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ESSAYS ON RISK, INSURANCE, AND ECONOMIC DEVELOPMENT

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DOCTORAL THESIS

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A dissertation submitted in fulfillment of the requirements for the degree of Doctor of Philosophy in the International Doctorate in Economic Analysis. Departament d'Economia i Història Econòmica.

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To my mother, Consol.
To my father, Ovidi, in loving memory.

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Thesis Outline

Still in 2022, more than 650 million people live in extreme poverty on less than \$1.90 a day. Two-thirds of them reside in Sub-Saharan Africa, where, despite two decades of unprecedent growth, 40 percent of the population live in extreme poverty. A fundamental, and sometimes forgotten, aspect of poverty is risk. Poor people do not only need to survive with low incomes but also with very variable and unpredictable ones. Families in the poverty line do not earn 2\$ each day, but they might earn 10\$ one day and 0\$ for the rest of the week. Earnings do not only vary across days but also across years. farmers might enjoy a good harvest in a year but suffer a bad harvest in the consecutive year depending on external shocks as climate variation, crop pests, or health problems. Job and business opportunities might be abundant in a particular year and then disappear the year after. Poor people need to have some savings or insurance mechanisms to survive, but most of them lack access to formal financial markets or government safety nets. They rely on informal risk-mitigation and insurance mechanisms to survive.

This thesis is studies how risk and informal risk-dealing mechanisms affect the economic development in Africa. Since the early 90s, A large literature in economics have detailed that even in some of the poorest areas in the world insurance levels are large: the consumption of the families tends to vary little with household-specific income shocks. Large insurance levels are sustained through elaborated informal mechanisms as gift transfers embedded in social networks, informal credit markets, marriage contracts, etc.[1] Nevertheless, dealing with risk through informal mechanisms is costly. At the micro level, the literature has shown how risk and risk-mitigation schemes can be costly in terms of labor career and business investments, education, migration, and health choices. This thesis studies the cost of risk, risk-mitigation techniques, and informal insurance at the aggregate economy—its implications on growth and welfare.

In Chapter 1, *The Aggregate and Welfare Effects of Completing Financial Markets in Agriculture*, I study how completing financial markets in agricultural risk affects agricultural productivity and welfare in a poor agrarian-based economy, rural Uganda. theoretically, I develop an heterogeneous-agent incomplete markets model in which households deal with risk by: (1) accumulating wealth at

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[1] Collins et al. (2009) is a fascinating book describing the hardships of the poor to make month's end and how they achieve so through enormous effort and using a large variety of informal credit, savings, and insurance strategies. For large insurance levels see the seminal paper of Townsend (1994), and for some of the mentioned informal mechanisms see Besley (1995). Udry (1994) and Rosenzweig and Stark (1989).

a depreciation rate—insurance technique—and (2) under-investing in agricultural intermediates and shifting investment from high productive and risky crops (as bananas) to low productive and safer crops (as beans)—risk-mitigation technique. The model shows that poor households optimally under-invest in agriculture and especially under-invest in the high productive crops. As households get richer their investment in both types of crops gets closer to profit maximization. Quantitatively, I motivate and calibrate the model with data from the Ugandan National Panel Survey, a nationally representative panel household survey with rich information on household's agriculture, consumption, income, and wealth. With the calibration that matches crop's production risk, household income and consumption risk, and other relevant moments, I find the following quantitative results. Completing financial markets increases agricultural production (and producitivity) by 29 percent while costly savings decrease. The two effects translate to an aggregate consumption increase of 28 percent while the consumption Gini increases in 0.01 points. The welfare gain, which also includes the gain in reducing consumption fluctuations, is a 32 percent increase in consumption equivalent variation.

Recent studies have documented a trade-off between insurance and growth across rural and urban areas as well as across the stages of development. In chapter 2, *Do the Poor Insure their Consumption Better? Empirical Evidence from Uganda*, I study the relationship between consumption insurance and economic levels across households in Uganda. Using the detailed panel household data from the UNPS, I compute insurance tests à la Townsend (regressing changes in idiosyncratic income to changes in consumption) along the quintiles of the consumption, income and wealth distributions in Uganda. I find that the transmission of idiosyncratic income shocks into consumption is lower for poor households than for rich households. This negative relationship between insurance and economic levels is driven by rural areas where most Ugandan households reside. In urban areas, the relationship is the opposite: rich households experience much larger levels of insurance than poor households. These results provide evidence of a potential trade-off between insurance and growth at the household level.

To achieve high insurance levels, many families rely on informal insurance through social networks—that is risk-sharing among relatives, villagers, or in general, risk sharing among other individuals. In chapter 3, *Excess of Transfer Progressivity in the Village*, with Francesco Carli and Raül Santaeulàlia-Llopis, we go at the micro level and study in detail informal insurance with primary data on consumption, income, and food transfers from an entire village in Malawi. Using the income

distribution and the food transfers in the village, first, we document that the level of transfer progressivity across households is large—with an income-to-transfer elasticity of 0.60. Then, we study which risk-sharing models can account for this large progressivity. We calibrate models with limited commitment, private information, and with the two frictions together under an OLG structure to our village. We also calibrate the first best scenario, complete markets. We find that the solution of the calibrated risk-sharing models imply constrained-efficient or efficient levels of progressivity that are substantially lower than the actual levels of progressivity in the village. To explore what drives the actual allocations, we introduce wedges in the LC and PI constraints and quantitatively single out the role of the ex-ante participation constraint. Interestingly, we find that these wedges tend to disappear if we decrease current village income to past productivity levels—i.e. a pre-fertilizers era. That is, the current transfers are similar to the efficient transfers that would emerge from past economic conditions. Interpreting these past contractual transfers as social norms, our results suggest that the currently inefficient excess of transfer progressivity in the village can be the result of norms that are sluggish to adapt to economic change.

Contents

Chapter 1

The Aggregate and Welfare Effects of Completing Financial Markets in Agriculture

This paper investigates the effects of completing financial markets in a poor agrarian-based economy: rural Uganda. To do so, I build a heterogeneous-agent incomplete markets model with endogenous agricultural income risk. Under the model, low-wealth households give up profitability to reduce risk exposure: they under-invest in inputs and shift inputs usage from a high productive and riskier technology—high crops—to a less productive and safer technology—low crops. I calibrate the model using the Ugandan National Panel Survey and compare it to a counterfactual economy with complete markets in agriculture. Quantitatively, I find the following results. First, completing financial markets increases agricultural production by 29 percent. It increases inputs usage and leads to a more efficient allocation of inputs within households—across technologies—and across households. Second, costly precautionary savings decrease. The two effects together lead to significant gains in consumption across the entire distribution, although consumption inequality increases. Altogether, completing financial markets in agriculture generates a welfare gain of 32 percent in consumption terms.

1.1 Introduction

The aggregate costs of incomplete markets has been an important macroeconomic question since the work of Lucas (1987) and a significant literature that followed after.[1] In developing economies, there has been extensive work on the impacts of risk and the levels of market incompleteness, yet aggregate evaluations have not been performed. This work aims to contribute to that by studying the aggregate effects of completing financial markets in the context of a poor agrarian-based economy.

In this context, households deal with risk with a large variety of informal strategies. Given an income process, households can smooth consumption through self-insurance and risk-sharing with other households —*risk-coping mechanisms*. The literature on insurance in developing countries shows that households can cope with idiosyncratic income risk up to a high degree but not completely, Townsend (1994) and other works.[2] If coping mechanisms are not perfect, households can mitigate risk exposure through income strategies —*income smoothing*. Yet most of the time at the cost of lower expected returns. The existing literature largely studies each risk-dealing mechanism in isolation, but they interact with each other (Morduch (1995)). There is micro evidence showing that better access to risk-coping mechanisms reduces income smoothing and therefore increasing profitability. When farmers in developing countries are offered insurance products, they tend to take riskier and more productive decisions, for example, higher fertilizer usage, Karlan et al. (2014), and shifting to more productive crops, Mobarak and Rosenzweig (2013), and Cai (2016).

In this paper, I extend a heterogeneous-agent incomplete markets model by incorporating both risk-coping and income smoothing mechanisms together. With this model, I evaluate the effects of completing financial markets in agriculture on aggregates—inputs usage, agricultural production and savings—and on welfare aspects—the consumption distribution, consumption volatility, and an aggregate welfare measure. In this context, this paper has two main contributions. First, in line with Donovan (2021) findings, this work highlights the importance of completing financial markets to increase productive investments in agriculture and lead to a more efficient allocation of inputs. To this respect, I extend to Donovan (2021) by showing that risk induces misallocation in agriculture also through

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[1] See, for example, Ríos-Rull (1994), Krusell and Smith (1998), Otrok (2001), Storesletten, Telmer, and Yaron (2001), De Santis (2007), Krusell et al. (2009), Dyrda and Pedroni (2018).

[2] Recent papers on insurance in developing countries include: Chiappori et al. (2014), Santaeulalia-Llopis and Zheng (2018), De Magalhães and Santaeulàlia-Llopis (2018), and Kinnan (2021).

technology choices within the agricultural sector and across households with different permanent components. Thus, this work theoretically and empirically emphasizes the importance of risk and technology choice in the context of agriculture. Second, this paper provides a careful welfare evaluation of the gains from completing markets by matching the consumption distribution and the consumption risk observed in the data. Consequently, the welfare results of this paper give an upper bound of the potential welfare gains of insurance policies in agriculture in developing countries. On this line, the model offers a framework to study agricultural policies typically applied or studied in the developing world—as rainfall insurance, input-subsidy schemes, or improved storing technologies.

The model represents an economy with households that ex-ante only differ in a permanent component on agricultural production, that live infinitely, and have standard preferences. Households can save in a risk-free asset at a depreciation rate and borrow up to an exogenous borrowing limit. Households obtain income from three sources: from investing in a high-returns and high-risk technology, high crops, from investing in a low-returns and low-risk technology, low crops, and from an exogenous non-agricultural income process. The economy represents a world with risk, where each household suffers idiosyncratic shocks on the different sources of income, and there are no aggregate shocks. Under this framework, there are two main mechanisms by which households deal with risk. The first mechanism, common to standard incomplete markets models, is precautionary savings. Households accumulate wealth to cope with the risk. The second mechanism, precautionary income choices or income smoothing, under which households with low wealth levels under-use inputs in both crops and shift the usage of inputs from high-returns crops to low-returns and safer crops to mitigate risk exposure.

I discipline the model to the region with the Ugandan National Panel Survey (UNPS), a nationally representative panel household survey with exhaustive information on agriculture, consumption, income, wealth. To motivate the model, I explore the agricultural production across crops and document two main findings. First, there is a strong positive correlation between crops' monetary yields and their riskiness. Crops that on average deliver higher yields such as plantain bananas, rice, and sugarcane, are associated with more volatile returns. Crops that deliver lower yields such as beans, cassava and finger millet, are associated with less volatile returns. Second, the household's share of agricultural production from the high-yield crops increases along with the wealth distribution. Households in the bottom 20 percent of the distribution obtain most of their agricultural production from low-yield crops; in comparison, households in the top 50 percent obtain most of their agricultural production from high-yield crops. Then, with the detailed questions about consumption, income, and wealth, this work computes such variables and their distributions for one of the poorest economies in the world.

I calibrate the model with the micro-data from the UNPS to key moments on agriculture, income, and liquid wealth in rural Uganda. With the calibrated model in hand, this paper first investigates the capacity to replicate key moments in the data. The framework of incomplete markets provides a theory for wealth and consumption inequality because their distributions are endogenous to the model.[3] Thus, one of the main objectives of this literature has been to account for the earnings, income, wealth, and consumption distributions mainly for the United States and other rich economies—e.g.. Nevertheless, for developing countries, we know little about the distributions of these key macroeconomic variables. De Magalhães and Santaeulàlia-Llopis (2018) provide a detailed description of such distributions for some countries in Sub-Saharan Africa. To the best of my knowledge, this work is one of the first to study the distributions of consumption, income, and wealth for an economy in a developing region using a quantitative theory. On this line, the calibrated model accurately replicates the consumption distribution, approximates relatively well the income distribution, and falls short on the wealth distribution. The model closely approximates the consumption risk observed in the data with standard and untargeted preferences on consumption. Having a close approximation of the entire consumption distribution and the consumption risk level in the economy are key aspects to discipline the welfare evaluation.

The paper's main results are obtained by comparing the benchmark economy with a counterfactual economy where the financial markets in agriculture are complete. To do so, I develop a planner's problem that replicates the competitive equilibria allocations of agricultural inputs and consumption under complete markets in agriculture. Under this case, agricultural inputs allocations are such that households maximize discounted expected profits. Considering that the focus is centered on agricultural decisions, I do not complete the markets for the non-agricultural income process. Instead, I assume that agents deal with these risky earnings under the financial market of the benchmark economy. By comparing the benchmark model with this counterfactual world, I obtain the main

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[3] incomplete markets models were orginially developed by Bewley (1986), Imrohoroğlu (1989), Huggett (1993), Aiyagari (1994).

results of the paper.

Completing financial markets in agriculture increases agricultural output by 29 percent. This output increase comes from higher usage of inputs, which increases by 57 percent, and from a more efficient allocation of the inputs. Within households, resources are transferred from the low-returns crops to the high-returns crops, while across households, resources are transferred from a combination of wealth-rich households to wealth-poor households and households with low agricultural components to households with high agricultural components. The increase in agricultural production leads to a 19 percent increase in household income. When financial markets in agriculture are complete, demand for precautionary savings falls. Given that in this economy, saving is costly at a depreciation rate, the impact on aggregate consumption is larger: average consumption increases by 28 percent. Another welfare-enhancing effect of completing markets is that average household consumption fluctuations decrease by 67 percent.[4]

Completing markets have substantial effects on the cross-sectional distributions of consumption, income, and wealth. Nevertheless, the numerical results suggest that the consumption distribution would slightly change: the consumption Gini index increases by 1 point. Completing markets has an egalitarian effect: consumption allocations no longer depend on agricultural shocks realizations. Nevertheless, in the calibrated economy, two inequality-enhancing effects outweigh the former effect. First, households with high permanent agricultural components experience the largest increase in agricultural production from completing markets. In the stationary equilibrium, these households are not uniformly distributed, but they are typically concentrated in the middle and top of the consumption distribution. Second, completing markets decreases costly precautionary savings, which are highly concentrated at the top of the distribution. With the three effects together, completing markets increases slightly proportionally more the consumption of the households at the middle-top of the distribution than at the bottom.

All these effects have important and heterogeneous effects on welfare. I compute the ex-ante welfare measure of completing markets in terms of consumption equivalent variations to provide an aggregate measure of them. Households would need to experience a 32 percent in their lifetime consumption to be indifferent between being born in the incomplete markets world and the world with complete markets in agriculture.

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[4] Average household variance over-time of the log of residual consumption decreases from 0.11 to 0.04.

Related Literature. This paper speaks and contributes to different pieces of literature. In terms of the framework, it relates to the macroeconomic literature on incomplete markets with investment risk. Besides other works, within this literature, Acemoglu and Zilibotti (1997) introduce costly diversification to provide a theory of development; Angeletos (2007) includes capital investment risk to study aggregate savings and income; while Quadrini (2000) endogenizes investment risk with entrepreneurial choices. On this line, the most related paper to this work is Donovan (2021). Under a general equilibrium model including agricultural and industrial sectors, the author studies how completing financial markets in agriculture increases agricultural TFP in India and reduces the observed cross-countries agricultural productivity gap. I contribute to his work in two aspects. First, I show that uninsurable risk leads to under-usage of inputs *and* redirects inputs usage to low productive technologies in agriculture *and* leads to misallocation across households with different permanent components. Second, I provide the welfare gains of completing financial markets in agriculture by carefully matching the consumption distribution and the consumption volatility observed in the data. This paper also relates to other studies investigating the low agricultural productivity in developing economies—Restuccia, Yang, and Zhu (2008), Yang and Zhu (2013), Lagakos and Waugh (2013), Adamopoulos and Restuccia (2014), Gollin, Lagakos, and Waugh (2014), and Chen (2017)—and particularly, to those studies focused on Sub-Saharan Africa—Gollin and Rogerson (2014), Restuccia and Santaeulália-Llopis (2017) and Chen, Restuccia, and Santaeulàlia-Llopis (2021). I contribute to that literature by showing that uninsurable risk leads to endogenous misallocation of agricultural inputs across crops and households. Most previous works in agriculture work with one technology function, here I show that it is important to account for technology choices in the agricultural world. By studying the welfare effects of incomplete markets in rural Uganda, this paper relates to the aforementioned literature on insurance in developing economies. Concerning this literature, this paper quantifies that even in the context of high consumption smoothing, the welfare impact of incomplete markets in the rural developing world might be large. The distortions on income and savings choices to obtain a smoothed consumption profile are important and translate to several losses in economic growth. In terms of the microeconomic literature, this work is heavily motivated by Rosenzweig and Binswanger (1992) work, while it also relates to the works of Morduch (1995) and Dercon and Christiaensen (2011). Finally, this paper can potentially contribute to the more recent literature studying insurance interventions in agriculture—Mobarak and Rosenzweig (2013), Karlan et al. (2014), Cai (2016), Cole and Xiong (2017). In this respect, In my immediate future research, I plan to introduce index-based insurance policies in my model to assess how much these policies account for the welfare gains of completing financial agricultural markets that I find in this paper.

Section 1.2 provides empirical motivation of the production functions and the income smoothing channels of the model. Section 3.3 presents the model, section 3.2 describes the data and measurement of the main variables, while section 3.4 describes the calibration procedure. In terms of results, section 1.6 discusses the main results based on the counterfactual exercise, while section 3.7 concludes.

1.2 Empirical Motivation

This section presents empirical evidence on the two production functions presented in the model: a high-returns and high-risk technology—high crops—and a low-returns safer technology—low crops. There is micro evidence showing that insurance products lead farmers to switch towards crops that are riskier but also more profitable.[5] To explore whether Ugandan farmers face a similar trade-off between productivity and risk at crop selection, here I study the relationship between monetary yields and risk across the main crops cultivated in Uganda.

The UNPS offers exceptionally rich agricultural data at the household level. After each of the two harvesting seasons, households are asked for their agricultural production and inputs usage. From the production side, households are questioned on the total production, the production devoted to sales, own consumption, gifted to other households, stored, for feeding animals, and elaborate food products. Households can report such production in a large variety of units including non-standards ones as dishes, pales, bunches, etc. To convert all agricultural production to kilograms, I computed the median conversion rates to kilograms reported by the households for each season, crop, and unit combination.

Most works on agricultural economics focus on quantity yields in terms of kilogram production per land unit. Yet, since the purpose here is to perform a comparison of economic yields across crops, it requires the use of a monetary measure of the yield. Given that a large fraction of the agricultural production is not sold,

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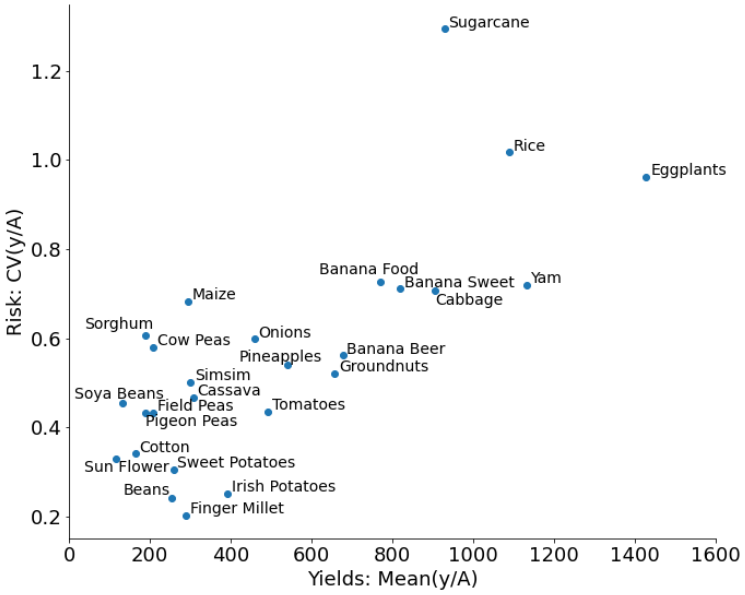
[5] in China, Cai (2016) finds that government-subsidized crop insurance raised the take-up of tobacco, a high-risk and high-return crop. In India, Mobarak and Rosenzweig (2013) have preliminary evidence that rainfall insurance products, which were offered under an experimental set-up, lead farmers to plant a riskier and more profitable portfolio of rice varieties.

assigning an adequate monetary measure to the unsold production is key. To do so, this work follows the procedure in De Magalhães and Santaeulàlia-Llopis (2018) and values unsold production using median consumption prices at the district level. For a more detailed explanation, see section 3.2. Dividing this measure of agricultural revenues over the land that each household devoted to the specific crop, one obtains a measure of crop monetary yields at the season and household level.

FIGURE 1.1: The Trade-off between Crops Monetary Yields and Risk in Uganda



Notes: The crops yields average and coefficient of variation are computed across variation at the seasonal level: I compute the average crop production in each season across households, and then use these averages as the observations to compute the measures. I include the main crops in Uganda that are cultivated with less than 2 years since planting. Data: UNPS first five waves.

Figure 1.1 plots the average yield and the coefficient of variation along the main crops cultivated in Uganda.[6] The correlation between crop yields and risk in the Figure is 0.81. Table 1.1 explores this association in more detail. In the first column of Table 1.1, pooling together households and waves observations, I compute the correlation between the average yields of the crops and three measures of risk of the yields of the crops: the standard deviation (SD), the coefficient of variation (CV), and the Gini. There is a strong positive correlation between crop yields and risk along with the three measures of risk.

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[6] The crops yields average and coefficient of variation are computed across variation at the seasonal level. first, I compute the average crop production in each season across households, and then use these averages as the observations to compute the measures. Figure 1.1 includes the main crops in Uganda that can be cultivated with less than 2 years since planting.

Note that by pooling together households and waves observations, the dispersion of the yields could be strongly driven by differences across household characteristics. To account for that, In the second column of Table 1.1, I compute the correlation of crops' average yields and measures of risk with variation only across waves. Each observation is the crop average yield in the specific wave and then given these waves observations, I compute the average of the yields, the measures of risk, and the correlation between them. Again, there is a strong positive correlation between average yields and the measures of risk. Then, to account for geographic heterogeneity, in columns three to six of Table 1.1, I repeat the same procedure but separately for each of the four administrative regions in the country: Central, East, North, and West. In every region, there is a strong positive correlation between yields and risk. Finally, considering that some of the crops are long-term investments which could be a source of spurious correlation, I recompute all the correlations aforementioned but excluding the crops that take more than two years since planting to be suitable for harvesting—crops like avocados, cocoa, mangoes, oranges, tobacco, or tea. The correlations between average yield and the measures of risk are again strongly positive by pooling households and waves together, or grouping across waves, and across the different regions of Uganda.

TABLE 1.1: Correlation Average Yields and Risk Measures among Crops.

Risk Measures	**Correlation**					
	Households-Waves	Variation across Waves				
		Nationwide	Central	Eastern	Northern	Western
All crops						
SD	0.97	0.99	0.99	0.94	0.98	0.84
CV	0.93	0.61	0.76	0.69	0.69	0.29
Gini	0.54	0.57	0.79	0.78	0.81	0.74
Excluding long-term crops						
SD	0.63	0.92	0.99	0.84	0.98	0.91
CV	0.45	0.81	0.83	0.47	0.69	0.27
Gini	0.63	0.83	0.82	0.75	0.81	0.58

Notes: In column (1), I consider the crops that at least had 50 household-season observations. For columns (2) to (6) I consider the crops that at least had 25 observations in each wave. To avoid confounding effects with long-term investments, in rows (4) to (6), I omit the crops that require at least 2 years after planting to generate yields. Data: UNPS first five waves.

The preferred specification which will be further used consists of the results in the crops when variation is computed across waves and long-term crops are excluded.[7] Under these crops, I group those of them above the median yield as high crops while those below it as low crops. The high crops are banana beer, banana food (matooke), banana sweet, cabbage, eggplants, groundnuts, Irish potatoes, onions, pineapples, pumpkins, rice, sugarcane, tomatoes, and yam. While the low crops are beans, cassava, cotton, dodo, cow peas, field peas, finger millet, maize, pigeon peas, simsim, sorghum, soya beans, sunflower, and sweet potatoes. Figure A.1 in the appendix shows the correlation plots between crops average yields and their coefficient of variation for the different specifications—pooling households and waves, across waves, across geographical units. Across specifications the high and low crops tend to vary little. In the case of using variation only across waves or variation across households and waves, the list of high crops and low crops is the same. while for the specifications across geographic units, there is more variability.

Most farmers in Uganda grow both types of crops. Table A.7 shows the proportion of households that grew low crops, high crops, and both of them per each wave; while Table A.5 provides sample statistics on both categories of crops. In the average wave, 63 percent of households grew high crops while 96 percent grew low crops.

Next, in line with the evidence in Rosenzweig and Binswanger (1992), I study the crops portfolio along with the wealth distribution of Ugandan farmers. Figure 1.2 a) plots the shares of high and low crops on total household agricultural production along 5 percent bins of the wealth distribution. To reduce the noise from income shocks and measurement error issues, household observations on crop production and wealth are computed as the average across the five waves.

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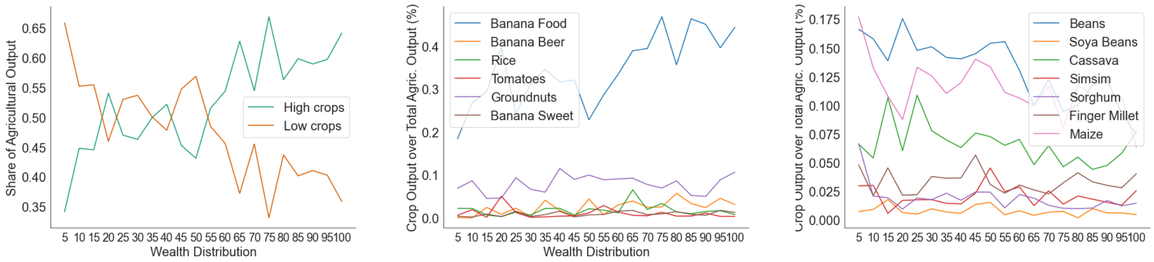
[7] Long-term crops are excluded given that the model does not consider fixed costs or time costs. Moreover, their valuation of the yields might be biased given that observations of farmers in the early stages of crop development are also included in.

FIGURE 1.2: Low vs High Crops Production along the Wealth Distribution



(A) High vs Low Crops

(B) High Crops

(C) Low Crops

Notes: crop production is measured in monetary terms using median consumption prices to account for non-sold agricultural production. The lists of the crops grouped in high crops and low crops is presented in section 1.2. Farmer's wealth includes land value, household assets, livestock, and farming capital. For each farmer, crops' production and wealth observations are averaged across waves. Data: UNPS first five waves.

The share of agricultural production coming from low crops and from high crops changes substantially along with the wealth distribution. For the poorest households in the economy, within the 0–5 and the 5–10 percent bin, around 60 percent of the total production comes from low crops while 40 percent is from high crops. As households become richer, the share of low crops in total production decreases. For households in the middle of the distribution, production comes roughly equal from low and high crops. While for households in the top of the wealth distribution, 80–85 to 95–100 bins, their agricultural income comes roughly 60 percent from high crops, 40 percent from low ones.

Plot 1.2 b) shows the shares of the 6 most cultivated high crops, while plot 1.2 c) the 6 most cultivated low crops along the wealth distribution. For the high crops, one observes that their increase in the shares of production along the wealth distribution comes mainly from banana food, matoke, the East African Highland bananas which are a main staple crop in the region. While for the wealth bottom 5 percent matoke represents 20 percent of the total production, for the wealth top 25 percent it represents more than 40 percent of the total agricultural production. From low-returns crops like beans, maize, and cassava one observe a steady decrease in the shares of total production as households wealth move to the top of the distribution. For both beans and maize, their shares go down roughly from 16 to 10 percent.

To check whether the trends observed in Figure 1.2 are significant and robust to different measures of household income and wealth, Table A.1 in the appendix provides the estimates of the elasticity of the proportion of output from high crops over output from low crops with respect to household consumption, income, wealth, and land size. The elasticities are significantly positive and large, while the R^2 of some of the regressions is also sizeable. Poorer households proportionally obtain their income more from low-returns crops while rich ones more from high crops.

1.3 Model

The model describes an agricultural economy where there is only one type of agents, households, which their only ex-ante difference is in a permanent component in agriculture $z \in \{z_l, z_{lm}, z_m, z_{mh}, z_h\}$. The economy is populated by a continuum of them with measure one.

Preferences. Households live infinitely and maximize expected utility

$$\mathbb{E}_0 \left[\sum_{t=0}^{\infty} \beta^t u(c_t) \right] \qquad u(c) = \frac{c^{1-\rho}}{1-\rho}$$

where $\beta \in (0,1)$ is a discount factor, $\mathbb{E}_0$ is the expectation at time 0. The utility flow at time t has ρ consumption curvature.

Technologies and shocks. Households obtain income from investing in two agricultural technologies and from an exogenous non-agricultural earning process. In terms of agriculture, households invest in a high-returns and riskier agricultural technology—y_h—, and a less productive and safer agricultural technology—y_l. Each technology is subject to household idiosyncratic shocks: θ and ε respectively. The production functions take the following form

$$\begin{aligned} y^h &= \theta z A (m_h)^{\alpha} \\ y^l &= \varepsilon z B (m_l)^{\gamma} \end{aligned}$$

where m_h and m_l are household's investment choices on each technology; z is the household-specific permanent component, γ, α represent the elasticity of inputs usage on the agricultural output; A, B are technology-neutral productivity factors.[8] The permanent component z covers households heterogeneity beyond

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[8] Note that the model assumes two decreasing returns to scale technologies with no fixed costs. Thus, the technological choice is not discrete but continuous: in optimality, all households will be investing in both crops. The first motive to use such specification and not a discrete choice is the evidence that most households in Uganda grow both low crops and high crops. The second

productivity differences. For example, an important aspect of agricultural heterogeneity is land endowments. Given that in Sub-Saharan Africa land tends to be in fixed supply, Restuccia and Santaeulália-Llopis (2017), in this work heterogeneity in land endowments is captured in the permanent component of the households.

The total agricultural output of the household is the sum of production from high and low crops, $y^a = y^h + y^l$. Then, the idiosyncratic shocks θ and ε are independent across households i and time t, identically distributed, and their logs jointly follow a multivariate normal distribution.

$$ln\theta_{it}, ln\varepsilon_{it} \sim MN\left(\begin{bmatrix}0\\0\end{bmatrix}, \begin{bmatrix}\sigma_\theta^2 & \sigma_{\theta\varepsilon}\\ \sigma_{\theta\varepsilon} & \sigma_\varepsilon^2\end{bmatrix}\right)$$

Where σ_θ^2 represents the variance of the high technology shock, σ_ε^2 the variance of the low technology shock, and $\sigma_{\theta\varepsilon}$ represents the covariance between the two shocks. Note that shocks take positive values—-production can be negative—and they are normalized $\bar{\theta} = \int \theta log MN(\theta, \varepsilon) d\theta = 1$ and $\bar{\varepsilon} = \int \varepsilon log MN(\theta, \varepsilon) d\varepsilon = 1$. Households have complete information on the shocks process and take expectations according to it.

Besides the agricultural income, households also obtain non-agricultural earnings from an exogenous stochastic process y_{na}, defined by the following autoregressive process of order one.

$$lny_{it+1}^{na} = b + \rho_z lny_{it}^{na} + u_{it} \qquad\qquad u_{it} \sim N(0, \sigma_{y_{na}}^2)$$

Risk-coping mechanism. There is ample evidence that households in rural-poor regions can smooth consumption through informal risk-coping mechanisms. Households use self-insurance strategies as crop storage, Fafchamps, Udry, and Czukas (1998), Kazianga and Udry (2006); livestock holdings, Rosenzweig and Wolpin (1993); and other buffer stocks, Paxson and Chaudhuri (1994); to smooth consumption. To incorporate that in the model, I assume households can save in a risk-free asset a at depreciation rate δ. Besides self-insurance, households also cope with risk by participating in risk-sharing schemes, as village level or local networks—e.g Udry (1994)—, kinship or caste networks—e.g. Kinnan and Townsend (2012), Munshi and Rosenzweig (2016). In the context of Sub-Saharan

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motive is that by precisely avoiding fixed costs, the model can inform better of the impact of uninsurable risk.

Africa, Malawi, De Magalhães and Santaeulàlia-Llopis (2018) find that an important part of household consumption comes from transfers from other households. Thus, in the model, I assume that besides saving, households can also borrow up to a borrowing limit $\underline{a}$ which is set based on the consumption coming from gifts in the Ugandan data. Karaivanov and Townsend (2014) estimate and contrast several models of exogenously incomplete markets—autarky, savings, savings-borrowing—endogenously incomplete markets—moral hazard, limited commitment—and full insurance using data on Thai households. One of their main findings is that the regime with exogenously incomplete savings and borrowing provides the best fit to the data for the rural sample.

1.3.1 Household's Problem

Consider the household's problem of the previous economy under stationarity. Households maximize lifetime welfare by choosing consumption, savings, and inputs levels along the periods. The problem in recursive form is defined by the Bellman equation associated with the state space of the economy. I define the state space of the economy in terms of three state variables: x, z, y_{na}. State variable x is a type of "cash on hand" variable, which is equal to the sum of agricultural income and asset returns. To correctly form expectations, households need to keep track of their permanent component z, and the current realization of the non-agricultural income process y_{na}. Having defined the state variables, the Bellman equation of the household problem is

$$V(x,z,y_{na}) = \underset{a',c,m'_h,m'_l}{\text{Max}}\ u(c) + \beta \mathbb{E}\left[V(x',z,y'_{na})\right] \tag{1.1}$$

subject to

$$a' \geq \underline{a} \tag{1.2}$$

$$c(x,z,y_{na}) + a'(x,z,y_{na}) + pm'_h(x,z,y_{na}) + pm'_l(x,z,y_{na}) = x + y_{na} \tag{1.3}$$

$$x' = \theta' zA\left(m'_h(x,z,y_{na})\right)^{\alpha} + \varepsilon' zB\left(m'_l(x,z,y_{na})\right)^{\gamma} + (1-\delta)a'(x,z,y_{na}) \tag{1.4}$$

$$ln\theta', ln\varepsilon' \sim MN(0,\Sigma) \tag{1.5}$$

$$lny'_{na} = b + \rho_y lny_{na} + u, \qquad u_t \sim N(0,\sigma_z^2) \tag{1.6}$$

where c, a', m'_h, m'_l are the policy functions that solve the household problem in state (x,z,y_{na}) and V is its associated value function. To reduce notation, current period variables x do not carry subscript t, while next period variables are denoted by the apostrophe sign, x'. Households know the process of the shocks and take expectations of future variables according to it—$\mathbb{E} := \mathbb{E}_{\theta,\varepsilon,y_{na},z}$. I omitted the dependency of the aggregate state's distribution on the household problem since I focus only on the stationary equilibrium.

Given that policy functions are the ones that maximize the value function, the derivatives of $a', m'_h m'_l$ with respect to V evaluated at the policy function value are equal to zero. Combining this envelope condition, Benveniste and Scheinkman (1979), with the first order conditions of the problem, the solution of the previous Bellman equation is characterized by the following set of equations

$$u_c\left(c(x,z,y_{na})\right) \geq \beta(1-\delta)\mathbb{E}\left[u_c\left(c(x',z,y'_{na})\right)\right] \tag{1.7}$$

$$pu_c\left(c(x,z,y'_{na})\right) = \beta\mathbb{E}\left[u_c\left(c(x',z,y'_{na})\right)\theta' zA\alpha\left(m'_h(x,z,y_{na})\right)^{\alpha-1}\right] \tag{1.8}$$

$$pu_c\left(c(x,z,y_{na})\right) = \beta\mathbb{E}\left[u_c\left(c(x',z,y'_{na})\right)\varepsilon' zB\gamma\left(m'_l(x,z,y_{na})\right)^{\gamma-1}\right] \tag{1.9}$$

and the budget constraint is

$$c(x,z,y_{na}) = x + y_{na} - a'(x,z,y_{na}) - pm'_h(x,z,y_{na}) - pm'_l(x,z,y_{na}) \tag{1.10}$$

the solution of the household problem is a set of policy functions in consumption, savings, and technological inputs, $c(x,z,y_{na})$, $c(x',z,y'_{na})$, $a(x,z,y_{na})$, $m'_h(x,z,y_{na})$, $m'_l(x,z,y_{na})$, that solves the system (1.7)–(1.8)–(1.9)–(1.10). To see some of the implications of risk in households choices, first note that equations (1.8) and (1.9) can be rewritten as

$$p = \frac{\mathbb{E}\left[u_c\left(c(x',z,y'_{na})\right)\theta'\right]}{u_c\left(c(x,z,y_{na})\right)}\beta zA\alpha\left(m'_h(x,z,y_{na})\right)^{\alpha-1} \tag{1.11}$$

$$p = \frac{\mathbb{E}\left[u_c\left(c(x',z,y'_{na})\right)\varepsilon'\right]}{u_c\left(c(x,z,y_{na})\right)}\beta zB\gamma\left(m'_l(x,z,y_{na})\right)^{\gamma-1} \tag{1.12}$$

Where p is the marginal cost, $zA\alpha(m'_h(x,z,y_{na}))^{\alpha-1}$ and $zB\gamma\left(m'_l(x,z,y_{na})\right)^{\gamma-1}$ are the marginal revenue of using inputs m_h and m_l, respectively. First note that if households can perfectly smooth consumption across states, then, optimal inputs usage is such that the discounted expected marginal return equalizes the price. Under this case, we are in profit maximization, which I am going to use for model comparison.[9]

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[9] Profit maximization implies marginal cost equalizes expected discounted marginal return:

$$p = \beta\mathbb{E}_\theta\left[\theta' zA\alpha m_h^{\alpha-1}\right] = \beta zA\alpha m_h^{\alpha-1} \tag{1.13}$$

$$p = \beta\mathbb{E}_\varepsilon\left[\varepsilon' zB\gamma m_l^{\gamma-1}\right] = \beta zB\gamma m_l^{\gamma-1} \tag{1.14}$$

If there is no perfect consumption smoothing across states, then the ratio of marginal utilities will differ from one. Under this context where the assets returns are negative by a depreciation rate, the ratio in expressions (1.11) and (1.12) will be lower or higher than one depending on the wealth level of the households. For the wealth-poor and the majority of households, it will be larger than one: the marginal utility of consuming today will be larger than the expected marginal utility of consuming tomorrow weighted by the agricultural shocks. Thus, marginal returns are going to be above marginal costs. Given that production functions have decreasing marginal returns, this implies that poor households under-invest in inputs with respect to profit maximization allocations. They optimally need to under-invest to reduce income risk, and thus reduce ex-post consumption risk. For the case of the wealth-rich households, the ratio of marginal utilities will be larger than one. Wealth-rich households hold precautionary savings that allow them to cushion when bad shocks happen. Given that in this economy it is highly costly to save, the wealth-rich over-invests in agricultural production, especially for the low crops, as a cheaper mechanism than accumulating more savings.

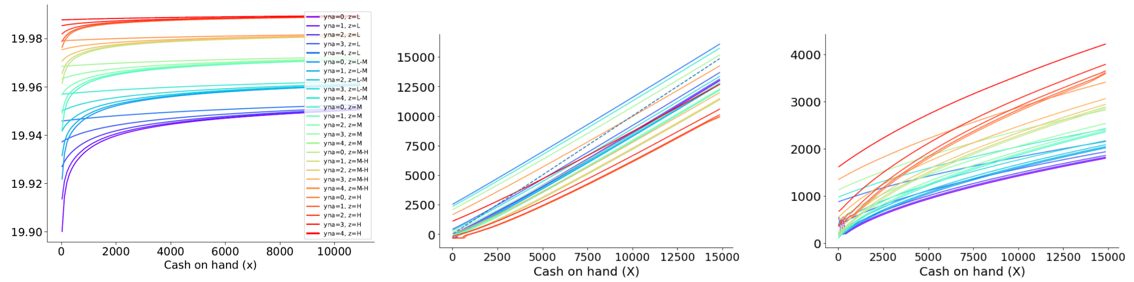
Household optimal inputs allocations do not maximize expected returns but maximize a combination of risk mitigation and expected profits. The presence of uninsurable risk not only distorts inputs usage in each technology but also leads to a shift in investment towards the safer technology. Dividing (1.11) by (1.12) optimal condition of inputs usage can be rewritten as

$$B\gamma\left(m_l'(x,z,y_{na})\right)^{\gamma-1}=\frac{\mathbb{E}\left[\theta' u_c\left(c(x',z,y_{na}')\right)\right]}{\mathbb{E}\left[\varepsilon' u_c\left(c(x',z,y_{na}')\right)\right]}A\alpha\left(m_h'(x,z,y_{na})\right)^{\alpha-1} \tag{1.15}$$

From equation (1.15), first, notice that the marginal utility is decreasing on consumption, and the consumption increasing on shocks realization. Note that if the high-technology is riskier, $\sigma_\theta > \sigma_\varepsilon$, for positive shocks, where the marginal utility is lower, the weight of θ realization will be higher than ε one. Nevertheless, for negative shocks the opposite is true. The low realizations of the ε shock are higher than the low realizations of θ. Precisely, since marginal utility is higher at lower realizations, the expectation in the denominator will be higher than in the nominator. As a consequence, marginal returns in the high technology are higher than in the lower one. There must be under-investment in the high technology with respect to the low technology to compensate for risk differentials. Again, if households could perfectly smooth consumption, marginal returns across technologies will equalize as in profit maximization allocations.

The size of the distortions depends on the capacity of households to cope with

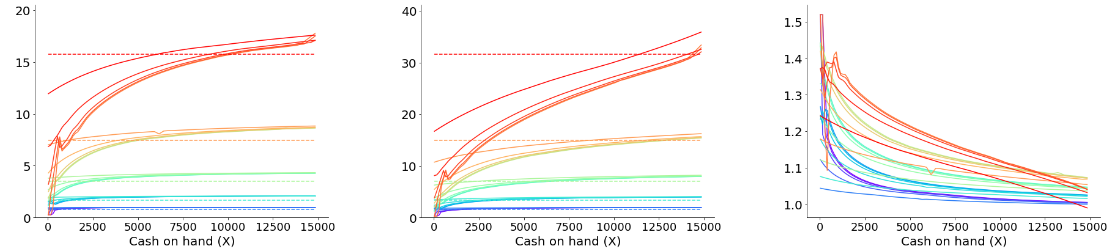
FIGURE 1.3: Households Optimal Choices



(A) Value Function

(B) Assets Policy

(C) Consumption Policy



(D) Policy Inputs Low

(E) Policy Inputs High

(F) Ratio Marginal Products

Notes: (b)–(e) plot the policy functions of the household problem and (a) the value function associated to it. These functions depend on the states cash-on-hand (x)—x-axis—agricultural permanent component z—dark-blue, clear-blue, green, orange, red—and the non-agricultural income realization y^{na}—shades within the primary colors. Doted lines in (d)–(e)–(f) represent discounted profit maximization allocations. Sub-figure (f) plots the ratio of expected marginal products between the high crops and the low crops given by the policy functions.

risk which depends on their wealth levels. Wealth-poor households are not able to avoid income volatility to translate into consumption volatility. As a consequence, they under-invest in inputs, and especially so for the more productive technology to limit risk exposure. On the contrary, wealth-rich households over-invest due to a lack of proper savings mechanisms.

In Figure 1.3d), I plot household's inputs low technology policy, and, in 1.3e), the inputs high technology policy across state x, and for the different realizations of state z and y_{na}. The dotted line represents the usage of inputs under expected profits maximization. Households in the bottom heavily under-invest in inputs for both high and low technologies with respect to the case of profit maximization. As households get richer they invest more and get closer to profit maximization allocations. The households on the top over-invest in the technologies and especially so for the low-productive technology.

In Figure 1.3f), I plot the ratio of the expected marginal products along the states variables. As described in (1.15), if households can perfectly smooth consumption, then this ratio should be equal to one. Households equalize the marginal products across technologies. Nevertheless, we observe that this ratio for the poor households is much above one. It is also much above one for the households with the higher permanent component. Given their limited ability to cope with the risk, they need to mitigate the risk by investing relatively less in the high crops, and therefore the marginal product,which has decreasing returns to scale, of the high crops will be higher. Also note that as households get richer, they can better cope with risk with accumulated wealth, and therefore, they reduce shifting resources to the safe crop for risk motives. In short, similar to Rosenzweig and Binswanger (1992), in this economy the production choices of the poor are more distorted by the presence of risk given their reduced ability to cope with it due to lack of accumulated wealth.

This model shows that even in the absence of fixed or adaptation costs, the poor might not invest enough and move to more productive technologies because of uninsurable risk. In this world, poor households might be facing a poverty trap: since they are poor, they cannot invest riskier and more profitable, and therefore, they remain poor. Nevertheless, here they face a poverty trap in a stochastic world, and that has two main implications with the standard poverty trap literature. First, In a stochastic world, poverty is not an absorbing state. Poor households might experience good shocks and move out of poverty. Second, in a stochastic economy, once-a-time big-push policies do not move households—or economies—to the high-productive technology. Only better insurance mechanisms and safety nets can alleviate the poverty trap.

1.3.2 Equilibria

Let $\lambda_t(x, z, y_{na})$ be the proportion of agents at time t in state (x, z, y_{na}). Let $x \in \mathcal{X}$, where $\mathcal{X} \equiv [0, +\infty)$, $z \in \mathcal{Z} \equiv \{z_l, z_m, z_h\}$ where $z_j \in \mathbb{R}_{++}$, and $y_{na} \in \mathcal{Y}_{na} \equiv \mathbb{R}_{++}$. Let $\mathcal{S}\mathcal{X} \times \mathcal{Z} \times \mathcal{Y}_{na}$.

Stationary Recursive Competitive Equilibrium Definition: The stationary RCE is defined by a stationary distribution $\lambda(x, z, y_{na}) = \lambda^*(x, z, y_{na})$, a transition function
$Q((x', z, y'_{na}), (x, z, y_{na}))$, a value function $V(x, z, y_{na})$, a set of policy functions $g(x, z, y_{na})\{c(x, z, y_{na}), a'(x, z, y_{na}), m'_h(x, z, y_{na}), m'_l(x, z, y_{na})\}$ such that:

1. Policy functions $g(x, z, y_{na})$ solve the household problem and $V(x, z, y_{na})$ is the associated value function.

2. Given policy functions $g(x,z,y_{na})$ the production market clears:

$$\begin{aligned}\int_{\mathcal{S}} c(x,z,y_{na})d\lambda^*(x,z,y_{na}) = & \int_{\mathcal{S}} \left[\theta z A(m_h'(x,z,y_{na}))^{\alpha} + \varepsilon z B\left(m_l'(x,z,y_{na})\right)^{\gamma}\right] d\lambda^*(x,z,y_{na}) - \\ & - \int_{\mathcal{S}} \left[p m_h'(x,z,y_{na}) + p m_l'(x,z,y_{na})\right] d\lambda^*(x,z,y_{na}) + \\ & + \int_{\mathcal{S}} y_{na} d\lambda^*(x,z,y_{na})\end{aligned}$$

3. The stationary distribution $\lambda^*(x,z,y_{na})$ associated with $g(x,z,y_{na})$ satisfies the law of motion

$$\lambda^*(x',z',y_{na}) = \int_{\mathcal{S}} Q((x',z,y_n a'),(x,z,y_{na}))d\lambda^*(x,z,y_{na})$$

In section A.1 in the appendix, I show the procedure and algorithms used to solve the model.

1.4 Data: Uganda National Panel Survey

This study uses the first five waves of the Ugandan National Panel Survey.[10] The UNPS is a nationally representative panel survey carried out by the Ugandan National Statistics and is part of the World Bank LSMS-ISA project. The Living Standards Measurement Survey, LSMS, is a representative household survey with a focus on living standards and inequality. The Integrated Survey on Agriculture, ISA, are surveys designed to capture all agricultural and livestock outputs, inputs and wealth. The UNPS sample is approximately 3,200 households and it is currently the longest panel of the LSMS-ISA project. The first wave started in 2009–10 and its initial sample was visited for two consecutive years: 2009–10 and 2010–11. In the fourth wave, 2013–14, one-third of the initial sample was refreshed and the five wave, 2015–16, uses the sample from 2013–14. The survey is implemented on an annual basis running from September till August in two visits that are approximately six months apart to better capture agricultural outcomes associated with the two cropping seasons of the country.

For a macroeconomic purpose, the main strength of the LSMS-ISA surveys is that for each household we can recover their consumption, income, and wealth dynamics. Having this triplet is rather unique, even for most rich countries, researchers cannot study the joint dynamics of the three variables from a single dataset. Yet, under this context, correctly computing the consumption, income,

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[10] Uganda National Panel Survey, the World Bank.

and wealth of the households is complicated. Deaton (2019) analyses the difficulties in measuring consumption and income from household surveys in developing countries and provides insights on the trade-offs between the different methodologies and types of data. In the following subsections, I thoroughly describe the process to compute the consumption, income, and wealth of the Ugandan households. As a general rule, this work follows the adjustments and procedures used in De Magalhães and Santaeulàlia-Llopis (2018). In the end, I provide summary statistics of the variables.

1.4.1 Consumption

The UNPS has a detailed section on household consumption divided into 3 sections: food items (last 7 days), non-food and non-durable goods (last month), and durable goods (last year). For each item, households are asked for the value of consumption from purchases, from home production, and received in-kind or free. The consumption value from each item is the sum from the three sources. Then, I define household aggregate consumption as the sum of consumption value for all food items and non-durable items. For each wave, I trim total household consumption at the bottom and top one percent to avoid the presence of outliers.

1.4.2 Income

Measuring household income in developing countries is especially difficult, Deaton (2019). Common to developed countries, self-reported income in surveys tends to have important amounts of measurement error. Yet, in the case of developing countries, a series of extra difficulties arise. Notably, a large fraction of households are self-employed which for them is both conceptually and practically more difficult to report the true value of their income than for salary workers. Moreover, most of these self-employed households are in agriculture where measurement is more difficult —especially when a substantial part of its production is not devoted to the market.

One of the main strengths of the LSMS-ISA surveys is to offer comprehensive household income information for several countries in Sub-Saharan Africa. Income information is provided from the household questionnaire (LSMS) and the agricultural questionnaire (ISA). In the household questionnaire, interviewees are asked about earnings coming from labor services, non-agriculture business operations, and other sources of income (rents, transfers, etc). Most households in rural Uganda obtain their income mainly through agricultural activities. In this context, having a correct account of agricultural income is key. Yet, given that it is a self-employed activity and has a large fraction of home production such correct accounting is difficult.

Accounting agricultural production

The ISA part of the survey particularly tries to measure in detail agricultural production and inputs by having a large set of precise questions on agriculture and livestock. Production questions are at the plot-crop level, inputs typically at the plot level, and livestock questions at the group of animals level. Yet, for an adequate computation of agricultural income, the researcher needs to make imputations, adjustments, and corrections which I describe next.

Units conversions to kilograms A first issue is that the amount of production and consumption on the items can be reported in non-standard unit measures. This is common in household surveys in developing countries. Households are asked to report the amount they produce of a given crop in any unit they wish varying from sacks, dishes, bunches, pieces, etc; to standard unit measures as kilograms. Unit conversions might vary along crops and seasons: a 100 kg sack of maize might not weigh the same as a 100 kg sack of coffee, and even for the same crops conversions might notably differ across particularly good and bad seasons. An advantage of the Ugandan agriculture questionnaire is that, for each season and harvested crop, it asks households to report the conversion rate of the reported unit to kilograms. With this information, for each agricultural season, I computed the median crop-unit conversion rates from the self-reported answers. Using median conversions instead of means prevents extreme values to have a strong influence on the measure. Then, for the seasonal crop-unit combinations whose median conversions were missing or had an extreme value, I use the median from the rest of the seasons if possible, and if not, I use direct conversions rates at the unit level. For some units, one might have a reasonable approximation of the conversion. Many measures in the questionnaire are associated with a standard conversion: 100 kgs sack, 10kg basket, 2kg basket, etc. Finally, for the units that do not have a standard measure associated with it, and had missing or extreme median conversion values, I assign a standard conversion to reduce measurement error. Note that these ad-hoc conversions will have little effect on the aggregate computations since the inability to compute a reasonable median conversion rate for those units comes precisely from the fact that there were very few cases of crop quantities reported with them. Yet, I use all these corrections to have a fair conversion to kilograms for all possible crop-unit combinations and all the seasons. The objective is to avoid under accounting agricultural production of a particular crop for a household from missing conversions, or over accounting because of an extreme value in the conversion rate.

The monetary value of unsold production: In developing countries, a large share of agricultural production is at the subsistence level. Markets are not well developed, and many farmers devote an important part of the production to their consumption. In the case of Uganda, only 24 to 29 percent of the agricultural production is devoted to the market. See Table A.2 where for each wave, presents the share of agricultural production devoted to the market, own consumed, stored, and gifted; and the proportion of farmers that did devote a part of their production to these usages. Thus, a second issue is how to evaluate this unsold production which is key for the measurement of household income, especially for those at the bottom distribution. Setting prices to evaluate non-marketed production in monetary terms is, in general, a difficult choice, Deaton (2019). One option is to use the prices at the gate computed through the households that did sell production. Nevertheless, these prices might not be a correct accounting of the opportunity cost of such agricultural production. De Magalhães and Santaeulàlia-Llopis (2018) argue that prices at the gate underestimate agricultural production. First, the sold items might only be a part of the harvested crops. The stems, leaves, roots, and other parts of the crops might not be sold for many crops, yet they are used for fuel and feeding animals. Second, prices at the gate are measured in the period after the harvest when supply is abundant and prices are likely to be the lowest of the entire year. Thus, the value of this agricultural production consumed afterward will be underestimated at using at the-gate prices. Yet it could also be that at the gate prices overestimate agricultural production when market opportunities differ a lot between subsistence farmers and those that do sell.

With all these arguments, this work follows the approach in De Magalhães and Santaeulàlia-Llopis (2018) and uses median consumption prices at the district level to evaluate unsold agricultural production. For the case of the main food crops, in the LSMS-ISA survey households are asked both for the selling production value and consumption value. Thus, for these crops, we can use consumption prices for a better estimate of the income coming from unsold agricultural production. To reduce the impact of measurement error, I use median prices for each crop. Both at the gate and consumption prices can differ a lot across locations in Uganda. In urban areas and the surroundings, food prices tend to be high, while crops supply and demand might differ a lot across locations. To account for geographical price differences, I compute crop median prices at the district level. There are 135 districts in Uganda, yet not all of them are part of the sample in all the waves. For those crops that a price at the district level cannot be computed, I use the price at the regional level, and, if this price was also absent, I use the nationwide price. Nevertheless, not all crops in the agriculture questionnaire have a consumption price. Some crops are mainly devoted to exports, like coffee, tea, or tobacco. For other crops, the consumption item might be too different than the crop produced, or, given its low frequency of consumption, they might not be included in the consumption section of the survey. For all these crops, I use prices at the gate, and again, to reduce measurement error and take into account geographic differences, I use median prices at the district level.

Following these steps, the computation of household's agricultural revenue is the sum of the self-reported value of sells plus the unsold production value measured with the adjusted kilograms production times district median consumption prices.[11]

Agricultural inputs: In the agriculture questionnaire, for each of the two seasons, households are asked for landholdings, land that the household has access to through use rights, intermediates, labor inputs, crops grown, and types of seeds used. Observations are at the plot level while crops and the quantification of production are both at the plot and crop level. In the survey, households are also asked for farm implements and machinery ownership, renting, and borrowing. For land usage, the questionnaire asks for total plot size, and size within the plot dedicated to each type of crop grown. The data counterpart of the agricultural investment variable in the model is the sum of the costs of fertilizer, pesticides, herbicides, seeds usage, cost of hired labor and transport costs. For the case of chemical fertilizer, organic fertilizer and pesticides, and herbicides, their costs are the total quantities (bought and non-bought) used of each inputs times its median price which can be recovered from the survey. In the case of seeds, the cost represents the spending on bought seeds. Non-bought seeds cannot be assigned a monetary value since the survey does not ask for their quantity usage.

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[11] For the waves 2013–14 and 2015–16 the self-reported sales values are extremely -and wrongly- low. To correct for that, for these waves, Instead of using each farmer's reported sell values, I compute their sell values by multiplying its kilogram sold production times the selling median district prices.

Labor, business, livestock, and other sources of income

In terms of business income, the UNPS asks whether any household member operated any non-agricultural enterprise, shop, trading business, or profession over the past 12 months. In the affirmative case, households are asked for the number of months the enterprise was in operation, and for these months, the average monthly gross revenues, wage expenditure, raw materials expenditure, and other operating expenses—fuel, kerosene, electricity. With this information, each enterprise's profits are computed by monthly gross revenues minus costs times the number of months the business was in operation. Total household business income is the sum across all businesses operated by household members.

In terms of formal and informal labor,for all household members five years old and above, the questionnaire asks for the labor supply and remuneration for the main job and a secondary job. Regarding the remuneration, the survey asks for the last cash payment and/or estimated cash value of in-kind payments for both the main and secondary job and the time that such payment covers. From that, I recover a weekly salary and I compute for each job, and each individual, the yearly labor income by multiplying the weekly salaries by the number of weeks and months the individual was reported to work during the last 12 months.[12] Thus, household labor income is the sum across household members of the yearly labor payments for the main job and a second job if existent.

In the agricultural questionnaire, households are asked for livestock ownership, sales, and buys, its outputs, inputs, and expenditure. The computation of livestock profits is given by the sum of net sales of animals, sells of meat, milk, and eggs, the value of unsold production, minus the costs: hired labor, feeding, access to water sources, vaccinations, deworming, insects treatment, curative treatment. The value of unsold production is estimated by the consumption value of livestock products coming from own production reported in the consumption section of the household questionnaire.

Finally, the household questionnaire also asks for other sources of income which consists of property income, investments, transfers, and other benefits.[13] I trim household business profits, salary labor income, livestock, and other sources of

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[12] To compute such averages, I assume that workers that reported payments in months worked four weeks in a month, those that reported in days worked 6 days a week, and those that reported in hours worked 60 hours per week. The last two numbers are based on the work of Tijdens (2012).

[13] property income consists of net actual rents and royalties from buildings and land. Investments consist of interests received from bank accounts, shares, dividends, bonds, and treasury bills. Current transfers and other benefits consist of pension and life insurance benefits, remittances, income from the sale of assets (except livestock), and other transfers as inheritance, alimony, scholarships, and other unspecified income.

income at 2.5 percent both tails because I found there tended to be more extreme values and the computation of such income sources entailed more assumptions. To be consistent with the model, I compute household total income as the sum of agricultural revenues, business profits, labor payments, livestock profits, other sources of income.

1.4.3 Wealth

The wealth of Ugandan households is recovered both from the agriculture questionnaire and the household questionnaire. In the household questionnaire, interviewees are asked for the amount and estimated value of their household assets.[14] From the agriculture questionnaire, households are asked for the amount and the estimated value of farm implements and machinery while they are also asked for the amount and type of livestock. To compute the value of the livestock, I use the median selling prices per animal category.

Land valuation in the Uganda LSMS-ISA is complicated. households were asked for the value of their plots only in the first two waves. In many regions of rural Africa, land markets might be missing or incomplete, see Restuccia and Santaeulália-Llopis (2017). Ownership of land is complex with an important role of traditional institutions, governments, and other non-market frictions. Under these circumstances, it might be difficult for households to have a good estimate of the market value of their land. Despite that, from the first two waves, the reported values of the plots do not seem unrealistic. In the survey, households are also asked how much they would get if they were to rent for one year the plot. The ratio of value versus rent seems to be coherent, with most values being between 5 and 75 meaning that a plot is valued from 5 up to 75 years of usage.

To have land value for the rest of the waves, I compute per acre median prices of land given its characteristics and location from the second wave—2010–11. To compute the prices, I first trimmed extreme observations on the size of the plot—at 1 percent—the per-acre price of the plot—at 5 percent—, and the ratio of plot value and one year rent—at 5 percent. Given this set of observations, I compute the median per-acre land prices grouping by counties and plot characteristics. In all waves, households are asked for the characteristics of each plot they hold in each season. They are asked for the location, ownership status, rights usage, and soil and water conditions of the plot. Given this set of categorical variables on plot characteristics, I obtain prices per each possible combination of them. Then,

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[14] housing and other buildings, non-agricultural land, furniture, household appliances, electronic devices, jewelry, vehicles, and other assets.

for the next waves, a price for each plot is assigned according to its characteristics. In concrete, I compute median land prices grouping by county, quality, distance to the plot, tenure system, water source, and topography.[15] Many combinations of these characteristics were not observed in the 2010–11 wave, but they might happen in the following waves. Thus, I replace missing values by filling in median prices computed at coarser levels: I first fill in with median prices computed at county-quality-usage level, then at county-quality level, county level, district level, and, finally, with the national median per acre price. With this set of land prices computed with the 2010–11 wave, I compute the value of the land of the households for the rest of the waves by multiplying each plot size times its matched price, adjusted by inflation, in terms of the location and characteristics of the plot. To be more consistent across waves, for the 2009–10 and 2010–11 waves, instead of using the reported value of the plots, I follow the same procedure and use the matched prices to estimate land value. Using the 2010–11 computed prices, the estimated land value for the 2009–10 wave correlates 0.51 with the household reported land values, and it has a very similar distribution in terms of mean, variance, and percentiles.

The total wealth of Ugandan households is computed by the sum of the value of their household assets, land, livestock, and farm capital. I trim observations at the top 1 percent of the wealth.

1.4.4 Summary of Consumption, Income, and Wealth of Ugandan Households

With all the steps described in the previous sections, I obtain the consumption, income, and wealth distributions of Uganda. As a first summary, Table 1.2 shows the average and the Gini level of each of the three variables at the household level for rural Uganda (columns 2 to 4) and for the whole country (columns 5 to 7) for each wave of the UNPS data. All values are in 2013 dollars.

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[15] There are 167 districts in Uganda, yet not all of them sampled in the UNPS. Distance to the plot: less than 15min, 15-30 min, 30-60 min, 1-2 hours, over 2 hours; tenure system: freehold, leasehold, Mailo (owned in perpetuity), customary; usage: own cultivated annual crops, own cultivated perennial crops, sub-contracted out, fallow, grazing, woodlot; land quality: good, fair, poor; water source: irrigated, rainfed, swamp/wetland; and topography: hill, plain, slope, valley. Some of these variables are coarser than in the survey.

TABLE 1.2: Consumption, Income and Wealth in Uganda: average per household and Gini measure. UNPS (09-15)

	Rural			**National**		
	Cons	Income	Wealth	Cons	Income	Wealth
2009-2010	1,462.50	1,472.12	3,938.95	1,706.01	1,725.71	4,417.34
	(0.36)	(0.57)	(0.62)	(0.38)	(0.58)	(0.67)
2010-2011	1,419.42	1,383.18	3,921.16	1,688.91	1,707.33	4,830.82
	(0.36)	(0.55)	(0.63)	(0.39)	(0.57)	(0.69)
2011-2012	1,582.88	1,620.54	4,182.69	1,802.07	1,844.67	4,914.58
	(0.34)	(0.55)	(0.61)	(0.37)	(0.55)	(0.66)
2013-2014	1,539.26	1,502.92	4,391.47	1,790.14	1,866.91	5,242.55
	(0.3)	(0.57)	(0.61)	(0.33)	(0.58)	(0.67)
2015-2016	1,466.62	1,733.13	3,731.18	1,711.10	2,121.46	4,577.79
	(0.31)	(0.58)	(0.6)	(0.35)	(0.58)	(0.69)
Average	1,494.13	1,542.38	4,033.09	1,739.65	1,853.22	4,796.62
	(0.33)	(0.56)	(0.61)	(0.36)	(0.57)	(0.67)

Notes: Values in 2013 US dollars. Data controlled for inflation. Gini index within parenthesis. Consumption includes food and non-durables consumption. Income includes crops revenues computed with median district crop consumption prices and selling prices when missing. Livestock profits, salary labor earnings, business profits and other sources of income. Wealth includes housing, household assets, land, livestock holdings, and farm capital. Data: UNPS first five waves.

The first point to take from Table 1.2 is in terms of data quality. Typically survey-based estimates of income are substantially lower than survey-based estimates of consumption, Deaton (2019). With the data and procedures used in this work, I find that average income levels are very close to consumption levels and sometimes larger. This is a positive indicator that consumption and especially income might be well measured in this context. Secondly, most Ugandan households are very poor. The average household income—and consumption—across waves is around 1500$ for rural Uganda and around 1800$ for the whole country. In per capita terms, this is around 300$ in rural and 360$ nationwide. Not only averages are low but inequality levels are notably high. Consumption inequality is high with Gini values from 0.30 to 0.36. Income inequality is substantially larger, with Gini values from 0.55 to 0.57. Wealth inequality has Gini values around 0.68 and 0.73.

A large part of the literature studying income inequality in developing countries uses consumption measures, see Alvaredo and Gasparini (2015). As observed here, this process might underestimate the values of income inequality, so that the values should be considered as lower bounds. Income inequality in rural areas is similar to inequality in the whole country. Nevertheless, across all the waves consumption and wealth inequality in rural areas are lower than at the national level. This is consistent with the results of De Magalhães and Santaeulàlia-Llopis (2018) and might hint at higher redistribution and/or insurance levels in rural areas with respect to urban ones.

In Table A.3 in the appendix, I present the previous table in per capita terms: Per each household, the variables are divided by their number of members. There are three main points to notice from this table. First, there has been substantial growth across the period spanned by the waves, from 2009 till 2016. The income per capita at the national level had a 71 percent accumulated increase while consumption had an accumulated increase of 44.8 percent. Just focusing on the rural households, there was a 67 percent accumulated increase of income while in consumption of 35 percent. Part of this increase, especially in consumption, comes from a reduction in household size. The persistent large increase at per-capita levels of consumption is an indicator that there has been a noticeable growth and increase in living standards in the economy during this period. Second, in per capita terms, the inequality levels tend to be much larger since poorer households tend to be larger. Inequality seems to have been rising across time yet not monotonically and mainly because of the very high levels of inequality observed in the last wave. A longer panel is necessary to extract conclusions on the dynamics of inequality in Uganda.

The high levels of inequality observed in Uganda at household and per-capita levels should be of concern for policymakers. First, they are likely to be a lower bound of the actual inequality in the country. The UNPS has a small sample, does not over-sample the rich, the questionnaire asks mostly about consumption items and income sources from a typical household, and one might expect the rich to under-report, especially on their income and wealth. Second, even ignoring all the sources that would potentially increase inequality, the numbers are very high. It is also noticeable that in rural areas inequality is also high, just slightly below the nationwide levels, a result that is quite surprising. This result rejects the idea of rural-poor economies where everyone is relatively equally poor. Thus, besides poverty outcomes, researchers should also focus on inequality aspects.

Table A.4 presents a summary of the composition of consumption, income, and wealth for rural Ugandan households. Food represents the big share of consumption expenditures. On average, 66 to 71 percent of the household consumption was on food. In terms of income, agriculture is the main source of earnings with almost all households engaging in crop production—around 90 percent of them—and representing around 50 to 56 percent of the total income in the economy. Most of this production, more than 70 percent, is at subsistence level. Despite that around 77 percent of households did sell some of their agricultural production, the aggregate value of these sales represents less than 30 percent of the total production value. The main source of living for rural Ugandan households is subsistence farming. The second main income source is non-agricultural business. Around 40 to 45 percent of households had earnings from an enterprise, and it represents around 20 to 25 percent of the total income of rural households. The third main source is wage labor. Around 30 to 40 percent of households had at least a member obtaining a salary from a job and it represents around 15 to 20 percent of total household income. In terms of the wealth of rural Ugandan households, it comes mainly from land holdings with an average household value of around 3000$ and household assets with an average household value of 1600$. Finally, for the average rural household in Uganda, livestock is not the main source of wealth and income: Less than 25 percent of households have livestock and with a value of around 1000$. Obviously, across regions, there could be a lot of heterogeneity in the composition of income and wealth.

The first takeover from these results is that rural Uganda does not seem to have experienced a period of structural transformation even if there was substantial growth. Rural Uganda has maintained during all these years an economy based on agriculture. A second takeover is that there is little discrete occupational choice at the household level. Most households engage in farming, and many of them also engage in business activities and/or wage labor. Similarly, a large share of farmers engaged in some sales, around 76 percent, yet the sold agricultural production represented less than 30 percent of the total agricultural production. For further details, tables A.8, A.9, A.10, present summary statistics of consumption, income, and wealth, respectively, by taking each household average across the waves.

1.5 Calibration

The parameter values in the model combine values from the literature, estimations from the UNPS micro-data, and calibration methods. First, I set the risk-aversion parameter ρ equal to two. This value is commonly used in the macroeconomics literature—e.g. Kaplan and Violante (2010), Lagakos, Mobarak, and Waugh (2020)—and within the range of commonly estimated values. Second, I set the discount factor equal to 0.96 used in Aiyagari (1994) and other authors. Third, I set the intermediate inputs shares α, γ equal to 0.4 from Restuccia, Yang, and Zhu (2008).

For the rest of parameters, the model is calibrated in stationary equilibrium to replicate key properties of the economy in rural Uganda. In concrete, since the objective of this work is to study the impact of uninsurable idiosyncratic risk, the calibration is performed to replicate moments on crops agricultural production distribution, crops risk, income and wealth levels, and the income risk observed in rural Uganda. There are two sets of statistics to discipline the model parameters: cross-sectional moments—averages and the Gini level of agricultural production—and panel data moments—volatility measures expressed as the average of households time-variance log of the variable. For the cross-sectional moments, instead of targeting a particular wave, I focus on the average moment across the waves. Some parameters are directly estimated by OLS, while volatility measures are calibrated targeting residuals of OLS regressions. Next, I describe more in detail how all parameters are calibrated.

Technology parameters and inputs price. I calibrate the inputs price p, the constant factors in each technology, A, B, to match the average agricultural production in high crops, in low crops, and reduce the distance to the inputs expenditure on both high and low crops.

TABLE 1.3: Parameter Values for the Benchmark Economy

	Parameter	Value	Source
Curvature of consumption	ρ	2	Literature
Discount factor	β	0.96	Literature
High technology inputs elasticity	α	0.4	Literature
Low technology inputs elasticity	γ	0.4	Literature
Intermediate inputs price	p	26.5	Calibration
High technology constant factor	A	275	Calibration
Low technology constant factor	B	181	Calibration
Std. Deviation high shock	σ_θ	1.03	Calibration
Std. Deviation low shock	σ_ε	0.857	Calibration
Covariance high and low shocks	$\sigma_{\theta,\varepsilon}$	0.11	Calibration
Autocorrelation non-agricultural income process	$\rho_{y_{na}}$	0.37	UNPS estimate
Std. deviation error term non-agricultural income process	σ_u	1.32	Calibration
Std. deviation error permanent productivity	σ_z	0.278	Calibration
Depreciation rate	δ	-0.0874	Calibration
Borrowing constraint	$\underline{a}$	329	UNPS estimate

Notes: ρ value from Kaplan and Violante (2010) and other works; β value from Aiyagari (1994) and other works; α, γ value from Restuccia, Yang, and Zhu (2008). p, A, B, σ_z, δ are calibrated targeting cross-sectional moments for which I use average values across the five waves. Risk parameters—σ_θ^2,σ_ε^2 $\sigma_{\theta,\varepsilon}$,$\sigma_u$—are calibrated targeting volatility measures of residuals in crop production and income.

Agricultural shocks. To calibrate the covariance matrix of the agricultural shocks, I targeted the average household harvest variation of crops production residuals. In the model production fluctuations will only be driven by household idiosyncatic shocks and changes in intermediates input usage. Nevertheless, in the data production fluctuations might also be driven by changes in land size, households characteristics, fixed household heterogeneities in preferences and other variables and aggregate shocks. To account for that, I follow the procedure in Kaboski and Townsend (2011) and purge the data of these factors with the regressions

$$ln(y_{it}^h) = \phi ln(Z_{it}^h) + \beta X_{it} + \gamma F_i + \psi T_t + ln\theta_{it} \tag{1.16}$$
$$ln(y_{it}^l) = \phi ln(Z_{it}^l) + \beta X_{it} + \gamma F_i + \psi T_t + ln\varepsilon_{it} \tag{1.17}$$

where y_{it}^h represents the production on high crops for a household i in wave t. Z_{it}^h represents a vector including land size and labor hours devoted to high crops. l superscript denotes the value of these variables for low crops. X_{it} represents a vector of household characteristics that might change over time: household size, and the gender, education, age, and age squared of the household head. F_i represents household fixed effects while T_t represents wave fixed effects. I run the same regression for the low crops. In the case of the high crops, the R^2 on the regression is 0.18 while for the low crops is 0.14. Then, using the estimated residuals of the regressions $\hat{\theta}_{it}, \hat{\varepsilon}_{it}$, I compute the individual average variance across time of the residuals in the high crops, the residuals in the low crops, and the individual average time-covariance of the crops. These are the data moments for which I set parameters σ_θ, σ_ε and $\sigma_{\theta\varepsilon}$ to replicate the harvest variation predicted by the model in stationarity. The parameter values are: $\sigma_\theta = 1.03$, $\sigma_\varepsilon = 0.857$ and $\sigma_{\theta\varepsilon} = 0.1275$.

Non-agricultural income process. For the non-agricultural income process, The OLS regression on $lny^{na}_{i,t} = b + \rho_y lny^{na}_{i,t-1} + u_{i,t}$ delivers the estimates of $\rho_{y_{na}} = 0.37$ and $\hat{\sigma}_u = 1$. In the model I set the persistence parameter $\rho_{y_{na}}$ from the OLS estimation while the value of the variance of the residual is set to replicate the level of income risk observed in the data—σ_u is equal 1.32. Again to measure income and consumption variation associated to risk, I use the approach of Kaboski and Townsend (2011) and compute the volatility measures using the residuals of log income and log consumption of the following regressions

$$ln(y_{it}) = \beta X_{it} + \gamma F_i + \psi T_t + u_{it} \tag{1.18}$$

$$ln(c_{it}) = \beta X_{it} + \gamma F_i + \psi T_t + e_{it} \tag{1.19}$$

where the set of regressors is the same as in the regressions to estimate the log residuals of high and low crops production except for crop specific variables.[16] The R^2 of the regressions are 4.3 percent in income and 4.6 percent on consumption. Finally, given the parameters $\rho_{y_{na}} = 0.37$, $\sigma_u = 1.32$, I discretize this AR(1) process into a five-state Markov chain using the Rouwenhorst procedure.

Permanent component: I approximate the household permanent component variable, which has unit mean, with five equally spaced points in logs on the interval $[-3\sigma_z, +3\sigma_z]$ and there is an equal mass of agents in each point. This is similar to the procedure in Huggett and Parra (2010). Given the previously calibrated parameters, σ_z is set to match the Gini level of agricultural production. As a consequence, σ_z captures the heterogeneity in agricultural production that is not explain by risk.

Depreciation rate and borrowing limit: The depreciation rate is set such that the aggregate savings in the economy match the average holdings in liquid wealth. Liquid wealth here includes crop storage, livestock holdings, household assets, and other sources of income. Other sources of income include remittances, alimony royalties, dividends, and other returns—these other sources of income

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[16] The vector of household includes log of total cultivated land size, household size, and the gender, education, age and age squared of the household head.

represent a very small part of the liquid wealth in rural Uganda. Then, δ is set to match the aggregate savings in the economy with the average value of liquid wealth in the data. The data moment is the average liquid wealth across waves and discounted by inflation and is equal to 1659\$. The calibrated value is $\delta = 0.0874$. This value is consistent with large costs to save in developing countries—Dupas and Robinson (2013), Donovan (2021), Lagakos, Mobarak, and Waugh (2020). The borrowing limit, $\underline{a}$ is set equal to the 90th percentile of the consumption coming from gifts in rural Uganda. This value is equal to 329\$.[17]

1.5.1 Model Performance

Table 1.4 part A shows the data targeted moments and the model counterparts while part B for some key untargeted moments.[18] Without targeting, the model approximates well the consumption volatility observed in the data.[19] Since this work is concerned about the welfare cost of incomplete markets, it is key that the model can reproduce the level of consumption risk observed in the economy. Then, in terms of the share of high and low crops across households, the model predicts an increase in the high crops share from the bottom to the top of the wealth distribution of 13 percent while in the data is of 20 percent. In terms of levels, the model falls short in predicting low crops usage, especially at the bottom. It predicts a share of 44 percent while in the data is 53 percent.

The calibration of the model targets the Gini of agricultural production (0.63) with no additional targets on cross-sectional distributional moments. With this in mind, the model approximates well the inequality levels observed in Rural Uganda. The income Gini that the model predicts is 0.52 while the average Gini moment across waves in the data is 0.56. In terms of liquid wealth, the under-prediction of the model is larger. While in the data the average Gini across waves

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[17] The 90th percentile is computed from the average consumption gifts distribution across waves. Using other percentiles, as the 50th (112\$), 75th(200\$), or 95th (436\$), does not notably change the outcomes of the economy.The reason for that is that in stationarity few households will be borrowing.

[18] the model cannot replicate the inputs usage in the data: inputs usage is very low given that very few households use fertilizers, pesticides, and other modern agricultural techniques. Moreover, inputs usage in the data might be low due to that the survey might not capture all the agricultural investments. In concrete, non-bought inputs usage which represents a large part of the inputs usage in Uganda might not be well captured. For example, in the case of seeds usage, it is not possible to value its non-bought investment.

[19] By targeting the income volatility, assuming standard preferences on consumption, and incomplete financial market that matches average liquid wealth and has a borrowing limit fixed by consumption household transfers, the consumption volatility in the model (0.11) is very close to the consumption volatility observed in the data (0.12).

is 0.67, in the model is 0.61. The consumption Gini index that the model predicts is 0.35 which is very close to the consumption Gini index in the data, 0.34.

TABLE 1.4: Benchmark Economy: Model vs Data Moments

A. Targeted Moments Description	Model	Data Target
Avg high crops output	640	648
Avg low crops output	349	352
Avg high crops expenditure	202	40
Avg low crops expenditure	123	36
Avg non-agric income	516	516
Avg Income	1504	1514
Avg Liquid Wealth	1673	1659
High crops volatility	1.02	1.02
Low crops volatility	0.72	0.72
High-low crops correlation across time	0.115	0.12
Income volatility	0.59	0.59
Gini Agricultural production	0.62	0.63

B. Untargeted Moments Description	Model	Data
Consumption volatility	0.11	0.12
Gini Consumption	0.35	0.34
Gini Income	0.52	0.56
Gini Liquid Wealth	0.61	0.67
Avg. Share Output High Crops	0.58	0.56
Share High Crops 20% wealth bottom	0.56	0.47
Slope Share High Crops on Wealth Distribution	0.13	0.2

Notes: Volatility and correlation measures are computed as the average household time-variance log of the variable —high crops production, low crops production, income, and consumption.

To further study the capacity of the model to account for observed inequality levels, Table 1.5 compares the income, wealth, and consumption cross-sectional distributions from the model with the data counterparts for the 2011–12 wave.

Although the model predicts a lower income Gini level than the Gini level observed in the data, the model does well at approximating the shares of income across the distribution. The model predicts that the top 50 percent holds 84 percent of the total income, in the data is 86. In the case of the extremes of the distribution—bottom and top 1, 5, and 10 percent—the approximation is still accurate. In terms of wealth, the model under-predicts inequality: the share of the top 50 is 84 percent while in the data is 92 percent, In the top extremes, the approximation is even worse: the model predicts that the top 10 percent holds 32 percent of the total liquid wealth, while in the data it is of 51 percent. In terms of consumption, the model replicates almost exactly the shares of the bottom and top and even for the extremes of the distribution. The share of the top 50 percent in the model is 74.67 while in the data of 73.7. The top 1 percent holds 3.4 consumption in the data, while in the model is 3.82.

Thus, the calibrated model can replicate the consumption cross-sectional distribution and the consumption risk observed in the data without specific targets on them. Having a proper approximation on both sets of consumption moments is key to have careful welfare evaluation.

TABLE 1.5: Income, Wealth and Consumption Inequality: Model vs Data.

	Gini	**Bottom**					**Top**				
		1	5	10	25	50	50	25	10	5	1
Data											
Income	0.55	0.03	0.26	0.77	3.59	13.91	86.18	64.80	40.64	27.80	10.53
Wealth	0.67	0.01	0.13	0.38	1.86	7.87	92.21	75.63	51.90	37.39	14.85
Consumption	0.34	0.17	1.16	2.80	9.51	26.34	73.70	48.09	25.18	14.74	3.82
Model											
Income	0.52	0.05	0.39	1.08	4.33	15.58	84.42	63.33	37.23	23.94	8.13
Wealth	0.61	-0.05	0.08	0.60	3.89	16.05	83.95	58.96	31.75	18.75	4.89
Consumption	0.35	0.16	1.04	2.51	8.89	25.33	74.67	48.42	24.67	14.03	3.40

Notes: None of the moments presented in the table is targeted in the calibration. In terms of cross-sectional dispersion moments, the only one targeted is the Gini level of agricultural production averaged across waves. Data: UNPS wave 2011–12.

1.6 Results

1.6.1 Counterfactual Economy: Complete Markets in Agriculture

The main results of this work are obtained by comparing the previous benchmark economy versus an economy where financial markets on agriculture are complete. To solve for this counterfactual world, I develop a social planner's problem that completes the agricultural financial market and then households deal with the non-agricultural income process with the assets market of the benchmark economy.

Consider first the social planner problem. The planner is able to allocate agricultural inputs allocations and consumption from the total agricultural production. To formulate the problem, I follow the approach in Maliar and Maliar (2003) and I represent the planner's problem in the form of two sub-problems. The first sub-problem is to distribute aggregate consumption across heterogeneous agents, which delivers the social period utility

$$U(C_t) = \underset{c_{i,t}}{\text{Max}} \int_i \omega_i u(c_{i,t}) di \tag{1.20}$$

$$\text{subject to} \qquad \int_i c_{t,i} di = C_t \tag{1.21}$$

where ω_i is the Pareto weight on individual i. The second sub-problem is to solve for the aggregate consumption that maximizes the social preferences

$$\underset{\{m^h_{i,t}, m^l_{i,t}, \}^{\infty}_{t=0}}{\text{Max}} \quad \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U(C_t) \tag{1.22}$$

$$\text{subject to} \quad C_t = \int_i \left[\theta_{it} z_i A {m^h_{i,t-1}}^{\alpha} + \varepsilon_{it} z_i B {m^l_{i,t-1}}^{\gamma}\right] di - p \int_i \left[m^h_{i,t}(s^t) + m^l_{i,t}(s^t)\right] di \tag{1.23}$$

$$C_t = Y_t - pM_t \tag{1.24}$$

where the planner does not observe individual shocks realizations $\theta_{it}, \varepsilon_{it}$, but knows its distribution. The first order conditions of the second problem are

$$\left[m^h_{it}\right] : \mathbb{E}_0 \left[\beta^{t+1} U_c(C_{t+1}) \alpha \theta_{i,t+1} z_i A {m^h_{it}}^{\alpha-1}\right] = \mathbb{E}_0 \left[\beta^t u_c(C_t) p\right] \tag{1.25}$$

$$\left[m^l_{it}\right] : \mathbb{E}_0 \left[\beta^{t+1} U_c(C_{t+1}) \gamma \varepsilon_{i,t+1} z_i B {m^l_{it}}^{\gamma-1}\right] = \mathbb{E}_0 \left[\beta^t u_c(C_t) p\right]. \tag{1.26}$$

$$\tag{1.27}$$

The planner's inputs allocations $m^h_{i,t}, m^l_{i,t}$ are independent of shock's realizations $\theta_{i,t+1}$ and $\varepsilon_{i,t+1}$ given that they are unobservable at the decision time. Then, given that there no aggregate shocks and agents prefer an smoothed profile of consumption, aggregate consumption is constant $C_t = C_{t+1}$ and also independent of the shock's realizations. Thus, the previous first order condition can be expressed as

$$\left[m^h_{it}\right] : \mathbb{E}_0 \left[\theta_{i,t+1}\right] \beta^{t+1} U_c(C_t) \alpha z_i A (m^h_{it})^{\alpha-1} = \beta^t u_c(C_t) p \tag{1.28}$$

$$\left[m^l_{it}\right] : \mathbb{E}_0 \left[\varepsilon_{i,t+1}\right] \beta^{t+1} U_c(C_t) \gamma z_i B (m^l_{it})^{\gamma-1} = \beta^t u_c(C_t) p \tag{1.29}$$

where $\mathbb{E}_0\left[\theta_{it+1}\right] = 1$ and $\mathbb{E}_0\left[\varepsilon_{i,t+1}\right] = 1$. Cancelling out terms we get to the expressions

$$\beta\alpha z_i A(m_{it}^h)^{\alpha-1} = p \tag{1.30}$$

$$\beta\gamma z_i A(m_{it}^l)^{\gamma-1} = p \tag{1.31}$$

that is, optimally, the planner equalizes the discounted expected marginal product of each individual i on both crops h, l to the marginal cost, the price. In other words, under complete markets inputs allocations are equal to expected discounted profit maximization. Isolating the inputs allocations from previous equations, we get

$$m_{h,i}^* = \left(\frac{p}{\beta\alpha A z_i}\right)^{\frac{1}{\alpha-1}} \text{ and } m_{l,i}^* = \left(\frac{p}{\beta\gamma B z_i}\right)^{\frac{1}{\gamma-1}}. \tag{1.32}$$

To solve for the first sub-problem, the distribution of welfare weights in the planner's economy is set to replicate the competitive equilibrium under complete markets. In this regard, I set the Pareto weights such that each agent consumes according to its permanent component. That is the shares of consumption across agents are equal to they expected shares on production. Thus, the consumption of an agent with productivity z_i is

$$c^*(z_i) = c_{it}(z_i) = z_i(Am_{h,i}^*)^{\alpha} + z_i B(m_{l,i}^*)^{\gamma} - p\left(m_{h,i}^* + m_{l,i}^*\right). \tag{1.33}$$

From the first sub-problem, note that the planner's optimal consumption allocations will be such that the Pareto weighted marginal utilities of consumption across agents equalize. As a consequence, the Pareto weights for agents i, j are set such that

$$\int_i \omega_i = 1 \qquad \frac{\omega_i}{\omega_j} = \frac{u^{-1}\left(c^*(z_j)\right)}{u^{-1}\left(c^*(z_i)\right)}. \tag{1.34}$$

The set of planner's allocations provides the allocations of agricultural inputs and the consumption coming from its production under complete markets on agriculture. Given these allocations, households decide how much to consume and save out of the non-agricultural income process under the financial markets of the benchmark economy. That is they solve the following problem in stationarity

$$V(a, z, y_{na}) = \underset{a',c}{\text{Max}} \;\; u\left(c^*(z_i) + c\right) + \beta\mathbb{E}\left[V(a', z, y_{na}')\right] \tag{1.35}$$

subject to

$$a' \geq \underline{a} \tag{1.36}$$

$$c(a,z,y_{na}) + a'(a,z,y_{na}) = (1-\delta)a + y_{na} \tag{1.37}$$

$$lny'_{na} = b + \rho_y lny_{na} + u, \qquad u \sim N(0,\sigma_z^2). \tag{1.38}$$

Finally, the definition of the stationary equilibria in the economy under complete markets on agriculture is analogous to the definition in section 1.3.2 with: the optimal allocations given by $m_h^*(z_i)$, $m_l^*(z_i)$, $c = c^*(z_i) + c(a,z,y_{na})$, $a'(a,z,y_{na})$; the transition function defined as $Q\left((a',z,y'_{na}),(a',z,y'_{na})\right)$; the stationary distribution as $\lambda^*(a,z,y_{na})$; Under the space $\mathcal{S} := \mathcal{A} \times \mathcal{Z} \times \mathcal{Y}_{na}$ where $\mathcal{A} = [\underline{a},\infty]$.

1.6.2 Aggregates and Productivity

Table 1.6 compares the aggregate agricultural inputs usage, agricultural output, income, assets, and consumption between the benchmark economy and the counterfactual one. Under complete markets, agricultural output increases by 28 percent while inputs usage increases by 54 percent. Thus, frictions on financial markets seem to play an important role to explain low inputs usage and low agricultural production in developing countries as highlighted in Donovan (2021). The total income of the households increases by 19 percent while costly unproductive assets accumulation reduces by 74 percent. As a consequence, household consumption increases by 271$ which represents a 28 percent increase. The larger increase in consumption than income is due to the fact that in this work consumption is not equal to income. Remember, from the budget constraint, aggregate consumption in stationarity is equal to $C = Y - pM - \delta A$. Thus, an important increase in consumption is coming from a reduction in savings and given that average consumption is much lower, the proportional change is much larger.

TABLE 1.6: The Effects of Completing Markets: Aggregates.

	Benchmarck	Complete Markets	Diff	**Diff (%)**
Agricultural				
Input	325.55	511.53	185.97	**0.57**
Output	990.26	1,279.59	289.33	**0.29**
Profits	663.65	765.52	101.87	**0.15**
Income	1,504.17	1,793.09	288.92	**0.19**
L. Wealth	1,673.25	429.66	-1,243.59	**-0.74**
Consumption	972.32	1,243.41	271.09	**0.28**

Notes: [1] The aggregate resource constraint of the economies in stationarity is: $C = Y_a - pM + Y_{na} - \delta A$, where Y_a repsents total agricultural output, M total input usage so that $Y_a - pM$ are total profits. C represents consumption, Y_{na} non-agricultural income and A the total assets holding in the economy.

The share of total input towards high-crops in complete markets is 67 percent while in the benchmark economy is 62 percent.

There are also productivity gains. Table 1.7 shows the increases in inputs usage and agricultural output for the two types of crops on average and across the permanent component of the households. Completing markets increases inputs usage of the high crops by 69 percent while in the low crops of 38 percent. This implies an increase in TFP since under complete markets households shift resources from low-return crops to high-return crops. The increase in inputs usage translates into an increase in high crops production in 33 percent while for low crops in 22 percent. Under incomplete markets, households investment depends on their permanent component but also on the wealth that they currently hold. Households wealth-rich will be over-investing in crops usage while poor ones will be under-investing. This implies that there are also productivity gains from transferring resources from wealth-rich households to poor ones and from households from low productive components to those with high permanent components. Table 1.7 shows that the increase in inputs usage and therefore production is substantially larger for the households with higher permanent components. While for the households with the lowest component the increase in inputs usage is 9 percent—a 15 percent increase in high crops and a decrease of 1 percent in low crops—for the households with the highest permanent component the increase is 46 percent—54 percent on high crops and 32 percent on low ones. Thus, completing markets also leads to a TFP increase from redistributing resources from households with low permanent components to households with high ones.

TABLE 1.7: The Effects of Completing Markets: Agricultural Inputs and Production across Crops and Agents Type.

	inputs Usage			**Output**		
	Total	High Crops	Low Crops	Total	High Crops	Low Crops
Average	0.57	0.69	0.38	0.29	0.33	0.22
Permanent Component						
Low	0.09	0.15	-0.01	0.03	0.05	-0.01
Middle-Low	0.22	0.31	0.07	0.09	0.13	0.03
Middle	0.35	0.47	0.15	0.14	0.18	0.06
Middle-High	0.47	0.62	0.23	0.18	0.23	0.09
High	0.46	0.54	0.32	0.18	0.21	0.13

Notes: Each value represents the proportional variation from the allocations in the incomplete markets economy to the allocations in the complete markets economy.

1.6.3 Distributional Effects

Table 1.8 shows the distributional effects of completing agricultural financial markets. For each variable in the rows—agricultural production, profits, income, and consumption—the first column shows the Gini of the variable change and in percentage terms between the benchmark economy and the complete markets one. Columns (2 to 5) show the changes in differences and percentage terms for the bottom and top 1, 5, 10, 25, and 50 percent for each variable.

There are several mechanisms at play regarding the distributional effects. In this work, the sources of inequality are risk -under three different income sources- and permanent differences in agricultural production. As a result, in the benchmark economy, the poor will be a combination of households with low permanent components and a continuation of bad shocks realizations in agriculture and the non-agricultural income process. The rich will be the opposite. In the complete markets world, agricultural production and income inequality increase. The lack of income smoothing makes households experiment a more volatile income and therefore translating to larger differences in the cross-sectional distribution.[20] As observed in Table 1.8, the gains in agricultural production of completing markets are concentrated in the top distribution of the cross-sectional distribution. As a consequence, household income inequality under complete markets increases.

In terms of consumption, the direction is less clear. Under complete markets consumption allocations are independent of shocks realizations. Conditional on the permanent component, households experiencing a sequence of agricultural bad shocks realizations or a sequence of good shocks will experience the same consumption. Thus, this mechanism notably reduces consumption inequality, it shuts down all consumption inequality coming from agricultural risk or, in other words, agricultural luck. Nevertheless, under the benchmark economy, rich household income decisions are also distorted, though close to profit maximization, and importantly, the rich accumulate costly precautionary savings. Completing agricultural markets reduces enormously, a 74 percent decrease, the need to store unproductive assets at depreciation rate δ. This increases consumption and especially for wealthy households. In this quantification, the last mechanism seem to dominate. The consumption proportional increase in the top of the distribution is slightly higher than in the bottoms. The consumption Gini increases by

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[20] Part of this result is due to the distribution of shocks is strongly positively skewed. Thus, ex-post, for the majority of households, those below the mean, it was optimal in profits to invest less than ex-ante profit maximization

0.01 points. Thus, under this exercise, completing agricultural markets slightly increase inequality.

TABLE 1.8: The Effects of Completing Markets: Distributional Effects

	Gini	**Bottom**					**Top**				
		1	5	10	25	50	50	25	10	5	1
Agric Output	0.01	2.03	3.44	4.22	10.26	35.90	61.54	111.94	167.53	162.33	162.00
(%)	0.02	0.08	0.08	0.07	0.10	0.18	0.21	0.28	0.38	0.36	0.36
Income	0.01	3.44	8.44	12.17	22.32	59.07	95.81	73.80	85.01	80.61	80.36
(%)	0.02	0.05	0.07	0.07	0.09	0.13	0.14	0.08	0.09	0.08	0.08
Consumption	0.01	17.20	51.05	63.67	84.54	116.59	148.64	201.81	219.29	217.26	217.04
(%)	0.02	0.11	0.25	0.26	0.24	0.24	0.23	0.27	0.28	0.27	0.27

Notes: The first column presents the proportional change in the Gini index between the incomplete markets economy and the economy with complete markets in agriculture. Rest of columns present the proportional change in agricultural output, income, and consumption holdings of the specific percentile group between the incomplete markets economy and the economy completing agricultural markets.

In terms of fluctuations, the consumption volatility after completing agricultural financial markets is 0.04, while in the benchmark is 0.11. This implies a 62 percent reduction of consumption risk on average across households.

1.6.4 Welfare Evaluation

Consider the ex-ante welfare comparison of the benchmark economy with the complete markets economy. The average welfare gain, in terms of consumption-equivalent changes (CEV), that results from completing risk markets is defined as the constant g over time and across agents percentage increase to consumption, c_{it}^{IM} that equalizes the utilitarian welfare to the value associated under complete markets

$$\int \mathbb{E}_0 \left[\sum_{t=0}^{\infty} \beta^t u((1+g)c_{i,t}^{IM}) \right] d\lambda^* = \int \mathbb{E}_0 \left[\sum_{t=0}^{\infty} \beta^t u(c_{i,t}^{CM}) \right] d\lambda^* \tag{1.39}$$

I find that on average these gains are equivalent to a 32 percent increase in consumption. Note that the gains are larger than the average increase in consumption even if inequality is increasing. This is due to the welfare gain associated to lower consumption fluctuations. Next, I plan to study the heterogeneity in this welfare gains.

1.7 Conclusion

Households in low-income countries live at much risk with low access to formal financial markets or government safety-nets. In this paper, I study the effects of completing financial markets in agriculture in the context of rural Uganda. To do so, I propose an incomplete markets model with an endogenous income process given by investment decisions on two agricultural technologies that differ on productivity and risk. Under this model, wealth-rich households invest in the two technologies close to profit maximization since they can cushion bad times with accumulated wealth. Nevertheless, since wealth-poor households have limited capacity to ex-post cope with risk due to minor wealth holdings, they optimally lower their inputs usage and shift inputs usage to the less productive and safer crops, reducing profitability and reducing risk exposure. I discipline the model with nationally representative panel household data from the UNPS, a dataset rich in agriculture, consumption, income, and wealth dynamics.

Comparing the benchmark economy with a counterfactual economy where financial markets in agriculture are complete, I find the following effects. First, completing markets notably increases agricultural production due to higher inputs usage and a more efficient allocation of inputs within households—across crops—and across households. Second, completing markets reduces the need for costly precautionary savings. The two effects combined lead to a significant increase in household consumption across the entire consumption distribution. Under complete markets, the consumption of the poor households significantly increases since their consumption allocations do not depend on the bad agricultural shocks realizations that they typically experience and the distortion of input choices that they suffer due to small wealth holdings. The consumption increase for middle and rich households is more prominent than for the poor. First, those households with high agricultural permanent components will experience the most significant gains in income from completing markets—and these households are concentrated in the middle and top of the distribution. Second, completing markets strongly reduces costly precautionary savings, which are mainly held by the rich. Another effect of completing agricultural financial markets is that it reduces average consumption fluctuations by more than half. Altogether, the welfare gain from completing markets in agriculture in this economy is significant, a 32 percent increase in consumption terms.

To conclude, this paper highlights the potentially large gains of completing markets in economies in the earlier stages of development. Not only completing markets have welfare-enhancing benefits in terms of eliminating consumption fluctuations, but also completing markets increases productive investments and leads to a better allocation of resources. Thus, well-functioning policies that provide insurance to the households could help promote growth and increase welfare in poor-rural areas. On this line, In immediate future research, I am introducing index-based insurance policies in the model to assess how much these policies could account for the welfare gains of completing financial markets that I find in this paper.

Chapter 2

Do the Poor Insure their Consumption Better? Empirical Evidence from Uganda

Using nationally representative panel household data, I study the difference in consumption insurance levels across the quintiles of the consumption, income, and wealth distributions in Uganda. I find that poor households do insure their consumption better than rich households. Under several econometric specifications, consumption insurance coefficients are notably—and in many cases statistically significantly—lower for the households in the bottom quintiles of the consumption and wealth distributions than for the households in the top quintiles. The results are driven by rural areas where most Ugandan households reside. In urban areas, the relationship between insurance and economic levels is the opposite: rich households experience much larger levels of insurance than poor households. Overall, the results suggests there is trade-off between insurance and economic levels across households.

2.1 Introduction

Poverty implies living with high levels of income risk with little access to formal financial markets or government safety nets. Nevertheless, even across some of the poorest areas in the world, households can deal with risk up to a high degree with informal insurance mechanisms—e.g.Townsend (1994) and Udry (1994). In this paper, I study whether insurance levels systematically differ across the economic levels of households in a developing country.

Answering this question can contribute to the micro and macro debate on insurance versus growth. At the micro-level, several studies have documented the costs of informal insurance in education (De Magalhaes, Koh, and Santaeulàlia-Llopis (2019)), health (Robinson and Yeh (2012)), migration decisions (Rosenzweig and Stark (1989)), and labor, savings, and business decisions.[1] At the macro level, studies have documented a trade-off between insurance and growth across rural and urban areas (e.g.Munshi and Rosenzweig (2016)) as well as across the stages of development. Santaeulalia-Llopis and Zheng (2018) find that the golden period of growth in China was associated with a large decrease in consumption insurance. In a work in progress, De Magalhaes, Martorell, and Santaeulalia-Llopis (2019) document that poor countries have larger insurance levels than rich countries. This paper studies whether the trade-off between insurance and growth across different economies is also observed across households within the same economy—across the cross-sectional distributions.

To study that, I compute consumption insurance coefficients across the quintiles of consumption, income, and wealth distributions of Uganda, and separately for the rural and urban areas of the country. The insurance coefficients are computed following two different econometric specifications. In the first specification (CRRA specification), under complete markets and households with identical preferences with a CRRRA utility form, the growth rate of individual consumption should only depend on the growth rate of aggregate consumption. Thus, a measure of consumption insurance consists of the coefficient estimate of regressing the growth rate of household consumption on the growth rate of household idiosyncratic income. Under full insurance, the coefficient should be equal to

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[1] In the context of Africa where kinship networks are particularly strong, informal insurance, which is associated with high redistribution pressures, disincentive labor supply, asset accumulation, and entrepreneurship activity—see Platteau (2009) for a discussion. Baland et al. (2016) find that mutual help in extended families reduces labor supply and entrepreneurship of the younger siblings. Boltz, Marazyan, and Villar (2020) observe that households take out loans to signal themselves as liquidity constrained and avoid sharing the accumulated wealth with relatives and friends. In lab-experiments, individuals pay an extra price to hide their income from relatives and friends—e.g. Jakiela and Ozier (2016), Boltz, Marazyan, and Villar (2020)).

zero while, under the complete absence of insurance, the coefficient should be equal to one. In the second specification (standard specification), I compute insurance coefficients following the standard econometric specification in the literature (as in Chiappori et al. (2014), Meghir et al. (2022), Kinnan (2021) and others). In this case, the measure of consumption insurance is the coefficient estimate of regressing log of household consumption on log of household idiosyncratic income. Similarly, if there is full insurance, household consumption should only depend on aggregate consumption and, therefore, the coefficient of household idiosyncratic income should be equal to zero—and under the complete absence of insurance, the coefficient should be equal to one.

In terms of data, I use the Ugandan National Panel Survey (UNPS) a nationally representative panel household survey that allows us to compute household consumption, income, and wealth dynamics. The UNPS is a survey under the umbrella of the World Bank Living Standards Measurement Study and the Integrated Surveys on Agriculture (LSMS-ISA). Measuring income is particularly difficult in poor countries mainly because most households are subsistence farmers.[2] the ISA part of the survey permits to have an accurate measure of a household's agricultural income since the survey is carefully designed to capture all agricultural and livestock production, costs, and farming assets holdings. Moreover, the LSMS part provides detailed information on consumption, non-agricultural income, and non-agricultural wealth. Thus, the UNPS data provides a nationally representative panel household data with a precise measure of household consumption, income, and wealth dynamics. This rather unique dataset allows us to study in detail insurance levels across the economic levels of the households.

In terms of results, this paper finds that poor households experience larger consumption insurance levels than rich households: as households move up on the distribution—on wealth and consumption—their insurance levels decrease. Under the CRRA specification, At the national level, full consumption insurance cannot be rejected for the households in the bottom quintile of the consumption distribution and the bottom quintile of the wealth distribution. The national trend is not purely driven by differences between urban and rural areas, already emphasized in Munshi and Rosenzweig (2016), De Magalhães and Santaeulàlia-Llopis (2018) and other works. In rural areas, where more than 70 percent of the country's population resides, poor households have substantially and statistically significant larger insurance levels than rich households. In urban areas

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[2] Measuring household income in poor countries is also difficult because a large part of the jobs and businesses are informal, and their earnings are erratic across time.

the opposite trend is observed: rich households, those in the top quintile of the income distribution and those in the top quintile of the wealth distribution, experience much higher levels of insurance and full consumption insurance cannot be rejected among the households in the top of the distributions.

Under the standard specification, the estimated coefficients are larger than under the CRRA specification—implying less insurance. Full consumption insurance cannot be rejected for most of the quintiles of the consumption, income, and wealth distributions. Nevertheless, The relationship between insurance and economic levels is equally observed in both econometric specifications. In Uganda, and, particularly, in rural areas, across the consumption distribution and the wealth distribution, poor households have much larger insurance levels than rich households. In urban areas, across the income distribution and the wealth distribution, the insurance levels of the households in the top quintile of the distributions are much larger than for the rest of the households.

The results are robust by running insurance test regressions without fixed effects, using the unbalanced panel, and testing insurance only for food consumption. Including or not fixed effects in the regressions have little effect on the estimated coefficients. Thus, the results are not driven by permanent different characteristics among rich and poor households. Using the unbalanced panel, the negative relationship between insurance and the wealth distribution in the whole country and rural areas is no longer observed, but the rest of the relationships observed in the balanced panel are maintained. A potential explanation for the larger levels of consumption insurance among the poor is that rich households could have different patterns of consumption in goods and services—as clothes, education expenditures, and medical expenditures—that do not necessarily need to exhibit a smoothed consumption for welfare maximization. Nevertheless, this potential confounder effect is rejected. Testing insurance only in food consumption delivers the same trends between insurance and economic levels as when testing insurance for total consumption.

The main contribution of this work is to provide novel empirical evidence of a trade-off between insurance and economic levels across households in the same economy. Knowing the existence of such trade-off is relevant for policymakers that attempt to promote pro-growth policies for the poor—poor households might be reluctant to follow such policies if it implies a loss in insurance—and for policies aiming to increase access to formal insurance among the poor—despite that the poor have large insurance levels, formal insurance might alleviate the observed trade-off between insurance and growth. These novel findings also provide better guidance to bringing (endogenous) incomplete markets models to the data. Differences in insurance levels across households along the cross-sectional distribution can be an important statistic to target at least in developing countries.

Related Literature. This work relates to the abundant literature on insurance in developing countries (e.g. Townsend (1994), Chiappori et al. (2014), Kinnan (2021)). More specifically, this work relates to the works that have documented a trade-off between insurance and growth. Munshi and Rosenzweig (2016) and De Magalhães and Santaeulàlia-Llopis (2018) show that the poor rural areas have substantially higher levels of insurance than rich urban areas. Santaeulalia-Llopis and Zheng (2018) document a trade-off between insurance and growth across the stages of development studying the golden period of growth in China, while De Magalhaes, Martorell, and Santaeulalia-Llopis (2019) document the existence of the trade-off between insurance and growth across poor and rich countries in the world. This work contributes to the aforementioned literature by documenting that a trade-off between insurance and economic levels is not only observed between economies but also between households in the same economy. Moreover, this work shows that the relationship between insurance and economic levels across rural and urban areas is the opposite: while in rural areas higher economic levels are associated with lower insurance, in urban areas higher economic levels are associated with higher insurance. this result provides further evidence that the two regions have different insurance mechanisms. Moll, Townsend, and Zhorin (2017) show that a large part of the macroeconomic outcomes between rural and urban Thailand could be explained by differences in the underlying financial frictions—limited commitment in rural areas and moral hazard in urban areas.

The paper is organized as follows. Section 2.2 discusses the data and the measurement of the key variables. Section 2.3 presents the framework for consumption insurance tests across distributions while section 2.4 presents the results. Finally, section 2.5 discusses the robustness of the results while section 2.6 concludes.

2.2 Data: Uganda National Panel Survey

This study uses the first five waves of the Ugandan National Panel Survey.[3] The UNPS is a nationally representative panel survey carried out by the Ugandan

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[3] Uganda National Panel Survey, the World Bank.

National Statistics and is part of the World Bank LSMS-ISA project. The Living Standards Measurement Study, LSMS, is a representative household survey with a focus on living standards and inequality. The Integrated Survey on Agriculture, ISA, are surveys designed to capture all agricultural and livestock outputs, inputs and wealth. The UNPS sample is approximately 3,200 households and it is currently the longest panel of the LSMS-ISA project. The first wave started in 2009–10 and its initial sample was visited for two consecutive years: 2009–10 and 2010–11. In the fourth wave, 2013–14, one-third of the initial sample was refreshed and the fifth wave, 2015–16, uses the sample from 2013–14.

In this work, I use the balanced panel and, hence, all households in the data are observed during the 5 waves. The balanced panel has a total of 1033 households. To study insurance levels separately for urban and rural areas, I construct balanced panels for each of the locations. the rural panel includes all the households in the survey that resided in rural areas during all the waves—791 households. Similarly, the urban panel includes all the households in the survey that resided in urban areas during all the waves—107 households.[4]

Performing consumption insurance tests requires precise measures of household income and consumption across different periods. Moreover, If we are interested in how these consumption insurance levels change across the wealth distribution, we also need a precise measure of household wealth. The main strength of the LSMS-ISA data is that it provides nationally representative panel household data from which we can recover the consumption, income, and wealth dynamics. Yet, correctly computing the consumption, income, and wealth of the households is difficult in this context. This work follows the procedures explained in detail in section 3.2—and, briefly, in the next paragraphs.

Measuring Consumption. household consumption includes the value of purchases, the value from home production and received in-kind or free, for all food items and non-durable items. Durable goods provide consumption but also a long-term investment in the household. Thus, since this work is concerned with the consumption insurance of the households, I omit durable goods from the consumption measure. to avoid the presence of outliers, I trim total household consumption at the bottom and top one percent in each wave.

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[4] In the balanced panel, 77 percent of the households resided in rural areas during all the waves, 10 percent in urban areas, and 13 percent of the households moved between rural and urban areas.

Measuring Income. household income is the sum of agricultural revenues, business profits, labor wages, livestock profits, and other sources of income. household's agricultural revenue is the sum of the self-reported value of production sold plus the value of the unsold production value which is measured with the adjusted kilograms crop unsold production times district median crop consumption prices. Unsold agricultural production accounts for the majority of the agricultural production in Uganda—less than 30 percent of the total agricultural production is devoted to the market—and, therefore, it is key to have a precise measure of this production. To do so, I follow the approach in De Magalhães and Santaeulàlia-Llopis (2018) using consumption prices at the district level which capture better the value of not selling the agricultural production: the value of not having to buy the crops. A correct measure also implies proper conversion rates to a single unit, in this case, kilograms. To convert all production into kilograms, I use median crop-unit conversion rates from the household's reported unit conversion rates. For more detail on the unit's conversion to kilograms and the monetary value assignment see .

Business income is the sum of profits across all businesses operated by household members. Each enterprise's profits are computed by monthly gross revenues minus costs times the number of months the business was in operation. Labor income is the sum across household members of the yearly labor payments — taking into account the number of months, weeks, days and hours worked and also including in-kind payments for the main job and a second job if existent. The computation of livestock profits is given by the sum of net sales of animals, sales of meat, milk, and eggs, the value of unsold production devoted to own consumption, minus the costs: hired labor, feeding, access to water sources, vaccinations, deworming, insects treatment, curative treatment. I trim household business profits, salary labor income, livestock, and other sources of income at 2.5 percent on both tails because I found there tended to be more extreme values and the computation of such income sources entailed more assumptions. After, I trim total household income at the bottom and top one percent.

Measuring Wealth. Household wealth is the sum of the value of their household assets, land, livestock, and farm capital. The value of household assets, livestock, and farm capital is given by the self-reported value if the household were to sell the as at the current moment.[5] Nevertheless, household farming land

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[5] household assets include housing and other buildings, non-agricultural land, furniture, household appliances, electronic devices, jewelry, vehicles, and other assets. Livestock includes... Farm capital includes

value needs to be estimated for most of the waves. households were asked for the value of their landholdings only in the first two waves. To have land value for the rest of the waves, I compute per acre median prices of land given its characteristics and location from the second wave—2010–11. To compute the prices, I first trimmed extreme observations on the size of the plot—at 1 percent—the per-acre price of the plot—at 5 percent—and the ratio of plot value and one-year rent—at 5 percent. Given this set of observations, I compute the median per-acre land prices grouped by counties and plot characteristics—quality, distance to the plot, tenure system, water source, and topography. I trim observations at the top 1 percent of the wealth.

A summary of the consumption, income, and wealth of the households in Uganda is presented in section 3.2.

2.3 Consumption Insurance Tests

In the benchmark of full-insurance tests, if markets are complete and ignoring preference shocks and demographic shocks, household consumption should be determined by average consumption. That is household consumption responds to aggregate risk but not to household idiosyncratic risk.[6] In this section, I perform full-insurance tests across the quintiles of the consumption, income, and wealth distributions. That is, for each quintile group in each of the distributions, I run regressions in which the explanatory variable is variation in household income, the dependent variable is variation in household consumption, and I control for aggregate shocks and household fixed effects. This follows the approach of Townsend (1994) and other authors studying insurance levels.

I perform consumption insurance tests for the whole country, and separately for rural areas and urban areas. A large part of the insurance literature in developing countries computes insurance tests at the village level. If there is full consumption insurance in the village, then, household consumption should comove one to one with village average consumption and be independent of household idiosyncratic risk. Yet villages—and cities—in developing countries are not completely isolated economies but embedded in larger regional or national economies. With the UNPS data, village insurance tests are not feasible since the sample is not representative at village levels but at the four main administrative regions of

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[6] See Altug and Miller (1990) Cochrane (1991), Mace (1991), Deaton et al. (1992),Townsend (1994), and others.

Uganda: Northern, Western, Eastern, and Central Uganda. Consequently, I perform insurance tests at the regional level. that is I measure the capacity of households to smooth consumption from income fluctuations produced at the household or village level. If there is full insurance, household consumption should only respond to regional aggregate risk. Measuring insurance at more aggregate levels has the advantage of capturing better the capacity of households to avoid income fluctuations to translate into consumption fluctuations. Households living in the same village might be experiencing similar shocks—as climate shocks, crops and pests diseases, price shocks, etc. As a consequence, a large level of consumption insurance might not reflect that these households can smooth their consumption well. By measuring aggregate shocks at the regional level, the insurance coefficients might provide a better picture of the actual capacity of households to smooth their consumption.

Finally, I perform the set of insurance tests for two econometric specifications. The first specification comes from assuming that households have CRRA utility while the second specification is the most commonly used in the literature. Under both specifications, I control for household fixed effects. As a consequence, the coefficient on the explanatory variable—measures of idiosyncratic income fluctuations—does not capture changes in income that are inherent to the permanent conditions of the household.

Insurance Tests: CRRA Specification. Assuming that agents are homogeneous on preferences with CRRA utility function, under full-insurance, the growth rate of household consumption growth should only vary with respect to the growth rate of region average consumption. The derivation of this result can be find in Appendix (B.1). Thus, we can test consumption insurance in each quintile group j of the consumption, income, and wealth distributions by testing $\beta_j = 0$ in the regression equations

$$\Delta lnc_{itr} = \alpha \Delta C_{tr} + \beta_j \Delta lny_{itr} + F_i + e_{itr} \qquad \forall i \in Q_j \tag{2.1}$$

In which $\Delta C_t, r$ represents the growth rate in average consumption from wave $t-1$ to wave t in region r. Δlnc_{itr} and Δlny_{itr} represent the growth rate in consumption and growth rate in income for household i belonging to quintile j. F_i represents household fixed effects and e_{itr} is the error term.

Insurance Tests: Standard Specification. Most of the literature uses a sligthly simplified test of the standard insurance test in (Cochrane (1991),Mace (1991),Townsend

(1994)) running the regression

$$lnc_{it} = \alpha C_{tr} + \beta lny_{it} + e_{it} \tag{2.2}$$

Following this approach, I test for consumption insurance in each quintile group j of the consumption, income, and wealth distribution by testing $\beta_j = 0$ in the regression equations

$$logc_{itr} = \alpha C_t r + \beta_j lny_{itr} + F_i + e_{itr} \qquad \forall i \in Q_j \tag{2.3}$$

in which the variables have the same definition as in the CRRA case except that now the observations are not difference across waves. The results of estimating equations (2.1) and (2.3) across quintiles of the distributions and regions are presented in the following section.

2.4 Results

Figure 2.1 presents the estimates of β_j in equation (2.1), CRRA case, for each quintile group j—from the bottom quintile (Q1) to the top quintile (Q5))—in each distribution—consumption (2.1a), income (2.1b), and wealth(2.1c)—for the whole country of Uganda (2.1-column-1), for rural areas (2.1-column-2), and for urban areas (2.1-column-3). The squared dots represent the point estimates of β_j and the vertical lines represent the 95% confidence interval under robust standard errors using White's estimator. N_Q represents the minimum number of observations across the quintile groups of observations. [7]

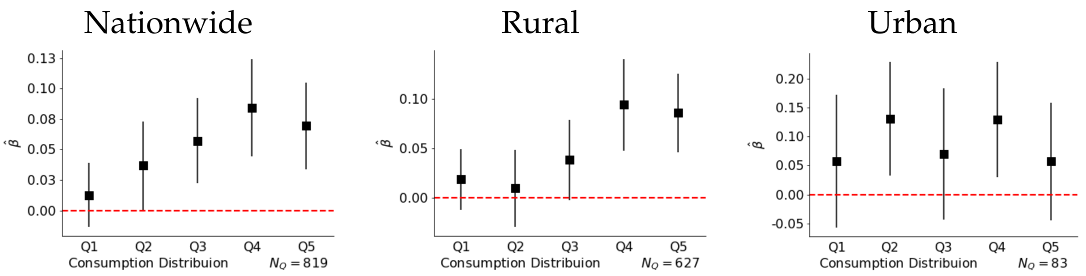
Households at the bottom of the distributions—in consumption and wealth—have substantially and statistically significant higher levels of insurance than the households at the top of the distributions at the national level. While for households in the first quintile of the consumption, income, and wealth distributions we cannot reject full consumption insurance, for the households in the rest of the quintiles full consumption insurance is always rejected. In magnitude terms, the coefficient estimate of idiosyncratic income changes to consumption changes is 0.018 for the households in the first quintile of the consumption distribution while the coefficient is 0.08 for the households in the top quintile.

---

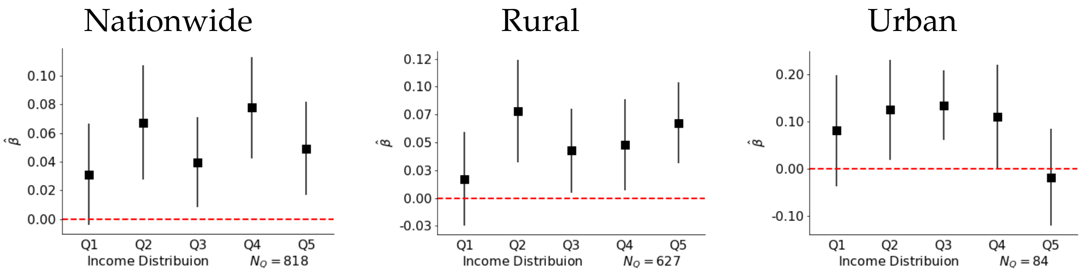
[7] For each specification, the number of observations in the regressions across the quintile groups are very similar but not exact.

FIGURE 2.1: Consumption Insurance Coefficients across the Consumption, Income and Wealth Distributions—CRRA Specification

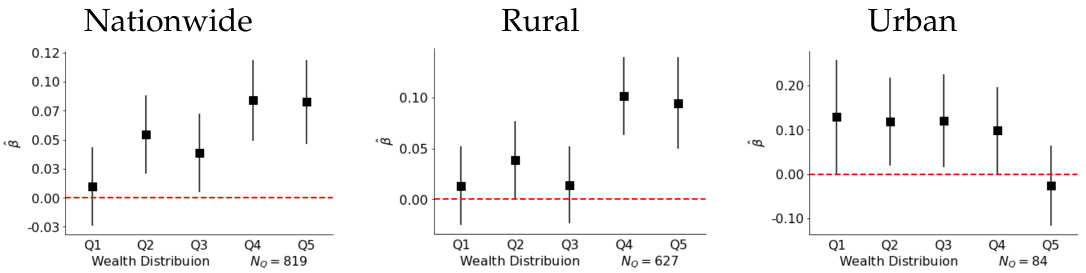
(a) Consumption



(b) Income



(c) Wealth



Notes: OLS estimates of β in regression equation $\Delta lnc_{itr} = +\alpha \Delta C_t r + \beta \Delta ln y_{itr} + F_i + e_{itr}$ for each quintile group—x-axis—of the consumption (a), income (b), and wealth (c) distributions for the whole country (column 1), for rural areas (column 2), and for urban areas (column 3). c_{itr} and y_{itr} denote consumption and income of household i in region r at period t, $C_t r$ denotes average consumption in region r at period t and F_i denotes household fixed effects. N_q denotes the minimum number of observations in the regressions across the five quintiles of the distribution. The red dotted-line denotes full consumption insurance. Balanced Panel of the first 5 waves of the UNPS.

Moreover, insurance coefficients in rural and urban areas across the distributions follow opposite trends. While in rural areas the coefficients along the distributions go in line with the nationwide results—poor households have significantly higher levels of consumption insurance—in urban areas, the relationship is the opposite: urban rich households experience higher consumption insurance.

In rural areas—Figure 2.1-column-2—full consumption insurance cannot be rejected for the first, second, and third quintiles of the consumption distribution and nor for the first, second, and third quintiles of the wealth distribution. Along with the income distribution, there is not a clear trend between insurance and economic levels. The insurance coefficient point estimate for the households in the top quintile of the consumption distribution is between 4 and 5 times larger—and significantly different—than the point estimate for the households in the bottom quintile. In the case of the wealth distribution, the insurance coefficient point estimate in the top quintile is more than 5 times larger—and significantly different—than the insurance coefficient of the bottom quintile.

In urban areas—Figure 2.1-column-1—full consumption insurance tends to be higher for those households at the top of the distributions. For the case of the income and wealth distribution, we observe that households in the top 40 percent of the distribution have larger insurance levels—albeit not significantly so—than the households in the rest of the distribution. Moreover, we cannot reject full insurance for the households in the top quintile of the income distribution and the households in the top quintile of the wealth distribution yet the estimate is not significantly different than for the rest of the quintiles in the distribution.

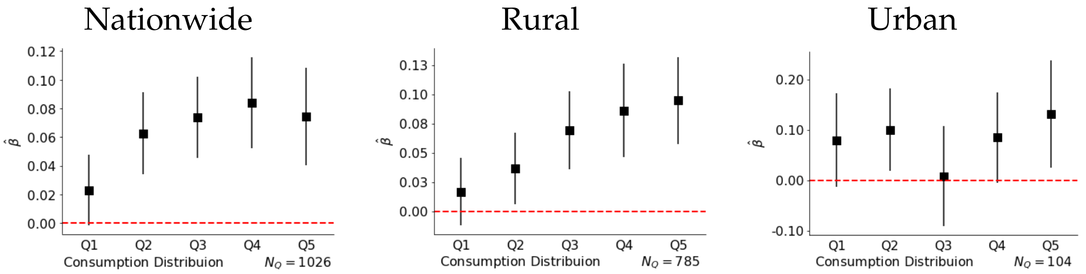
Figure 2.2 presents the estimates of β_j in equation (**??**), standard case, for each quintile group j of the consumption (2.2a), income (2.2b), and wealth (2.2c) distributions for the whole country (2.1-column-1), for rural areas (2.1-column-2), and for urban areas (2.1-column-3).

Testing insurance across quintile groups using the standard specification in the literature delivers very similar trends to the CRRA utility specification: higher levels of consumption and wealth are associated with lower levels of insurance in Uganda, especially in rural areas.

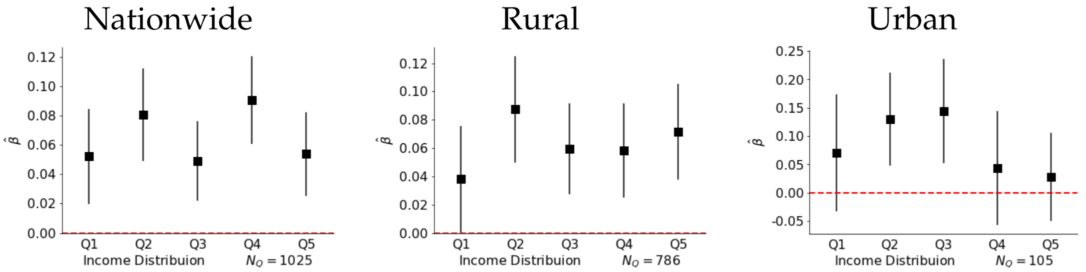
Although the trends do not change much across specifications, the levels do. Under the standard specification, the coefficients are notably larger—implying less insurance—than in the case with the CRRA specification. As a consequence, there are fewer quintiles groups where full insurance cannot be rejected. Full insurance cannot be rejected for the bottom quintile of the consumption distribution—in rural areas, and nationwide (slightly)—and the bottom quintile of the wealth distribution in rural areas. In urban areas, full consumption insurance cannot be rejected for the middle quintile in the consumption distribution, the first and second top quintiles in the income distribution, and the top quintile in the wealth distribution.

FIGURE 2.2: Consumption Insurance Coefficients across the Consumption, Income and Wealth Distributions—Standard Specification

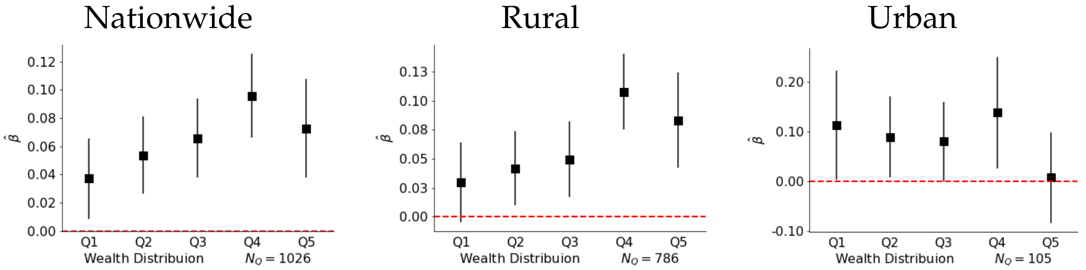
(a) Consumption



(b) Income



(c) Wealth



Notes: OLS estimates of β in regression equation $lnc_{it} = +\alpha C_t + \beta lny_{it} + F_i + e_{it}$ for each quintile group—x-axis—of the consumption (a), income (b), and wealth (c) distributions for the whole country (column 1), for rural areas (column 2), and for urban areas (column 3). c_{it} and y_{it} denote consumption and income of household i at period t, C_t denotes region average consumption and F_i denotes household fixed effects. N_q denotes the minimum number of observations in the regressions across the five quintiles of the distribution. The red dotted-line denotes full consumption insurance. Balanced Panel of the first 5 waves of the UNPS.

2.5 Robustness

In this section, I run several regressions to evaluate the robustness of the results. All Figures are presented in the appendix. The trends between insurance and economic levels observed in section 2.4 are still present once we do not control for fixed effects and once the outcome variable is food consumption instead of total consumption (food plus non-durable items). However, under running the regressions under the unbalanced panel the negative relationship between insurance and wealth levels is not observed.

Regressions without Fixed Effects to check whether the previous results might be strongly driven by household permanent characteristics that differ across distributions, I run the insurance test regressions under the CRRA specification and the Standard Specification without fixed effects. That is, I test for $\beta = 0$ in equations (2.1) and (2.3) without F_i. Figure B.1 and Figure B.2 show the coefficient estimates across the quintiles in the consumption, income, and wealth distributions for the two specifications respectively.

For the case of the CRRA specification, Controlling or not for household fixed effects has little effect on the coefficients estimates. The nationwide, rural and urban trends of insurance coefficients across the quintiles in each of the distributions are almost the same with or without including fixed effects in the regressions. The levels are also very close. In the case of the standard specification, under no fixed effects there is not a negative relationship between insurance levels and the quintiles in the wealth distribution but the relation is flat—both nationwide and in rural areas. Albeit the estimates and their dispersion of the coefficients under no fixed effects are different, we do observe the same negative relationship between consumption levels and consumption insurance nationwide and in rural areas. In the urban areas, the trend between insurance coefficients and economic levels does not change from the specification with or without fixed effects—there is not a consistent trend between insurance and growth across the three distributions. In general, the trends observed under fixed effects are similar to the coefficient estimates under no fixed effects.

Unbalanced panel All previous regressions used the balanced panel from the first 5 waves of the UNPS. Here, as a robustness check, I use the unbalanced panel which allows us to observe more households but during fewer periods. The unbalanced panel contains 4140 households, the unbalanced rural panel contains 2989 households, and the unbalanced urban panel contains 790 households. Figure B.3 shows the coefficient estimates of β under CRRA specification along quintiles and along the regions and Figure B.4 for the case of the standard specification. The main difference between the results under the unbalanced panel from the balanced panel is that the negative relationship between insurance and wealth levels observed at the national level and in rural areas is no longer observed—there is a flat relationship between wealth and insurance using the unbalanced panel. The rest of the results, the negative relationship between insurance and consumption levels at the national level and in rural areas, and the positive relationship between income and wealth levels in urban areas, still hold.

Food Consumption Poor households in Uganda seem to insure their consumption better than rich households. However, a potential explanation for this relationship could be that rich households consume more non-food goods and services—clothes, education, medical expenditures, etc.—which their consumption does not necessarily have to be smoothed across years. Some of the non-durable items, like clothes, last more than a year, while others, like education and medical expenditures, do not need to follow a smoother process for the welfare of households. Education expenditures might vary largely depending on the age of the children, while we should expect medical expenditures to follow an erratic process based on health shocks.

Here, I perform insurance tests only for food consumption. If from other items we should not necessarily expect a smoother process for utility maximization, in terms of food consumption, we would expect that if both poor and rich households can fully insure, then, their food consumption should not substantially vary across years given idiosyncratic shocks.

Figure B.5 and Figure B.6 plot the insurance coefficients on food consumption across the consumption, income, and wealth distributions for the CRRA specification and the standard specification respectively. The main takeover is that the patterns of food consumption insurance along the distributions follow very closely to the patterns of total consumption insurance. Thus, the results of the relationship between insurance and economic levels across regions in section 2.4 are not driven by different patterns in non-food consumption across poor and rich households.

We also observe in Figure B.5 and Figure B.6 that insurance levels in food consumption tend to be larger than with total consumption. On average the coefficients in both figures are smaller and, in particular, under food consumption, we cannot reject full insurance for more quintiles groups: as the second and third quintiles in the nationwide consumption distribution (CRRA case) and the bottom quintiles in the consumption and wealth distributions nationwide (standard case).

Under the different robustness checks, the estimates of the insurance coefficients and their significance vary. Nevertheless, the general trend that higher economic levels are associated with lower insurance levels in rural areas as well as the whole country still holds. Also, the positive relationship between insurance and economic levels in urban areas still holds across the different robustness specifications.

2.6 Conclusion

This paper documents a trade-off between insurance and economic levels across the consumption and wealth distributions of Uganda. Poor households ensure their consumption better than rich households. This result is driven by rural areas where the negative relationship between insurance and economic levels is larger. In urban areas, we do not observe such trade-off but the opposite, the richer the households, the better they insure their consumption.

The existence of such a trade-off between insurance and economic levels across households can have important implications in the development world. Pro-growth policies may incur a welfare loss in terms of insurance reduction and, consequently, poor households might be reluctant to adopt growth strategies.[8] Financial integration policies among the poor, yet perhaps not strongly demanded, might help to alleviate the trade-off. The empirical results from this paper also bring relevant information to the risk-sharing literature. Recent theoretical and quantitative works have included different insurance mechanisms between rural and urban areas, consistent with the results in this work and previous literature. A similar approach might be necessary for modeling insurance between poor and rich households in developing economies. Standard endogenous or exogenous incomplete markets models would hardly deliver the trade-off documented in this work.

For all the reasons above, a more profound analysis is necessary to determine the extent of the findings in this paper. First, the inconsistent trends with the income distribution are hardly arguable from the fundamentals of the economy—rather measurement error or other factors could be beyond it. Second, the results of this study are limited to Uganda. Performing a similar exercise with a much bigger sample of countries is also necessary. Third, using alternative and more recent measures of insurance as the Blundell, Pistaferri, and Preston (2008) approach plus using data with longer and more populated panels would allow us to extend the empirical results presented in this work.

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[8] The low adoption of products, technologies, or services that supposedly favor growth is a common observation in developing countries. From education choices, fertilizer usage, and other agricultural investments, market participation, business practices, and other investments.

Chapter 3

Excess of Transfer Progressivity in the Village

With Francesco CARLI and Raül SANTAEULÀLIA-LLOPIS

Using primary data on food transfers for a complete village in rural Malawi, we find that the extent of transfer progressivity across households is large—with an income-to-transfer elasticity of 0.60. The solution to village-calibrated versions of endogenously incomplete market models arising from limited commitment (LC) and private information (PI)—through hidden effort and income—imply constrained-efficient levels of progressivity that are substantially lower than the actual levels of progressivity in the village. The reduction of costly-state verification takes the constrained-efficient transfers closer to the first best—i.e. full insurance. Yet, the first best implies a level of transfer progressivity that is still lower than that of the village. To explore what drives the actual allocations, we introduce wedges in the LC and PI constraints and quantitatively single out the role of the ex-ante participation constraint. Interestingly, we find that these wedges tend to disappear if we decrease current village income to past productivity levels—i.e. a pre-fertilizers era. That is, the current transfers are similar to the efficient transfers that would emerge from past economic conditions. Interpreting these past contractual transfers as social norms, our results suggest that the currently inefficient excess of transfer progressivity in the village can be the result of norms that are sluggish to adapt to economic change.

3.1 Introduction

The large but imperfect insurance levels in village economies—e.g. Townsend (1994)—has let to a debate on which frictions—namely, limited commitment, hidden income, and moral hazard—can explain the insurance arrangements in village economies, Ligon, Thomas, and Worrall (2002), Karaivanov and Townsend (2014), Kinnan (2021), and others. In this paper, we add to the debate by asking ourselves: what is the role of transfer progressivity in risk-sharing economies? Is the transfer progressivity optimal through the lens of the canonical risk-sharing models? If not, what are the frictions that prevent optimality?

To answer these questions we use the following approach. First, we use primary income, consumption, and food transfer data containing all the households in a village in Malawi, and we document a series of stylized facts about the economy of the village. (1) the progressivity level in the village is high with an income-to-transfer elasticity of 0.60. (2) The transfers in the village are large, representing 28.9 percent of the total agricultural production. Moreover, we find that the majority of the households were involved in transfers, and we do not find evidence of strong clusters among income groups, religion, or other social groups. (3) the transmission of idiosyncratic income shocks to consumption is small—we cannot statistically reject full insurance in the village.

Second, we take the canonical risk-sharing models—models with Limited Commitment (LC), Private Information (PI), the two frictions together (PILC), and the complete markets model (FB)—and we calibrate and quantify them to the village. To accommodate the models to the data, we build the models in an Overlapping Generations (OLG) setup—allowing for inter-generational redistribution—and with permanent productivity differences—allowing for redistribution of initial conditions. Our calibration of the models follows a simple approach. In terms of the preference parameters, we take standard values from the literature with an annual discount factor of 0.975, a degree of risk aversion equal to one—e.g. Kocherlakota (1996)—and a subsistence level chosen following Bick, Fuchs-Schündeln, and Lagakos (2018), and De Magalhães and Santaeulàlia-Llopis (2018). The remaining parameters are determined by the income process, which is also common across all our models. To estimate the income process, first, after removing the year-fixed effects (average growth), we recover the age-fixed effects for our three age groups—young, adult, and old. Second, we estimate the permanent and transitory components of income by exploiting the panel dimension of our income data. Given the calibration, we simulate the models in steady state and contrast them to the village facts (1), (2), (3).

We find that the constrained-efficient risk-sharing models undershoot the level of transfer progressivity (1) with values ranging from 0.21 to 0.25. the total transfers (2) are also smaller representing less than 11 percent of total agricultural production. The PI model gets closer to the insurance level observed in the economy, but the LC and the PILC model predict much lower insurance (3). The reduction of costly-state verification takes the constrained-efficient transfers closer to the First Best—i.e. complete markets. Yet, the FB implies a level of transfer progressivity and aggregate transfers that are still lower than that of the village. To explore whether results are driven by the parameterization of preferences, we solve the models for a large range of values and study their capacity to replicate (1), (2), and (3). We find that with alternative parameterizations, the models still largely fail to explain the large transfer progressivity and size observed in the village.

The risk-sharing literature has focused on understanding what are the frictions that prevent full insurance. Our results bring a new perspective and direction to the debate. The transfer progressivity levels and size in the data are even larger than with complete markets. Our village is not at the efficient point in terms of risk-sharing, but it is not its lack of risk-sharing, but it is the excess of transfers progressivity that makes the village to be far from optimality.

Third, to explore what can explain the excess of transfer progressivity in the village, we introduce wedges in the LC and PI constraints and quantitatively single out the role of the ex-ante participation constraint. Then, we decrease current village income to past productivity levels. Interestingly, we find that these wedges tend to disappear if we decrease the current village income. That is, the current transfers are similar to the efficient transfers that would emerge from past economic conditions. Platteau (1991) considers that the institutional build-up of peasant societies based on social norms and customs induced large redistributions mechanisms to ensure the survival of the whole group—see also the moral economy approach, Scott (1977). Interpreting past contractual transfers as social norms, our results suggest that the currently inefficient excess of transfer progressivity in the village can be the result of norms that are sluggish to adapt to economic change.

Related Literature. Our paper mainly speaks to the literature on endogenously incomplete markets with applications to development—Ligon, Thomas, and Worrall (2002), Karaivanov and Townsend (2014), Li and Ligon (2019), Golosov, Troshkin, and Tsyvinski (2016), Kinnan (2021). Our contribution to this literature is threefold. First, methodologically, we depart from existing works distinguishing risk-sharing models by testing first order conditions implications on consumption data and provide a quantitative evaluation of the models with complete village data. Second, we show that the village-calibrated risk-sharing models fall short in explaining the data: there is an excess of transfer progressivity in the village. Third, we add a mechanism to study frictions based on social norms and we show that these frictions help to rationalize the observed transfers. Our work also contributes theoretically to the literature on endogenously incomplete markets (Kocherlakota (1996), Li and Ligon (2019), Sanchez, Monge-Naranjo, Lochner, et al. (2016), Ábrahám and Laczó (2018)) by adding reasons for redistribution—permanent differences plus and overlapping generations setup—and by providing a solution for endogenously incomplete markets under these sources of heterogeneity. Fafchamps and Lund (2003), De Weerdt and Dercon (2006), Fafchamps and Gubert (2007), Ambrus, Mobius, and Szeidl (2014), and other works use complete village data to study risk-sharing networks and their transfers behavior also in the context of low-income countries. We add to the literature by documenting the distribution of transfers over the income distribution and by studying the optimality of this distribution of transfers. Our interpretation of social norms relates to the the literature on social norms, informal redistribution, and development in Africa—Platteau (1991), Platteau (2009), Baland, Guirkinger, and Mali (2011) Jakiela and Ozier (2016), Boltz, Marazyan, and Villar (2020), and others. We show evidence that they might play a large role in explaining the large but imperfect insurance levels in village economies.

The paper is organized as follows. Section 3.2 discusses the village data and provides the empirical results. Section 3.3 presents the OLG risk-sharing models while section 3.4 discusses the calibration strategy. Section 3.5 shows the quantitative results while section 3.6 explores social norms as frictions to rationalize the quantitative results. section 3.7 concludes.

3.2 The Data: A Complete Village in Southern Malawi

We use primary data from a complete village in the region of Balaka in Southern Malawi collected in 2018 and 2019. Our data consist of the entire set of 242 households in the village containing household and person-specific data for a total of 1067 individuals. Our surveys took place from July to September, starting after the main harvest of the year—occurring around May and June—to minimize recall bias and guarantee a quality measure of household agricultural production.

We designed our survey to capture the entire budget constraint of the households and the food transfers network in the village. To do so, first, we followed the standards of the LSMS-ISA surveys to measure the consumption, income, and wealth of households in rural Sub-Saharan Africa. Second, to identify the network of transfers in the village, we asked households to report, for each possible food item, the quantities of the item received from and given to any person outside the household. If the person belonged to the village, we started our matching protocol to connect the person to his or her household. This procedure allows us to have the complete structure of food transfers happening within the village.

3.2.1 Consumption and Income in the Village

Measuring consumption and income presents several hardships in village economies. The lack of well-operating markets and the large subsistence levels hinder the monetary valuation of household consumption and income. Moreover, a clear-cut distinction of private property tends to be absent in regions where property rights are embedded with traditional systems of land tenure.[1]

To have a proper measurement of household consumption and income, we applied the following procedure. First, we adopted the standards of ISA-LSMS by providing an extensive survey with particularly detailed questions on food consumption and agricultural production. Second, we analyzed the answers to key variables just after the interview to be able to retake the questions to the households containing potential outlier observations. Third, we converted all food consumption and agricultural production quantities to a single unit—kilograms—using a price-unit conversion method as in De Magalhães and Santaeulàlia-Llopis (2018). Then, we use village-median consumption prices to assign a monetary value to the non-bought food consumption and the unsold agricultural production.[2]

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[1] In our village, only 44 percent of households reported that they have the right to sell land, while 12 percent of households reported that the village chief could prevent them from selling or bequeast land. See Table C.2 in the appendix for a description of land sizes, values, and rights in the village. The lack of well-operating land markets is not particular to our village but extended to many Sub-Saharan African regions (e.g.Platteau (1991), Restuccia and Santaeulália-Llopis (2017), Gottlieb and Grobovšek (2019)).

[2] For the case of cotton production we use median selling price across the cotton farmers in the village.

Table 3.1 presents a summarized description of the village economy. Panel (a) shows the main statistics of the CIW and land distributions in the village. Panel (b) presents the composition of the income in the village while panel (c) presents the composition of the agricultural production.

TABLE 3.1: The Village Economy

(a) Consumption Income and Wealth Distributions

	Consumption	Income	Wealth	Land Acres
Household Level				
Mean	729.63	679.56	1,296.71	2.62
Median	688.30	492.37	587.00	2.30
Var–log	0.29	0.95	1.11	0.54
Per Capita Level				
Mean	199.19	176.71	357.38	0.76
Median	159.32	106.13	141.10	0.50
Var–log	0.41	0.98	1.14	0.66

(b) Income Composition

	Agriculture	Wage Labor	Ganyu	Business	Gov,NGO,Rem
Income Share	0.61	0.18	0.11	0.10	0.10
Households Share	0.98	0.14	0.33	0.15	0.64

(c) Agricultural Production

	Maize	Groundnuts	Groundbean	Sw. Potatoes	Pig. Peas	Nkhwani
Production Share	0.50	0.43	0.01	0.01	0.02	0.02
Household Share	0.96	0.63	0.07	0.07	0.42	0.12

Notes: (a) Consumption and income flows at the year level. Monetary variables in 2019 US dollars not adjusted by purchasing power parity. Land in acres. Consumption includes food plus non-durables items; Income includes net agricultural production, labor earnings—wage labor, and ganyu—non-agricultural business profits, and transfers—government, NGOs, remittances. Wealth includes household assets, land value, livestock, and farm capital. (b) Income source share of the total household income in the village and share of households that engaged in each income source activity. (c) Agricultural production shares across the main crops in the village and the share of households that cultivated the crops.

The village we study is poor, unequal, and based upon subsistence agriculture. Average household annual consumption is 729.63 and income is 679.56 in 2019 US dollars.[3] In per capita terms, this is an annual consumption of 199.19$ and income of 176.71$.[4] Although almost all households hold land and with a median size of 2.3 acres, the total wealth in the village is small, with an average wealth holdings of 1296.71$ at the household level. Even if practically all households engage in subsistence farming, inequality within the village is large. The

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[3] Unless stated otherwise, all monetary values in this work, expressed in $, are in 2019 US dollars not adjusted by purchasing power parity.

[4] From the World Bank national accounts data, and OECD National Accounts data files, 2019 Malawi GDP per capita was 539.74$.

variance in logs of the consumption, income, and wealth distribution are 0.29, 0.95, and 1.11, respectively. As a comparison, in rural Malawi the values are 0.41, 0.98, 1.49—ISA-LSMS 2010, De Magalhães and Santaeulàlia-Llopis (2018).[5] Thus, income inequality in our studied village is very close to the income inequality observed in entire rural Malawi, but the transmission of income inequality into consumption inequality and wealth inequality is much lower.

Almost all households in the village engage in farming with maize being the main crop grown—96 percent of the households grew maize. Consequently, the main economic activity in the village is agriculture representing 60 percent of the total income of the village. Labor earnings represent 25 percent of the economy: 16 percent coming from formal labor and 10 from Ganyu labor—an informal labor system common in Malawi and Zambia. Albeit it is a rural village, 15 percent of the households ran non-agricultural businesses and the income from these business activities represents 15 percent of the total income in the village. Transfers from outside the village represent less than 10 percent of the total income of the households. Agriculture in the village is based upon maize and groundnuts. The two crops represent 50 percent and 46 percent of the total agricultural production. Maize production is mainly devoted to self-consumption: only 7 percent of households sold maize. Groundnuts are the main sold crop in the village, yet only 22 percent of households sold groundnuts.[6]

Our village has an economy characterized by low market interaction. Most households are subsistence farmers, and when sales do happen they are mostly at the local market. Yet, households in the village are not independent economic units, a large number of non-market transfers occur within the village. In the next section, we focus on the measurement and structure of the food transfers in the village.

Transfers: Net and Given To measure food transfers, we followed the literature on risk-sharing networks—e.g. Fafchamps and Gubert (2007)—and we carefully designed a set of questions to capture the food transfers network in the village. In the consumption section, for each food item, we asked households how much they consumed during the last 7-days (the gold standard recall period in food consumption in household surveys), how much of the consumption came from own-production, purchases, and transfers from other persons outside the household. In terms of these transfers, for each food item, we asked the households to report the quantities received and from which persons they received the food. If

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[5] As further a comparison, In the United States the variance in logs of consumption is 0.79, income is 0.97, and wealth is 2.11—using PSID data, De Magalhães and Santaeulàlia-Llopis (2018).

[6] See Table C.4 in the appendix for a description of sales across crops in the village.

the person belonged to the village, we started our matching protocol to connect the person to his/her household using a household roster to match the households immediately during the interview. If we could not immediately match the households, then we started a set of questions on the characteristics of the person (gender, approximate age, sub-village residence, and nickname) to be able to match the household ex-post. Similarly, in the consumption section, we asked households to report, for each food item, the quantities given to any person excluding household members. If the person belonged to the village, we started our matching protocol by first using the household roster and if the match could not be found, we started the set of questions for the ex-post match. This procedure allows us to have a complete network of food transfers in the village.

The network of food transfers in the village is large without evidence of cluster groups. Despite the short period of the 7-days recall, 193 households reported receiving food from other villagers, and 180 households reported giving food to other villagers. Both rich and poor households participate together in the transfers. In the appendix, Table C.5 panel (a) shows that the number of transfers was similar within and between the quintile groups of the income distribution in the village. We also do not find evidence that the food transfers network connections are clustered among groups that share specific sociodemographic characteristics.[7] Not only the number of transfers is large and widespread across villagers' characteristics, but the quantities transferred are sizeable—especially for the poorer households. Table C.5 panel (b) shows the share of food transfers on total food consumption value on average in the village and across the food consumption quintiles. On average, food transfers represented 8 percent of total household consumption. For poor households, the share of food transfers on total food consumption is much larger: 14 percent for the households in the bottom quintile of the distribution.

The small number of connections with households or institutions outside the village relative to a high number within the village validates our approach of modeling the risk-sharing in the village as a closed economy. The large number of households involved in food transfers and across all the income distribution motivates to model the risk-sharing at the village level including all households.

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[7] We ran several dyadic regressions to explain the food transfers matches between household pairs and we found that having similar household characteristics such as household head age, gender, marital status, education or religion did not significantly increase the probability of the match.

3.2.2 Transfer Progressivity in the Village

We use a transfer function to estimate the degree of transfer progressivity. We can write post-transfer income $\tilde{y}$ as

$$\tilde{y} = y - T(y)$$

where y is pre-transfer income and $T(y)$ captures the net transfers for a given household. If $T(y) > 0$, then the transfers given are larger than the transfers received, that is, the households is net giver. The opposite occurs for $T(y) < 0$ that makes the household a net receiver. To study the degree of transfer progressivity we use a class of functions common in public finance to estimate tax-subsidy progressivity Feldstein (1969) defined by

$$T(y) = y\left(1 - \lambda y^{-\phi}\right)$$

with $\lambda \geq 0$ and $\phi \geq 0$. The parameter ϕ determines the degree of transfer progressivity, which is the key object of our analysis. This function has been recently to capture the degree of income tax progressivity in quantitative macro with heterogeneous agents (Persson (1983), Benabou (2000), Heathcote, Storesletten, and Violante (2017)). For reference, note that the estimate for the U.S. is $\phi = 0.11$. Note that we can write post-transfer income as

$$\tilde{y} = y - T(y) = (1 - \tau(y))y$$

where $\tau(y)$ is the average transfer rate (ATR). [8]

$$\tau(y) = \frac{T(y)}{y} = 1 - \lambda y^{-\phi}$$

Using the previous expression we measure the level of transfer progressivity in the village. Note that we can write the ratio of post-transfer and pre-transfer

---

[8] If positive, we can think about this as the average "tax" rate. If negative, then we have the average "subsidy" rate. The marginal transfer rate (MTR) is

$$\frac{\partial T(y)}{\partial y} = 1 - (1 - \phi)\lambda y^{-\phi}$$

A transfer scheme is labeled as progressive (regressive) if the ratio of marginal to average tax rates is larger (smaller) than one for every level of income. When $\phi = 0$, implies that the MTR and the ATR are identical and their ratio is one. Indeed, note that if $\phi = 0$, then $\tau(y) = \tau$ is a flat rate tax (no progressivity). Instead, if $\phi > 0$ the ratio is larger than one (progressive transfers). The opposite occurs with $\phi < 0$.

income as

$$\frac{\tilde{y}}{y} = 1 - \tau(y) = \lambda y^{-\phi}$$

hence, taking logs on both sides we find:

$$\ln \frac{\tilde{y}}{y} = \ln \lambda - \phi \ln y \tag{3.1}$$

That is, to find the degree of transfer progressivity in an economy we need income, transfers received and transfers given. Since we have more transfers given than received, we show results re-scaling the amount of received transfers by each household by the same factor such that the total amount received equates to the total amount of transfers given. For comparison, we also show the no re-scaling estimates.

As is standard in the estimation of the degree of progressivity, we group households by income groups (e.g. Heathcote, Storesletten, and Violante (2017) use 50 income groups on the PSID sample for the U.S.). Our sample size limits the use of this strategy, we use 4 income groups—we also used 10 and 5 groups. Using our complete village data, we estimate $\phi = 0.60$ for agricultural production. If we use total income (larger recalls) we get $\phi = 0.51$. Since we can only measure food transfers, we stick to the results for agricultural production.

Consumption Insurance

To study risk-sharing models in village economies, a key moment for the evaluation is the insurance level. That is, we are interested in how idiosyncratic income affects consumption patterns. To study these patterns we run the following regressions

$$\text{Levels}: \quad c_{it} = cons. + \zeta y_{it} + i.wave + \theta x_{it} \tag{3.2}$$

$$\text{F.D.}: \quad dc_{it} = \zeta d\epsilon_{it} + i.wave + \theta x_{it} \tag{3.3}$$

$$\text{Levels}: \ln c_{it} = \zeta \ln y_{it} + i.wave + \theta x_{it} \tag{3.4}$$

$$\text{F.D.}: d \ln c_{it} = \zeta d \ln y_{it} + i.wave + \theta x_{it} \tag{3.5}$$

where $dx_t = x_t - x_{t-1}$. We do this for consumption levels c and also for log levels $\ln c$. Further, x_{it} includes a set of individual characteristics such as household size, education (head), livestock, land (area and value), total wealth. In some specfidcations yield.

We are particularly interested in our specifications (2) and (4) that test for full insurance. Our results speak to a high degree of consumption insurance, see Table 3.2. This is perhaps not surprising, given the high degree of transfer progressivity in the village.

TABLE 3.2: Insurance Tests

	Data, Food Consumption			
	(1)	(2)	(3)	(4)
Maize	0.173	0.059	0.104	-0.009
Maize, KG	0.115	-0.031	0.095	-0.040
Groundnut, KG	0.125	0.059	0.113	0.060
Pigeonpeas, KG	-0.020	-0.016	-0.001	-0.041
All Crops	0.166	0.017	0.166	0.015
Net Prod.	0.141	-0.001	0.140	0.004
Labor Inc.	0.034	-0.009	0.058	-0.038
Ganyu	0.005	-0.015	-0.018	-0.018
Bus. Profits	0.081	-0.064	0.174	-0.096
Total Inc.	0.093	-0.062	0.098	-0.047

	Data, Total Consumption			
	(1)	(2)	(3)	(4)
Maize	0.154	0.032	0.104	-0.018
Maize, KG	0.165	0.117	0.119	0.054
Groundnut, KG	0.147	0.092	0.120	0.067
Pigeonpeas, KG	-0.035	-0.027	0.015	-0.016
All Crops	0.128	-0.078	0.137	-0.035
Net Prod.	0.095	-0.089	0.120	-0.024
Labor Inc.	0.038	-0.004	0.106	0.008
Ganyu	0.010	-0.036	0.001	-0.023
Bus. Profits	0.098	-0.042	0.188	-0.099
Total Inc.	0.114	-0.113	0.109	-0.124

Notes: Constructing some averages from All Crops to Total Inc., we find that for food consumption the corresponding tests are: 0.087, -0.022, 0.103, and -0.030. The average for total consumption is 0.081, 0.009, 0.110 and -0.050. The benchmark data trims 5% of the residual changes in income and consumption across waves.

3.3 OLG-Model with LC and PI

3.3.1 Environment and Planner's Problem

Environment We consider a simple OLG setup where there is a measure μ_0 of new born agents at each period. Each agent lives for 3 periods, and faces exogenous survival probabilities from age 0 to age 1 and from age 1 to age 2 equal to γ_1 and γ_2 respectively. The age-structure of the population is described by a measure $\mu = (\mu_0, \mu_1, \mu_2)$. Agents can be of two types, $i \in \{1, 2\}$. The type i of an agent indexes her permanent productivity α^i, where $\alpha^2 > \alpha^1$. In addition to her permanent productivity α^i, the income of an agent of age a in time t depends on the age profile $g(a; i)$ and on the realization of an income shock ϵ^i_a. Specifically, the income of an agent of type i, at age a, in time t, is $y^i_{a,t} = \alpha^i + g(a; i) + \epsilon^i_a$. The income shock ϵ^i_a has an i.i.d. distribution $\pi(\epsilon)$ over $\mathcal{E} = \{\epsilon_h, \epsilon_l\}$, where $\epsilon_h > \epsilon_l$, for $a = 0, 1$, and $\epsilon_2 = 0$, i.e. agents receive no shock in old age. Let the probability of receiving a high income shock be $\pi(\epsilon_h) = p$ and that of a low shock be $\pi(\epsilon_l) = 1 - p$, where $p\epsilon_h + (1 - p)\epsilon_l = 0$. Finally, the age structure of the population is stationary.[9]

In this environment, we characterize stationary constrained-efficient allocations, where the ability of the planner to transfer resources across agents is restricted by private information and limited commitment frictions. First, while individuals know their history of shocks ϵ^a, the planner's only source of information are the reports provided by an agent himself, and the planner can only condition transfers on the history of reports provided by an agent. A stationary allocation is then a list of consumption functions $\{c^i_{a,\sigma^a}\}$ which depend on an agent's type i, age a, and history of reports σ^a. Second, consumption allocations $\{c^i_{a,\sigma^a}\}$ need to satisfy interim participation, since agents have limited commitment and may choose to exit the contract and revert to autarky.

---

[9] This is achieved by setting $\mu_0 = \psi\mu_1$ of new born agents at each period, where μ_1 is the measure of age 1 agents and ψ is their fertility rate, and ψ to satisfy

$$\begin{aligned} \mu^i_1 &= \gamma_1 \mu^i_0 \\ \mu^i_2 &= \gamma_1 \gamma_2 \mu^i_0 \\ \psi &= \frac{2 - \gamma_1 - \gamma_2 + \gamma_1\gamma_2}{\gamma_1}. \end{aligned}$$

Planner's problem. A constrained-efficient allocation is the solution to the planner's problem

$$
\begin{aligned}
\max_{\{c^i_a(\epsilon^a)\}} \sum_{i\in\{1,2\}} \mu^i_0 \Big\{ & pu(c^i_{0,h}) + (1-p)u(c^i_{0,l}) \\
& + (\beta\gamma_1)\Big[p^2u(c^i_{1,hh}) + p(1-p)u(c^i_{1,hl}) + (1-p)pu(c^i_{1,lh}) + (1-p)^2u(c^i_{1,ll})\Big] \\
& + (\beta^2\gamma_1\gamma_2)\Big[p^2u(c^i_{2,hh}) + p(1-p)u(c^i_{2,hl}) + (1-p)pu(c^i_{2,lh}) + (1-p)^2u(c^i_{2,ll})\Big]\Big\}
\end{aligned}
\tag{3.6}
$$

subject to the aggregate resource constraint,

$$
\begin{aligned}
\lambda : C = \sum_{i=\{1,2\}} \mu^i_a \left(\sum_{a=\{0,1,2\}} C^i_a\right) = \sum_{i=\{1,2\}} \mu^i_0 \Big\{ & pc^i_{0,h} + (1-p)c^i_{0,l} \\
& + \gamma_1\left[p^2c^i_{1,hh} + p(1-p)c^i_{1,hl} + (1-p)pc^i_{1,lh} + (1-p)^2c^i_{1,ll}\right] \\
& + \gamma_1\gamma_2\left[p^2c^i_{2,hh} + p(1-p)c^i_{2,hl} + (1-p)pc^i_{2,lh} + (1-p)^2c^i_{2,ll}\right]\Big\} \\
\le \sum_{i=\{1,2\}} & \left\{py^i_{0,h} + (1-p)y^i_{0,l} + \gamma_1\left[py^i_{2,h} + (1-p)y^i_{1,l}\right] + \gamma_1\gamma_2 y^i_2\right\} \\
= \sum_{i=\{1,2\}} & \mu^i_a \left(\sum_{a=\{0,1,2\}} Y^i_a\right) = Y
\end{aligned}
\tag{3.7}
$$

individual rationality (ex-ante participation):

$$
\begin{aligned}
\lambda^i_0 :\ & pu(c^i_{0,h}) + (1-p)u(c^i_{0,l}) \\
& + \beta\gamma_1\Big[p^2u(c^i_{1,hh}) + p(1-p)u(c^i_{1,hl}) + p(1-p)u(c^i_{1,lh}) + (1-p)^2u(c^i_{1,ll})\Big] \\
& + \beta^2\gamma_1\gamma_2\Big[p^2u(c^i_{2,hh}) + p(1-p)u(c^i_{2,hl}) + p(1-p)u(c^i_{2,lh}) + (1-p)^2u(c^i_{2,ll})\Big] \\
& \quad \ge pu(y^i_{0,h}) + (1-p)u(y^i_{0,l}) + \beta\gamma_1[pu(y^i_{1,h}) + (1-p)u(y^i_{1,l})] + \beta^2\gamma_1\gamma_2 u(y^i_2) \quad \text{for } i = 1,2
\end{aligned}
\tag{3.8}
$$

limited commitment (interim participation):

$$\begin{aligned}\lambda^i_{0,h}:\ & u(c^i_{0,h})+\beta\gamma_1[pu(c^i_{1,hh})+(1-p)u(c^i_{1,hl})]+\beta^2\gamma_1\gamma_2[pu(c^i_{2,hh})+(1-p)u(c^i_{2,hl})]\\ & \geq u(y^i_{0,h})+\beta\gamma_1[pu(y^i_{1,h})+(1-p)u(y^i_{1,l})]+\beta^2\gamma_1\gamma_2 u(y^i_2) \quad \text{for } i=1,2\end{aligned}\tag{3.9}$$

$$\begin{aligned}\lambda^i_{0,l}:\ & u(c^i_{0,l})+\beta\gamma_1[pu(c^i_{1,lh})+(1-p)u(c^i_{1,ll})]+\beta^2\gamma_1\gamma_2[pu(c^i_{2,lh})+(1-p)u(c^i_{2,ll})]\\ & \geq u(y^i_{0,l})+\beta\gamma_1[pu(y^i_{1,h})+(1-p)u(y^i_{1,l})]+\beta^2\gamma_1\gamma_2 u(y^i_2) \quad \text{for } i=1,2\end{aligned}\tag{3.10}$$

$$\lambda^i_{1,hh}:\ u(c^i_{1,hh})+\beta\gamma_2 u(c^i_{2,hh})\geq u(y^i_{1,h})+\beta\gamma_2 u(y^i_2) \quad \text{for } i=1,2\tag{3.11}$$

$$\lambda^i_{1,lh}:\ u(c^i_{1,lh})+\beta\gamma_2 u(c^i_{2,lh})\geq u(y^i_{1,h})+\beta\gamma_2 u(y^i_2) \quad \text{for } i=1,2\tag{3.12}$$

$$\lambda^i_{1,hl}:\ u(c^i_{1,hl})+\beta\gamma_2 u(c^i_{2,hl})\geq u(y^i_{1,l})+\beta\gamma_2 u(y^i_2) \quad \text{for } i=1,2\tag{3.13}$$

$$\lambda^i_{1,ll}:\ u(c^i_{1,ll})+\beta\gamma_2 u(c^i_{2,ll})\geq u(y^i_{1,l})+\beta\gamma_2 u(y^i_2) \quad \text{for } i=1,2\tag{3.14}$$

$$\lambda^i_{2,hh}:\ u(c^i_{2,hh})\geq u(y^i_2) \quad \text{for } i=1,2\tag{3.15}$$

$$\lambda^i_{2,lh}:\ u(c^i_{2,lh})\geq u(y^i_2) \quad \text{for } i=1,2\tag{3.16}$$

$$\lambda^i_{2,hl}:\ u(c^i_{2,hl})\geq u(y^i_2) \quad \text{for } i=1,2\tag{3.17}$$

$$\lambda^i_{2,ll}:\ u(c^i_{2,ll})\geq u(y^i_2) \quad \text{for } i=1,2\tag{3.18}$$

and truth-telling (incentive-compatibility):

$$\begin{aligned}\delta^i_{0,h}:\ & u(c^i_{0,h})+\beta\gamma_1[pu(c^i_{1,hh})+(1-p)u(c^i_{1,hl})]+\beta^2\gamma_1\gamma_2[pu(c^i_{2,hh})+(1-p)u(c^i_{2,hl})]\\ & \geq u(c^i_{0,l}+y^i_{0,h}-y^i_{0,l})+\beta\gamma_1[pu(c^i_{1,lh})+(1-p)u(c^i_{1,ll})]+\beta^2\gamma_1\gamma_2[pu(c^i_{2,lh})+(1-p)u(c^i_{2,ll})]\end{aligned}\tag{3.19}$$

$$\delta^i_{1,hh}:\ u(c^i_{1,hh})+\beta\gamma_2 u(c^i_{2,hh})\geq u(c^i_{1,hl}+y^i_{1,h}-y^i_{1,l})+\beta\gamma_2 u(c^i_{2,hl})\tag{3.20}$$

$$\delta^i_{1,lh}:\ u(c^i_{1,lh})+\beta\gamma_2 u(c^i_{2,lh})\geq u(c^i_{1,ll}+y^i_{1,h}-y^i_{1,l})+\beta\gamma_2 u(c^i_{2,ll})\tag{3.21}$$

The associated *first order conditions* (FOCs) are:

At age $a=0$

$$c^i_{0,h}:\qquad u'(c^i_{0,h})\left[p\left(\mu^i_0+\lambda^i_0\right)+\lambda^i_{0,h}+\delta^i_{0,h}\right] = \mu^i_0 p\lambda\tag{3.22}$$

$$c^i_{0,l}:\qquad u'(c^i_{0,l})\left[(1-p)\left(\mu^i_0+\lambda^i_0\right)+\lambda^i_{0,l}\right]-\delta^i_{0,h}\,u'(c^i_{0,l}+y^i_{0,h}-y^i_{0,l}) = \mu^i_0(1-p)\lambda\tag{3.23}$$

At age $a = 1$

$$c^i_{1,hh} : u'(c^i_{1,hh}) \left[p^2 \beta \gamma_1 \left(\mu^i_0 + \lambda^i_0 \right) + (\lambda^i_{0,h} + \delta^i_{0,h}) p \beta \gamma_1 + \lambda^i_{1,hh} + \delta^i_{1,hh} \right] = \mu^i_0 p^2 \gamma_1 \lambda \tag{3.24}$$

$$c^i_{1,hl} : u'(c^i_{1,hl}) \left[p(1-p) \beta \gamma_1 \left(\mu^i_0 + \lambda^i_0 \right) + (\lambda^i_{0,h} + \delta^i_{0,h}) (1-p) \beta \gamma_1 + \lambda^i_{1,hl} \right] - \delta^i_{1,hh} u'(c^i_{1,hl} + y^i_{1,h} - y^i_{1,l}) = \mu^i_0 p (1-p) \gamma_1 \lambda \tag{3.25}$$

$$c^i_{1,lh} : u'(c^i_{1,lh}) \left[(1-p) p \beta \gamma_1 \left(\mu^i_0 + \lambda^i_0 \right) + (\lambda^i_{0,l} - \delta^i_{0,h}) p \beta \gamma_1 + \lambda^i_{1,lh} + \delta^i_{1,lh} \right] = \mu^i_0 (1-p) p \gamma_1 \lambda \tag{3.26}$$

$$c^i_{1,ll} : u'(c^i_{1,ll}) \left[(1-p)^2 \beta \gamma_1 \left(\mu^i_0 + \lambda^i_0 \right) + (\lambda^i_{0,l} - \delta^i_{0,h}) (1-p) \beta \gamma_1 + \lambda^i_{1,ll} - \delta^i_{1,lh} \right] = \mu^i_0 (1-p)^2 \gamma_1 \lambda \tag{3.27}$$

At age $a = 2$

$$c^i_{2,hh} : u'(c^i_{2,hh}) \left[\beta^2 \gamma_1 \gamma_2 p^2 \left(\mu^i_0 + \lambda^i_0 \right) + (\lambda^i_{0,h} + \delta^i_{0,h}) \beta^2 \gamma_1 \gamma_2 p + (\lambda^i_{1,hh} + \delta^i_{1,hh}) \beta \gamma_2 + \lambda^i_{2,hh} \right] = \mu^i_0 \gamma_1 \gamma_2 p^2 \lambda \tag{3.28}$$

$$c^i_{2,hl} : u'(c^i_{2,hl}) \left[\beta^2 \gamma_1 \gamma_2 p (1-p) \left(\mu^i_0 + \lambda^i_0 \right) + (\lambda^i_{0,h} + \delta^i_{0,h}) \beta^2 \gamma_1 \gamma_2 (1-p) + (\lambda^i_{1,hl} - \delta^i_{1,hh}) \beta \gamma_2 + \lambda^i_{2,hl} \right] = \mu^i_0 \gamma_1 \gamma_2 p (1-p) \lambda \tag{3.29}$$

$$c^i_{2,lh} : u'(c^i_{2,lh}) \left[\beta^2 \gamma_1 \gamma_2 (1-p) p \left(\mu^i_0 + \lambda^i_0 \right) + (\lambda^i_{0,l} - \delta^i_{0,h}) \beta^2 \gamma_1 \gamma_2 p + (\lambda^i_{1,lh} + \delta^i_{1,lh}) \beta \gamma_2 + \lambda^i_{2,lh} \right] = \mu^i_0 \gamma_1 \gamma_2 p (1-p) \lambda \tag{3.30}$$

$$c^i_{2,ll} : u'(c^i_{2,ll}) \left[\beta^2 \gamma_1 \gamma_2 (1-p)^2 \left(\mu^i_0 + \lambda^i_0 \right) + (\lambda^i_{0,l} - \delta^i_{0,h}) (1-p) \beta^2 \gamma_1 \gamma_2 + (\lambda^i_{1,ll} - \delta^i_{1,lh}) \beta \gamma_2 + \lambda^i_{2,ll} \right] = \mu^i_0 \gamma_1 \gamma_2 (1-p)^2 \lambda \tag{3.31}$$

A Pareto-efficient allocation is the solution to the planner's problem (3.6), subject to feasibility (3.7) and individual rationality (3.8). A constrained-efficient allocation with LC is a solution to the planner's problem (3.6), subject to feasibility (3.7), individual rationality (3.8), and interim participation (3.9)-(3.18). A constrained-efficient allocation with PI is a solution to the planner's problem (3.6), subject to feasibility (3.7), individual rationality (3.8), and incentive-compatibility (3.19)-(3.21). A constrained-efficient allocation with LC and PI is a solution to the planner's problem (3.6), subject to feasibility (3.7), individual rationality (3.8), interim participation (3.9)-(3.18), and incentive-compatibility (3.19)-(3.21).

Discussion Consider first, as a benchmark, an environment where the multipliers satisfy $\lambda^i_{0,\cdot} = \lambda^i_{1,\cdot} = \lambda^i_{2,\cdot} = \delta^i_{0,\cdot} = \delta^i_{1,\cdot} = 0$. Because of stationarity, this implies that the the limited commitment and private information constraints do not bind for any type, age, and history, and we are in the first-best scenario. The ensuing allocation is Pareto efficient and has two important features. First, there is complete intra-temporal insurance, meaning that all agents within age a and permanent type i consume the same, independently of current and past realizations of their income ϵ. Thus, $c^i_{0,h} = c^i_{0,l} \equiv c^i_0$, and $c^i_{a,hh} = c^i_{a,hl} = c^i_{a,lh} = c^i_{a,ll} \equiv c^i_a$, for $a = 1,2$. Second, the allocation is inter-temporally efficient for both types: $u'(c^i_0) = \beta u'(c^i_1) = \beta^2 u'(c^i_2)$. Finally, the extent of redistribution across types depends on the ex-ante participation constraints (3.8): combining the first-order conditions, we obtain $\frac{u'(c^1_a)}{u'(c^2_a)} = \frac{1+[\lambda^2_0/\mu^2_0]}{1+[\lambda^1_0/\mu^1_0]}$. If the multipliers $\lambda^i_0 = 0$ as well, then there is full redistribution between types, i.e. two agents with same age a but different permanent types i are assigned the same consumption. Thus $c^i_a = c_a$. Differently, if $\lambda^i_0 > 0$ (which can occur for type $i = 2$ only), then there is a permanent difference on consumption levels of the two types of agents. Hence, if $\lambda^2_0 > 0$ and $\lambda^1_0 = 0$, then $1 + \lambda^2_0/\mu^2_0 = \frac{u'(c^1_0)}{u'(c^2_0)} = \frac{u'(c^1_1)}{u'(c^2_1)} = \frac{u'(c^1_2)}{u'(c^2_2)}$.

If instead some of the multipliers $\lambda^i_{0,\cdot}$, $\lambda^i_{1,\cdot}$, $\lambda^i_{2,\cdot}$, $\delta^i_{0,\cdot}$, or $\delta^i_{1,\cdot}$ are positive, the allocation must be distorted to satisfy the limited commitment and/or the private information problem. As a result insurance is incomplete and agents bear part their idiosyncratic uncertainty. Moreover, the allocation fails to be inter-temporally efficient. Finally, the allocation is history dependent, meaning two agents at the same age and type type and with same income consume different amounts because their income differed in the past.

We start focusing on age 0 after realization h. Using equation (3.22), note that if $\lambda^i_{0,h} = 0$, i.e., the *LC* constraint of type i at age 0 after a realization h (equation (3.9)) does not bind, then no extra consumption is needed to incentivize commitment. In contrast, if $\lambda^i_{0,h} > 0$, then (3.22) implies that in order to ensure that an individual with type i, age 0, and realization h honors the contract, the marginal utility $u'(c^i_{0,h})$ needs to decrease, *ceteris paribus*. The same occurs if $\delta^i_{0,h} > 0$, hence the incentive-compatibility constraint (3.19) binds. When $\lambda^i_{0,h} > 0$ and $\delta^i_{0,h} > 0$, the planner needs to increase $c^i_{0,h}$ to incentivize commitment and to incentivize truthful reporting. Consider instead individuals at age 0 after a realization l: in this case, if $\lambda^i_{0,l} > 0$, then the marginal utility $u'(c^i_{0,l})$ needs to decrease, *ceteris paribus*. nevertheless, if $\delta^i_{0,h} > 0$, hence the incentive-compatibility constraint (3.19) binds, the marginal utility $u'(c^i_{0,l})$ needs to decrease, *ceteris paribus*. Thus, when (3.10), (3.9), and (3.19) all bind, there is a tension between the limited commitment and the private information frictions, and the planner may have to increase or decrease $c^i_{0,l}$ depending on which friction is stronger. The intuition is that with private information punishments need to happen along the equilibrium path: in order to discourage misreporting at $a = 0$ when $\epsilon_0 = \epsilon_h$, the planner distorts consumption ensuing a low realization $\epsilon_0 = \epsilon_l$.

Focusing on age 1 after history realization hh, from equations (3.22) and (3.24), note that if $\lambda^i_{0,h} = \lambda^i_{1,hh} = \delta^i_{0,h} = \delta^i_{0,hh} = 0$, i.e., the *LC* and *IC* constraints at age 0 and 1 after realizations h and hh (equations (**??**)-(**??**)), (3.19)-(3.20)) do not bind, then $u'(c^i_{0,h}) = \beta u'(c^i_{1,hh})$.

This together with equation (3.22) also implies that $u'(c^i_{0,h}) = \beta u'(c^i_{1,hh})$. That is, there is an intergenerational (intratemporal) link between individuals with age 0 and individuals with age 1. Since we focus on stationary equilibria, the consumption $c^i_{1,hh}$ is also tomorrow's consumption for an individual of type i and history h, when tomorrow's history hh. In contrast, if $\lambda^i_{0,h} > 0$ and/or $\delta^i_{0,h} = 0$, and $\lambda^i_{1,hh} = 0$, and $\delta^i_{0,hh} = 0$ then only the limited commitment constraint and/or the incentive-compatibility constraint for individuals at age 0 with realization h binds, whereas the limited commitment and incentive-compatibility constraints for individuals at age 1 with realization hh are slack. In this instance, we know from before that $c^i_{0,h}$ needs to adjust to incentivize commitment and/or truth-telling of type i at age 0 after the realization h; equations (3.24) and implies that also age 1 consumption of the same agent, $c^i_{1,hh}$, with first period realization h (and second period realization h) increases to incentivize age-0 commitment and age-0 truth-telling. In this way, consumption is history dependent: age 1 consumption depends on the realization of income at age 0. In particular, since $\lambda^i_{1,hh} = 0$ and $\delta^i_{1,hh} = 0$, the planner adjusts $c^i_{0,h}$ and $c^i_{1,hh}$ to guarantee intertemporal efficiency, as (3.22) and (3.24) imply that $u'(c^i_{0,h}) = \beta u'(c^i_{1,hh})$. If instead $\lambda^i_{1,hh} > 0$ or $\delta^i_{1,hh} > 0$, then the limited commitment constraint at age 1, (3.11), or the incentive-compatibility at age 1, (3.19), bind. Then, $c^i_{1,hh}$ is used to incentivize commitment or truth-telling both at age 0 in (3.9) and at age 1 in (3.11). As a result and the planner also distorts the intertemporal allocation of consumption: equations (3.22) and (3.24) give us that $u'(c^i_{0,h}) > \beta u'(c^i_{1,hh})$.

Finally focusing on age 2 after history realization hh, from equations (3.22), (3.24), and (**??**) if $\lambda^i_{0,h} = \lambda^i_{1,hh} = \lambda^i_{2,hh} = \delta^i_{0,h} = \delta_{1,hh} = 0$, i.e., the LC constraints at age 0, 1, and 2 after realizations h and hh (equations (3.9), (3.11), and (3.15)) and the incentive-compatibility constraints at age 0 and 1 after realizations h and hh (equations (3.19), (3.20) do not bind, then $u'(c^i_{0,h}) = \beta u'(c^i_{1,hh}) = \beta^2 u'(c^i_{2,hh}) = \lambda$. Again, the marginal utility of giving consumption to individuals of age 2 after a realization hh needs to equate the marginal utility (loss) of aggregate endowment. This together with equation (3.22) and (3.24) implies that $u'(c^i_{0,h}) = \beta u'(c^i_{1,hh}) = \beta^2 u'(c^i_{1,hh})$, so that there is an intergenerational (intratemporal) link between individuals with age 0, age 1, and age 2. In contrast, if $\lambda^i_{0,h} > 0$ (or $\lambda^i_{1,hh} > 0$) or $\delta^i_{0,h} > 0$ but $\lambda^i_{2,hh} = 0$, then $c^i_{2,hh}$ adjusts to incentivize commitment of type i at age 0 after the realization h. In other words consumption at age 2 depends on the history at age 0 (or age 1). Since $\lambda^i_{2,hh} = 0$ intertemporal optimality still holds: $u'(c^i_{1,hh}) = \beta u'(c^i_{2,hh})$. In instead $\lambda^i_{2,hh} > 0$, then the planner also distorts the intertemporal allocation of consumption: equations (3.24) and (3.28) imply that $u'(c^i_{1,h}) > \beta u'(c^i_{2,hh})$.

3.4 Calibration Strategy

Ours is an OLG framework and we use three adult-age groups of approximately fifteen years each. In this context, we use a value for the discount factor of $\beta = 0.684$, which corresponds to an annual discount factor of 0.975. Following the literature on endogenously incomplete markets (Kocherlakota (1996), Ligon, Thomas, and Worrall (2002), Ábrahám and Laczó (2018) etc.), we choose our utility function to be logarithmic, i.e. $\sigma = 1$. The subsistence level is chosen following Bick, Fuchs-Schündeln, and Lagakos (2018) and also De Magalhaes, Martorell, and Santaeulalia-Llopis (2019). Note that our chosen parameters are common across all our model specifications including our benchmark model with limited commitment and private information and also model specifications that are subsets of our benchmark model in which we include only limited commitment or only private information frictions. The complete markets specification also shares the same chosen parameters.

The remaining parameters are determined by the income process, which is also common across all our model specifications. To estimate the income process we use the following steps. First, after removing the year-fixed effects (average growth) in our measure of logged income, we recover the age-fixed effects using a dummy for three age groups in the following regression

$$\ln y_{it} = \sum_{age} \mathbf{1}_{age}\beta_{age} + \ln u_{it} \quad \text{with} \quad \ln u_{it} \sim N(0, \sigma_{\ln u})$$

with $age = \{0, 1, 2\}$.[10] We use three age groups that in our estimation of the income process correspond to 17-35, 36-55, and plus 55. Note that life expectancy is 65 in Malawi—probably smaller in the rural areas. Then, we define the age effect as $g(age) = exp(\beta_0 + \sum_{age \neq 0} \mathbf{1}_{age}\beta_{age})$ which implies $g(0) = 0.978$, $g(1) = 1.099$ and $g(2) = 0.815$.[11] Second, we exploit the panel dimension of our data in order to estimate the permanent and transitory components of income,

$$\ln u_{it} = \ln \alpha_i + \ln \varepsilon_{it} \quad \text{with} \quad \ln \varepsilon_{it} \sim N(0, \sigma_{\ln \varepsilon})$$

then, we write our income process as

$$y_{it} = \alpha_i g(age)\varepsilon_{it}, \tag{3.32}$$

with $\alpha_i = exp(\ln \alpha_i)exp(-0.5var(\ln \alpha_{it}))$ and $\varepsilon_{it} = exp(\ln \varepsilon_{it})exp(-0.5var(\ln \varepsilon_{it}))$. Note that since $\ln u$ and $\ln \varepsilon$ follow a normal distribution, then $\ln \alpha$ also follows a normal distribution. Then, both α and ε follow log-normal distributions and we normalize their respective mean to one. In our income process (3.32), α_i captures the individual-specific permanent productivity component (fixed-effect), $g(age)$ captures the age profile and ε_{it} captures a transitory *iid* shock. We plot the associated distributions of income, the permanent component, and transitory shock as well as the age profile in Figure 3.1. We find

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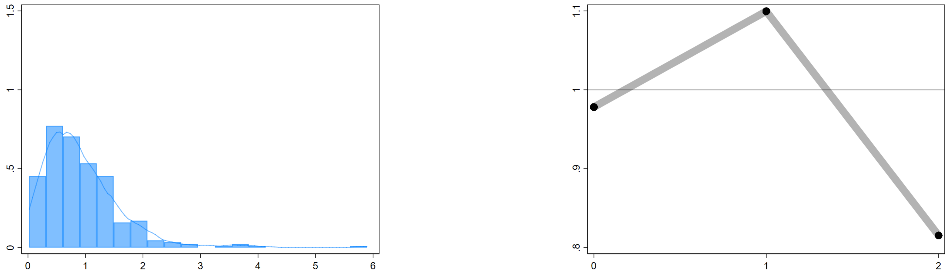
[10] That is, we only keep the dummy (constant) associated with the first year of observation, 2018. Then, we normalize average income to one.

[11] We renormalized the age effects to one by constructing the mean log devitation $\ln \widehat{g(age)} = \ln g(age) - \sum_i \frac{\ln(age)}{n}$ and reconstructing $g(age) = 1 + \ln \widehat{g(age)}$.

that the variance of the permanent component is larger by a factor of (0.500/0.232=) 2.15 than the variance of the transitory component (this factor is 2.50 in logs). In logs, we find that the variance of the permanent component contributes to 70.5% of the variance of income.

FIGURE 3.1: Income Process

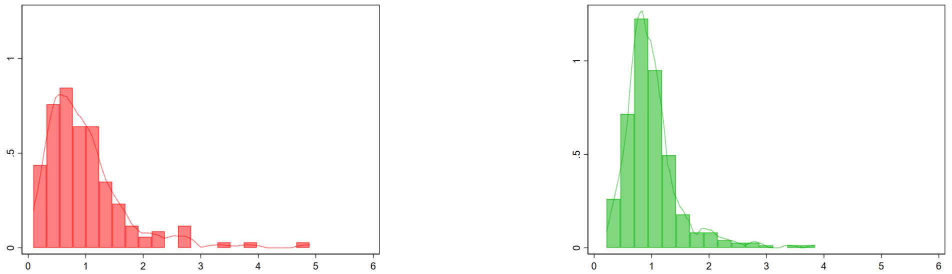


(a) Distribution of income, $\Phi(y)$

(b) Income Age Profile, $g(age)$

(c) Distr. Permanent Component, $\Phi(\alpha)$

(d) Distr. transitory component, $\Phi(\varepsilon)$



Notes: (a) shows the distribution of income (in logs) in the village. The next plots show the distribution of the elements in our estimated income process: the age profile, $g(age)$, (b), the distribution of the permanent component (α), and the distribution of the transitory shocks ε (d).

Then, we discretize α and ε in $Q = 2$ quantiles. That is, the distribution is separated in two groups: above the median and below the median. Precisely, for each $x = \{\alpha, \varepsilon\}$, we define two values:

$$x_L = median(x) - \mu$$
$$x_H = median(x) + \mu\kappa,$$

where we choose the value of μ such that x_L matches the average income below the median, i.e., $\mu = median(x) - \sum_i \mathbf{1}_{x_i<median(x)} \frac{x_i}{0.5n}$. Then, given μ, we choose κ such that x_H matches the average income above the median.

3.5 Quantitative Results

Our main quantitative exercise consists of comparing the constrained-efficient transfers implied by the village-calibrated model and the transfers in the actual village data. That is, given our calibration strategy that reproduces the income distribution (and income process) in the village, what is the optimal level of transfer progressivity implied by our model? And how does it compare with the data? We assess these questions in Section 3.5.2. Further, we assess the implications that the constrained-efficient allocations have on consumption insurance and redistribution in Section **??**.

3.5.1 Model consumption and transfer allocations

In this section, we first characterize numerically the Pareto efficient allocation in Definition 3.3.1 for the parameter values $\mu_0^i = 1$, $\beta = 1$, $\gamma_1 = \gamma_2 = 1$, $u(c) = \log(c)$, the income age-profile $g = (0.978, 1.099, 0.815)$, permanent productivities $\alpha_1 = 0.5803$, $\alpha_2 = 1.9096$, and i.i.d. income shocks $\epsilon_l = 0.6815$, $\epsilon_h = 1.3204$.[12]

Figure 3.2 shows the autarky and the first-best consumption paths of type 1 and type 2 agents for all possible histories of income shocks (ϵ_0, ϵ_1). The solid line corresponds to the first-best consumption of a household of type i, whereas the dashed line shows her consumption in autarky. From the discussion in the previous subsection, we know that the first-best allocation has two important properties. First, there is complete intra-temporal insurance, i.e., the consumption of a type i household at age a is independent of the realization of the idiosyncratic income shock. Formally, $c^i_{0,h} = c^i_{0,l} = c^i_0$, $c^i_{1,hh} = c^i_{1,hl} = c^i_{1,lh} = c^i_{1,ll} = c^i_1$, and $c^i_{2,hh} = c^i_{2,hl} = c^i_{2,lh} = c^i_{2,ll} = c^i_2$. Second, the first-best allocation is inter-temporally efficient: because of stationarity and because aggregate resources are constant over time, the planner must be indifferent between assigning to an agent one unit of consumption in the current or in the next period (age). Formally, $u'(c^i_0) = \beta u'(c^i_1) = \beta^2 u'(c^i_2)$. In the numerical illustration, we have chosen $\beta = 1$. Thus, the first-best consumption path of a type i agent is constant across states and age, i.e., $c^i_0 = c^i_1 = c^i_2$. The only variation in first-best consumption is across types, as a result of the binding ex-ante participation constraint (3.8) of type 2 households.

Next, for the same parameter values, we consider constrained-efficient allocations with LC as defined in Definition 3.3.1. Figure 3.3 compares the consumption paths for such economy with first-best and autarky consumption paths. Specifically, the dash gray line corresponds to the first-best consumption allocation that we already represented in Figure3.2, the dashed line to consumption in autarky, and the solid line to the consumption trajectories that satisfy the limited commitment problem. Overall, the limited commitment friction reduces the planners' ability to transfer resources across. In particular the limited commitment constraints for type 1 households binds at histories (ϵ_h, ϵ_h) and (ϵ_l, ϵ_h), and are slack for all other ages and histories. Thus, $\lambda^1_{a,\cdot} = 0$ except from $\lambda^1_{1,hh} > 0$ and $\lambda^1_{1,lh} > 0$. Equations (3.22) and (3.23) give us $u'(c^1_{0,h}) = \lambda = u'(c^1_{0,l})$. Thus, type 1 households receive full insurance at age 0. nevertheless, insurance for type 1 households

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[12] For a discussion of the calibration strategy see Section 3.4.

is incomplete at age 1. Formally, the first order conditions (3.24) and (3.25) imply

$$\beta u'(c^1_{1,hl}) = \lambda = \beta u'(c^1_{1,hh}) \left[1 + \frac{\lambda^1_{1,hh}}{\beta\mu^1_0 p^2\gamma_1}\right] > \beta u'(c^1_{1,hh})$$
$$\beta u'(c^1_{1,ll}) = \lambda = \beta u'(c^1_{1,lh}) \left[1 + \frac{\lambda^1_{1,hh}}{\beta\mu^1_0 p(1-p)\gamma_1}\right] > \beta u'(c^1_{1,lh})$$

which imply $c^1_{1,hl} < c^1_{1,hh}$ and $c^1_{1,ll} < c^1_{1,lh}$. We conclude that insurance for type 1 households at age 1 is incomplete. Also, relative to the first-best solution, the consumption allocation of type 1 households is distorted inter-temporally. Combining equations (3.22) with (3.24) and (3.25) we obtain

$$u'(c^1_{0,h}) = \lambda > \beta\Big[p\ u'(c^1_{1,hh}) + (1-p)\ u'(c^1_{1,hh})\Big].$$

which implies that type 1 households expected consumption is relatively larger at age 1 than at age 0. Similarly to the first-best scenario, type 2 households' ex-ante participation constraint (3.8) binds. nevertheless, differently from the first-best solution, the limited commitment constraints (3.10), (3.14), and (3.18) bind. Formally these three constraints binding imply that $c^2_{0,l} = y^2_{0,l}$, $c^2_{1,ll} = y^2_{1,l}$, $c^2_{2,ll} = y^2_2$, i.e., type 2 households consume their autarky endowment at age 0 when their idosyncratic shock is ϵ_L, as well as at age 1 and age 2 following history (ϵ_L, ϵ_L). Also, because the limited commitment constraint of type 2 households binds at age 0 binds following a high realization of the idiosyncratic income shock, insurance for type 2 agents is incomplete at age 0 as well: $c^2_{2,h} > c^2_{2,l}$. Formally, the multiplier $\lambda^2_{0,h} > 0$ as well, so that equations (3.22) and (3.23) give

$$u'(c^2_{0,h}) \left[1 + \frac{\lambda^2_0}{\mu^2_0} + \frac{\lambda^2_{0,h}}{p\ \mu^2_0}\right] = \lambda = u'(c^2_{0,l}) \left[1 + \frac{\lambda^2_0}{\mu^2_0} + \frac{\lambda^2_{0,l}}{(1-p)\mu^2_0}\right].$$

Finally, the consumption allocation of type 2 households is distorted inter-temporally. For example, consider the consumption path following history (h,h). From the top-left quadrant in Figure 3.3 we observe that $u'(c^2_{0,h}) > \beta[pu'(c^2_{1,hh}) + (1-p)u'(c^2_{1,hl})]$. We get the same conclusion combining (3.22), (3.24), and (3.25)

$$\begin{aligned} &u'(c^2_{0,h}) \left[1 + \frac{\lambda^2_0}{\mu^2_0} + \frac{\lambda^2_{0,h}}{p\mu^2_0}\right] \\ &\quad = \lambda = \beta\left\{pu'(c^2_{1,hh}) \left[1 + \frac{\lambda^2_0}{\mu^2_0} + \frac{\lambda^2_{0,h}}{p\mu^2_0} + \frac{\lambda^2_{1,hh}}{\mu^2_0 p^2\gamma_1}\right] + (1-p)u'(c^2_{2,hh}) \left[1 + \frac{\lambda^2_0}{\mu^2_0} + \frac{\lambda^2_{0,h}}{p\mu^2_0}\right]\right\}. \end{aligned}$$

Next, we characterize constrained-efficient allocations with PI as defined in Definition 3.3.1. In Figure 3.4, the dash gray line corresponds to the first-best consumption allocation , the dashed line to consumption in autarky, and the solid line to the consumption trajectories that in addition to the aggregate resource (3.7) and individual rationality (3.8), satisfy the incentive-compatibility constraints (3.19)-(3.21). In this problem, all the constraints (3.19)-(3.21) bind for both type 1 and type 2 households. As a result, insurance at age 0 and age 1 is incomplete. Second, the allocation is distorted intertemporally. To see the first property of constrained efficient allocations, notice that from (3.22) and (3.23), we have

$$u'(c_{0,h})^i \left[1 + \frac{\lambda_0^i}{\mu_0^i} + \frac{\delta_{0,h}^i}{p}\right] = \lambda = u'(c_{0,l}^i)\left[1 + \frac{\lambda_0^i}{\mu_0^i}\right] - \frac{\delta_{0,h}^i}{1-p} u'(c_{0,l}^i + y_{0,h}^i - y_{0,l}^i)$$

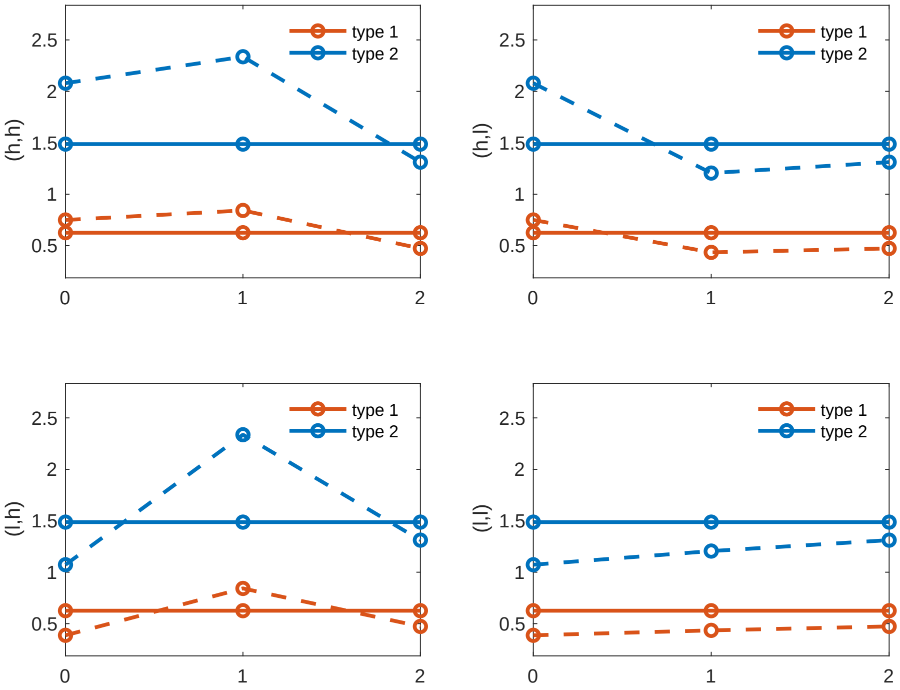
hence $c_{0,h}^i > c_{0,l}^i$, and combining similarly (3.24) and (3.25) and equations (3.26) and (3.27) we reach similar conclusion at age 1: $c_{1,hh}^i > c_{1,hl}^i$ and $c_{1,lh}^i > c_{1,ll}^i$. The allocation of both types of households is also distorted intertemporally, at all ages. In particular, combining (3.24) and (**??**) respectively give us

$$\begin{aligned}\beta u'(c_{1,hh}^i)\left[1 + \frac{\lambda_0^i}{\mu_0^i} + \frac{\delta_0^i}{\mu_0^i p} + \frac{\delta_{1,hh}^i}{\beta \mu_0^i p^2 \gamma_1}\right] &= \lambda \\ = \beta u'(c_{1,hl}^i)\left[1 + \frac{\lambda_0^i}{\mu_0^i} + \frac{\delta_0^i}{\mu_0^i p}\right] &- \frac{\delta_{1,hh}^i}{\beta \mu_0^i p(1-p)\gamma_1} \beta u'(c_{1,hl}^i + y_{1,h}^i - y_{1,l}^i)\end{aligned}$$

which imply $c_{1,hh}^i > c_{0,h}^i > c_{1,hl}^i$. Following a similar argument we can show that $c_{1,lh}^i > c_{0,l}^i > c_{1,ll}^i$, and combining (3.28) and (3.29) it is easy to derive the $c_{2,hh}^i = c_{1,hh}^i > c_{1,hl}^i > c_{2,hl}^i$ and $c_{2,lh}^i = c_{1,lh}^i > c_{1,ll}^i > c_{2,ll}^i$.

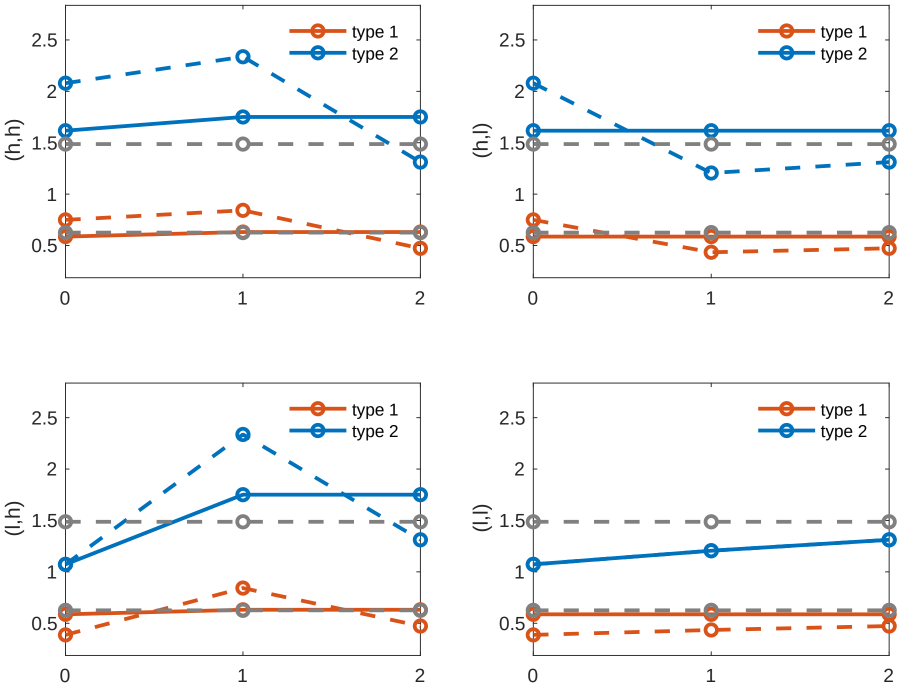
Finally, we characterize constrained-efficient allocations with LC+PI as defined in Definition 3.3.1. As in the problem with private information, the constraints (3.19)-(3.21) bind. As in the problem with limited commitment, (3.10), (3.14), and (3.18) for type 2 agents bind. so that $c_{0,l}^2 = y_{0,l}^2$, $c_{1,ll}^2 = y_{1,l}^2$, $c_{2,ll}^2 = y_2^2$. Moreover, (3.18) binds for type 1 households as well, so $c_{2,ll}^1 = y_2^1$. The intuition is that the private information friction spreads present and future consumption with consumption being higher at histories with a high realization of the idiosyncratic income shock. For example, $c_{0,h}^i > c_{0,l}^i$, $c_{1,hh}^i > c_{1,hl}^i$, as well $c_{1,hh}^i > c_{1,lh}^i$.Thus, the private information friction relaxes interim participation at histories with a high realization ϵ_H, so that (3.11) and (3.12) are now slack. On the other hand, the private information friction exacerbates interim participation at histories with a low realization ϵ_L, so that (3.11). and (3.18) binds for type 1 households as well. It is easy to show that also in this economy insurance is incomplete, and the allocation is distorted intertemporally.

FIGURE 3.2: Complete Markets and Autarky: Life Cycle Consumption



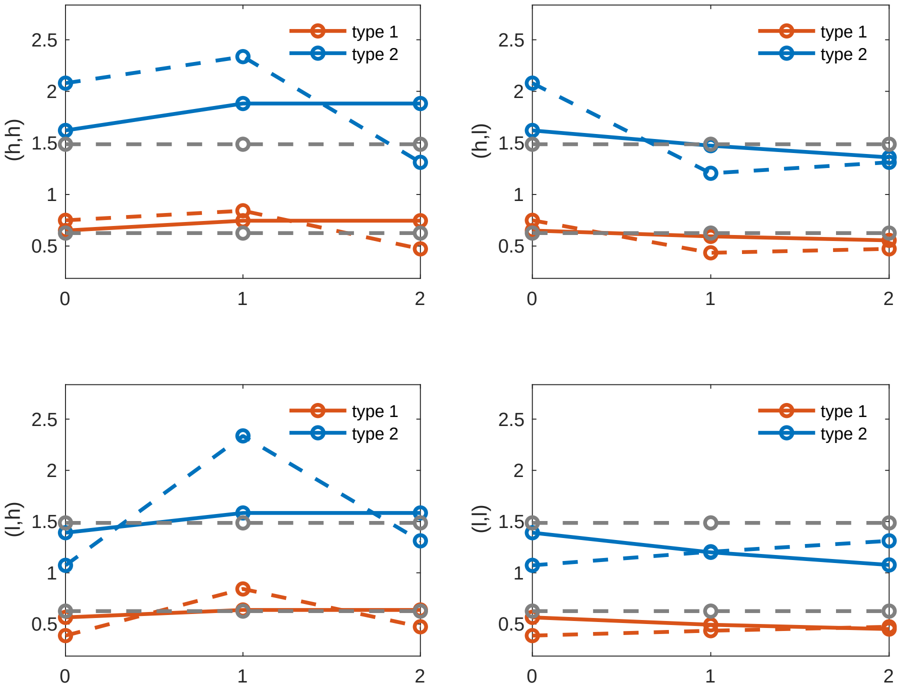
Notes: Complete markets life-cycle consumption allocations (solid lines) and the life-cycle profile in the village—autarky consumption allocations (dotted lines)—per each permanent productivity type (high types, α^2, in blue, low types, α^l, in red), and per each possible combination of shocks realizations $(\varepsilon_0, \varepsilon_1) = (h, h)$, $(\varepsilon_0, \varepsilon_1) = (h, l)$, $(\varepsilon_0, \varepsilon_1) = (l, h)$, and $(\varepsilon_0, \varepsilon_1) = (l, l)$.

FIGURE 3.3: Limited Commitment Model vs Autarky: Life Cycle Consumption



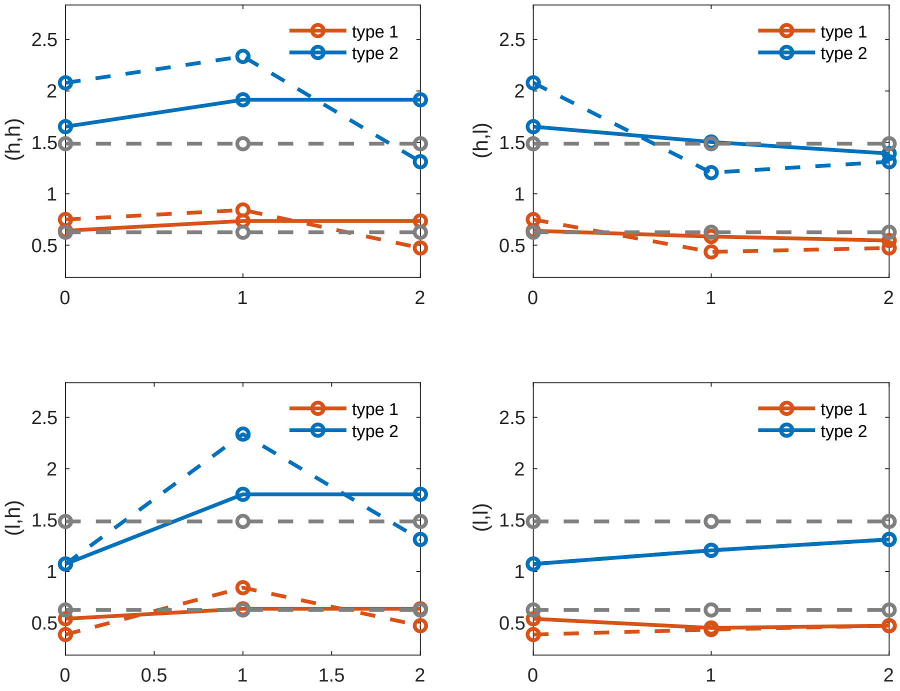
Notes: Limited Commitment model life-cycle consumption allocations (solid lines) and the income life-cycle profile in the village—autarky consumption allocations (dotted lines)—per each permanent productivity type (high types, α^2, in blue, low types, α^l, in red), and per each possible combination of shocks realizations $(\varepsilon_0, \varepsilon_1) = (h, h)$, $(\varepsilon_0, \varepsilon_1) = (h, l)$, $(\varepsilon_0, \varepsilon_1) = (l, h)$, and $(\varepsilon_0, \varepsilon_1) = (l, l)$.

FIGURE 3.4: Private Information Model vs Autarky: Life Cycle Consumption



Notes: Private Infomration model life-cycle consumption allocations (solid lines) and the income life-cycle profile in the village—autarky consumption allocations (dotted lines)—per each permanent productivity type (high types, α^2, in blue, low types, α^l, in red), and per each possible combination of shocks realizations $(\varepsilon_0, \varepsilon_1) = (h, h)$, $(\varepsilon_0, \varepsilon_1) = (h, l)$, $(\varepsilon_0, \varepsilon_1) = (l, h)$, and $(\varepsilon_0, \varepsilon_1) = (l, l)$.

FIGURE 3.5: Model with Private Information & Limited Commitment: Life Cycle Consumption



Notes: Private Information and Limited Commitment model life-cycle consumption allocations (solid lines) and the income life-cycle profile in the village—autarky consumption allocations (dotted lines)—per each permanent productivity type (high types, α^2, in blue, low types, α^l, in red), and per each possible combination of shocks realizations $(\varepsilon_0, \varepsilon_1) = (h, h)$, $(\varepsilon_0, \varepsilon_1) = (h, l)$, $(\varepsilon_0, \varepsilon_1) = (l, h)$, and $(\varepsilon_0, \varepsilon_1) = (l, l)$.

3.5.2 Optimal Transfer Progressivity

We now reconduct our estimation of the transfer progressivity of transfers using the model simulated data at the steady state. Clearly, as we have shown, these transfers obey the history of shocks in the model. Here, however, we are interested in describing the patterns of transfers over the income distribution—as we do in the data where the history of shocks is not observable.

Table 3.3 shows the progressivity level and other key moments of the risk-sharing models—PI&LC, LC, PI, FB—calibrated at the steady state versus the data counterparts. The progressivity level (ϕ) in the village is around twice as large as the optimal progressivity values given by the models. The complete markets model (FB) generates the largest progressivity (0.35) since the planner does not need to provide extra consumption so that the rich households do not want to renegade from the contract (LC) or hide their income profile information (PI). The average transfer value (T/Y) goes in the same direction: the transfers are much larger in the data than in the models where the FB is the model that generates a larger transfers level—yet half of the actual transfers level in the village.

TABLE 3.3: Optimal Transfer Progressivity vs. Data

	Data	PI& LC	LC	PI	FB
ϕ	0.60	0.21	0.27	0.25	0.35
T/Y	28.9	9.4	11.2	10.9	14.0
σ_c^2	0.29	0.24	0.22	0.22	0.18
CMT	0.05	0.21	0.15	0.07	0.00
$\ln c_1/c_0$	0.05	0.08	0.10	0.01	0.00
$\ln c_2/c_0$	-0.02	0.08	0.11	-0.03	0.00

Notes: With $\ln \frac{\tilde{y}}{y} = \lambda - \phi \ln y$, ϕ represents the transfer progressivity level, T/Y the average transfers size, σ_c^2 the variance in log consumption, CMT the insurance coefficient à la Townsend, $\ln c_1/c_0$. Column (1) shows the values computed or estimated from the village data. Columns (2) to (5) present the moments that each of the calibrated risk-sharing models deliver in steady state.

For the rest of the moments, the models tend to get more close to the data. The variance in log consumption (σ_c^2) in the village is 0.29 while across the different models it takes values from 0.18 to 0.24. The private information model generates an insurance coefficient—(CMT), see section 3.2.2 for the specification of the coefficient—of 0.07 while in the data the estimated coefficient is 0.05. The rest of the models predict insurance levels notably lower than in the data, except for the FB which implies full insurance, and, therefore, the coefficient is zero. Finally, in terms of the consumption differences across ages ($\ln c_1/c_0$, $\ln c_2/c_0$), the models also fail to replicate the consumption life-cycle profile in the village.

Departing from the existing results in testing risk-sharing economies, we find that once we carefully calibrate the risk-sharing models to the village, they fall short to explain the high progressivity and high insurance levels observed in the village. The models also fail to explain the transfer levels and the consumption profiles in our village.

3.5.3 Can Alternative Parameters Get the Model Closer to the Data?

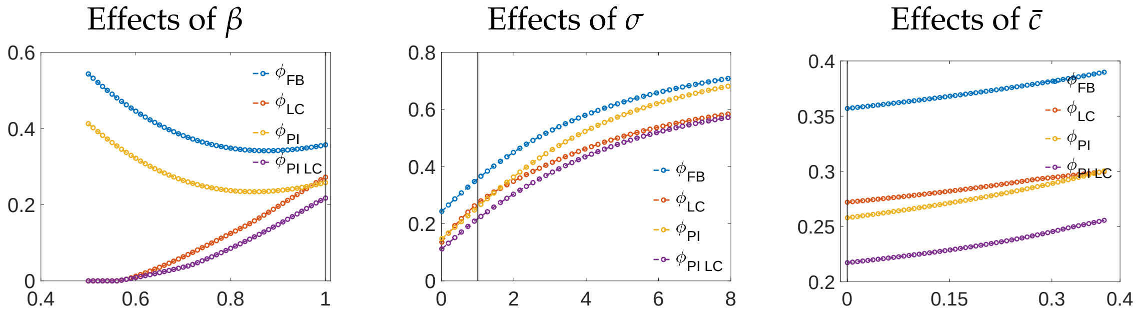
A potential reason why the models cannot generate the high transfers and progressivity observed in the village is that, perhaps, the standard preference values in the literature do not fit in the context of our village. To explore that, we solve the risk-sharing economies in steady state for a large range of preference values and study the behavior of key moments in these economies.

Figure 3.6 shows the effect of the persistence parameter (first column), the degree of risk aversion (second column), and the subsistence requirement (third column), on the transfers progressivity (a), the aggregate transfers (b), and the insurance level (c) under the calibrated-simulation of the models—LC, PI, PILC, FB. The main takeover is that only for unrealistic preference values and only for particular moments, the models can get close to the data moments. Varying the persistence parameter only increases the progressivity and transfer size that the models generate for very low and unrealistic values—only for values of $\beta = 0.5$ the FB and to less extent the PI get closer to the observed high progressivity and high levels on aggregate transfers. Increasing the risk-aversion parameter—above 4 in the case of the FB and PI, above 8, for the LC and PILC—brings the models to the progressivity observed in the village. Nevertheless, for these values of risk-aversion, the aggregate transfers generated by the models are still far from the aggregate transfers in the village. Finally, by increasing the subsistence parameter the models cannot generate the transfer progressivity nor the transfer size observed in the village.

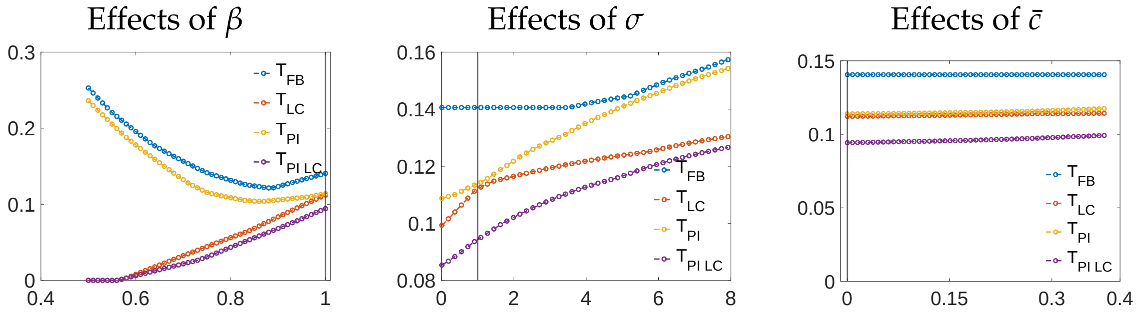
Figure 3.6 shows that for particular parameter values some models can do well in approximating some of the moments. In Figures C.1 and C.2 in the appendix, we explore the joining behavior of the progressivity, consumption variance, insurance coefficient, and other moments for a range of values in the preference parameters.

Figure 3.6: Sensitivity to Parameters: Comparative Statics of β, σ and $\bar{c}$

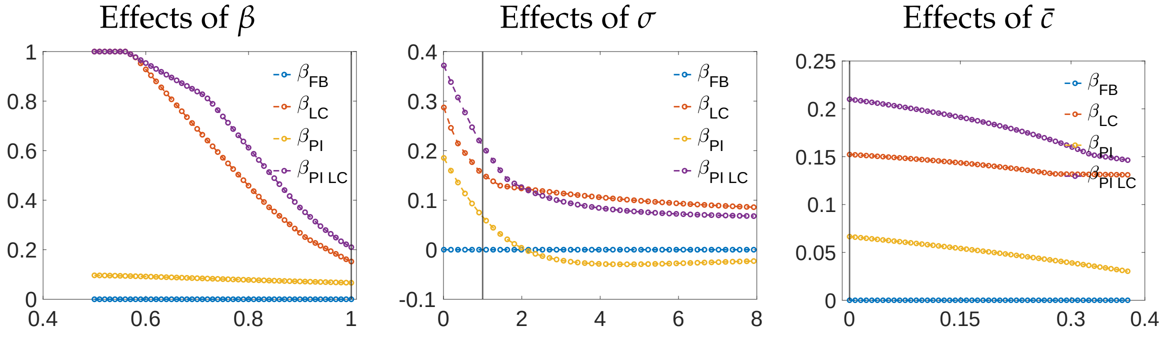
(a) Effects on Progressivity ϕ



(b) Effects on Aggregate Transfers T/Y



(c) Effects on Insurance



Notes: progressivity level (a), aggregate transfers (b), and insurance levels (c) moments under solving the models—LC, PI, PILC, FB—in steady state across values of the persistence parameter (β, column 1), the risk-aversion parameter (σ, column 2), and the subsistence level paramenter ($\bar{c}$, column 3).

3.6 Social Norms as Frictions: Inference from Past Optimal Transfers

First, we conduct a limited insurance accounting exercise in Section 3.6.1. Precisely, we introduce wedges in the participation and incentive compatibility constraints to assess which wedges matter most in explaining the differences between model and data. We find that the wedge on the ex-ante participation constraint is particularly useful in generating the degree of transfer progressivity observed in the village. Second, we use our OLG setting to endogenize these wedges as sluggish social norms passed from elders to younger generations that incentivize redistribution and social insurance in Section 3.6.2.

3.6.1 Limited Insurance Accounting

The constrained-efficient allocations from our calibrated-village economy show an implied level of transfer progressivity that is smaller than that of the village. In this context, it is plausible that the transfers that we observe in the village are subject to additional frictions that move transfers away from their constrained-efficient counterparts. Here, we introduce wedges to capture these potential additional frictions on the participation and incentive compatibility constraints.

A wedge on the ex-ante participation constraint (ω pain on α_H). This implies:

$$\underbrace{\sum_{\varepsilon_0 \in \mathcal{E}} \pi(\varepsilon_0) \left[u\left(c^i_{0,t}(\varepsilon_0)\right) + \beta\gamma_1 \sum_{\varepsilon_1 \in \mathcal{E}} \pi(\varepsilon_1) \left[u\left(c^i_{1,t+1}(\varepsilon_0,\varepsilon_1)\right) + \beta\gamma_2 \, u\left(c^i_{2,t+2}(\varepsilon_0,\varepsilon_1)\right)\right]\right]}_{\text{Welfare in the contract}}$$
$$\geq ! \underbrace{\sum_{\varepsilon_0 \in \mathcal{E}} \pi(\varepsilon_0) \left[u\left(y^i_{0,t}(\varepsilon_0)\right) + \beta\gamma_1 \sum_{\varepsilon_1 \in \mathcal{E}} \pi(\varepsilon_1) \left[u\left(y^i_{1,t+1}(\varepsilon_0,\varepsilon_1)\right) + \beta\gamma_2 \, u\left(y^i_{2,t+2}(\varepsilon_0,\varepsilon_1)\right)\right]\right]}_{\text{Value of consumption in autarky} \neq \text{Welfare in autarky}} \tag{3.33}$$

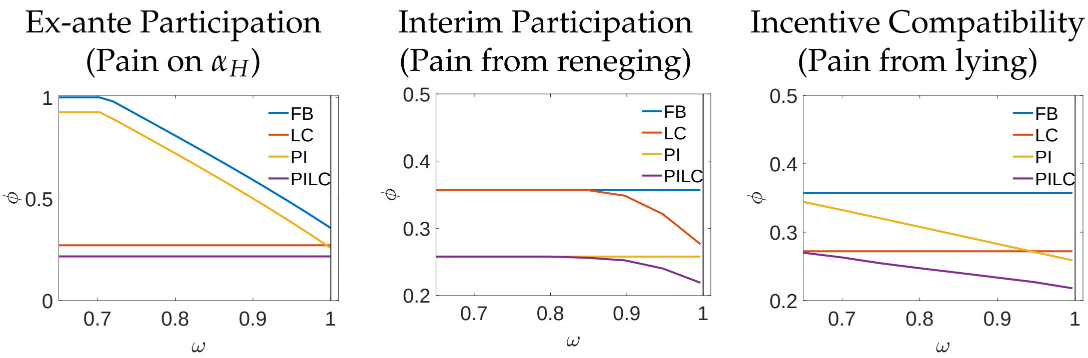
If $\omega < 1$, then not accepting the contract is more painful than the value of consumption in autarky. The quantitative implications of this wedge for transfers over the income distribution are in Figure 3.7. A way to rank wedges is in terms of their welfare cost: What is the welfare cost of ω (ex-ante participation, first best): -5.36%

3.6.2 Inference from an Optimal Past

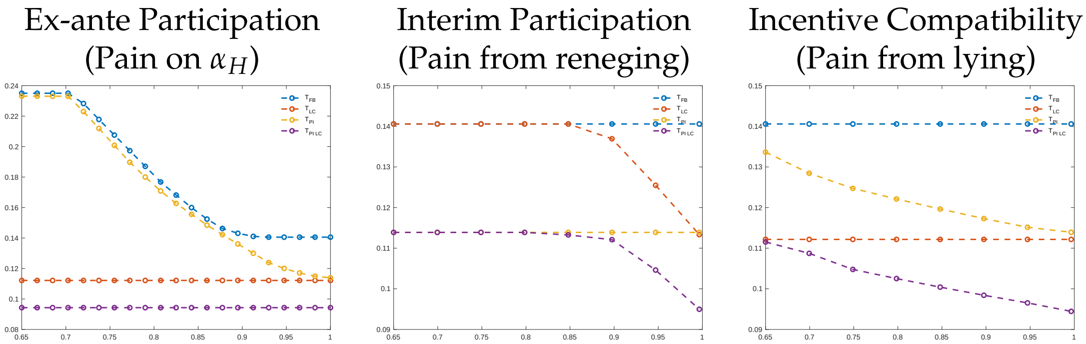
Here, we entertain the possibility that the current allocations reflect an optimal past in which the technological environment was harsher. For example, consider a scenario

FIGURE 3.7: The Effects of Wedges on Transfer Progressivity and Size

(a) Effects on progressivity ϕ



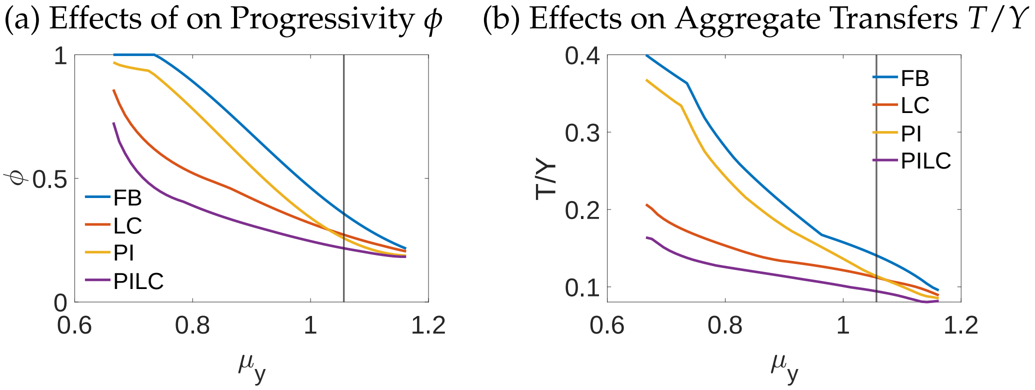
(b) Effects on T/Y



Notes: The effect of wedges in the ex-ant participation constraint (column 1), in the interim participation constraint (column 2), and in the incentive compatibility constraint (column3) on the transfer progressivity (a) and the transfer size (b) that the risk-sharing models generate. Models solved at steady state.

in which the village income is reduced by half which can represent a not-distant pre-fertilizer era. The implications for transfer progressivity and level are shown in Figure 3.8. Clearly, lowering the village income increases progressivity and transfer size. In the benchmark PILC economy with a half drop, one gets to the levels of progressivity observed in the data. This implies that the wedge ω tends to disappear and the allocations of high progressivity and transfer size emerge as optimal endogenously in a non-distant past.

FIGURE 3.8: The Effects of Technological Improvements: A Pre-Fertilizer Era


(a) Effects of on Progressivity ϕ (b) Effects on Aggregate Transfers T/Y

Notes: Transfers progressivity (a) and transfer size (b) of solving the the risk-sharing models in steady state for a range of values on average income in the economy (x-axis). The vertical line shows the actual level of income in the village.

3.7 Conclusion

Across rural areas in low-income countries, social insurance through informal transfers allows families to smooth their consumption well. In this work, we study the optimality of such transfers in a village in Malawi.

Using rich consumption, income, and food transfers data for the entire village, we document that the transfer progressivity is large, with an income-to-transfer elasticity of 0.60. Next, we study the optimal levels of progressivity by solving village-calibrated versions of OLG endogenously incomplete markets models—LC, PI, PILC—and the complete markets model. Our quantitative exercise shows that the constrained-efficient transfers progressivity and levels are much lower than the levels observed in the village. There is an excess of transfer progressivity in the village.

To explore what drives the excess of transfer progressivity, we introduce wedges in the LC and PI constraints and study the dynamics of the optimal contracts when decreasing current village income to past productivity levels. We find evidence that the optimal contract in our current OLG setting generated by these deep frictions is close to one of an economic environment with lower productivity. As we show, this implies that social norms that are sluggish to economic change can explain the current inefficient allocations. Hence, frictions beyond the standard LC and PI that we use in our framework could potentially explain the current allocations.

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Appendix A

Appendix Chapter 1

A.1 Solving the Benchmark Model

Heterogeneous agents models can be difficult to solve given that they rarely have closed-form solutions. In this section, I describe the steps to solve the benchmark model. First, in order to reduce the dimensionality of the problem, I assumed that agricultural shocks were iid and therefore households do not need to keep track of them to form expectations. Thus, investment in both crops, the shocks in both crops, and accumulated savings can be group together in a single state variable "cash-on-hand", x. However, to have a better match with the income and wealth distribution, I assumed that the non-agricultural income, z, had a persistence component and therefore households need to keep track of it to form expectations.

First, note that the problem is relatively complex in terms of computing expectations. On one hand, households need to form expectations of the agricultural shocks that follow a multinormal distribution. To compute such integral, I use the Gauss-Hermite quadrature rule which is a numerical integral method that allows to approximate integrals using a relative small number of nodes. Given a fixed z' the expectation of the value function given the shocks θ, ε is

$$\mathbb{E}_{\theta,\varepsilon}[V(x', z, y'_{na})] = \int_{\mathbb{R}^2_+} V\left((1-\delta)a' + \theta' z A(m'_h)^{\alpha} + \varepsilon' z B(m_l)'^{\gamma}, z, y'_{na}\right) lnMN(\theta', \varepsilon') d(\theta', \varepsilon')$$

Where $lnMN(\theta', \varepsilon')$ is the density of the log-Multinormal distribution on θ', ε'. The Gauss-Hermite quadrature rule consists in approximating this integral by the following weighted sum

$$\mathbb{E}_{\theta,\varepsilon}[V(x', z, y'_{na})] \approx \sum_{j_\theta=1}^{J_\theta} \sum_{j_\varepsilon=1}^{J_\varepsilon} \omega_{j\theta} \dot{\omega}_{j\varepsilon} \dot{V}\left((1-\delta)a' + \theta_{j\theta} z A(m'_h)^{\alpha} + \varepsilon_{j\varepsilon} z B(m_l)'^{\gamma}, z, y'_{na}\right)$$

where $\{\omega_{j\theta},\omega_{j\varepsilon}\}$, $\{\theta_{j\theta},\varepsilon_{j\varepsilon}\}$ are, respectively, the weights and nodes in the dimensions θ, ε, derived from the unidimensional Gauss-Hermite quadrature rule. Note that, since in this exercise it is a multidimensional integral, I use the tensor product version of the Gauss-Hermite quadrature rule, and because the shocks are correlated, I rewrite the integral in terms of uncorrelated variables using The Cholesky decomposition. To do so, I follow the steps in Maliar and Maliar (2014). To have a correct approximation of the variance of the shocks distribution, I use a relatively large number of nodes in each dimension,20, so that the total number is 200, the approximation of the multidimensional integral has good performance. [1] Then, for the non-agricultural income process, I discretize the AR(1) process into a five-state Markov chain using the Rouwenhorst procedure. Thus, the expectation of the value function of the problem is approximated as following

$$\mathbb{E}_{\theta,\varepsilon,y_na}[V(x',z,y'_{na})] \approx \sum_{i=1}^{5} \pi_{,y_{na},y'_{nai}} \cdot \sum_{j_\theta=1}^{J_\theta} \sum_{j_\varepsilon=1}^{J_\varepsilon} \omega_{j\theta} \cdot \omega_{j\varepsilon} \cdot V\left((1-\delta)a' + \right.$$
$$+ \theta_{j\theta} zA(m'_h)^{\alpha} + +\varepsilon_{j\varepsilon} zB(m_l)'^{\gamma}, z, y'_{nai}.$$

For the solution of the household's problem, I use the method of value function iteration in continuous form. Value function iteration consists on using the contraction mapping of the Bellman equation as an iterative operator to find the fixed point on the value function. To solve each iteration and have a new guess of the value function till the fixed point is achieved, I do the following. For each permanent state z, and tomorrow possible shocks realization of y_{na}, I interpolate with cubic-splines the value function of tomorrow along the x dimension, $V^k(x,z,y_{na}) = V^k_{f(x)}(x,z,y_{na})$, where k denotes the number of the iteration on the value function. Then, for 100 nodes on x the 5 states of z, and 5 states of y_{na}, I maximize the RHS of the Bellman operator on the variables c, m'_h, m'_l, a'. Then, the effect of m'_h, m'_l, a' on tomorrow's expected value function is given by the cash-on-hand tomorrow $x' = w_j(1-\delta)a' + \theta_{j_\theta} m'^{\alpha}_h + \varepsilon_{j_\varepsilon} Bm'^{\gamma}_l$, which goes into the interpolated value function, $V^k_{f(x)}(x,z,y_{na})$ for each state z, y_{na}. Finally, the expectation of the value function given these choices is $\sum_{k=1}^{5} \pi_{y_{na},y'_{na,k}} V^k_{f(x)}(x',z,y'_{na,k})$. To maximize such function under fourchoices variables and the linear budget constraint, I use a trust-region algorithm for constrained optimization offered by the SciPy library in Python language. Given that the constraint is linear, it follows the implementation of Byrd-Omojokun Trust-Region SQP method, Omojokun (1989), Byrd, Gilbert, and Nocedal (2000). After having used several different optimization routines, I found that the trust-region algorithm was delivering the most robust and accurate results. Also, accordingly to the SciPy package, it is the most

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[1] Using other methods, as Montecarlo integration, not even with very large number of points, as 10,000, I do not get the same accuracy and of course the computational cost is several orders higher.

versatile constrained minimization algorithm and the most appropriate for large-scale problems, as it is the exercise here.

Once a solution is found, the maximized value of the function becomes the next guess of the value function, $V^{k+1}(x, z, y_{na})$. I iterate this process till $\|V^{k+1}(x, z, y_{na}) - V^{k}(x, z, y_{na})\|_{\infty} < \epsilon$, where ϵ is the tolerance error and is set-up at 10^{-7}. To speed-up the computation of the household problem I parallelize the algorithm. In a recursive problem, the solution for each state of the economy is independent of the rest of states, and therefore the problem is "embarrassingly parallel" in computing terminology. I follow the steps in Fernández-Villaverde and Valencia (2018) to parallelize the value function iteration of the problem.

Once I obtain the solution of the household problem, I solve for the stationary invariant distribution using Monte-Carlo simulation. I simulate an economy of 1,000,000 of households for 250 periods. All agents start equal in assets, inputs investment, realization of the non-agricultural shock and differ on the realization of the agricultural shock. With that I have the initial states of the households x_0, z_0. For the rest of the periods, I do the following. Given previous period non-agricultural shock's realizations $y_{na,t}$ I obtain next period ones $y_{na,t+1}$ by random sampling according to the probabilities in the transition matrix $\pi_{y_{na,t}, y_{na,t+1}}$ and I obtain the agricultural shocks θ_{t+1},ε_{t+1} by taking random draws according to the probabilities of the Gauss-Hermite weightings vector for each possible state (θ, ε). Then, given an state $s_t = \{x_t, z, y_{na,t}\}$, I compute next period state for the endogenous variable $x_{t+1} = (1-\delta)a'(x_t, z, y_{na,t}) + \theta_t A m'_h(x_t, z, y_{na,t})^{\alpha} + \varepsilon_t B m'_l(x_t, z, y_{na,t})^{\gamma}$, given the sample of shocks and the interpolated policy functions $a'(x_t, z, y_{na,t})$, $m'_l(x_t, z, y_{na,t})$, $m'_h(x_t, z, y_{na,t})$ obtained by solving the household problem. I repeat the process till the states probability distribution converges. I make use again of parallelization methods to speed-up this process. Note that each individual time series is independent of the other individual time series, and therefore we can parallelize through the N households in the simulation.

A.2 Tables and Figures

TABLE A.1: Households' Crop Portfolio along Consumption, Income, Wealth and Land levels

Log*log*	Output high crops over low crops			
Income	0.9249			
	(0.0209)			
Consumption		0.9881		
		(0.0457)		
Wealth			0.4340	
			(0.0188)	
Land Size				0.4525
				(0.0163)
Intercept	-1.2281	-1.9060	1.9291	5.0645
	(0.1508)	(0.3389)	(0.1516)	(0.0219)
N	5958	5958	5958	7037
R2	0.25	0.07	0.08	0.10

Notes: Coefficients and their standard errors under parentheses of running the regressions of the following form: $log y_{it}^{h} - log y_{it}^{l} = \beta_0 + \beta_1 log x_i + u_{it}$. Where y_{it}^{h} is the household's agricultural production in high crops, y_{it}^{l} is the household-s agricultural productionin low crops, and x_i is the household's time-average consumption—column (1)—income—column (2)—wealth—column (3)—and land size—column (4). The sample is restricted to households with positive agricultural production. Data: UNPS first 5 waves.

TABLE A.2: Agricultural Production Allocations of Ugandan Households

Wave	Share Production to:				Proportion Farmers did:			
	Sell	Cons	Stored	gift	Sell	Cons	Stored	gift
2009	0.25	0.57	0.04	0.06	0.73	0.93	0.35	0.58
2010	0.24	0.60	0.05	0.06	0.78	0.98	0.34	0.63
2011	0.25	0.59	0.05	0.06	0.79	0.98	0.33	0.64
2013	0.29	0.54	0.06	0.06	0.75	0.96	0.40	0.59
2015	0.29	0.56	0.07	0.05	0.77	0.99	0.44	0.57

Notes: Columns (1) to (4) show the share of agricultural production devoted to the market (1), to own consumption (2), stored (3), and gifted to other households(4). Columns (5) to (8) show the proportion of farmers that sold (5), own consumed (6), stored (7), and gifted (8) some part part of their agricultural production. Data: UNPS first 5 waves.

Table A.3: Consumption, Income, and Wealth in Uganda, per Capita Levels. Average and Gini level

	Rural				**National**			
	Cons	Income	Wealth	HH Size	Cons	Income	Wealth	HH Size
2009-2010	265.33	276.48	711.95	6.53	323.28	330.65	754.67	6.37
	(0.36)	(0.59)	(0.62)		(0.41)	(0.6)	(0.65)	
2010-2011	235.47	244.37	641.10	7.15	277.35	281.97	689.41	7.11
	(0.38)	(0.59)	(0.64)		(0.41)	(0.59)	(0.66)	
2011-2012	258.98	265.44	624.05	7.52	293.17	297.69	686.94	7.48
	(0.39)	(0.58)	(0.61)		(0.41)	(0.58)	(0.64)	
2013-2014	326.00	331.36	854.75	5.79	401.05	426.03	1,011.21	5.62
	(0.33)	(0.6)	(0.61)		(0.39)	(0.62)	(0.66)	
2015-2016	358.17	463.08	840.73	5.40	449.72	588.71	1,036.96	5.24
	(0.38)	(0.63)	(0.61)		(0.44)	(0.65)	(0.69)	
Average	288.79	316.14	734.52	6.48	348.91	385.01	835.84	6.36
	(0.37)	(0.6)	(0.62)		(0.41)	(0.61)	(0.66)	

Notes: Values in 2013 US dolars. Data controlled for inflation. Gini index within parenthesis. Consumption includes food and non-durables consumption. Income includes crops revenues computed with median district crop consumption prices and selling prices when missing. Livestock profits, salary labor earnings, business profits and other sources of income. Wealth includes housing, household assets, land, livestock holdings, and farm capital. Data: UNPS first five waves.

TABLE A.4: The Composition of Consumption, Income, and Wealth in Rural Uganda

Wave	**Consumption**		**Income**				**Wealth**			
	Food	*Nofood*	*Agric*	*business*	*Lvsk*	*Labor*	*Assets*	*Land*	*Lvstk*	*farmK*
09–10	1,462.50		1,472.12				3,938.95			
	(0.36)		(0.57)				(0.62)			
	965.03	576.83	860.84	623.82	287.85	766.82	1,485.29	3,246.29	1,016.39	NaN
	[2026]	[1935]	[1892]	[932]	[480]	[849]	[2021]	[1586]	[495]	[0]
10–11	1,419.42		1,383.18				3921.16			
	(0.36)		(0.55)				(0.63)			
	996.23	471.49	779.96	682.13	233.08	785.24	1,757.64	3,141.67	941.99	24.73
	[1948]	[1941]	[1777]	[844]	[466]	[744]	[1944]	[1497]	[481]	[1778]
11–12	1,582.88		1,620.54				4,182.69			
	(0.34)		(0.55)				(0.61)			
	1,126.33	504.55	1,011.88	916.14	353.22	866.11	1,389.81	3,652.78	979.42	18.62
	[2115]	[2109]	[1852]	[850]	[478]	[625]	[2070]	[1694]	[473]	[1822]
13–14	1,539.26		1,502.92				4,391.47			
	(0.30)		(0.57)				(0.61)			
	1,050.36	523.50	929.51	923.45	234.24	866.26	1,817.46	2,787.16	925.99	73.38
	[2264]	[2263]	[2072]	[966]	[594]	[717]	[2264]	[1902]	[614]	[2102]
15–16	1,466.62		1,733.13				3,731.18			
	(0.31)		(0.58)				(0.60)			
	974.07	496.31	999.78	894.92	267.17	440.30	1,402.40	2,559.19	1,068.37	17.27
	[2335]	[2330]	[2032]	[940]	[545]	[752]	[2333]	[1901]	[571]	[2134]

Notes: Values in 2013 US dollars. Data controlled for inflation. (Gini), [observations]. C-*nofood* consists of non-durable goods. Non-agriculture business; I-*livestock* net income from livestock; I-*labor* income from salary labor. W-*hh* value of household assets; W-*farm* value of farming capital and livestock, Land not included in.

TABLE A.5: Summary High and Low Crops, Average across Waves

	High Crops	Low Crops
Output	658.61	354.75
Land area	1.43	2.45
Input usage	41.88	36.88
Output over land	491.85	149.37
Inputs over land	29.2	14.89
Cultivate–1	0.63	0.96
Cultivate–2	0.76	0.99

Notes: Monetary output and input expenditure. Cultivate–1 is the share farmers that harvested the crops (average across waves). Cultivate–2 is the share of households that harvested the crops at some wave. Data: UNPS first five waves.

TABLE A.6: Summary Production, Inputs, and Yields on High and Low Crops

Wave	**Household Level**						**Per Acre**			
	y_h	y_l	A_h	A_l	m_h	m_l	$\frac{y_h}{A_h}$	$\frac{y_l}{A_l}$	$\frac{m_h}{A_h}$	$\frac{m_l}{A_l}$ 1
09–10	673.96	328.91	0.88	2.22	32.23	41.96	763.64	148.43	36.51	18.94
10–11	402.59	354.03	1.31	1.76	21.69	18.30	307.61	200.95	16.57	10.38
11–12	554.55	406.38	1.75	2.89	56.93	44.24	316.45	140.42	32.49	15.29
13–14	775.15	350.85	1.88	3.05	59.66	42.72	413.16	115.17	31.80	14.02
15–16	886.78	333.57	1.35	2.35	38.57	37.18	658.42	141.87	28.64	15.81
Avg	658.61	354.75	1.43	2.45	41.81	36.88	491.85	149.37	29.20	14.89

Notes: Where y represents monetary production in 2013 US dollars, A represents land size in acres, m represents inputs expenditure in US2013\$. h denotes variables for high crops, l for low crops. Data: UNPS first five waves.

TABLE A.7: Share of Farmers Growing High Crops and Low Crops

	High Crops	Low Crops	Both Crops
2009–10	0.62	0.93	0.61
2010–11	0.68	0.97	0.67
2011–12	0.69	0.97	0.67
2013–14	0.61	0.96	0.59
2015–16	0.65	0.97	0.62

Notes: Proportion of farmers that harvested high crops, column (1), harvested low crops (2), and harvested both types of crops (3) per each data wave. Data: UNPS first 5 waves.

TABLE A.8: Consumption Summary Rural Uganda, UNPS 09/11 to 15/16. Each Household Average across Waves

	Total	Food	Non-Durables	Durables	Total Gift	Food Gift
Obs	3,157.00	3,157.00	3,149.00	3,147.00	3,157.00	3,157.00
Mean	1,514.90	1,010.54	509.93	34.73	157.68	66.99
SD	876.56	549.90	451.24	129.57	175.04	128.96
Min	187.81	0.00	24.48	0.00	0.00	0.00
Median	1,311.65	897.68	381.36	3.72	112.19	22.65
Max	6,562.70	4,432.91	5,567.39	3,238.64	2,722.51	2,722.51
Gini	0.30	0.29	0.40	0.85	0.49	0.71

Notes: Distributions of consumption variables at year level—average across waves, in US$, including purchases, own-production and gifts. Total represents total consumption— food consumption plus non-durables non-food items consumption. Durables includes consumption in durables, total gift represents households consumption coming from gifts from other households, and food gifts represents the food consumption Data: UNPS first 5 waves.

TABLE A.9: Income Summary Rural Uganda, UNPS 09/11 to 15/16. Each Household Average across Waves

	Total	Agriculture	business	Livestock	Wage Labor
Obs	3,158.00	2,926.00	1,886.00	1,304.00	1,846.00
Mean	1,577.53	899.63	680.87	236.77	781.87
SD	1,733.63	1,364.22	998.87	278.00	1,073.23
Min	24.98	0.00	-601.17	-36.35	0.03
Median	1,025.23	489.88	326.72	150.17	357.53
Max	22,504.55	21,563.46	10,732.99	2,518.07	9,723.33
Gini	0.50	0.58	5.31	0.64	0.62

Notes: Distribution of income variables at year level—average across waves, in US$. Total represents the aggregate household income coming from agricultural revenues, column (2), business profits (3), livestock profits (4), and paid labor including both formal and informal labor (4). Data: UNPS first 5 waves.

TABLE A.10: Wealth Summary UNPS 09/11 to 15/16. Each Household Average Across Waves

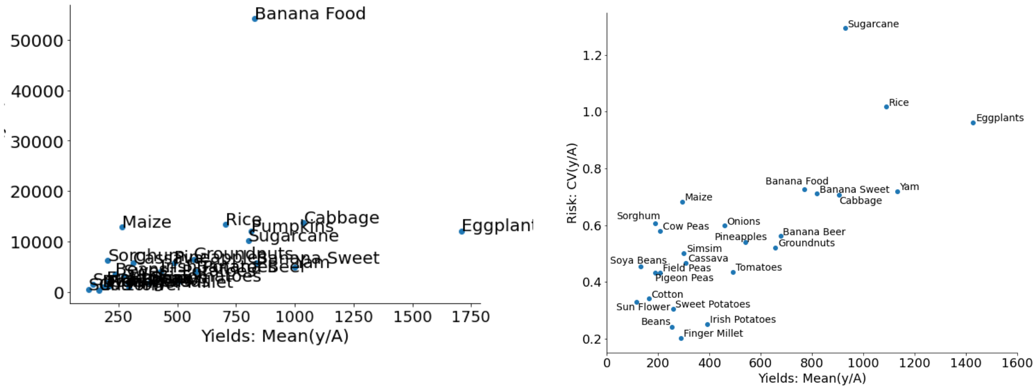
	Total	Hh Assets	$\widehat{land}$	Livestock	Farming Capital
count	3,158.00	3,148.00	2,755.00	1,337.00	2,810.00
mean	3,872.88	1,334.62	2,991.84	789.52	29.47
std	5,653.66	3,102.28	4,734.32	1,196.96	547.62
min	0.00	0.00	0.00	3.48	0.00
50%	2,198.47	454.88	1,681.38	419.30	9.05
max	92,052.43	72,802.40	86,134.28	13,724.26	29,000.74
Gini	0.57	0.70	0.56	0.59	0.73

Notes: Distribution of wealth variables at year level—average across waves, in US$. Total represents the households aggregate wealth from household assets—column (2) including dwelling value—the estimated value of agricultural land (3), livestock holdings (4), and farming capital (5)—tools, machinery, etc. Data: UNPS first 5 waves.

FIGURE A.1: No long-term Crop's Yields vs Risk: Average vs Coefficient of Variation (CV), UNPS (09-16)

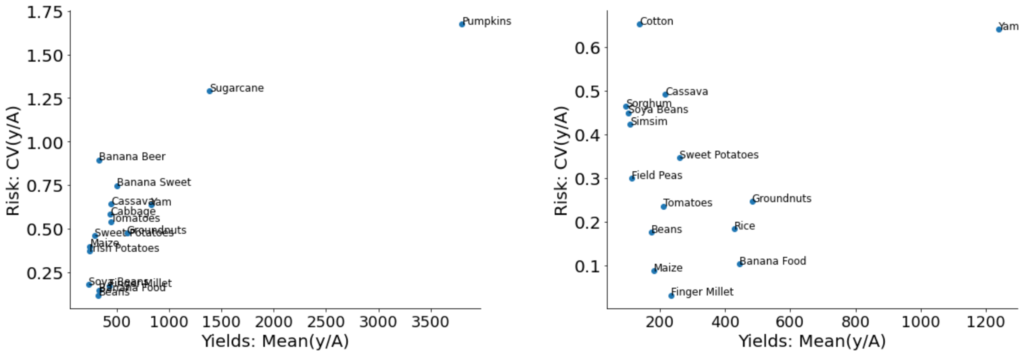
(A) Uganda pooling households and seasons

(B) Nationwide Uganda



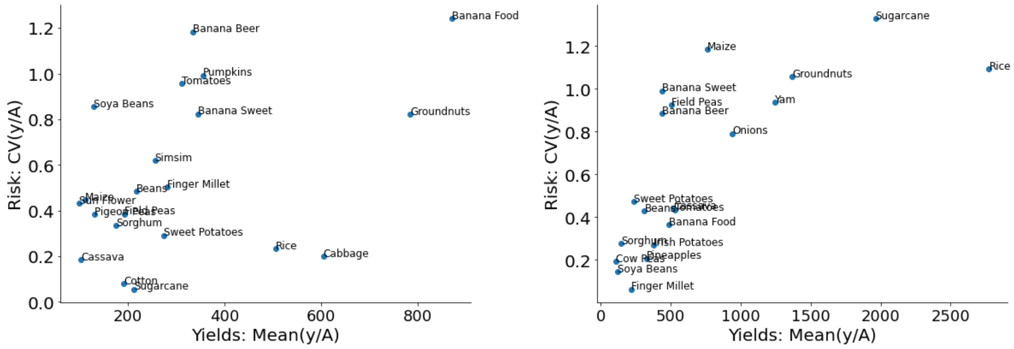
(C) Central Uganda

(D) Eastern Uganda



(E) Northern Uganda

(F) Western Uganda



Notes: Include the main crops in Uganda that are cultivated with less than 2 years since planting. In sub-figure (a), agricultural yields—crop revenue over land usage—are pooled across households and seasons. In sub-figure (b)-(f), The crops yields average and coefficient of variation are computed across variation at the seasonal level: I compute the average crop production in each season across households, and then use these averages as the observations to compute the measures. Sub-figure(b) includes all Uganda, while figures (c) to (f) study the correlation of crops yields and risk for each of 4 main administration units in Uganda:Central Uganda, Eastern Uganda, Northern Uganda, and Western Uganda. Data: UNPS first five waves.

Appendix B

Appendix Chapter 2

B.1 Complete Markets Tests Derivation

Under complete markets the Competitive Equilibria is Equivalent to the Pareto Optimal solution. Agents are identical in preferences. The economy has infinite time horizon and in each period a different state of the economy (s_t) is realized. s^t denotes the history of realized states from time 0 to time t. The Social Planner problem is

$$\sum_i^N \omega_i \sum_t^\infty \sum_{s^t} \beta^t \pi(s^t) u(c_i(s^t)) \tag{B.1}$$

the Lagrangian is

$$\mathcal{L}(c_i(s^t)) = \sum_i^N \omega_i \sum_t^\infty \sum_{s^t} \beta^t \pi(s^t) u(c_i(s^t)) - \lambda_t \{\sum_i^N c_i(s^t) - \sum_i^N y_i(s^t)\} \tag{B.2}$$

And the first order conditions are

$$\left[c_i(s^t)\right] : \omega_i \beta_t \pi(s^t) u_{c_i}(c_i(s^t)) = \lambda_t \tag{B.3}$$

$$\left[c_j(s^t)\right] : \omega_j \beta_t \pi(s^t) u_{c_j}(c_j(s^t)) = \lambda_t \tag{B.4}$$

$$[\lambda_t] : \sum_i^N c_i(s^t) = \sum_i^N y_i(s^t) \tag{B.5}$$

dividing (B.3) by (B.4):

$$\frac{u_{c_i}(c_i(s^t))}{{}_{c_j}(c_j(s^t))} = \frac{\omega_j}{\omega_i} \tag{B.6}$$

full risk-sharing implies that the ratio of marginal utilities of consumption across agents remains constant over time and states of the world.

Taking logs on FOCS

$$ln\omega_i + ln\beta^t + ln\pi(s^t) + lnu_{c_i}(c_i(s^t)) = ln\lambda_t \tag{B.7}$$

aggregating over all individuals

$$\sum_{i}^{n}\{ln\omega_i + ln\beta^t + ln\pi(s^t) + lnu_{c_i}(c_i(s^t))\} = Nln\lambda_t \tag{B.8}$$

$$\overline{ln\omega} + ln\beta + ln\pi(s^t) + \overline{u_{c_i}(c_i(s^t))} = ln\lambda_t \tag{B.9}$$

equating (B.3) and (B.9) we get:

$$lnu_{c_i}(c_i(s^t)) + \overline{lnu_{c_i}(c_i(s^t))} = ln\omega_i - \overline{ln\omega} \tag{B.10}$$

this is the main equation to perform insurance tests.

Setting Pareto weights equal across agents and assuming a CRRA utility function identical across agents, $u(c_i(s^t)) = \frac{c_i(s^t)^{1-\theta}}{1-\theta}$, then, the marginal utility is $u_{c_i}(c_i(s^t)) = c_i(s^t)^{-\theta}$ and (B.10) becomes

$$ln(c_i(s^t)^{-\theta}) - N^{-1}\sum_{i}^{N} ln(c_i(s^t)^{-\theta}) = 0 \tag{B.11}$$

$$ln(c_i(s^t) = \overline{ln(c(s^t)} \tag{B.12}$$

finally, substrating previous consumption we get:

$$\Delta ln(c_i(s^t) = \Delta\overline{ln(c(s^t)} \tag{B.13}$$

therefore, with the previous equation and using panel data, we can test complete markets test with the following regression equation

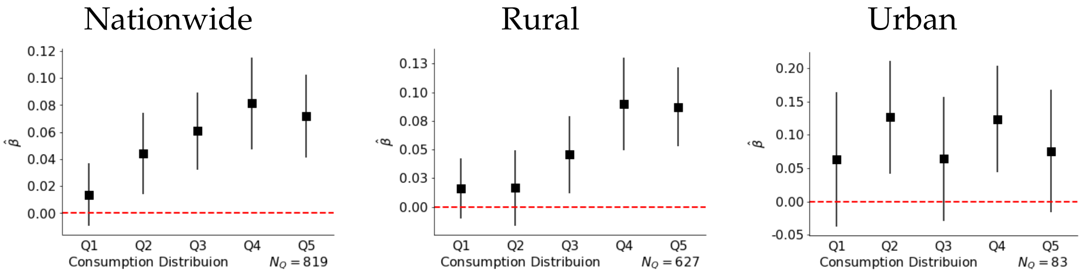
$$\Delta ln(c_i(s^t) = \alpha\Delta\overline{ln(c(s^t)} + \beta\Delta lny_i(s^t) \tag{B.14}$$

in which complete markets implies $\alpha = 1$ and $\beta = 0$.

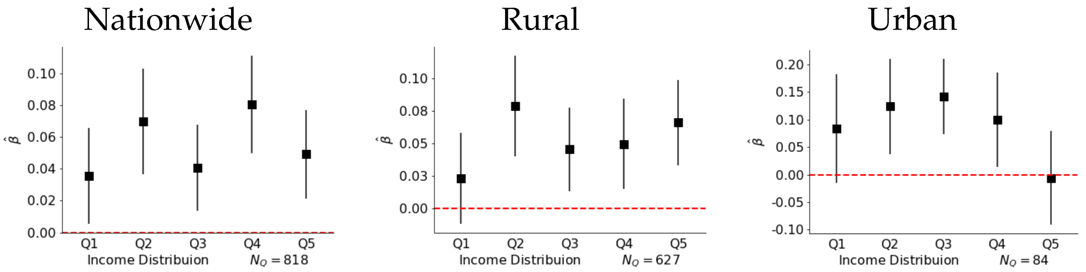
B.2 Figures

FIGURE B.1: Robustness Check: Regressions Without Fixed Effects—CRRA Specification

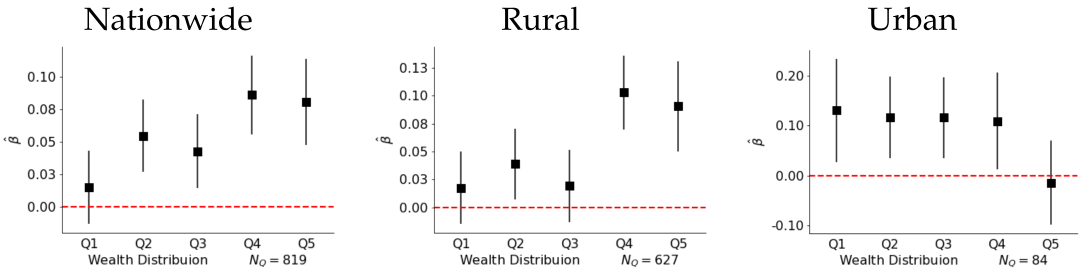
(a) Consumption



(b) Income



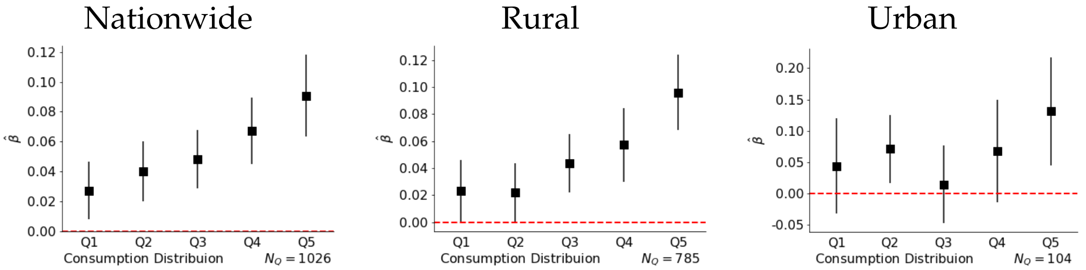
(c) Wealth



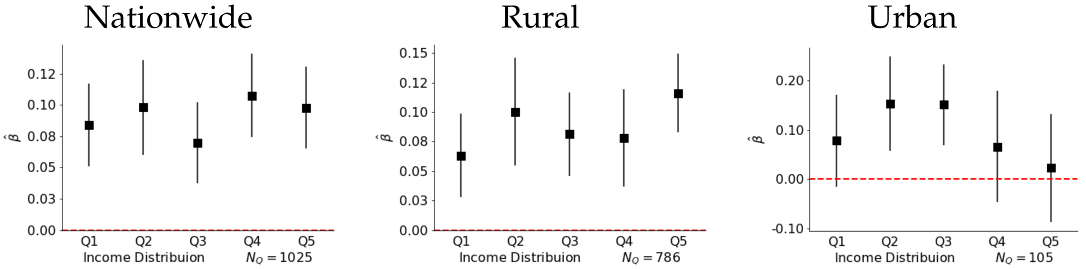
Notes: OLS estimates of β in regression equation $\Delta lnc_{it} = +\alpha \Delta C_t + \beta \Delta lny_{it} + F_i + e_{it}$ for each quintile group—x-axis—of the consumption (a), income (b), and wealth (c) distributions for the whole country (column 1), for rural areas (column 2), and for urban areas (column 3). c_{itr} and y_{itr} denote consumption and income of household i in region r at period t, $C_t r$ denotes region average consumption in region r at period t and F_i denotes household fixed effects.0.30 N_q denotes the minimum number of observations in the regressions across the five quintiles of the distribution. The red dotted-line denotes full consumption insurance. Balanced Panel of the first 5 waves of the UNPS.

FIGURE B.2: Robustness Check: Regressions Without Fixed Effects—Standard Specification

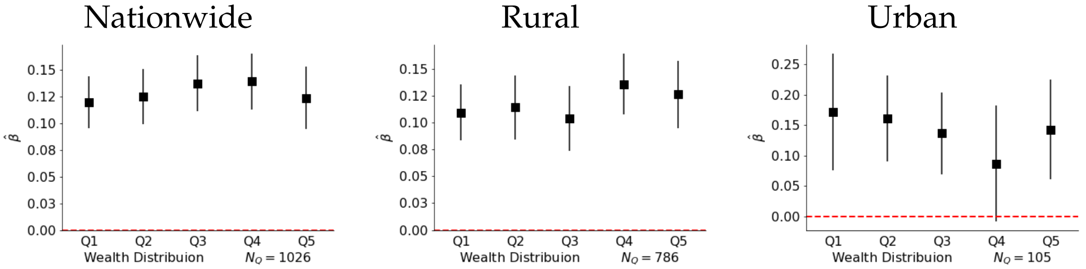
(a) Consumption



(b) Income



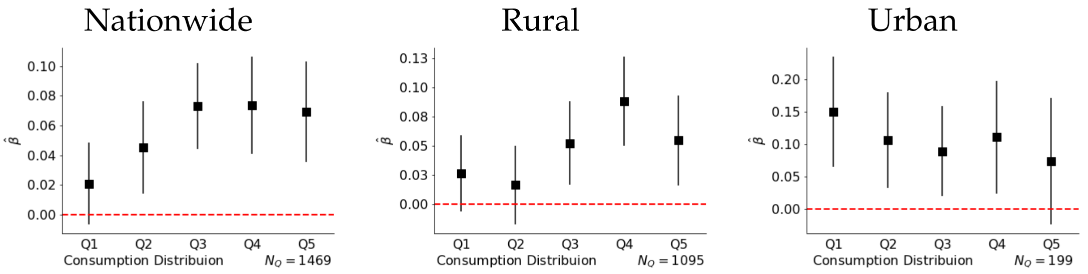
(c) Wealth



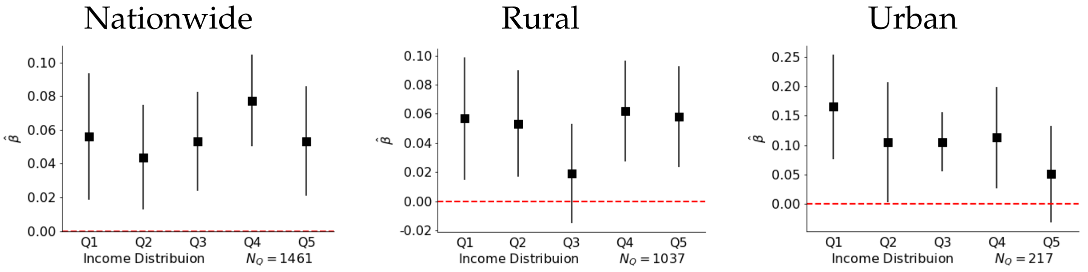
Notes: OLS estimates of β in regression equation $lnc_{it} = +\alpha C_t + \beta \Delta lny_{it} + F_i + e_{it}$ for each quintile group—x-axis—of the consumption (a), income (b), and wealth (c) distributions for the whole country (column 1), for rural areas (column 2), and for urban areas (column 3). c_{it} and y_{it} denote consumption and income of household i at period t, C_t denotes region average consumption and F_i denotes household fixed effects.0.30 N_q denotes the minimum number of observations in the regressions across the five quintiles of the distribution. The red dotted-line denotes full consumption insurance. Balanced Panel of the first 5 waves of the UNPS.

FIGURE B.3: Robustness Check: Unbalanced Panel—CRRA Specification

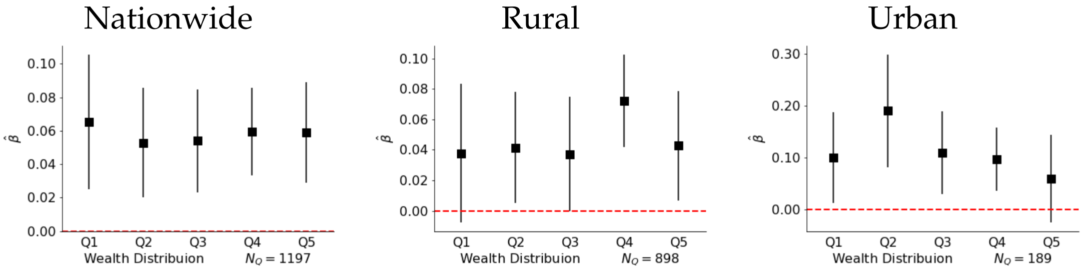
(a) Consumption



(b) Income



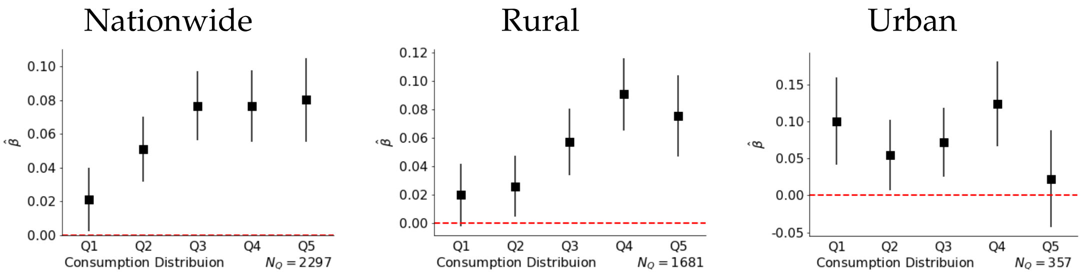
(c) Wealth



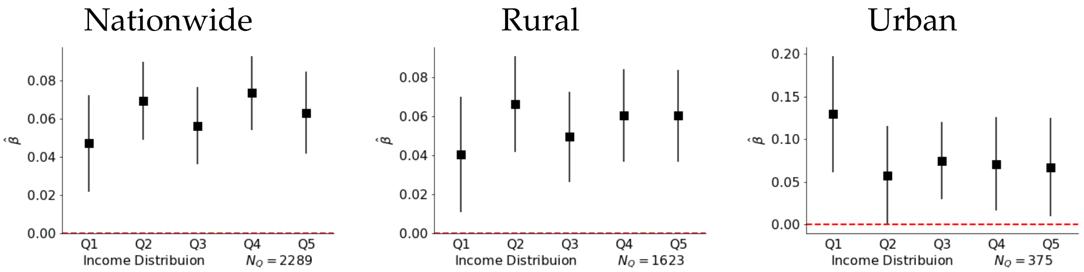
Notes: OLS estimates of β in regression equation $\Delta lnc_{it} = +\alpha \Delta C_t + \beta \Delta lny_{it} + F_i + e_{it}$ for each quintile group—x-axis—of the consumption (a), income (b), and wealth (c) distributions for the whole country (column 1), for rural areas (column 2), and for urban areas (column 3). c_{itr} and y_{itr} denote consumption and income of household i in region r at period t, $C_t r$ denotes region average consumption in region r at period t and F_i denotes household fixed effects.0.30 N_q denotes the minimum number of observations in the regressions across the five quintiles of the distribution. The red dotted-line denotes full consumption insurance. Unbalanced Panel of the first 5 waves of the UNPS.

FIGURE B.4: Robustness Check: Unbalanced Panel—Standard Specification

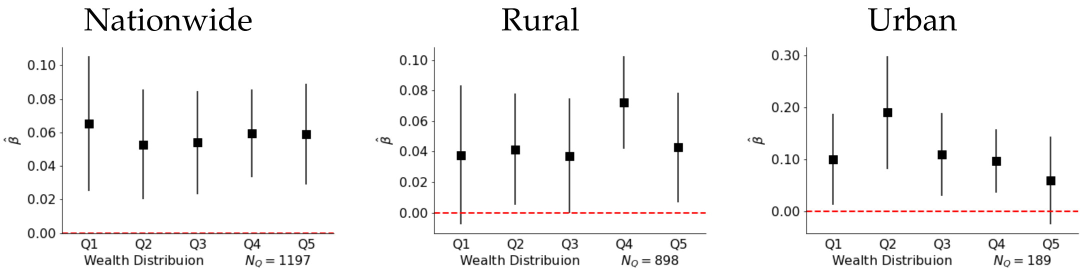
(a) Consumption



(b) Income



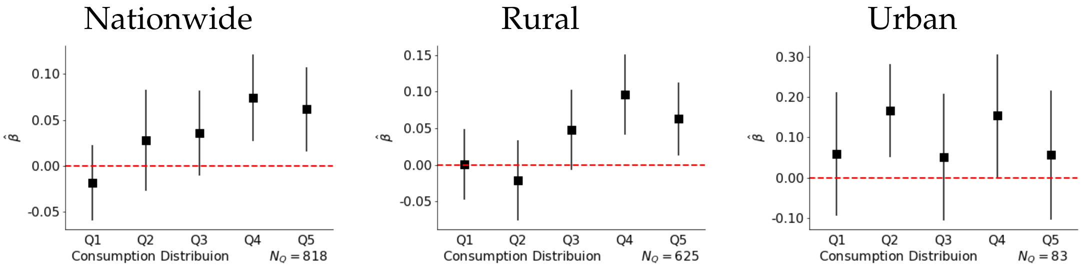
(c) Wealth



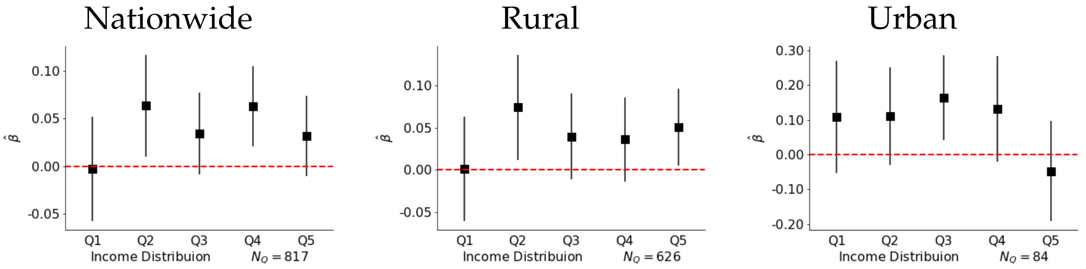
Notes: OLS estimates of β in regression equation $lnc_{it} = +\alpha C_t + \beta \Delta lny_{it} + F_i + e_{it}$ for each quintile group—x-axis—of the consumption (a), income (b), and wealth (c) distributions for the whole country (column 1), for rural areas (column 2), and for urban areas (column 3). c_{it} and y_{it} denote consumption and income of household i at period t, C_t denotes region average consumption and F_i denotes household fixed effects.0.30 N_q denotes the minimum number of observations in the regressions across the five quintiles of the distribution. The red dotted-line denotes full consumption insurance. Unbalanced Panel of the first 5 waves of the UNPS.

FIGURE B.5: Robustness Check: Testing Food Consumption Insurance—CRRA Specification

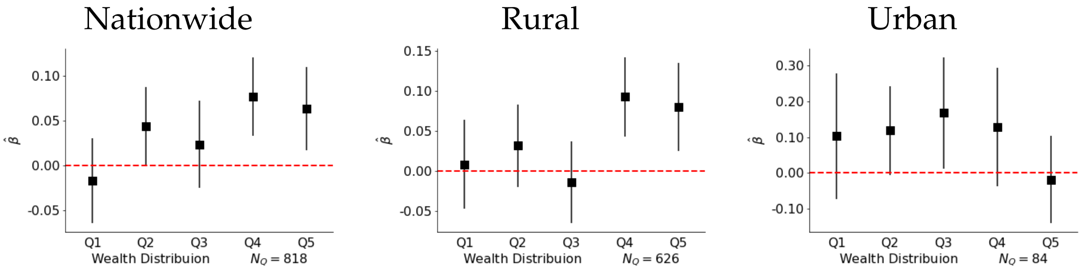
(a) Consumption



(b) Income



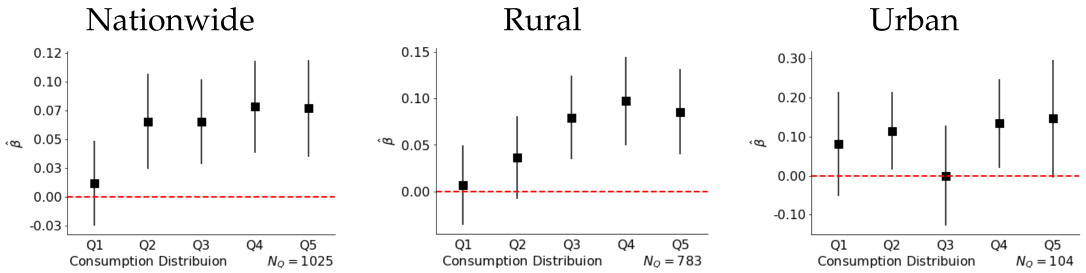
(c) Wealth



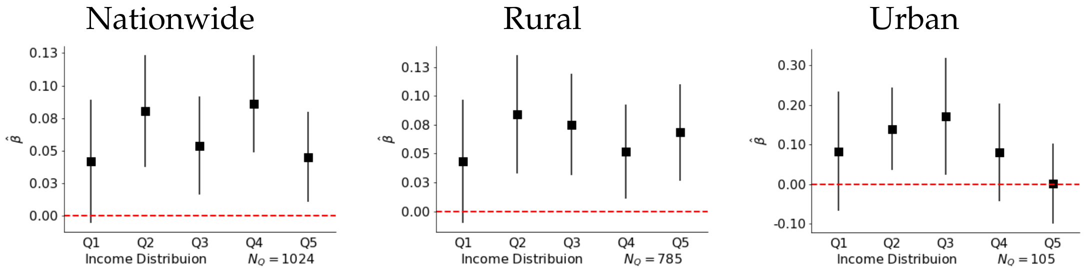
Notes: OLS estimates of β in regression equation $\Delta lnfood_{itr} = +\alpha \Delta C_t r + \beta \Delta lny_{itr} + F_i + e_{itr}$ for each quintile group—x-axis—of the consumption (a), income (b), and wealth (c) distributions for the whole country (column 1), for rural areas (column 2), and for urban areas (column 3). $food_{itr}$ and y_{itr} denote food consumption and income of household i in region r at period t, $C_t r$ denotes region region average consumption and F_i denotes household fixed effects.0.30 N_q denotes the minimum number of observations in the regressions across the five quintiles of the distribution. The red dotted-line denotes full consumption insurance. Balanced Panel of the first 5 waves of the UNPS.

FIGURE B.6: Robustness Check: Testing Food Consumption Insurance— Standard Specification

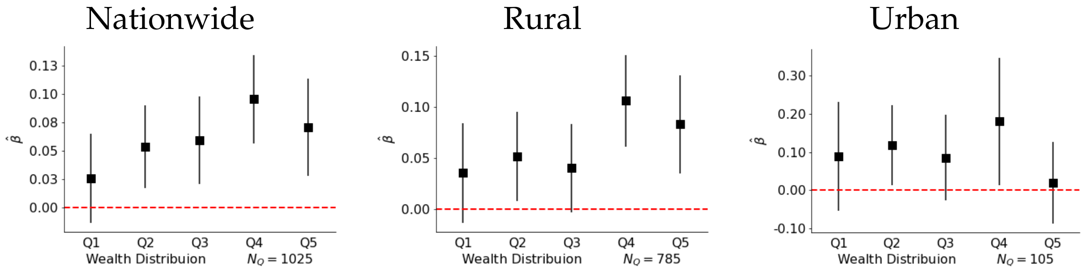
(a) Consumption



(b) Income



(c) Wealth



Notes: OLS estimates of β in regression equation $lnfood_{it} = +\alpha C_t + \beta lny_{it} + F_i + e_{it}$ for each quintile group—x-axis—of the consumption (a), income (b), and wealth (c) distributions for the whole country (column 1), for rural areas (column 2), and for urban areas (column 3). $food_{it}$ and y_{it} denote food consumption and income of household i at period t, C_t denotes region average consumption and F_i denotes household fixed effects.0.30 N_q denotes the minimum number of observations in the regressions across the five quintiles of the distribution. The red dotted-line denotes full consumption insurance. Balanced Panel of the first 5 waves of the UNPS.

B.3 Tables

TABLE B.1: Proportion of Households that Reported a Shock during last 12 Months

	Shock	Drought	Flood	Health	Prices	Labor	Pests	Erosion	Others
Total	42.79	28.82	3.30	9.71	1.96	0.64	3.69	0.44	7.20
by Reside									
Rural	46.69	32.95	3.77	9.99	2.27	0.49	4.21	0.54	7.29
urban	28.38	13.58	1.57	8.68	0.82	1.20	1.74	0.07	6.84
by C. Quin									
Q1	45.53	31.80	3.59	9.42	1.12	0.36	2.37	0.60	7.70
Q2	42.87	29.74	3.42	9.12	1.71	0.44	3.06	0.44	6.21
Q3	43.30	28.95	3.87	10.05	2.35	0.40	3.75	0.64	7.14
Q4	43.51	29.32	3.27	9.64	2.55	0.88	4.43	0.32	6.97
Q5	38.76	24.32	2.35	10.33	2.07	1.12	4.93	0.20	7.97
by Region									
Central	42.00	26.39	0.78	10.61	1.33	1.25	3.64	0.39	8.86
Eastern	38.74	24.31	5.14	10.65	4.19	0.51	6.84	0.44	6.49
Northern	53.08	40.41	5.88	8.92	1.67	0.30	2.42	0.24	7.22
Western	35.76	22.93	1.52	8.43	0.70	0.37	1.82	0.74	5.73
by Gender									
Male	41.74	28.39	3.24	8.88	2.00	0.67	4.02	0.42	7.00
Female	44.50	29.53	3.40	11.06	1.89	0.59	3.19	0.46	7.51
By Age									
<30 y.o.	37.50	23.50	2.63	8.85	1.50	1.26	2.41	0.24	7.12
30-50 y.o.	42.21	28.24	3.20	9.00	2.06	0.74	3.59	0.51	7.86
>50 y.o.	45.62	31.71	3.70	10.87	1.92	0.30	4.25	0.44	6.38
By Wave									
2009-2010	61.80	47.97	2.16	15.73	2.99	1.17	6.59	0.83	12.32
2010-2011	44.90	27.96	3.90	13.20	2.01	0.53	2.83	0.25	7.46
2011-2012	36.38	20.49	5.21	7.21	2.08	0.58	3.24	0.58	6.48
2013-2014	39.45	27.34	3.33	6.77	2.18	0.37	nan	0.41	5.13
2015-2016	30.25	19.30	1.89	5.29	0.45	0.49	1.89	0.08	4.22

Notes: Flood also includes irregular rains (asked in the last 13/14 and 15/16 waves) Agr. Prices shocks include households that reported Unusually High Costs of Agricultural Inputs and/or Unusually Low Prices for Agricultural Output. Health: Serious Illness or Accident of Income Earner(s), Serious Illness or Accident of Other Household Member(s), Death of Income Earner(s), Death of Other Household Member(s). Labor shocks include: Reduction in the Earnings of Currently (Off-Farm) Employed Household Members, Loss of Employment of Previously Employed Household Members (Not Due to Illness or Accident). Pests: Unusually High Level of Crop Pests & Disease, Unusually High Level of Livestock Disease. Data: UNPS first 5 waves.

TABLE B.2: Proportion of Shocks along Consumption Quintiles: Urban vs Rural Uganda

	Shock	Drought	Flood	Health	Prices	Labor	Pests	Erosion	Others
					Rural				
Q1	45.97	32.19	4.05	9.16	1.10	0.29	2.49	0.62	7.73
Q2	44.09	31.36	3.05	9.39	1.67	0.24	2.64	0.52	6.43
Q3	45.26	32.11	4.29	9.62	2.76	0.43	4.70	0.62	6.34
Q4	46.04	31.89	3.67	9.91	2.43	0.48	4.38	0.52	7.10
Q5	47.40	32.00	3.29	11.49	3.00	1.14	6.64	0.29	9.06
					Urban				
Q1	35.34	18.17	1.86	11.30	0.72	0.86	1.54	0.29	7.73
Q2	33.43	16.57	3.00	9.57	0.71	1.00	0.74	0.00	8.29
Q3	30.09	16.33	1.58	7.74	1.43	1.29	2.35	0.00	6.02
Q4	28.80	15.62	1.43	8.60	1.15	1.58	1.87	0.00	6.45
Q5	26.93	12.03	1.29	8.31	0.86	1.00	2.77	0.14	7.59

Notes: Flood also includes irregular rains (asked in the last 13/14 and 15/16 waves) Agr. Prices shocks include households that reported Unusually High Costs of Agricultural Inputs and/or Unusually Low Prices for Agricultural Output. Health: Serious Illness or Accident of Income Earner(s), Serious Illness or Accident of Other Household Member(s), Death of Income Earner(s), Death of Other Household Member(s). Labor shocks include: Reduction in the Earnings of Currently (Off-Farm) Employed Household Members, Loss of Employment of Previously Employed Household Members (Not Due to Illness or Accident). Pests: Unusually High Level of Crop Pests & Disease, Unusually High Level of Livestock Disease. Data: UNPS first 5 waves.

Appendix C

Appendix Chapter 3

C.1 Data

TABLE C.1: Summary of the Household head's Characteristics in the Village

Gender	
Male	0.67
Female	0.33
Marriage Status	
Married/cohabited	0.71
Divorced	0.14
Widowed	0.11
Separated	0.02
Never married	0.02
Religion	
Muslim	0.79
Christian	0.20
Traditional	0.00

Education	
No education	0.21
Primary Standard 1	0.07
Primary Standard 2	0.05
Primary Standard 3	0.07
Primary Standard 4	0.08
Primary Standard 5	0.09
Primary Standard 6	0.09
Primary Standard 7	0.13
Primary Standard 8	0.07
Secondary form 1	0.04
Secondary form 2	0.05
Secondary form 3	0.01
Secondary form 4	0.03
University/Training College	0.00

Notes: Household heads' gender, marital status, religion, and education in the village.

TABLE C.2: Land Summary

(a) Land Size and Value Distribution

	N Plots	Acres	If Rent	Value	Value/Rent	Acre Price	Acr P1	Acr P2
Avg	1.85	2.68	22,183.15	313,492.12	15.34	130,755.10	1.88	1.18
Std	0.97	2.01	22,309.78	508,657	19.16	223,710.02	1.11	0.68
Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25%	1.00	1.40	10,000	76,250	6.74	50,000.00	1.20	0.64
Median	2.00	2.43	16,000	172,500	10.29	98,701.30	1.55	1.00
75%	2.00	3.50	27,000	350,000	18.71	144,166	2.40	1.50
Max	8.00	15.00	135,000	5,000,000	206.25	3,035,147	8.00	4.00

(b) Land Property

	Right		Can Chief Prevent		Land
	To Sell	Bequeath	Sell	Bequeat	Dispute
Yes	0.44	0.44	0.12	0.12	0.13

Notes: Panel (a) shows the distribution of number of plots, land size (in acres, total, first plot and second plot), land value (in terms of potential one-year rent, the total reported value, the ratio of value on one year rent, and the per acre price) in the village. Monetary values are in 2019 US dollars. From the households that have access to land, Panel (b) shows the proportion of households that have the right to sell the land (column 1), bequest the land (2), that the chief can prevent them to sell land (3) or prevent them bequeasting the land (4). Column (5) is the proportion of households that reported to experience land disputes during the last rainy season.

TABLE C.3: Agricultural Production Main Harvest (kg)

	Maize	Gnut	GdBean	SwPotatoe	Millet	Sorghum	PPeas	Cotton	Nkhwani	Tomatoe	Therere	Tanaposi
Obs	236	156	17	18	4	6	103	3	29	8	20	2
Mean	338	167	33	146	18	25	45	90	42	19	19	100
10%	100	25	5	24	5	4	6	30	9	1	5	36
Median	250	150	25	100	10	20	25	50	40	9	10	100
90%	560	350	70	215	38	50	100	165	50	53	50	164
max	5,600	750	100	750	50	50	300	194	200	60	75	180

Notes: Distribution of agricultural production across crops during the main harvest of the year. Obs represents the number of households in the village that cultivated the crop. Mean, 10th percentile, median, 90th percentile and maximum value of each crop production distribution in the village. Production in Kgs.

TABLE C.4: Main Harvest Sells: A Closed and Subsistence Economy

	Maize	Grndnut	SwPpotatoes	PigPeas	Cotton	Tomatoes
Total Selling						
% Households	0.07	0.22	0.02	0.19	0.01	0.01
Mean (Kg)	62.50	123.04	52.50	35.91	89.67	66.67
Selling within villagers						
% Households	0.05	0.04		0.03		0.01
Mean (Kg)	67.92	132.50		34.14		60.00
Selling in village to outsiders						
% Households	0.02	0.15	0.02	0.12	0.01	
Mean (Kg)	51.67	121.18	40.62	39.77	122.00	
Selling outside village						
% Households		0.02		0.02		
Mean (Kg)		133.33		18.50		

Notes: Along the crops, proportion of households that sell part of their agricultural production and the average quantity sold for total sales, sales only within the village, sales in the village to outsiders, and sells outside the village.

TABLE C.5: Food Transfers in The Village across the Income Distribution

(a) Food Transfers Connections Across Quintiles

$i \setminus j$	0-20%	20-40%	40-60%	60-80%	80-100%
0-20%	28	22	47	33	26
20-40%	22	36	37	43	44
40-60%	47	37	50	37	46
60-80%	33	43	37	30	44
80-100%	26	44	46	44	30
Total	156	182	217	187	190
%	16.7	19.5	23.3	20.1	20.4

(b) Transfers as Share of Total Food Consumption

	Aggregate	Quintiles				
		0-20%	20-40%	40-60%	60-80%	80-100%
Share	0.08	0.14	0.08	0.10	0.06	0.04
Obs	193	41	41	42	36	33

Notes: Panel (a) shows the number of food transfers across quintile groups in the income distribution. Number of food transfers during last 7-days. Panel (b) shows the ood transfers received as the share of total food consumption. Quintiles of the income distribution in the village. Observations represent the number of food transfers that happen in our village.

TABLE C.6: Summary Food Transfers (last 7 days)

(a) Transfers Within vs Outside the Village

Village	Obs	Avg($)	std($)	Median ($)
Within	648	0.49	1.02	0.20
Outside	59	0.62	1.17	0.27

(b) 10 Most Transferred Items within the Village

		Quantity (Kg)		Value ($)	
Item	Obs	Mean	Med	Mean	Med
Thobwa*	84	0.93	0.71	0.25	0.19
Cassava	52	1.13	0.95	0.24	0.20
salt	45	0.12	0.11	0.08	0.07
Sweet potatoes	44	1.48	1.26	0.16	0.13
pigeon Peas	43	0.77	0.60	0.25	0.19
Maize (mgaiwa)	43	1.61	1.25	0.43	0.34
Goundnut	41	1.00	0.50	0.54	0.27
chicken	37	3.06	3.28	3.89	4.17
Maize (refined)	34	2.18	1.50	0.57	0.39
banana	34	1.78	1.14	0.21	0.13

Notes: Panel (a) shows the number of transfers and the average, standard deviation, and median transfer value for the transfers within the village and for the transfers between the village and outside. Panel (b) presents the number of transfers, the average and median quantity and average and median value of the transfers across the 10 most transferred food items within the village. Thobwa is a porridge made from white maize and millet or sorghum.

TABLE C.7: Determinants of Link Formation in the Food Transfers Network

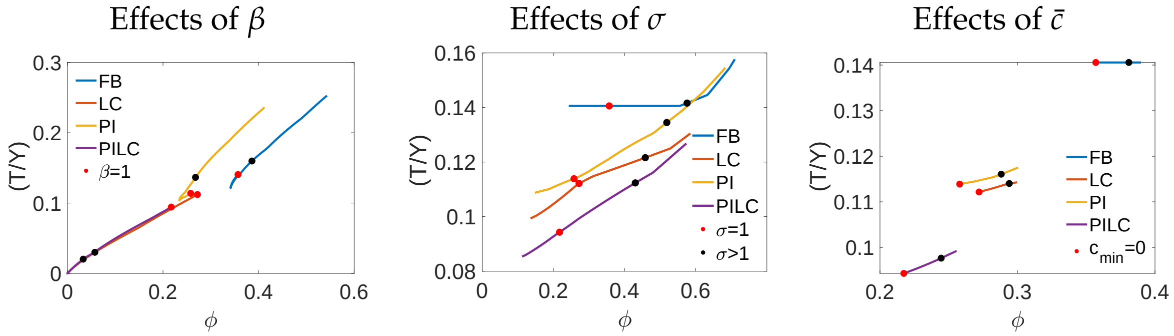
	(1)	(2)	(3)	(4)
Income	(0.0010)	(0.0010)		(0.0012)
Land Area	-0.0005	-0.0007*		-0.0006
	(0.0004)	(0.0004)		(0.0004)
Sub-Village		0.0406***		0.0413***
		(0.0026)		(0.0026)
Religion			0.0055***	0.0041**
			(0.0019)	(0.0019)
Age			-0.0001**	-0.0001**
			(0.0001)	(0.0001)
Education			-0.0005*	-0.0005*
			(0.0003)	(0.0003)
Gender			0.0036*	0.0039*
			(0.0021)	(0.0020)
Marital Status			-0.0052**	-0.0041**
			(0.0021)	(0.0021)
Intercept	0.0187***	0.0054***	0.0184***	0.0060**
	(0.0016)	(0.0014)	(0.0025)	(0.0027)
R-squared	0.0000	0.0216	0.0007	0.0235
	0.0001	0.0217	0.0010	0.0239
N	20301	20301	19503	19503

Notes: Estimation of the coefficients and robust SE estimates in regression equation $y_{ij} = \beta_0 + \beta_1|x_i - x_j| + \beta_3\mathbf{1}_{\{z_i=z_j\}} + \varepsilon_{ij}$ in which y_{ij} takes 1 if there was a food transfer between household i and j, 0 if no transfer occurred between the two households. $|x_i - x_j|$ represents the absolute distance between quantitative characteristics of households i and j. x includes in (1) distance in income and distance in land area; in (3) distance in household heads' age and distance household heads' years of education; in (4) including all of them. $\mathbf{1}_{\{z_i=z_j\}}$ takes one if both households i and j share characteristic z, 0 otherwise: z includes in (2) living in the same sub-village, in (3) household head sharing the same religion, sharing gender, and sharing marital status; in (4) including all the previous variables. We observe that the only two characteristics for which more similarity relates to higher probability of a food transfer link—5 percent signficance level—are living in the same sub-village and sharing religion, albeit the last one is not significant at the 1 percent.

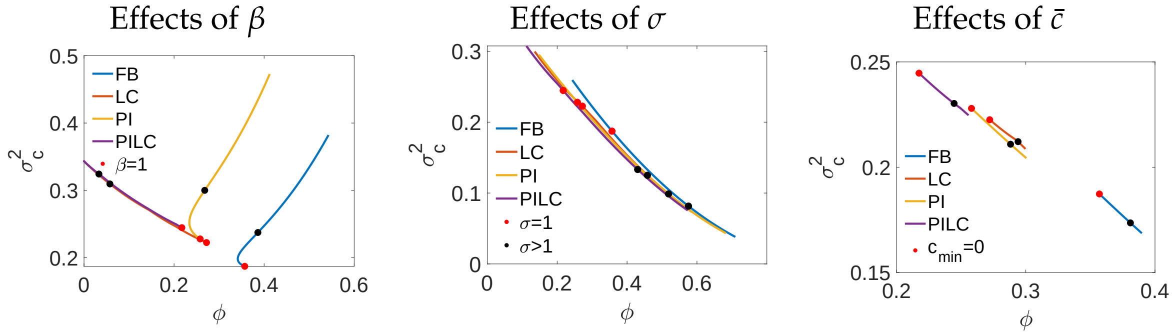
C.2 Comparative Statics

FIGURE C.1: Joint Sensitivity of Progressivity, Aggregate Transfers, Consumption Variance, and Insurance to Preference Parameters

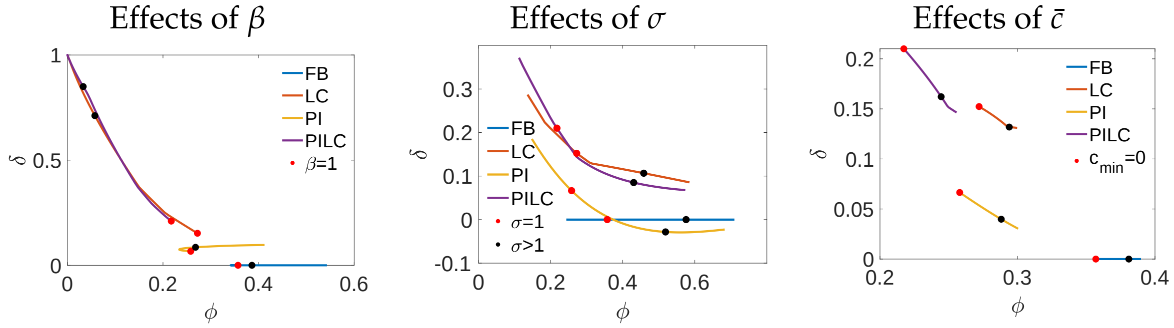
(a) Moments: Transfers T/Y and Progressivity ϕ



(b) Moments: Variance of log consumption σ_c^2 and Progressivity ϕ



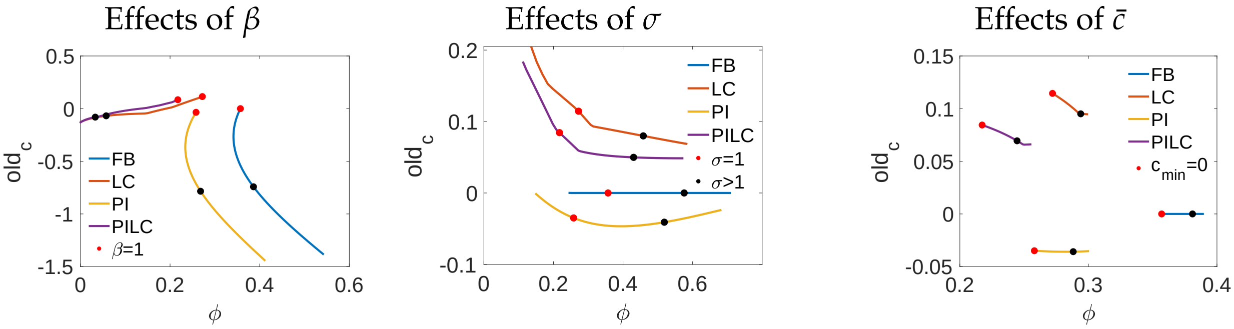
(c) Moments: Townsend δ and Progressivity ϕ



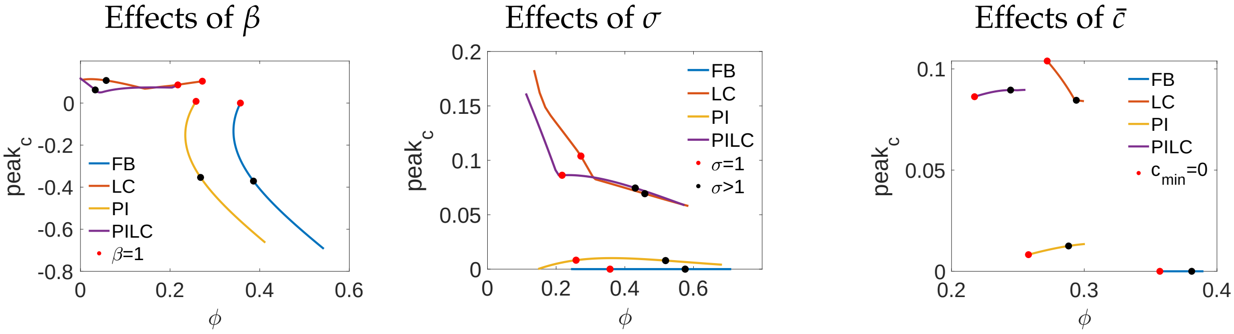
Notes: progressivity and transfers (a), progressivity and consumption variance (b), progressivity and insurance coefficient (c) join moments moments under solving the models—LC, PI, PILC, FB—in stationary across a large range of values of the persistence parameter (β, column 1), the risk-aversion parameter (σ, column 2), and the subsistence level parameter ($\bar{c}$, column 3).

FIGURE C.2: Joint Sensitivity of Consumption Life-Cycle Moments and Progressivity to Preference Parameters

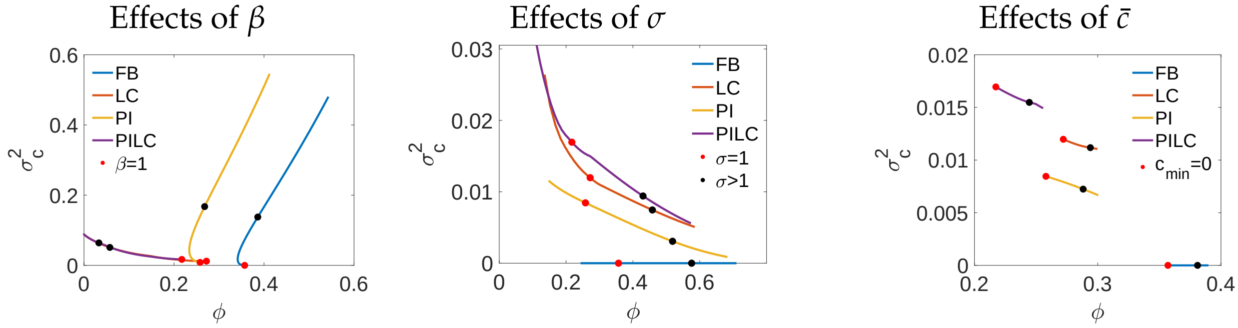
(d) Moments: Consumption when old (log deviation from first age) and Progressivity ϕ



(e) Moments: Peak of consumption (log deviation from first age) and Progressivity ϕ



(f) Moments: Variance of log normalized consumption over the life cycle and Progressivity ϕ

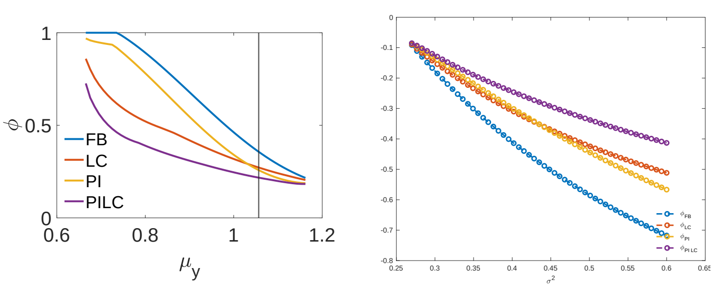


Notes: consumption when old and progressivity (d), peak consumption and progressivity (e), variance consumption over the life-cycle and progressivity (c) join moments moments under solving the models—LC, PI, PILC, FB—in stationary across a large range of values of the persistence parameter (β, column 1), the risk-aversion parameter (σ, column 2), and the subsistence level parameter ($\bar{c}$, column 3).

C.3 More on Social Norms and Wedges

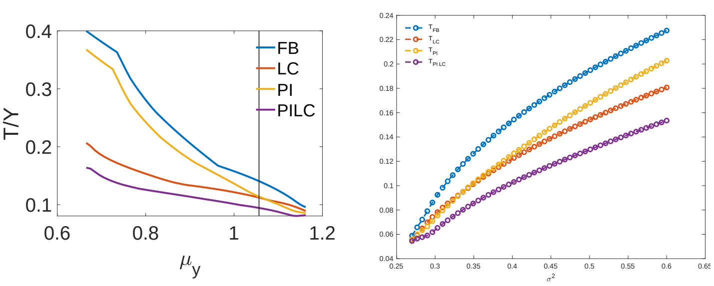
FIGURE C.3: Effects of Mean y and Variance y (Changing $\varepsilon's$)

(a) Effects on Progressivity ϕ



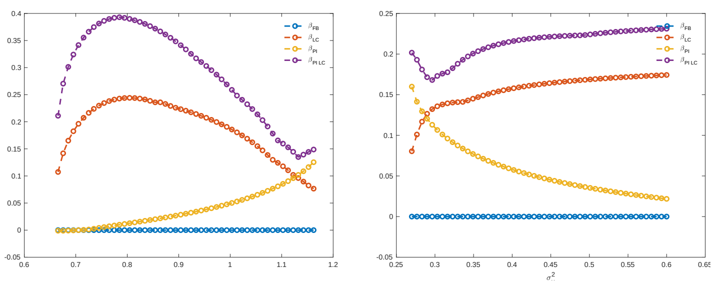
Effect of Mean(y) Effects of $var(y)$ Contour Plots

(b) Effects on Aggregate Transfers T/Y



Effect of Mean(y) Effects of $var(y)$ Contour Plots

(c) Effects on Insurance



Effect of Mean(y) Effects of $var(y)$ Contour Plots

Notes: Transfers progressivity (a), transfer size (b), and insurance level—Townsend coefficient, (c)—of the risk-sharing economies in steady state for a range of values on the average income (column 1), the variance of the income shocks (column 2), and the join changes in average income and income variance (column 3).