in \{S\}} \pi_S(\theta^R, x_S, a) \\ & + 1_{e' \in \{B\}} \left(\pi_B(\theta^R, x_S, x_B, l, a) - w F M_B\right) \end{aligned} \tag{14}$$

where X denotes expenditures and Y income 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 occupational and expenditure (including the decision to purchase $\hat{c}_S$ amount on the market) 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'.

2.1.4 On efficiency of the competitive equilibrium

In an economy without transaction costs ($Q_S = 0$), households choose the income-maximizing occupation irrespective of their consumption bundle. Transaction costs for staples imply that their shadow (internal) valuation, represented by the Lagrange multiplier on constraint (13), will vary across the household distribution. For staple producers, it can lie anywhere between $\lambda_S \in [1, 1+Q_S]$, depending on the household's consumption and production patterns. In contrast, the shadow price is always equal to the market price $1+Q_S$ for urban households, implying that food will be generally under-produced from the perspective of the urban

sector.



(a) Shadow price of staples across household types

(b) Production impact of FISP

Figure 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 and is not represented in these figures. The shadow price of food is the Lagrange multiplier on Equation (13) in Section 2.1.3. "Staple farmer" and "cash crop farmer" represent households with the same productivity and assets. "Productive cash crop farmer" is a cash crop farmer with a higher level of rural productivity. The subsistence threshold corresponds to $\bar{c}_S$ in the model, and Section 3.3 explains the construction of the undernourishment threshold.

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

These PE production patterns interact in GE through our model economy's incomplete asset market structure. In particular, households cannot trade state-contingent financial claims to perfectly insure their consumption fluctuations caused by 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 imperfectly insurable risks and transaction costs 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 one-shot endowment economy with a risk-averse representative household facing risky occupation choice between farming and manufacturing in the presence of transaction costs for food procured by laborers (and the manufacturing price is the same in both sectors). The equilibrium mass of both occupations is determined by the representative household choosing the probability of becoming a farmer such that both occupations lead to the same equilibrium payoff. Markets are similarly incomplete as the occupation risk cannot be perfectly insured. The interaction between the transaction costs and the incomplete market structure generates precautionary behavior, and the laissez-faire price system fails to coordinate actions to achieve efficient outcomes. In particular, *overfarming* characterizes the laissez-faire competitive equilibrium: the precautionary household chooses an inefficiently high probability of becoming a farmer as the occupation choice induces food price risk, markets are incomplete, and food is cheaper in the farming sector.[4]

In our quantitative incomplete market economy, the interaction of urban migration risk and transaction costs similarly generates excessive selection into farming. Households are also exposed to occupation-specific productivity fluctuations, giving rise to typical precautionary savings and associated pecuniary externalities, as studied, e.g., in Davila et al. [2012]. As preferences are non-homothetic, households are more sensitive to food consumption risk. Thus, staple-targeting ISPs reduce precautionary distortions by ensuring food supply in both rural and urban areas and more dynamically by facilitating asset accumulation among farmers and effectively reducing the urban migration risk. While this suggests that ISPs may be welfare-improving for both redistributive and efficiency reasons, the GE effects will generally increase prices of all goods relative to food, calling for a comprehensive quantitative

[4]Strictly speaking, the competitive equilibrium is constrained inefficient as the representative household could increase their expected utility by reducing the probability of becoming a farmer. Introducing a state-contingent asset market or an optimal transfer schedule can restore the first-best efficiency.

evaluation.

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 productivity A_M. The markets for capital and labor are competitive and centralized. All urban workers receive the same wage w per efficiency unit θ^U. The firm's problem reads:

$$\pi_M = \max_{K,L}\{p_M K^\alpha (A_M L)^{1-\alpha} - (1+\tau_w) wL - (r+\delta)K\} \tag{15}$$

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:

$$L = \int \left(\mathbf{1}_{\{e'=M\}}\theta^U - \mathbf{1}_{\{e\in\{M,S\},e'=B\}} FM_B - \mathbf{1}_{\{e\in\{S,B\},e'=M\}} F_M\right) dG \tag{16}$$

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

We are considering financing the subsidy program with either labor taxes or foreign aid. The total expenditures X_G are given by:

$$X_G = p_X \tau_S \int x_S dG_{z,a,e'\in\{S,B\}} \tag{17}$$

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

$$\text{labor tax}: X_G = \tau_w w\Big(\int dG_{z,a,e'=M} - F_M \int dG_{z,a,e'=M,e=\{S,B\}} - FM_B \int dG_{z,a,e'=B}\Big) \tag{18}$$

$$\text{foreign aid}: X_G = FA \tag{19}$$

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

2.4 Current account

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

$$c_B^F = a_D p_B^{b_D} \tag{20}$$

Furthermore, the economy imports intermediate inputs at an exogenously given price p_X. The following equations summarize the current account's (CA) structure:

$$CA = X - M - rK^F + FA \tag{21}$$

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

$$M = p_X \Big(\int x_S dG_{z,a,e'=S} + \int (x_S + x_B) dG_{z,a,e'=B} \Big) \tag{23}$$

Prices and decision rules determine imports M and exports X, the foreign-supplied capital stock K^F, and foreign aid FA (used for funding government programs, if any).

In the baseline allocation targeting the Malawian economy in 2010, we assume that the country's current account (CA) is balanced.[5] 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 $CA = 0$. In all other allocations (including foreign aid cases), the foreign capital is fixed at the baseline allocation of FISP with labor taxation, implying that the current account will generally not equal zero in those cases.

2.5 Welfare measurement

Throughout our quantitative analysis, most reported outcomes come from comparisons of stationary distributions. However, our baseline welfare measure accounts for the associated transition paths (a discussion of which, together with an example, can be found in Section

[5] This assumption implies that the net foreign asset position of the country is also 0.

4.5). In particular, we compare allocations using a utilitarian social welfare metric reflecting the consumption-equivalent changes in welfare. By the latter, we mean the averages of the permanent percentage changes in consumption that make each society member indifferent between the pre-reform steady-state and a transition induced by an unexpected reform (assuming a perfect foresight over the evolution of the post-reform economy). In order to further clarify our results, we also utilize a long-run welfare metric, which reports the average of the permanent percentage changes in consumption, generating indifference between the pre- and post-reform allocations for each member of the society constructed using the pre-reform stationary distribution.

3 Empirical application

We apply our framework to the case of Malawi, the country with the largest ISP in SSA. In Section 3.1, we first introduce the data sources that allow us to perform the empirical analysis. Section 3.2 discusses mapping the model to the empirical setting. In Sections 3.3-3.5, we develop a calibration strategy disciplining our model's parameters based on the literature, the institutional setting, and the simulated method of moments. While Section 4 contains quantitative results of our model, we use these datasets again in Section 5 when conducting a comparative cross-sectional and dynamic cross-country regression analysis of empirical and simulated datasets.

3.1 Data sources

Our empirical work rests on two main 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 on the share of the undernourished population, the share of irrigable land, the share of rural population, total population, and GDP per capita. Table 8 in Appendix D 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 revenue 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 latter, we use household-level data on the 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.[6] 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 similar to those in the 2010 cross-section. Table 9 in Appendix D 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% of its population living in rural areas and primarily engaged in small-scale, non-mechanized, and subsistence-based agriculture. Around 40% of rural households cultivate only maize. Most of the agricultural production becomes self-consumed without entering the market. Cash crops

[6]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).

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 harvests and high prices of maize, 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, who have later been 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.[7] The feasibility of implementing effective targeting and rationing of subsidized inputs is further weakened by active secondary markets for subsidized inputs in SSA (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 conservatively follow this approach because foreign donors financed only 7%-18% of the FISP costs between 2005-2010 (as discussed in Chirwa and Dorward [2013]). Moreover, Malawi's government only introduced farmers' income taxation in 2010 and only on farmers selling cash crops (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.[8] These gaps can be particularly large in Africa as, before reaching fi-

[7] 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.

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

nal 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.[9] 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 correlates negatively with the presence of active local markets and positively with the distance to administrative centers (so-called "bomas"), proxies of frictions in market access.

We model the causes for the difference between producer and consumer prices of cash crops differently than for staple crops. Cash crop farmers pay a per-period maintenance cost FM_B instead of the per-unit transaction costs. We follow this approach as the empirical cash crop expenditure share ψ_B is significantly lower than that of staples ψ_S, and cash crops often cannot be directly consumed as they are significantly harder to process at home than maize.[10]

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 (Chen et al. [2023]).[11]

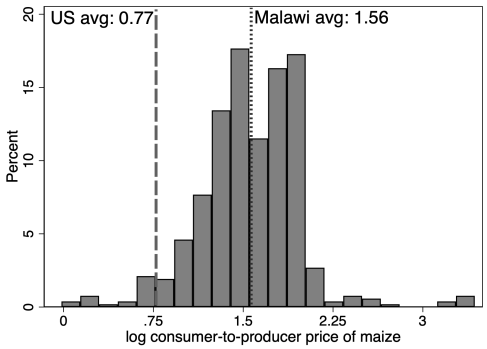
On top of representing fixed transaction costs, the cash crop maintenance cost FM_B can also capture all additional outlays required for production. In the case of tobacco cultivation,

reach different conclusions and find evidence of significant market power among intermediaries.

[9] 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 compare the wholesale price of wheat flour and edible byproducts to the price received by farmers for wheat grain.

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

[11] While outside of the scope of this paper, Manysheva [2022] analyzes the impact of land market reforms on resource allocation and productivity in a framework similar to ours.



(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. The data is for Malawi from the 2010 wave of LSMS. The average relative price of wheat for the US is from the USDA Wheat Yearbook Tables 2015-2020.

these can capture the costs of building curing barns and hiring additional labor during the work-intensive curing stage. Finally, notice that upon paying the per-period maintenance cost FM_B, cash crop farmers can increase their total revenue by producing both crops simultaneously (as long as p_B is not too high). This structure captures additional gains due to crop diversification and rotation, allowing for improved income insurance and smoothing of labor throughout the agricultural year.

Open economy. We model the key aspects of the open economy in detail because introducing FISP or other government programs may alter the current account, which implies that the economy wastes or uses resources it does not have. The current account serves as an additional dimension of welfare where its negative 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.[12] According to FAOStat, Malawi exported the vast majority of its cash crop output, with the associated revenue accounting for almost all of the country's export revenue in 2005-2011. Motivated by these

[12]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.

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

We denominate the 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, finding a job, and the large financial commitments of rural migrants required for maintaining social links with their extended families.[13] 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 that characterize the developing world as Lagakos et al. [2020] document it.

Financial frictions. We assume household assets are relatively illiquid to finance the within-period purchases of agricultural inputs, i.e., $\kappa \in (0, 1)$. This illiquidity aligns with 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], Ambler et al. [2020], and Aggarwal et al. [2022] show that randomized cash grants given to Malawian farmers generate positive investment responses, suggesting that

[13]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.

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 eight parameters such that the implied model dynamics match relevant empirical facts. Tables 1 and 2 summarize the estimation procedure and parameters chosen. As robustness checks, Tables 3 and 4 evaluate our model along non-targeted dimensions and investigate the changes in key moments as we switch off the relevant frictions.

Preferences. We assume that households evaluate their consumption bundle with a 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 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), similar to calibration strategy of Donovan [2021].[14] We define the undernourishment level $\tilde{c}_S = 0.11$ to be such that the baseline allocation has $\bar{u} = 20\%$ of undernourished households with staple consumption below $\tilde{c}_S$, as in 2010 Malawi.[15]

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

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

[15] We choose the undernourishment rate of 20% falling between reports by the Global Hunger Index (21.8%) and FAOStat (14-16%).

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]	6.3	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.

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.

Regarding the external demand for cash crops (20), we estimate it using the 1962-2019 FAOStat data for Malawi by running the following regression:

$$\log(D_t) = A_D + b_D \cdot \log P_t + \epsilon_t \tag{24}$$

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 on the nominal value of output by the total quantity produced). We focus on tobacco exports as this is Malawi's most important export good. 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 (20) 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.[16]

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

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

Parameter	Value	Target/Source
Preferences		
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	0.62	Our estimates from LSMS
Urban AR(1) persistence ρ^U	0.49	Our estimates from LSMS
Rural AR(1) standard deviation σ^R	0.87	Our estimates from LSMS
Urban AR(1) standard deviation σ^U	1.12	Our estimates from LSMS

Table 2: Externally calibrated parameters

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 assume it to be equal to the recommendation of 25 kgs per ha in the Malawi Country Report by Mabaya et al. [2021]. The same source also quotes the average 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 an average yield of 2.2 tonnes per ha, implying a value for 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 reported for 2010 Malawi in Chirwa and Dorward [2013].[17] Third, we set $\kappa = 0.1$ targeting 70% of cash crop farmers using a suboptimal amount of inputs, as found in the fieldwork by 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.[18]

For the manufacturing production function, we set the capital output-share of $\alpha = 40\%$ in line with David and Venkateswaran [2019], assuming a relatively 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 18% urban population share 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].[19] 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 Midrigan and Xu [2014]. We fix the savings rate at $r = 5\%$ and solve for the level of foreign capital supplied to the manufacturing firm K^F such that the current account is balanced in the baseline calibration.

Household productivity process. We draw on the panel dimension of the Malawi LSMS dataset for 2010 and 2013 to parameterize the idiosyncratic productivity processes. In the case of rural households, we regress the log of household-level agricultural output 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, schooling years, number of adults in the household and total kgs of fertilizer used. In the case of urban households, we regress the log of earnings per hour of work on a similar vector of con-

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

[18] 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.

[19] 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.

trols (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 $\theta^j_{i,t}$ as measures of our idiosyncratic productivity shocks. Allowing for persistent shocks, we assume that both rural θ^R and urban θ^U 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 $j \in \{R, U\}$. Our finding is that working in the urban sector is relatively riskier as the annualized persistence of rural and urban productivity shocks amounts to 0.57 and 0.49 with 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].[20]

3.4 Non-targeted moments

Table 3 reports 13 overidentifying moments we have not targeted in calibration. First, the implied GDP share of the agricultural sector equals 30%, in line with the World Bank data for Malawi in 2010. 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 revenue input product equal to 1.3, above the empirical one of 0.8 in the LSMS data.

Fourth, we leverage the RCT evidence in Aggarwal et al. [2022] on randomized cash transfers worth 193% of 2010's average annual rural income disbursed among all households living in 150 Malawian villages between 2019 and 2020 (less than 1% of population). The intervention targeted relatively small villages with relatively higher poverty levels and populations below 100 households. Aggarwal et al. [2022] found a 22% increase in the total value of harvest on the impact of this cash grant. We measure the impact of this RCT in our model as the average PE impact of a cash grant worth 193% of average rural income disbursed among the bottom 50% of rural households (in terms of consumption) to account for the unobserved heterogeneity within targeted villages. On impact, the agricultural output of the treated households increases by 16% on average.

[20] Appendix E contains the productivity estimation results. 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 Aggarwal et al. [2022]	22%	16%
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.

Finally, we implement an array of inequality indicators reported in De Magalhaes and Santaeulalia-Llopis [2018]. Our frictional calibration 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 further validation of the estimation's strategy, Table 4 shows the impact of switching off the key frictions of our framework on the simulated moments targeted in the calibration 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, as evinced by significant changes in both the APG and the urbanization rate. In our incomplete market setting, transaction costs emerge as a novel friction driving productivity gaps between sectors, with households reducing their food consumption risk by excessively selecting into farming.

Importantly, our simple model with risky migration in Appendix A exhibits similar dynamics concerning Q_S. As transaction costs increase in that framework, we observe increasing gaps in the share of the rural population and the APG between the laissez-faire

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	6.3	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).

competitive equilibrium and the constrained efficient allocation.

Finally, the financial friction operating through the working capital constraint is more important than usual because $\beta(1+r)$ is significantly below 1.[21] 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

With the model calibrated to the economy of Malawi in 2010, Section 4.1 identifies the macroeconomic impact of the large-scale agricultural input subsidy program by comparing the stationary distribution of calibrated post-reform allocation to the pre-reform one without FISP. We also evaluate FISP under two alternative scenarios: (i) in PE with households optimizing their decisions with 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.

We explain the welfare results in Section 4.2 through discussions of the transition path and the winners and losers from the perspective of households, both before and after the reform. Figure 3 shows these results.

Utilizing the full extent of our structural model, we consider three more counterfactual exercises. In Section 4.3, we look for the optimal choice of the staple subsidy rate. Section

[21] 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.

4.4 shows the effect of redirecting public spending from FISP to infrastructural development investment that reduces transaction costs. Finally, Section 4.5 shows the impact of negative productivity externalities due to undernourishment. Figures 4-7 and Table 6 contain the results of these exercises.

4.1 The impact of FISP in Malawi

To fully describe the impact of FISP, in Table 5, each column corresponds to a step towards a complete evaluation of FISP. Column 2 shows the PE evaluation of FISP, with prices fixed at their no-subsidy equilibrium levels. Without price adjustments, quantities react sharply, with the share of land devoted to staples increasing by 43%, together the productivity of staple farming increasing by 153%, and the staple output increasing by 336%. While these changes are large, they are corroborated by the RCT evidence mentioned in Section 3.4 validating the effects of cash grants in the PE version of our model. As staple farming becomes more lucrative than urban work or cash crop farming, the share of the urban population and the manufacturing output both drop by 45% and 60%, while cash crop output falls by 68%. As fertilizer imports increase significantly and the cash crop exports drop,[22] 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 dispersion of the average revenue product of inputs (ARPX) in agriculture and the number of people in the less productive rural sector increase. While the consumption-equivalent welfare gain of the average society member seems large at 12.0%,[23] it pales next to the unaccounted-for program cost of 17% of GDP. 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.

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 tax-

[22] The share of cash crops exported in Table 5 in PE increases by whole 214% precisely due to the collapse in cash crops' output and no change in the export demand (as the cash crop price in PE does not change).

[23] As prices are not allowed to adjust in this allocation, this welfare metric cannot account for the transition.

	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	-	+11.9%	+2.9%	-1.0%
Consumption equivalent welfare - urban	-	+2.5%	+6.0%	+0.3%
Consumption equivalent welfare - rural	-	+14.9%	+1.9%	-1.4%
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 eqm." refers to the case of introducing FISP without changes in market prices. "Foreign aid" refers to the case of introducing FISP with changes in all market prices but without introducing τ_w for financing government spending. "Labor tax" adds equilibrium adjustment in τ_w to the latter scenario and is also the equilibrium we calibrate to the Malawi data. "Dispersion in ARPX" denotes the standard deviation of the log average revenue product of inputs. We define the agricultural productivity gap as the ratio of the "nominal value of manufacturing output net of spending on entry costs per urban worker" to the "nominal value of agricultural output net of spending on maintenance costs and inputs per farmer" in value-added terms. The consumption-equivalent measure of welfare change accounts for transitional dynamics.

ation. In this case, the effects of this large-scale subsidy program feed into the broader economy through the equilibrium adjustment of prices, muting the large PE response. In response to the input-driven increase in productivity of the staple sector, food becomes cheaper as the relative prices of cash crop p_B, manufacturing good p_M, and labor w increase by 27%, 39%, and 73%, respectively. 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. As the increased relative price of cash crops stabilizes the PE effects in the cash crop sector, the output and productivity in this market remain almost unaffected. The import and export margins adjust, resulting in a balanced current account. Similarly, the increasing prices of manufacturing goods and labor stabilize the outflow of people from urban to rural areas, resulting in just an 8% drop in the urbanization rate. Despite the decline in urbanization, manufacturing output increases by 9% for two reasons. On the one hand, poorer households increase their demand for non-food due to non-homothetic preferences. On the other hand, fixed capital rental rates allow for replacing lost urban labor with capital. 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 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.[24] Overall, we find large welfare gains induced by the aid-financed FISP equivalent to a 2.9% increase in consumption on average.

The fourth column presents the complete GE response of the model with a 19% labor income tax levied on urban workers. 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 ARPX doubling.[25] The urban-rural inequalities remain

[24]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.

[25]The overall dispersion of ARPX in both GE cases increase significantly more than the sum of respective changes in this dispersion for staple and cash crop farmers individually because FISP significantly lowers the marginal costs and, due to the optimizing behavior of households, also the marginal (and average) return on inputs for staples without affecting the average level of ARPX for cash crops, which increases the difference between marginal products of cash crops and staple producers, doubling the overall dispersion. In the PE

similarly large as in the "foreign aid" case despite the labor income taxation. Overall, accounting for the reform's financing cost shows that FISP generates welfare losses equivalent, on average, to a 1.0% drop in consumption, overturning the welfare improvements found in the PE and aid-financed cases.

Comparing the PE and GE allocations helps think about the consequences of potential scaling up of micro input subsidy interventions. 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, many margins of the PE intervention show excess sensitivity. For instance, it overstates the productivity gains for staples by a factor of 5 and cash crops by a factor of 50. Similarly, it significantly overstates the impact of FISP on land reallocation. However, 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 because PE does not account for lower relative consumer prices of staples. Our analysis shows that implementing policies at scale with GE effects ignored may lead to the opposite of the intended results, with the opposite estimated signs of welfare impact across the PE and GE cases.[26]

4.2 Transition dynamics and welfare

We complement the analysis regarding the effects of FISP by comparing household welfare gains, for which taking the transition path into account is necessary. Figure 10 in Appendix E shows an example of transition path dynamics induced by a change from $\tau_S = 0.0$ to $\tau_S = 0.81$ under the balanced government budget, our baseline FISP calibration in 2010 Malawi. We increase τ_S gradually in 5 periods following the evidence on actual implementation in Malawi as discussed in Benson et al. [2024].[27]

The adjustment process of the Malawian economy is sluggish because scaling up individ-

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

[26]The GE welfare impact of FISP that ignores transition, and so measured equivalently to the PE case, amounts to -8%.

[27]For smoothing the transition computation, we introduce a corresponding gradual reform over five years in all of our reform allocations. See Appendix C for a detailed algorithm description.

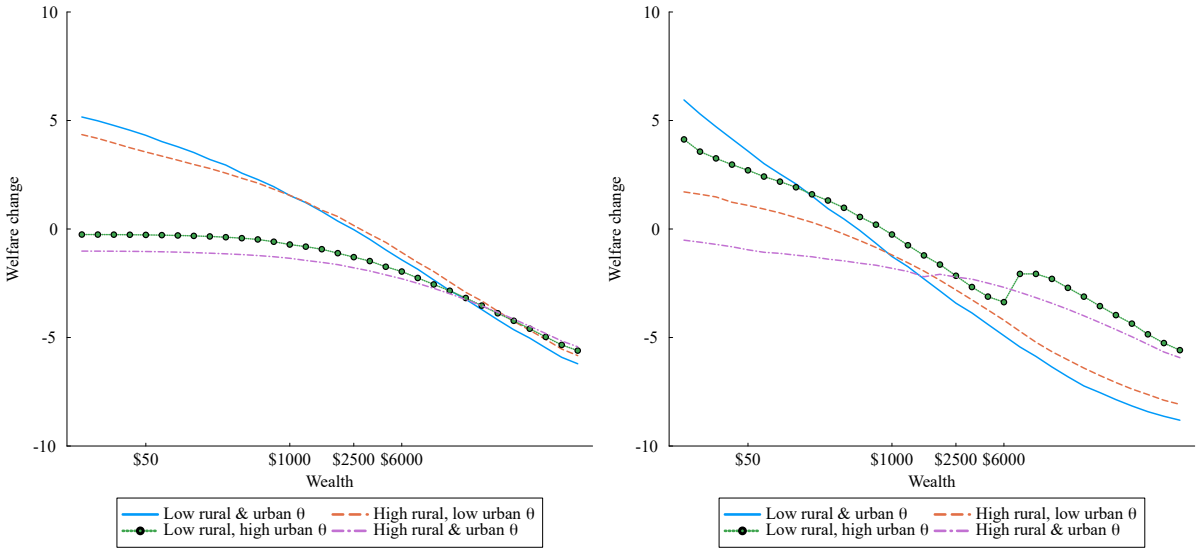
ual agriculture production and reallocating the labor force from the rural to the urban sector requires the accumulation of savings. Staple productivity and the APG increase relatively slowly, similar to the decline in the urbanization rate. These slow-moving adjustments go hand-in-hand with gradual 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.

FISP generates a 1.0% total welfare loss upon accounting for these transitional dynamics, with 0.3% welfare gains for urban and 1.4% welfare loss for rural households. Comparatively, the long-run welfare loss amounts to 8%, and the PE welfare gain amounts to 12%.[28] The welfare gains of FISP accounting for transition fall between these two cases for two reasons. First, the distortions due to labor taxes are lower than in the final steady-state due to a slow depopulation of urban areas and, therefore, a larger tax base along the transition. Secondly, relative prices of non-food goods are lower early on in the transition. As the economy's poor are concentrated in rural areas, they lose on the increased relative prices only in the later periods.

Figure 3 decomposes the welfare changes among rural and urban populations across different levels of assets and time horizons. The program generates sizable welfare gains for asset-poor farmers with low rural productivity and asset-poor workers with low urban productivity. These gains arise as FISP makes food easier to produce in rural areas and cheaper to procure in urban areas. Households with higher productivity or assets lose out as non-homothetic preferences imply that they spend relatively less on food and still incur the costs of the policy through labor taxation or a lower price of food produced. There are relatively few urban workers with lower asset positions, so FISP effectively favors poorer households in rural areas. While all urban-rural inequality indicators increase in the long run, the differences between short- and long-run welfare gains reveal that farmers initially benefit from improved mobility.[29]

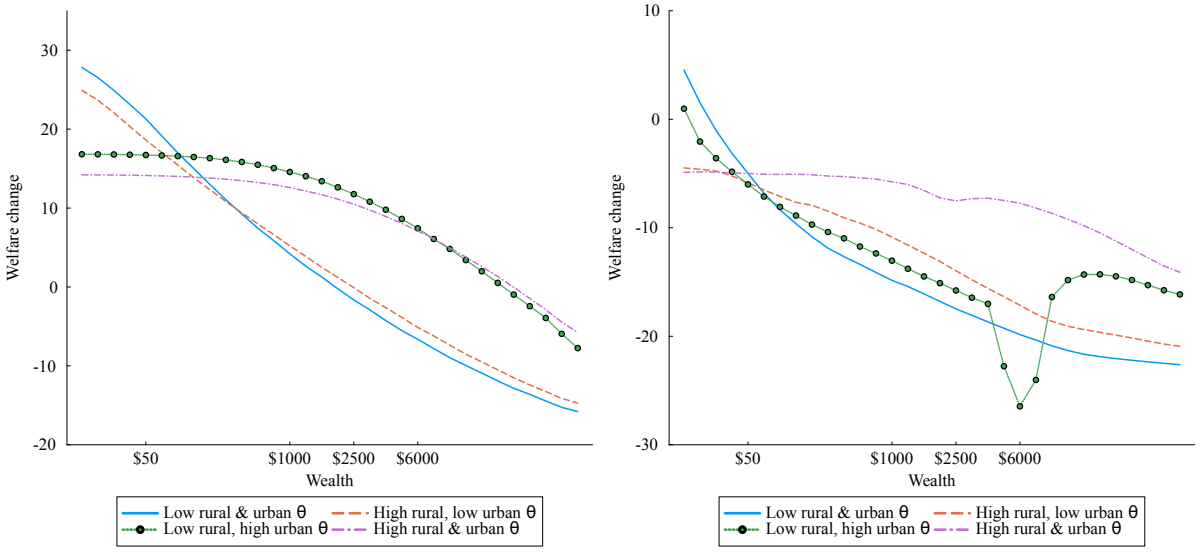
[28] Aid financed subsidy program delivers a 2.9% welfare increase when taking the transition into account; see Figure 11 in Appendix E.

[29] 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.



(a) Urban workers

(b) Farmers



(c) Urban workers, only long run

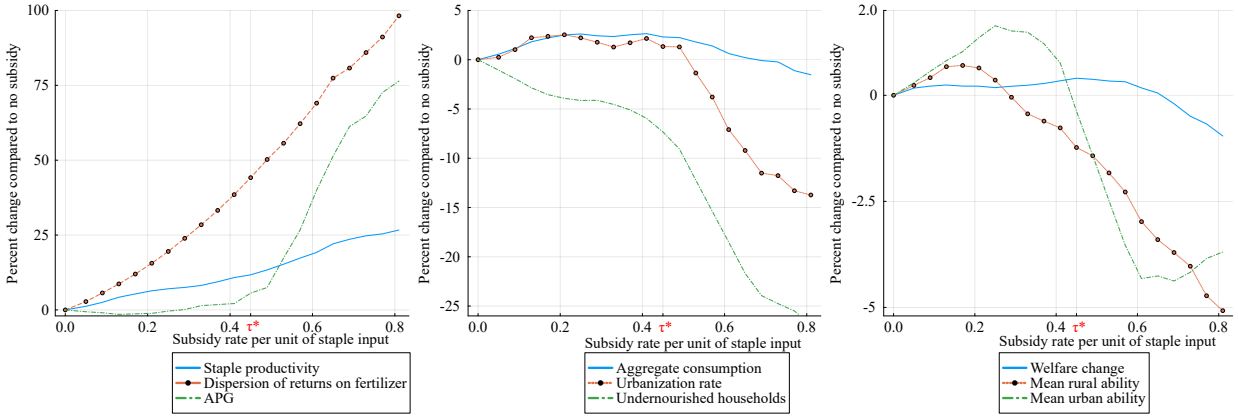
(d) Farmers, only long run

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. Only the long run refers to the implied consumption equivalent welfare change that ignores the transition period from the perspective of the initial, pre-subsidy households.

4.3 Changing the size of FISP in Malawi

We have shown that the high FISP subsidization rate induces sizable welfare losses in Malawi. Nevertheless, our comparative statics of τ_S (relative to no-subsidy equilibrium) in Figure 4 show that it is possible to rescale the program so that the average member of society benefits from FISP.



(a) Productivity (b) Consumption and urbanization (c) Welfare and talent

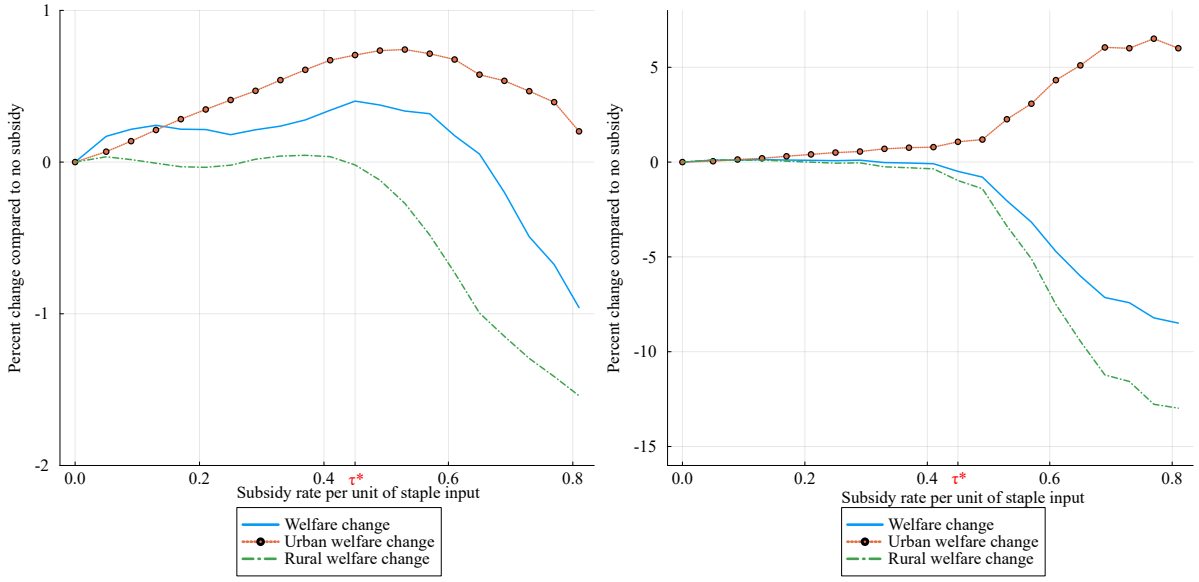
Figure 4: The impact of FISP in Malawi under different subsidy rates τ_S

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 transition paths induced by reforms. $\tau^* = 45\%$ refers to the policy choice maximizing the overall welfare.

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 as the subsidy policy induces a significant reduction in the marginal revenues of staple farmers. The urban-rural misallocation, proxied by APG, weakly decreases for a small enough τ_S as the urbanization rate grows, indicating that FISP can improve the overall allocation of resources in the macroeconomy. However, increasing τ_S beyond $\tau_S^* = 45\%$ generates sharp increases in APG, as excessive subsidization reduces the share of households working in manufacturing, which leads to increases in the value-added per laborer at a rate exceeding that of subsidies, increasing agricultural productivity per farmer.

Panel (b) shows that while FISP distorts production, it always helps the poorest house-

holds, as indicated by monotonic reductions in the share of the undernourished population. A subsidy rate of $\tau_S^* = 45\%$ increases aggregate consumption by up to 3% and optimally balances distortions due to increased labor income tax rate and misallocation with benefits of improved redistribution towards the poorest households and increased urbanization rate. An optimally sized FISP increases the urbanization rate because, on the one hand, it makes food cheaper for everyone, and, on the other, it helps farmers accumulate savings required to cover migration costs.[30]



(a) Transition (b) Long-run

Figure 5: The welfare impact of FISP in Malawi under different subsidy rates for urban and rural households

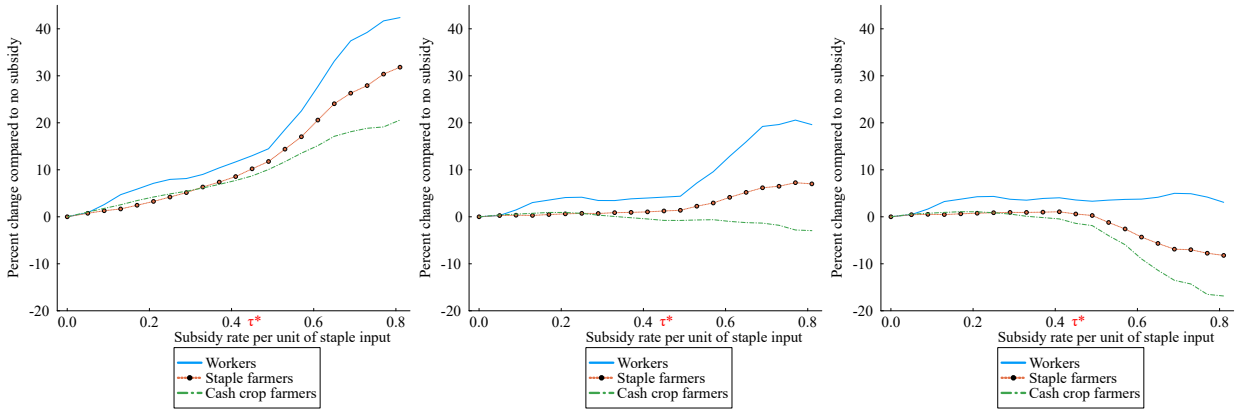
Note: Panel (a) shows the impact of subsidy rates on welfare gains relative to the no subsidy equilibrium, accounting for transition paths induced by reforms; panel (b) ignores the transition paths and only compares the steady-state to steady-state welfare gains. $\tau^* = 45\%$ refers to the policy choice maximizing the overall welfare. The optimal subsidy rate when considering only the long-run welfare is 13%, which leads to a 0.13% welfare gain.

The above welfare trade-offs induced by FISP are visible in panel (c). The allocation of talent in the economy improves for the optimally-sized FISP, with the average agricultural ability in rural areas increasing by up to 2% and the average urban ability increasing by

[30]While this important dynamic effect is absent from our simple model in Appendix A, supporting asset accumulation in our highly frictional calibration counteracts the distortionary effects of farming subsidies and, therefore, creates room for FISP to reduce the overall overfarming inefficiency.

up to 3%. Despite the potentially large changes induced by FISP in the economy, the range of welfare changes is between -1.0% and 0.4% for the whole range of τ_S considered. Therefore, large-scale agricultural input subsidy programs have limited scope for determining the economy's fate from the industrial policy point of view.

However, Figure 5 shows that the relatively flat profile of the welfare response masks the differential impact of FISP across the urban-rural divide. In panel (a), we depict the baseline welfare change accounting for transition dynamics, and in panel (b), we focus on steady-state comparisons. In both panels, we observe that large input subsidies disproportionately benefit urban workers, accounting for the transition paths and significantly lowering the magnitude of divergence in welfare gains and losses across the two groups relative to only considering long-run changes, even eliminating losses for rural households for smaller subsidy levels. Therefore, accounting for the short-run benefits of FISP in terms of increasing occupational mobility is critical for correctly evaluating the policy's aggregate and distributional effects.



(a) Staple (b) Cash crop (c) Manufacturing

Figure 6: The impact of FISP in Malawi on the consumption of each group under different subsidy rates τ_S

Note: Panels (a)-(c) show the impact of subsidy rates on the total consumption of staple, cash crop, or manufacturing good across occupations 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 transition paths induced by reforms. $\tau^* = 45\%$ refers to the policy choice maximizing the overall welfare (accounting for the transition).

Figure 6 shows why urban workers benefit more from larger τ_S: 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. Furthermore, while staple-supporting ISPs disproportionately hurt cash crop farmers, the most important redistribution induced by the program is in moving resources from the agricultural toward the urban sector.

4.4 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. Therefore, to the extent that transaction costs for food are due to the lack of appropriate infrastructure — as Figure 2 (b) indicates — we consider the effects of reallocating public funds from FISP into directly reducing the underlying frictions, corresponding to infrastructural investments into 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 (Asher and Novosad [2020], Morten and Oliveira [2023]) and improves food security (Blimpo et al. [2013], Gollin and Rogerson [2014]). In both cases, we assume "foreign aid" financing to be conservative regarding the benefits of infrastructural investment by not allowing the benefits of a larger tax base in the cities to increase welfare gains.

The first column of Table 6 repeats the relative changes in key statistics induced by the aid-financed FISP 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, relative to the "No FISP" allocation.

The economy reacts quite differently to infrastructure investment than to FISP. Although

	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			
Consumption equivalent welfare	+2.9%	+3.2%	+26.9%
Consumption equivalent welfare - urban	+6.0%	+5.5%	+9.4%
Consumption equivalent welfare - rural	-8.2%	+2.5%	+32.4%
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.

the share of people remaining in rural areas drops by up to 25%, the improved allocation of talent allows for a slight increase in the output of staples and cash crops and a large increase of up to 59% in the manufacturing output. The economy's overall allocation of key resources becomes more efficient as urban-rural consumption inequality drops by up to 33%, and the APG drops by up to 30%. Non-food goods become relatively cheaper while the undernourished share of the population declines by up to 47%, and up to a 49% increase in total consumption. While the allocation reducing only Q_S induces similar welfare gains to FISP, the case with spillovers into reducing F_M yields up to 27% welfare gains with larger gains for rural households, suggesting that infrastructure investments may be more cost-effective uses of public funds than FISP.

4.5 FISP in the presence of productivity externalities

Our quantitative analysis of FISP's benefits thus far has been relatively conservative, as supporting food production could also address negative productivity externalities due to undernourishment. Studying agricultural households in Sierra Leone, Strauss [1986] showed that the productivity of farmer households is negatively affected by cuts in calorie intake, with especially strong effects present among the poorest. Given that FISP increases the food supply at both micro and macro levels, we now stipulate that both the productivity of farming technology and the labor productivity of workers are negatively affected by increases in the incidence of undernourishment $\bar{u}$ above the baseline level of 20% in 2010 Malawi:

$$\text{Farming: } y(\theta^R, x_j, \bar{u}) = \exp\{-\gamma \cdot (\bar{u} - 0.2)\}\theta^R l_j^{\phi} x_j^{\zeta}, \ j \in \{S, B\} \tag{25}$$

$$\text{Manufacturing: } Y(K, L, \bar{u}) = K^{\alpha} \left(\exp\{-\gamma \cdot (\bar{u} - 0.2)\} A_M L\right)^{1-\alpha} \tag{26}$$

Figure 7 shows how much stronger are the social benefits of FISP upon allowing for such negative externalities arising through undernourishment. Focusing on the baseline measure of welfare accounting for transition dynamics, FISP can generate up to a 1% welfare gain if the productivity elasticity γ equals 0.75 (as opposed to a 1% welfare loss in our baseline model with $\gamma = 0$). The gradient of welfare changes is much steeper in this elasticity if we consider the long-run welfare measure. As in both cases, the "break-even elasticity"

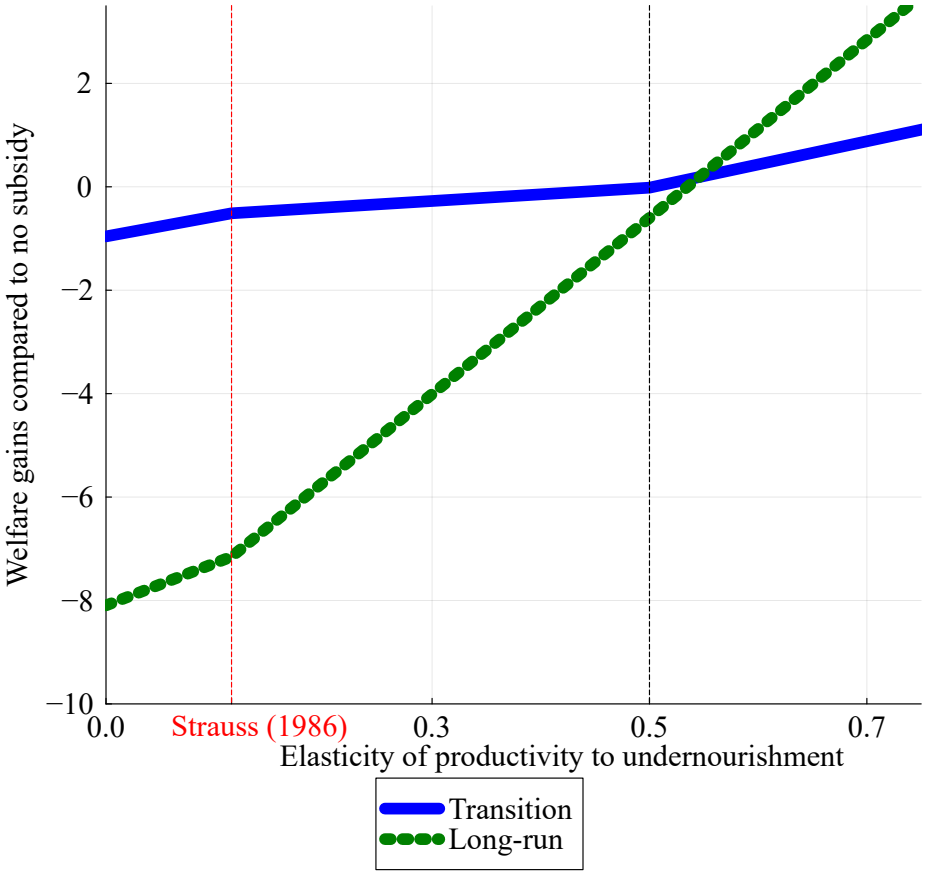


Figure 7: Welfare impact of FISP and the sensitivity of productivity to undernourishment

Note: The figure shows the welfare impact (either accounting for transition or only long-run) of introducing FISP with $\tau_S = 0.81$ and labor tax financing under different values of parameter γ in equations (25) and (26) (relative to the no subsidy equilibrium). The red line corresponds to the elasticity in Strauss [1986] of 0.1155 and the black line to the elasticity of 0.5 required for a welfare-neutral FISP.

justifying the large FISP intervention in Malawi is around 0.5, and the empirically relevant elasticity of around 0.12 from Strauss [1986] suggests that this channel may not be sufficient to justify the large input subsidy program in Malawi.[31]

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

5 Empirical validation: model vs data

This section shows that the model-generated dynamics align well with the data. In Table 7, we compare cross-sectional regressions run on data from our baseline steady-state against the data from 2010 Malawi. Then, in Figure 8 we conduct a "macro diff-in-diff" analysis of a panel of SSA countries implementing large-scale ISPs and compare those with transitions induced by FISP in our model.

5.1 Micro-evidence from Malawi

Table 7 assesses the model's predictions on the cross-sectional distribution of households in the equilibrium with subsidies, contrasted with non-targeted moments from the 2010 Malawian cross-sectional LSMS data. Motivated by Proposition 1 showing that transaction costs drive land allocation choices, we investigate the relationships between the choice of household's share of land devoted to staples and outcome variables such as the amount of fertilizer used, the gross value of harvest and the share of harvest self-consumed (unsold). While the causal relationships between our outcome and control variables run in both directions, this is so in the empirical and model-simulated datasets. As such, our aim is not to find unbiased coefficients of interest but rather to provide further evidence that our calibrated framework generates empirically plausible behavior.

To this end, we simulate half a million households in the FISP stationary equilibrium and compute standard errors by bootstrapping 1000 sample populations equal to the LSMS sample size. We remove factors not modeled in our framework from the empirical regressions by including village fixed effects and a vector of household controls such as sex, age, marital status, religion, language, schooling years of the head of household, household size, and farm size. We ensure the comparability of the estimates across regressions by normalizing all variables by their respective means.

First, there is a strong negative association between allocating more land to staples and inputs used ($\hat{\beta}^{model} = -0.82$ vs. $\hat{\beta}^{data} = -0.46$), implying that the static effect of benefiting more from FISP due to higher fertilizer use and therefore allocating more land to staples is relatively weak compared to the dynamic effect of collateral constrained or low productivity

	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.

households selecting into staple farming.

Second, negative associations between the share of land devoted to maize and gross value of harvest ($\hat{\beta}^{model} = -1.87$ vs. $\hat{\beta}^{data} = -1.12$) indicate that the cultivation of staples is not a revenue-maximizing choice, in line with the existence of credit market frictions lowering fertilizer use among the poorer staple farmers and the presence of transaction costs that lead to a shift in the crop choice.

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

5.2 Cross-Country evidence

Results from the FISP allocation show that the program generates substantial increases in agricultural productivity and reductions in undernourishment. Similarly, we showed that FISP affects migration choices and structural transformation, with the exact sign of effects depending on the program's size. We validate these predictions by comparing evidence from the event study of 10 SSA countries that introduced large-scale ISPs around the 2000s with our model's predictions. By further comparing the evolution of relative crop prices, we also

validate the quantitative importance of GE forces in altering the magnitude of all effects in our analysis.

Our approach leverages the heterogeneous timing of reforms introducing ISPs in the Callaway and Sant'Anna [2021] estimator with the control group of never-treated countries.[32] Table 8 in Appendix D summarizes the 1980-2020 FAOStat data used together with the treatment classification of countries.

Figure 8 shows evidence of the impact of ISPs on fertilizer use, agricultural yields, market prices, land allocation, and the shares of undernourished and rural populations. In the data, we find that such interventions double fertilizer use by increasing application rates by up to 10kg per ha and significantly increase yields of staples by up to 25% without affecting cash crop yields. As the share of land devoted to staples does not change on the impact of ISPs, increases in the supply of staples 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 8 p.p. (approx. 35%). We also find that the urban-rural migration decisions may indeed be responsive to the macroeconomic effects induced by ISPs, and more so in the long run. Notably, for all the variables analyzed, the assumption of parallel trends holds well, lending credence to our identification strategy.

Finally, although entirely non-targeted, our model does an excellent job of matching the signs and magnitudes of effects at work and the rate of transition dynamics. While the only exception is the counterfactual behavior of changes in the urbanization rate, we showed in Section 4.3 that our model can also well predict reductions in the share of the rural population in case of a smaller FISP.

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

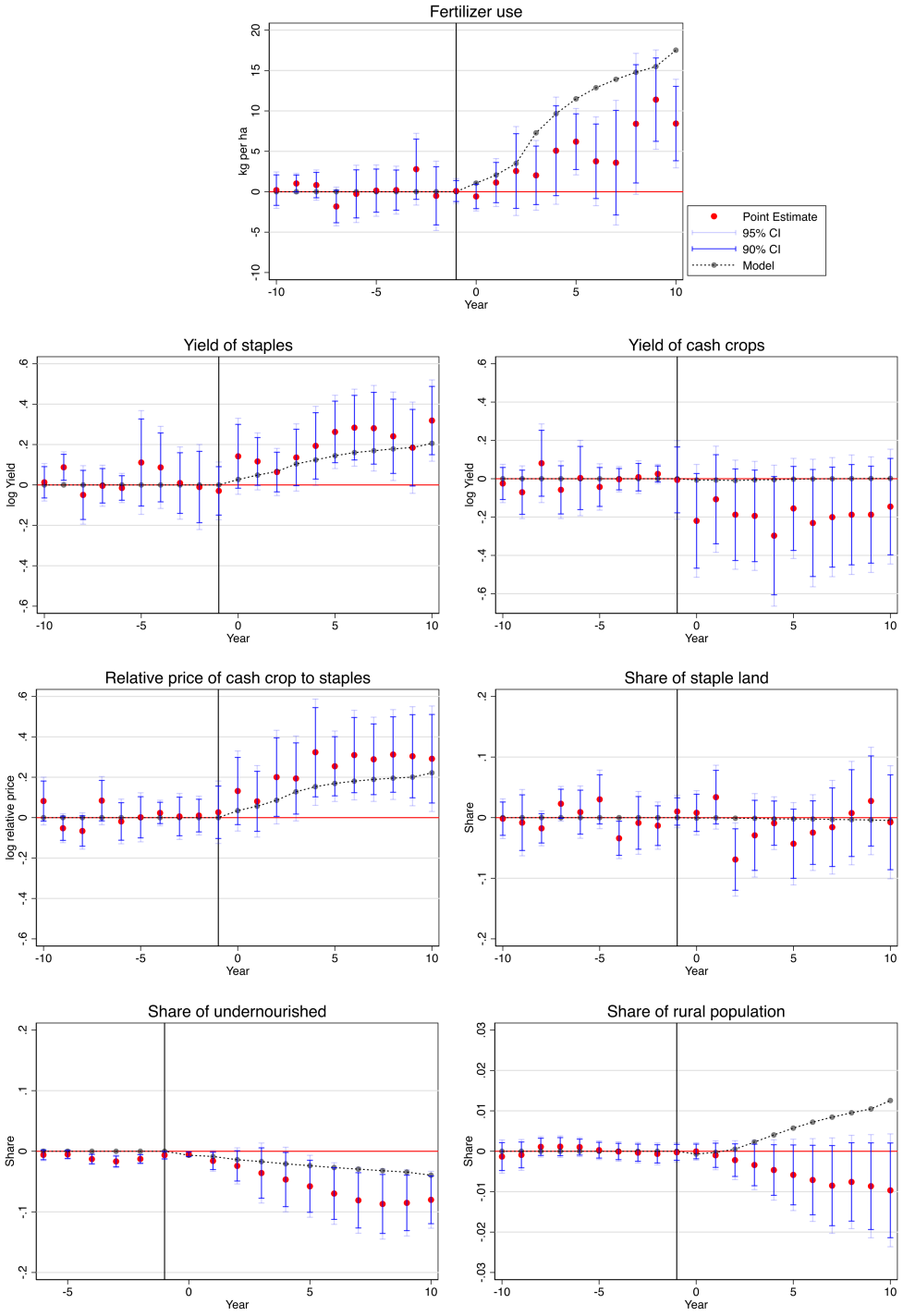


Figure 8: Event study of ISPs' impact in empirical and simulated data

Note: The figure presents the Callaway and Sant'Anna [2021] event study of introducing ISPs in SSA with the control group of countries that did not implement ISPs. Yields and relative prices are log terms, and fertilizer is in kilograms used per hectare. Standard errors are clustered at the country level. Model results refer to the transition path following the introduction of FISP in the calibrated Malawian economy with $\tau_S = 0.81$ and labor taxation.

6 Conclusion

A secure food supply is critically important everywhere, especially in countries where food shortages occur periodically. An active agricultural policy is often a popular candidate for raising living standards. Therefore, many SSA countries have implemented large-scale input subsidies that support 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 a fundamental belief in market forces in the 1970s and 80s to, starting at the end of 1990s, a gradual acknowledgment of severe frictions in developing countries that may 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 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. We also quantify the increased welfare benefits of Malawi's program in the scenario of undernourishment yielding negative externalities on productivity. 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 such as studying the optimal design of ISPs upon introducing capacity constraints on the subsidized amount of inputs awarded and active secondary markets, allowing households to overcome these institutional constraints. One could also use our framework to study the consequences of endogenous transaction costs, e.g., due to agricultural intermediaries with market power.

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Appendices

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

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:

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

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 9 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 $APG = \frac{\dot{\chi}}{1-\chi}$, 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.*

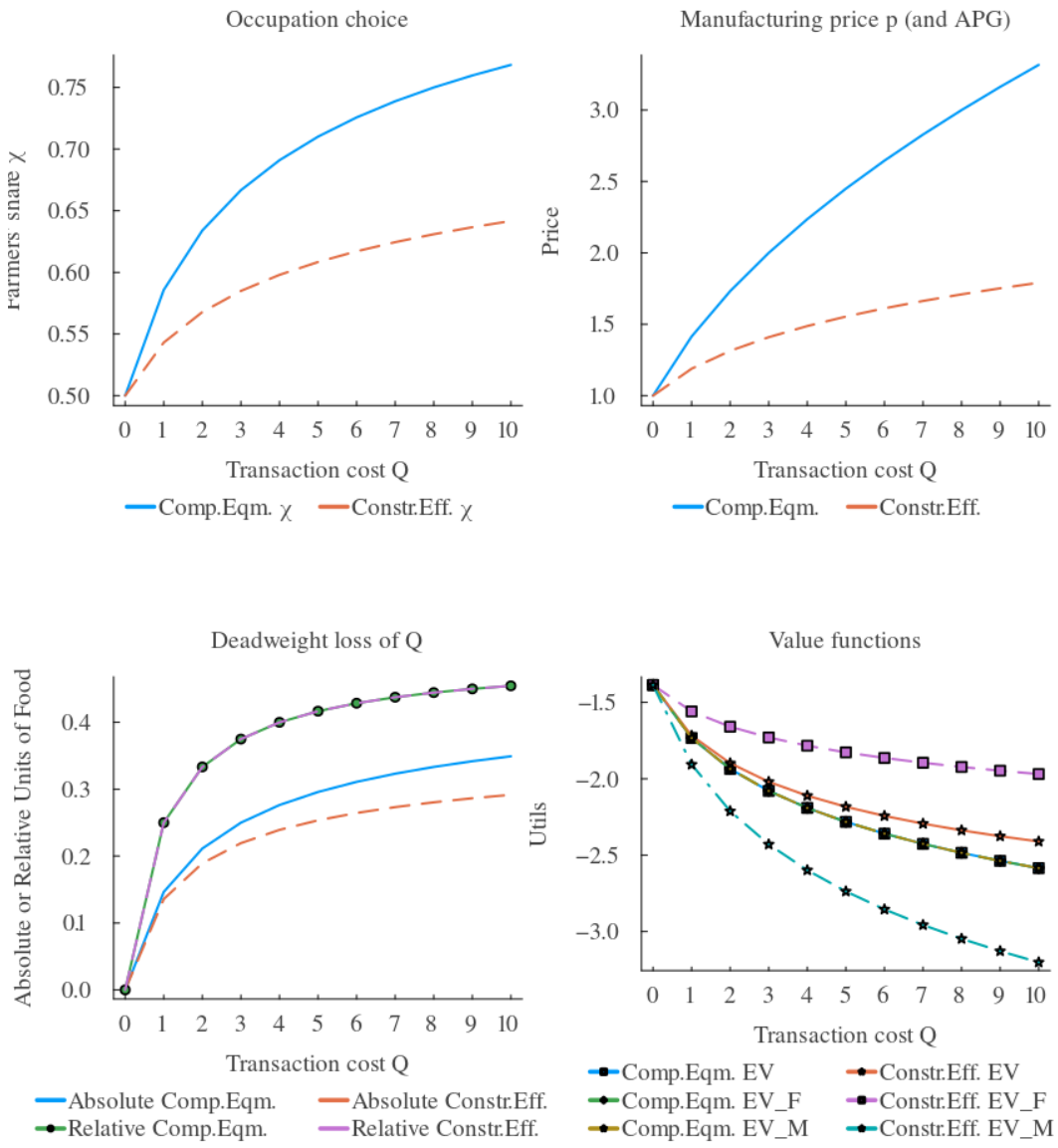


Figure 9: Competitive equilibrium and constrained efficient allocations in simple model

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 (15) as follows:

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

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

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 (18) 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.[33] Then, we approximate these decisions and outcomes for each possible value of C. Using all of those, we solve the dynamic problem (15) for optimal C, a', e'.

[33] 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 represent the shadow price of staples λ_S discussed in Section 2 by the sum of λ_2 and λ_3 for the staple farmer and of λ_2 and λ_4 for the cash crop farmer (see details below). We now show how we solve each case of occupational choice.

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 (21) 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 (25), (26) & (27) into definition of C in (19), 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 (28) 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 (as explained in Appendix C). The content of C changes though, in this case:

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

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

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

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

This case requires that $q_S > c_S$:

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

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

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

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

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

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

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

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

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

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 decisions can be separated. If it is violated, then we need to consider the case of $q_S \leq c_S$, as described below.

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

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

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

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

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

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

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

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

Taking FOCs:

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

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

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

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

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

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 (56), (57) and (58) into the definition of C in (46) 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 $P_S = \left(\psi_S^{\epsilon}(1+Q_S)^{1-\epsilon} + \psi_B^{\epsilon} p_B^{1-\epsilon} + \psi_M^{\epsilon} p_M^{1-\epsilon}\right)^{\frac{1}{1-\epsilon}}$. Production decision takes into account this higher internal price for staples and hence similar to equation

(39):

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

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 (60) and (61), and then plugging the latter into (53), 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 (68). For now ignore it, and just plug it back to the definition of C in (46):

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

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

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

Implying that:

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

Plugging (74) back into (68) allows us to arrive at the expression that can be used for solving for c_S:

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

We first find the numerical solution to (75) 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 (75) to obtain λ_S:

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

and then (74) 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:

$$\begin{aligned}
\min_{c_S,c_B,c_M,x_S,q_S,x_B,q_B,l} & c_S + Q_S \max(c_S - q_S, 0) + p_B c_B + p_M c_M - q_S - p_B q_B \\
& + (1-\tau_B)\, p_X x_B + (1-\tau_S)\, p_X x_S \\
& + \lambda_1 (C - \left(\psi_S \left(c_S - \bar{c}_S\right)^{\frac{\epsilon-1}{\epsilon}} + \psi_B c_B^{\frac{\epsilon-1}{\epsilon}} + (1-\psi_S-\psi_B)\, c_M^{\frac{\epsilon-1}{\epsilon}}\right)^{\frac{\epsilon}{\epsilon-1}}) \qquad (78) \\
& + \lambda_2 (q_S - \theta (1-l)^{\phi} x_S^{\zeta}) \qquad (79) \\
& + \lambda_3 (q_B - \theta l^{\phi} (x_B)^{\zeta}) \qquad (80) \\
& - \lambda_B (\kappa a - (1-\tau_B)\, p_X x_B + (1-\tau_S)\, p_X x_S) \qquad (81)
\end{aligned}$$

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

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

$$\begin{aligned}
\min_{c_S,c_B,c_M,x_S,q_S,x_B,q_B,l} & c_S + p_B c_B + p_M c_M - q_S - p_B q_B \\
& + (1-\tau_B)\, p_X x_B + (1-\tau_S)\, p_X x_S \\
& + \lambda_1 (C - \left(\psi_S \left(c_S - \bar{c}_S\right)^{\frac{\epsilon-1}{\epsilon}} + \psi_B c_B^{\frac{\epsilon-1}{\epsilon}} + (1-\psi_S-\psi_B)\, c_M^{\frac{\epsilon-1}{\epsilon}}\right)^{\frac{\epsilon}{\epsilon-1}}) \qquad (82) \\
& + \lambda_2 (q_S - \theta (1-l)^{\phi} x_S^{\zeta}) \qquad (83) \\
& + \lambda_3 (q_B - \theta l^{\phi} (x_B)^{\zeta}) \qquad (84) \\
& - \lambda_B (\kappa a - (1-\tau_B)\, p_X x_B + (1-\tau_S)\, p_X x_S) \qquad (85)
\end{aligned}$$

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 (88) and λ_3 from (89), equations (85), (86), (87) and (90) 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:

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

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

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

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:

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

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

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

$$= \Big[\frac{\zeta\theta}{(1+\lambda_B)}\Big]^{\frac{1}{1-\zeta}}\frac{\big(p_X(1-\tau_B)(1-\tau_S)\big)^{-\frac{\zeta}{(1-\zeta)}}}{\Big[\Big[p_B(1-\tau_S)^{\zeta}\Big]^{\frac{1}{1-\phi-\zeta}} + \Big[(1-\tau_B)^{\zeta}\Big]^{\frac{1}{1-\phi-\zeta}}\Big]^{\frac{\phi-1+\zeta}{1-\zeta}}} \tag{108}$$

$$= \Big[\frac{\zeta\theta}{(1+\lambda_B)}\Big]^{\frac{1}{1-\zeta}}\frac{\Big[\Big[p_B(1-\tau_S)^{\zeta}\Big]^{\frac{1}{1-\phi-\zeta}} + \Big[(1-\tau_B)^{\zeta}\Big]^{\frac{1}{1-\phi-\zeta}}\Big]^{\frac{1-\phi-\zeta}{1-\zeta}}}{\big(p_X(1-\tau_B)(1-\tau_S)\big)^{\frac{\zeta}{(1-\zeta)}}} \tag{109}$$

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

With $q_S \leq c_S$ the problem reads:

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

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):

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

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

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

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

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

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

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

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

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

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

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

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

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

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 (128), (129) and (132) 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 (154) and (155) in (157), we get the following expression for q_S:

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

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

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

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

From the price index equation (144) adjusted for the shadow price of staples, and the staple consumption FOC (133) combined with (130) 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 (165), 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 (165) for solving for λ_2. Do this for each θ value, and interpolate for all possible consumption values C. Let us call this approximation $c_{S,UC}^{B}(C)$ (as consumption bundle coefficients in an approximation, not related to cash crop). We do this for each case

corresponding to whether q_S is greater or smaller than c_S, we calculate TC_B and check if the working capital constraint is satisfied and $\lambda_2 \in [1, 1+Q_S]$, otherwise we set expenditures to $Y_B = \infty$.

- Then we create a second function $\lambda_{2,WCC}(C)$, for each productivity θ and wealth a, assuming that the working capital constraint is binding, i.e. that $\lambda_B > 0$. Here, we use equation (152) 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 (165), 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.

C Recursive competitive equilibrium

C.1 Equilibrium definition

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

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

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 (9)
- The aggregate allocations solve the manufacturing firm's problem in equation (15)
- the labor market clears:

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

- 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 (19) or as in Equation (18).

- 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 (21)-(23) regarding the current account clears either because K_t^F adjusts, we refer to the equilibrium as balanced current account equilibrium

C.2 Numerical implementation

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

D 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%)
Gross domestic product (USD million)	43,335	(88,093)	16,706	(45,912)
Population size (million)	34.5	(40.3)	10.7	(13.9)
Share of land irrigable	1%	(1%)	1%	(2%)

Table 8: FAO 1980-2020 panel data summary

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

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

Table 9: 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.

E Additional results

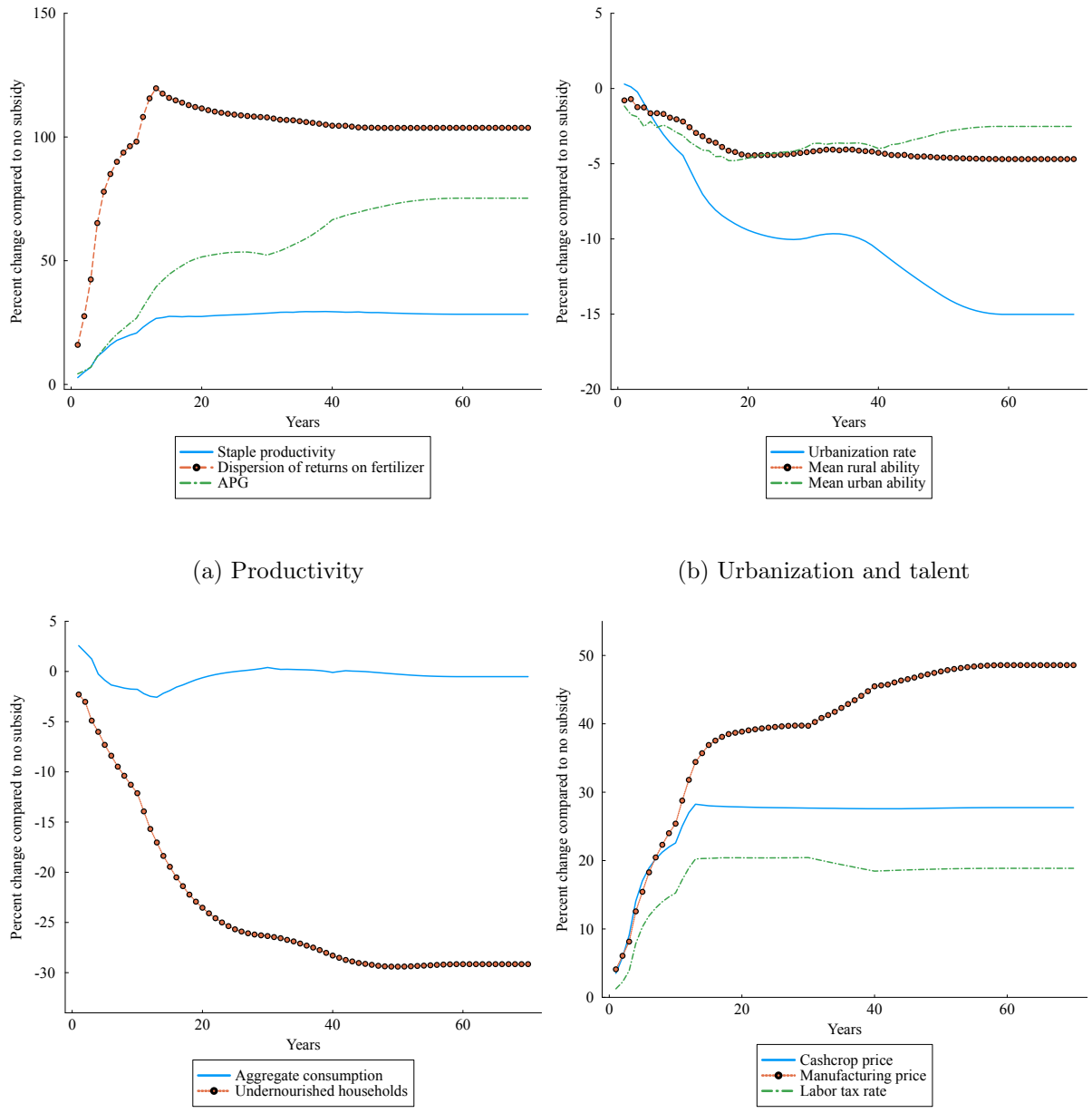
	$\log(income_{i,t}^{Urban})$	$\log(income_{i,t}^{Rural})$
Married	0.15***	-0.028
	(0.019)	(0.088)
Age	0.35***	-0.001
	(0.024)	(0.007)
Age^2	-0.004***	-0.00004
	(0.0002)	(0.00007)
Female	0.510***	-0.077
	(0.086)	(0.082)
Schooling years	1.098***	0.063***
	(0.068)	(0.013)
No. of adults in HH	0.303***	0.013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

Table 10: Heckman-corrected determinants of earnings in urban and rural panels

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

Table 11: AR1 estimates of productivity processes

Note: Table reports persistence of $\theta_{i,t}^j$ (taken as residuals in regressions of Table 10) and standard deviation of residuals $\epsilon_{i,t}^j$ in $\log(\theta_{i,t+1}^j) = \rho_\theta^j \theta_{i,t}^j + \epsilon_{i,t}^j$ with $\epsilon_{i,t}^j \sim N(0, \sigma^{j2})$ and $j \in \{R, U\}$. For our calibration, we annualize these coefficients by inverting how an AR(1) would unconditionally be observed at a tri-annual frequency. That is, we assume that $\rho_1 = \rho_3^{\frac{1}{3}}$ and $\sigma_1 = \frac{\sigma_3}{\sqrt{1+\rho_1^2+\rho_1^4}}$, with index 3 corresponding to the empirical estimates and 1 to the annualized parameters.



(a) Productivity

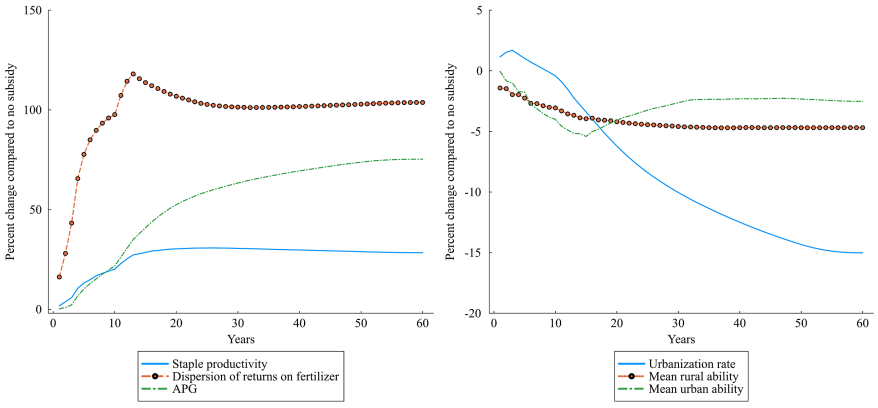
(b) Urbanization and talent

(c) Consumption

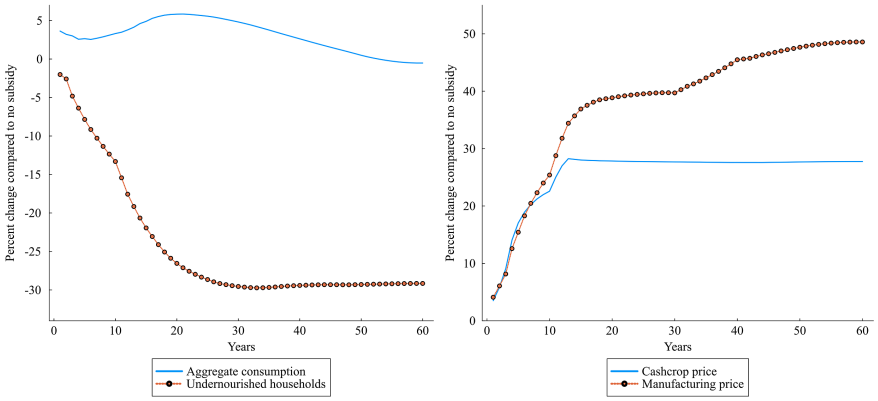
(d) Prices

Figure 10: Transitional dynamics after introducing $\tau_S = 0.81$ in Malawian economy financed through taxation

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.



(a) Productivity (b) Urbanization and talent



(c) Consumption (d) Prices

Figure 11: Transitional dynamics after introducing $\tau_S = 0.81$ in Malawian economy financed through foreign aid

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 foreign aid.