# The Impact of Climate Change and Financial Frictions on Agricultural Productivity

*-Working Paper-*

Latest version of the working paper

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**Abstract**

This paper studies how climate-induced declines in land productivity interact with financial frictions to shape agricultural productivity and welfare. I develop a two-sector general equilibrium model with heterogeneous farmers who choose between traditional and modern production technologies. Modern farming requires intermediary inputs that must be financed in advance, giving rise to endogenous borrowing constraints due to limited contract enforceability. Climate change is modeled as a reduction in land productivity, which lowers pledgeable income and tightens credit constraints. Qualitatively, climate damage leads to substantial welfare losses and lower agricultural productivity. Partial equilibrium results show that financial constraints not only distort input use but also change the intertemporal price of consumption, especially for less wealthy agents. In general equilibrium financial frictions reduce welfare through their effect on relative prices of consumption goods. The aggregate amplification effect is modest under the baseline parameterization. The findings highlight that financial market imperfections influence both the level and composition of agricultural productivity and can exacerbate the economic consequences of climate change.

# 1 Introduction

Agricultural productivity is a key predictor for international income differences. In developing economies, agricultural productivity is not only lower in absolute terms but also relative to the rest of the economy. Nevertheless, poor countries have a higher employment share in agriculture. At the same time, the agricultural sector is most exposed to climate related damages (Nath, 2021; Yohe and Schlesinger, 2002; Tol, 2009). Consequently, understanding how climate change effects agricultural productivity is of utmost importance.

While a large literature has documented the agricultural productivity gap, less attention has been paid to how climate change interacts with existing frictions in rural economies. More specifically, many developing economies are plagued by weak financial institutions. Financial frictions impede the adoption of intermediary inputs in the production process. An extensive amount of empirical literature has shown that intermediary inputs are underemployed in the agricultural sector in many developing economies (Donovan, 2021; Restuccia et al., 2008). Credit and borrowing play an important role of the agricultural sector since intermediary inputs such as fertilizers, pesticides and improved seeds must be purchased before production takes place. Empirical evidence shows that credit constraints hinder the adoption of modern inputs significantly and can explain part of the agricultural productivity gap. Consequently, this paper asks: to what extent do climate shocks amplify financial frictions and reduce agricultural productivity?

For this purpose I build a two sector general equilibrium economy with a rural and an urban population. In this model, farmers face an technological choice between operating a modern farm using intermediary inputs and a traditional farm which only uses farmer's labour and land as inputs. My model contributes to the literature by combining a dynamic occupational choice framework with agricultural productivity and climate change. I assume that climate change impedes the ability of farmers to borrow money since their pledge-able income declines. In consequence, the agricultural productivity is worsened by more than proportional to the decline in productivity caused by climate change. Therefore to mitigate the economic impact that climate change has policy should also focus on the financial side and provide the right tools for farmers.

*Related Literature.* This research is connected to several strands of the literature. Firstly, it relates to the development literature focusing on agricultural productivity. Chen et al. (2023) and Chen (2017), for instance focuses on the consequences of missing land-markets and institutional restrictions on land ownership for agricultural productivity. Both factors hinder the development of the agricultural sector. Donovan (2021), on the other hand, show that agricultural risk in combination with subsistence requirements for food lead to a lower adoption of intermediary inputs for agricultural use. This dampens productivity. Other papers focus on such as worker sorting across sectors (Lagakos and Waugh 2013), policy barriers to efficient farm size (Adamopoulos and Restuccia, 2014) or exposure to uninsurable shocks (Donovan, 2021). More recently, using the insight of a spatial trade model, Farrokhi and Pellegrina (2023) highlight the effect of trade in intermediates and set-up cost for the adoption of modern agriculture. Similarly, Sotelo (2020) focus on domestic frictions in the distribution of goods combined with forces from international markets, that lead to lower agricultural productivity. My paper will focus on set up cost and fincancial frictions which hinder the adoption of modern agricultural goods. In contrast to the previous literature I amend their research by examining the effects of climate change on technology adoption. Climate change is modeled by an exogenous decline in agricultural productivity.

Secondly, my model uses the framework provided by occupational choice models. The modeling of the financial friction and entrepreneurship follows the standards introduced by Moll (2014); Buera and Shin (2013); Buera et al. (2021); Itskhoki and Moll (2019). Buera et al. (2015) provides a good overview of financial frictions in the macro-development literature. The focus of this paper, will be the impact of financial friction on the uptake of intermediate technologies in the agricultural sector and its interaction with climate change. The latter will be modeled by a decreasing land productivity of farms caused by soil degradation, droughts and increased frequency of extreme weather events, such as floods and heatwaves, which systematically reduce average crop yields and lower the efficiency of agricultural production. Farmers need to borrow from financial intermediaries to obtain agricultural inputs, yet financial markets are incomplete as contracts are not fully enforceable like Buera et al. (2011).

The remainder of the paper is organized as follows. Section 2 introduces the model, including preferences, technology, and the general equilibrium structure. Section 3 presents the survey data used to calibrate key parameters, drawing on detailed longitudinal cross-country data from the LSMS-ISA program by the World Bank, which covers agricultural productivity in Sub-Saharan Africa. Section 4 examines both general equilibrium and partial equilibrium responses to climate-induced productivity shocks. The first section examines the partial equilibrium effects of climate damage and financial frictions. The second part takes price effects into account showing that climate damage reduces welfare and lowers the price of intermediary goods as demand decreases, while financial frictions have a limited aggregate effect under the current parameterization. Section 5 concludes.

I find an interaction between climate-induced productivity declines and the modernization of agriculture. Two competing mechanisms may be at play. On the one hand, as farmers become poorer, and if financial contracts are not fully enforceable, they may be unable to borrow in order to access modern technologies. At the same time, the overall supply of assets in the economy declines due to falling incomes. This can trigger a negative feedback loop in which farmers who previously adopted modern inputs are forced to revert to traditional farming methods, thereby amplifying the productivity decline.

# 2 Model

This section introduces the baseline model, which I use to evaluate the interaction between financial frictions, and climate change. The economy has two sectors, $a$ (agriculture) and $m$ (manufacturing). The agricultural sector consists of modern farms that use intermediary inputs such as fertilizers and pesticides, and traditional ones that are solely dependent on labor and cultivated land. The manufacturing sector provides intermediary inputs to modern farms as well as manufacturing consumption and investment. The agricultural goods price is the numeraire.

The population of the economy is split between rural and urban $i \in \{r, u\}$. Rural workers are those who cultivate land to farm and urban workers provide their labour to the manufacturing sector. The share of rural agents is marked by $\mu$ and the corresponding share urban workers is $1 - \mu$. All agents are infinitely lived. I assume that urban agents are hand-to-mouth consumers. Hence there is no labour mobility between urban and rural regions. Rural workers are heterogenous in their wealth $a_i$ and farming ability $z_i$. They face an intertemporal savings decision, which determines their asset holdings. Their farming ability follows a log-normal AR(1) process: $\log z_{t+1} = \rho \log z_t + \epsilon_{t+1}$.

In each period farmers choose the technology they want to operate: whether they want to adopt intermediary inputs and have a modern farm or whether they cultivate a traditional farm. The decision is based on their access to funds and their comparative advantage $z_i$ in operating a farm. Access to funds is limited through an endogenous borrowing constraint, rooted in a contract enforcability problem. I model farms in tradition of span of control model Lucas Jr (1978). Modern farms have a per period operational cost, similar to Farrokhi and Pellegrina (2023).

## 2.1 Preferences

Time is discrete and there is the continuum of farmers indexed by $i$. They are endowed with some farming skill $z$ which follows a log-AR(1) process. Furthermore, each farmer is endowed with the same amount of land, normalised to 1, which they can use for farming. Chen (2017) and Chen et al. (2023) show that untitled land and the unequal distribution of land can explain a large portion of the agricultural productivity gap. However, the focus of this paper lies on financial frictions and technology adoption. Thus, I abstract from the distortionary effect of missing land markets. Individuals take expectations over future realisations of their productivity. Agents derive utility from consuming agricultural goods ($c_a$) and manufacturing goods ($c_m$) which are bundled in a CES aggregator similar to Donovan (2021); Chen (2017); Adamopoulos and Restuccia (2014) . The intratemporal preferences can be represented by the following utility function:

$$U_i = \mathbb{E}\left[\sum_{t=0}^{\infty} \beta^t \frac{(C_t^i)^{1-\gamma}}{1-\gamma}\right], \text{ where } C_t^i = \left[\omega \left(c_a^i\right)_t^{\frac{\sigma-1}{\sigma}} + (1-\omega)\left(c_m^i\right)_t^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}$$

The superscript $i$ indexes whether the household belongs to the urban or rural population.

## 2.2 Technology

There are two production sectors, the agricultural and the manufacturing sector. The agricultural sector is run and owned by farmers. Secondly, the manufacturing sector supplies the agricultural input $m$, manufacturing consumption $c_m$ and investment. This setup largely follows Donovan (2021). The manufacturing sector uses capital and labour as inputs for production. The latter is in-elastically supplied by the urban population.

Zooming in on the production function of traditional farms:

$$F_t^T(l) = \exp\{z_{it}\}(Dl)^{\tau} \tag{1}$$

which only use farmer's specific skill $z$ and land $l$ in the production process. $D$ represents the damage caused by climate change. Secondly, agricultural goods can also be produced using modern inputs, such as fertilizers, pesticides/herbicides/fungicides and feed supplements, in addition to the farmers skill and land:

$$F_t^M(l,m) = \exp\{z_{it} + \nu\}(D_t l)^{\theta} m_t^{\alpha} \tag{2}$$

where $l$ is again the land used in production, $m$ are intermediary inputs produced by the non-agricultural sector. They fully depreciate after use. $\theta$ and $\alpha$ is the output elasticity with respect to land and intermediaries. In contrast to traditional farms, modern ones require a set-up cost $\kappa^M$, which is associated with the opportunity cost of traveling to the next market and purchasing intermediaries. This cost drives a wedge between optimal intermediary usage and actual usage as we will see later.
Given the interest rate and the price of intermediary goods, a modern farm's profit function is given by:

$$\pi^M = p_a F^M(l,m) - (1+r)(p_m m + p_a \kappa^M) \tag{3}$$

where $r$ is the interest rate and $p_a$ is the price of the agricultural good. The key feature is that farms need to borrow funds in advance to purchase the intermediary since they are bought before the harvest. This gives rise to the following first order equation:

$$m_{i,t}^* = \left(\frac{p_a \cdot \alpha \cdot \exp\{z_{it} + \upsilon\} \cdot (Dl)^{\theta}}{(1+r)p_m}\right)^{\frac{1}{1-\alpha}} \tag{4}$$

Note that this is the optimal quantity of intermediary inputs that farmers would purchase if they are unconstrained. Naturally the quantity is decreasing in the price $p_m$ of intermediaries and its financing cost $(1+r)$. If farmers choose to operate a traditional farm there profits are simply given by:

$$\pi^T = p_a F^T$$

The production function of the manufacturing sector is the following:

$$M = A_m K_m^{\epsilon} N_m^{1-\epsilon}$$

$A_m$ is the sector specific total factor production technology, $K_m$ is capital used in production and $N_m$ is labour. $\epsilon$ constitutes the elasticity of output with respect to capital and $1-\epsilon$ the elasticity with respect to labour. Capital is rented from financial intermediaries and labour is hired from a perfectly competitive labour market. The first-order conditions equate the marginal product of the production factor with its marginal cost, since we abstract from any frictions in this market:

$$w = (1-\epsilon) A_m \left(\frac{K_m}{N_m}\right)^{\epsilon} \tag{5}$$

$$r = \epsilon A_m \left(\frac{N_m}{K_m}\right)^{1-\epsilon} \tag{6}$$

$$\tag{7}$$

## 2.3 Recursive formulation

Individuals maximise expected lifetime utility by choosing consumption and next periods assets. In addition, they choose a production technology - modern or traditional farming. Modern farmers also choose the intensity of intermediate inputs, subject to financial constraints.

Let the individual state be $s \equiv (a, z)$, where $a$ denotes assets and $z$ idiosyncratic agricultural productivity. At the beginning of each period workers observe their productivity and asset level as well as the prices. Next, they face a technological choice. This mirrors canonical models of occupational choice and financial frictions (Buera et al., 2015). The occupational choice can be stated as follows.

The individuals value function satisfies

$$v(a, z) = \max\{v^{mod}(a, z), v^{trad}(a, z)\} \tag{8}$$

$$\tag{9}$$

**Modern Farming:** An individual operating a modern farm solves:

$$v^{mod}(a, z) = \max_{a',\, c,\, m \in [0, \bar{m}(a, z; \phi)]} \Big\{ u(c) + \beta\, \mathbb{E}_{z'|z}[v(a', z')] \Big\} \tag{10}$$

$$\text{s.t. } PC + a' \leq (1+r)a + p_a z F^M(l, x) - (1+r)(p_a \kappa^m + p_m m), \quad c \geq 0, \quad a' \geq 0 \tag{11}$$

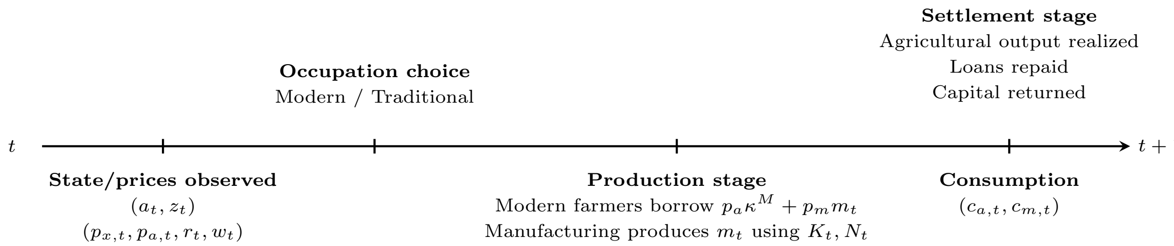
Modern production requires a fixed cost $\kappa^M$ and the purchase of intermediate inputs $m$ at price $p_m$. These expenses must be financed up front, giving rise to an endogenous upper bound $\bar{m}(a, z; \phi)$ on input usage, which captures borrowing constraints parameterized by $\phi$. Crucially, technology adoption depends not only on productivity but also on wealth. Poor but highly productive individuals may be unable to operate modern farms because they cannot finance the fixed cost or the optimal scale of intermediate inputs. This feature generates misallocation driven by financial constraints.

**Traditional Farming:** An individual operating a traditional farm solves

$$v^{trad}(a,z) = \max_{a',\,c} \Big\{ u(c) + \beta\, \mathbb{E}_{z'|z}[v(a',z')] \Big\} \tag{12}$$

$$\text{s.t. } PC + a' \le (1+r)a + p_a z F^T(l), \quad c \ge 0, \quad a' \ge 0$$

Traditional farming does not require fixed costs or intermediate inputs and is therefore unconstrained by credit market frictions.

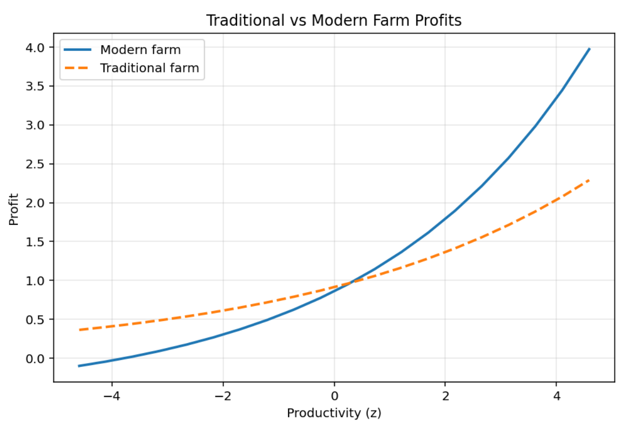



The Euler equation for households is given by:

$$u'(c_t) = \beta \mathbb{E}[(1 + r + \frac{\delta y(a,z)}{\delta a})u'(c_{t+1})] \tag{13}$$

The term $\frac{\delta y(a,z)}{\delta a}$ captures the marginal benefit of additional assets through the relaxation of borrowing constraints. When individuals are financially constrained, saving not only yields the market return $r$ but also increases future profits by allowing operation at a larger and more efficient scale. In the absence of financial frictions, this term vanishes and the Euler equation collapses to the standard form. The consumption of the urban population is trivially given by $(1-\mu)w_t = C_t^u$. Figure 1 shows the profits and thus income generated by each of the technologies for different levels of idiosyncratic productivity $z$.

Figure 1: Profits




## 2.4 Financial markets

1

Farmers have access to perfectly competitive financial intermediaries, receiving deposits, rent capital $k$ at rate $R$ and lend the funds required to purchase intermediary goods $p_m m$. I restrict the analysis to the

[1]There are several papers using similar notions to justify the borrowing constraint. An elaborate example is: **?**Buera et al. (2011)

case where borrowing and capital rental are within a period, implying that financial wealth is nonnegative ($a \geq 0$).

Financial frictions arise due to limited enforceability of financial contracts. In particular, farmers may renege on their financial commitments after production has taken place. In such a case they can keep a fraction of their revenues but loose their deposits $a$ at the financial intermediary as a punishment. Farmers then regain access to financial markets in the following period. The farmers incentive constraint is thus given by [2]

$$\begin{aligned} p_a \exp\{z_{it} + \nu\}(Dl)^{\theta} m_t^{\alpha} - (1+r)(p_a \kappa^m + p_m m_t) + (1+r)a_t \geq \\ (1-\phi) p_a \exp\{z_{it} + \nu\}(Dl)^{\theta} m_t^{\alpha} + a \end{aligned} \tag{14}$$

The upper limit of such a contract can be solved implicitly for a maximum level $\bar{x}$. The parameter $\phi$ captures the extent of frictions in financial markets. $\phi = 1$ corresponds to the case of perfect credit markets, and $\phi = 0$ implies complete self-financing. The credit limits $\bar{m}(a, z_i, \phi)$ is the largest possible quantity extended consistent with entrepreneurs choosing to abide by their credit contracts. The static condition is sufficient since individuals gain full excess to financial market in the next period. From the equation it is evident that rental limits increase with farmers ability $z_i$. Similarly it increases with wealth $a$ since the potential loss from defaulting becomes larger.

The financial constraint highlights the role of climate damage, captured by a lower $D$. A decline in $D$ reduces realized output for any given input choice, which lowers the surplus available to service financial obligations. Since only a fraction $\phi$ of revenues is pledgeable, climate damage disproportionately reduces pledgeable income relative to total production. This weakens the incentive compatibility constraint and tightens borrowing limits $\bar{m}(a, z_i, \phi)$.

As a result, climate related productivity damages propagate through financial markets by endogenously amplifying credit frictions. Lower productivity reduces borrowing capacity, forcing farmers to scale back input use, which further depresses output. This feedback mechanism implies that climate damages generate effects beyond direct production losses, leading to persistent declines in productivity through constrained access to capital and intermediary inputs.

## 2.5 Stationary Competitive Equilibrium

A stationary competitive equilibrium is composed of: an invariant distribution of wealth and farming skill $G(a, z)$, with the marginal distribution of $z$ denoted $\mu(z)$, policy functions $c(a, z)$ $a'(a, z)$, $o(a, z)$; rental limits $\bar{m}_j(a, z_j; \phi)$; and prices $w$, $r$, $p_m$ and $p_a$ such that:

1. **Individual Optimization:** Given $\bar{x}_j(a, z_j; \phi)$, $w$, $r$, $p_m$ and $p_a$, the individual policy functions $c(a, z)$, $a'(a, z)$, $o(a, z)$, solve the household problems (X) and satisfy the manufacturing firm's FOC's (X).

2. **Rental Limits:** $\bar{x}_j(a, z_j; \phi)$ are the most generous limits satisfying condition (X), and:

$$\bar{m}_j(a, z_j; \phi) \leq m^*(z_j)$$

3. **Market Clearing Conditions:**

   - Agricultural goods market:

$$\mu \int c_a^r dG(a, z) + (1-\mu) c_m^u = \int_{\{o(a,z)=F\}} \exp\{z_{it} + \nu\}(D_t l)^{\theta} m_t^{\alpha} - \kappa^m + \exp\{z_{it}\}(Dl)^{\tau} dG(a, z)$$

[2] also see Buera et al. (2011)

- Intermediate goods market:

$$\int_{\{o(a,z)=F^M\}} m_t dG(a,z) + \mu \int_{\{o(a,z)=F^M\}} c^r_{m,t} dG(a,z) + (1-\mu)c^u_{m,t} + \frac{\delta}{p_m}\frac{K}{N} = \int K_t^{\epsilon} N_t^{1-\epsilon} dG(a,z)$$

- Capital markets :

$$K^d = \mu \int a dG(a,z)$$

- Labour markets :

$$N_t^d = (1-\mu)\bar{N}_t$$

4. **Stationary Distribution:** The joint distribution of wealth and farming skills is a fixed point of the equilibrium mapping:

$$g(a', z') = \int \delta_D(a' - a(a,z)) \cdot f(z' \mid z) \cdot g(a,z)\, da\, dz$$

Farming ability evolves according to the exogenous log-AR(1) process:

$$\log z_{t+1} = \rho \log z_t + \varepsilon_{t+1}$$

with $\varepsilon_{t+1} \sim \mathcal{N}(0, \sigma_\epsilon^2)$.

# 3 Quantitative Estimation

## 3.1 Data

I use a detailed longitudinal cross-country dataset on agricultural productivity in Sub-Saharan Africa from the "Standards Measurement Study–Integrated Surveys on Agriculture" (LSMS-ISA) program by the World Bank. The surveys are specifically designed to study the agricultural sector and provide an extensive collection of plot-level data, including important geographic variables as well as socioeconomic variables of farmers. I benefit from the harmonised panel dataset provided by Bentze and Wollburg (2025), which includes data from seven Sub-Saharan African countries, including Ethiopia, Malawi, Mali, Niger, Nigeria, Tanzania, and Uganda, from 2008 to 2021. This data allows for a profound analysis of farm characteristics over time and country. I utilise the data to estimate production functions.

## 3.2 Parameters and Moments

In total there are 16 parameters to be calibrated. 10 technology parameters: $(\{\nu, D, L, A, \theta, \alpha, \tau, \epsilon, \delta\, \kappa^M\})$, 4 preference parameters $\{\sigma, \omega, \gamma, \beta\}$, and 2 parameters governing the evolution of productivity $(\{\rho, \sigma_\epsilon\})$. At this stage, parameter values are chosen solely to illustrate the economic mechanisms of the model. Unless stated otherwise, parameters are not formally calibrated or estimated and should be interpreted as illustrative. The purpose of this parameterization is to demonstrate how financial frictions interact with technology adoption and productivity, not to match specific empirical moments.

**Production.** I estimate the production technology separately for traditional and modern plots using plot-level panel regressions. The empirical specification closely follows the production functions introduced before.

*Traditional farms.* For traditional plots, output is produced using land only. I estimate the following fixed-effects regression:

$$\ln y_{it} = \tau \ln l_{it} + \mathbf{X}'_{it}\beta + \mu_i + \varepsilon_{it}, \tag{15}$$

where $y_{it}$ denotes plot-level output, $l_{it}$ is cultivated land, and $\mathbf{X}_{it}$ includes labor inputs, weather shocks, manager characteristics, and detailed agro-ecological controls. Plot fixed effects $\mu_i$ absorb time-invariant productivity differences across plots. The coefficient $\tau$ identifies the land elasticity for traditional farms.

*Modern farms.* For modern plots, output depends on both land and intermediate inputs. I estimate:

$$\ln y_{it} = \theta \ln l_{it} + \alpha \ln x_{it} + \mathbf{X}'_{it}\beta + \mu_i + \varepsilon_{it}, \tag{16}$$

where $x_{it}$ is a composite measure of modern intermediate inputs, including improved seeds and inorganic fertilizer expenditures. The coefficient $\theta$ identifies the land elasticity for modern farms, while $\alpha$ captures the elasticity with respect to modern inputs. All elasticities are identified from within-plot variation over time. Plot fixed effects remove time-invariant heterogeneity in land quality, farmer ability, and baseline productivity. As a consequence, the level productivity advantage of modern technology is not identified in these regressions and is calibrated separately to match cross-sectional output moments. The estimated elasticities correspond directly to the technology parameters of the model. From the data I obtain the following values for $\theta, \tau$ and $\alpha$. The fixed cost of operating the modern production technology, $\kappa^M$, is calibrated to match the observed adoption rate of modern farms in the data. For a given value of $\kappa^M$, I solve the household problem under fixed prices and compute the stationary distribution of assets and productivity. Using this distribution, I evaluate farm profits under modern and traditional technologies and determine optimal technology choice at the plot level. The implied share of modern farms in the model is then compared to its empirical counterpart. I choose $\kappa^m$ such that the model-generated adoption rate equals the observed adoption rate in the data (30%).

**Preferences.** $\{\sigma, \omega, \gamma, \beta\}$ - I follow the macro-development literature in setting the discount factor to $\beta = 0.95$ and the coefficient of relative risk aversion to $\gamma = 2.5$. The remaining preference parameters, $\sigma$ and $\omega$, govern the elasticity of substitution between agricultural and market consumption and the relative importance of agricultural goods in consumption, respectively. These parameters are not calibrated at this stage and will be disciplined using values from the existing literature in future quantitative exercises.

# 4 Results

This section addresses the central research question by examining how financial frictions shape agricultural productivity and welfare within the model economy. Before turning to general equilibrium effects, it is useful to isolate the partial-equilibrium mechanisms through which $D$ and $\phi$ affect production, borrowing, and intertemporal choices.

## 4.1 Partial-Equilibrium Mechanisms: Separating $D$ and $\phi$

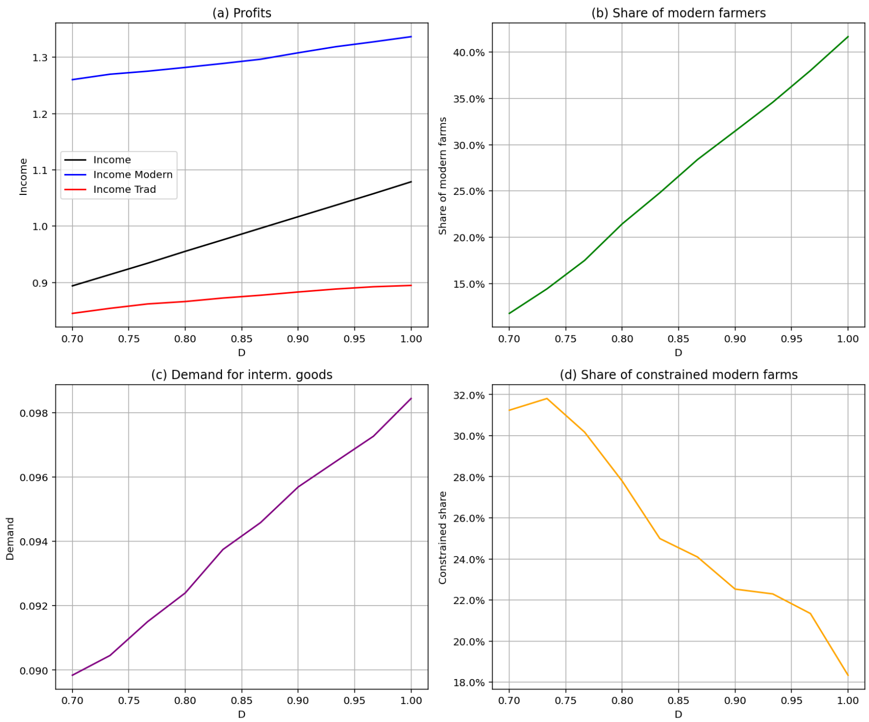
A change in $D$ operates primarily through the production side of the economy. From equation 4, a reduction in $D$ lowers the marginal product of intermediary inputs and therefore reduces the optimal demand for modern inputs by modern farms. Since farm profits depend directly on $D$, both modern and traditional farmers experience a decline in income when $D$ falls. This constitutes a first-order effect: lower productivity

Table 1: Model Parameters, Values, and Calibration Strategy

| **Parameter** | **Description** | **Value** | **Calibration Target / Source** |
|---|---|---|---|
| $a_{\min}$ | Borrowing constraint | 0 | No borrowing in baseline |
| $\beta$ | Discount factor | 0.95 | Buera et al. (2011) |
| $\mu$ | Share of rural workers | 40% | LSMS-ISA Data |
| $\gamma$ | Risk aversion (CRRA) | 2.5 | Literature |
| $L$ | Labor endowment of urban workers | 1 | Normalized |
| $A_m$ | Productivity Manuf. sector | 0.35 | |
| $\epsilon$ | Capital elasticity (Manuf sector) | 0.33 | |
| $D_t$ | Climate damage on land productivity | 1 | Normalized |
| $\theta$ | Labor elasticity (modern farms) | 0.41 | FE regression: modern plots |
| $\tau$ | Labor elasticity (traditional farms) | 0.41 | FE regression: traditional plots |
| $\alpha$ | Intermediate input elasticity | 0.22 | FE regression: modern plots |
| $\nu$ | Modern-farm productivity premium | 1 | |
| $\kappa^m$ | Fixed cost of modern technology | 30 % | Matches share of modern farms |
| $\delta$ | Capital depreciation | 0.05 | Buera and Shin (2013) |
| $\rho$ | Persistence of productivity shocks | 0.9 | |
| $\sigma_\epsilon$ | Std. dev. of productivity shocks | 0.2 | |

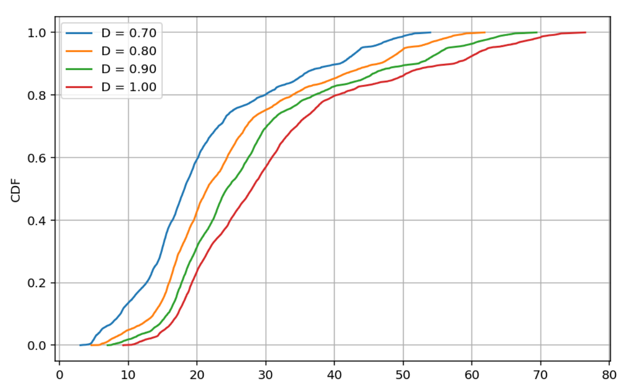
reduces profits, which directly lowers disposable resources and induces adjustments in consumption and savings decisions. In addition, $D$ affects pledgeable income in financial markets (see equation 14). A lower $D$ reduces the amount of income that can be pledged to intermediaries, thereby tightening the borrowing constraint. This further depresses the adoption of modern inputs and reduces productivity. Hence, changes in $D$ operate through two channels: Firstly, a technological channel that directly reduces productivity and profits. Secondly, a financial collateral channel that tightens borrowing constraints. Graph 2 a) shows the impact of a reduction in $D$ while keeping $\phi$ and prices fixed. Note that the fall in average income is more pronounced than the fall of modern or traditional farmers profits due to composition effects. When $D$ drops, some farmers switch from modern to traditional farming, amplifying the drop in average income. The share of modern farmers can be seen in figure 2 b). Similarly, the drop in modern farming inputs conditional on choosing the modern farming technology is depicted in figure 2 c) as well as the share of constrained farmers conditional on adopting a modern technology in figure 2 d).

Figure 2: The effect of climate damage on modern farmers



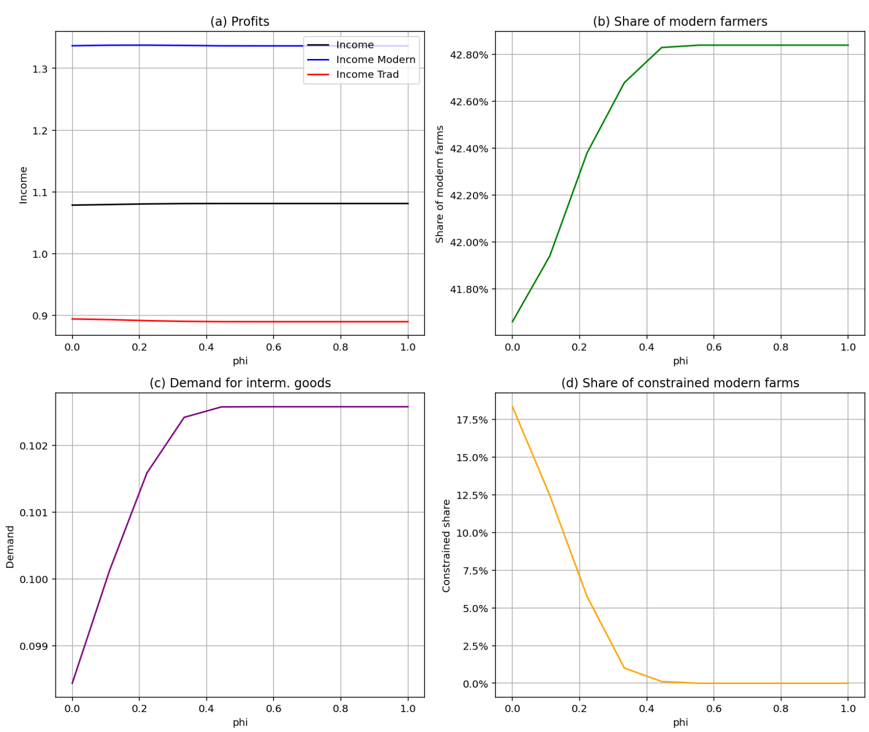

To show the impact on savings of a decrease in D I plot the CDF of the invariant distribution of assets (see Figure 3). A decline in $D$ has effects; firstly it shifts the distribution of assets to the left, making agents less wealthy, and secondly it thickens the left tail of the distribution indicating that the precautionary savings motive is enhanced. Whereas the former is the result of a level effect on savings due to reduced income, the latter is the result of an increased savings ratio from poor households.

Figure 3: CDF of a across different levels of climate damage



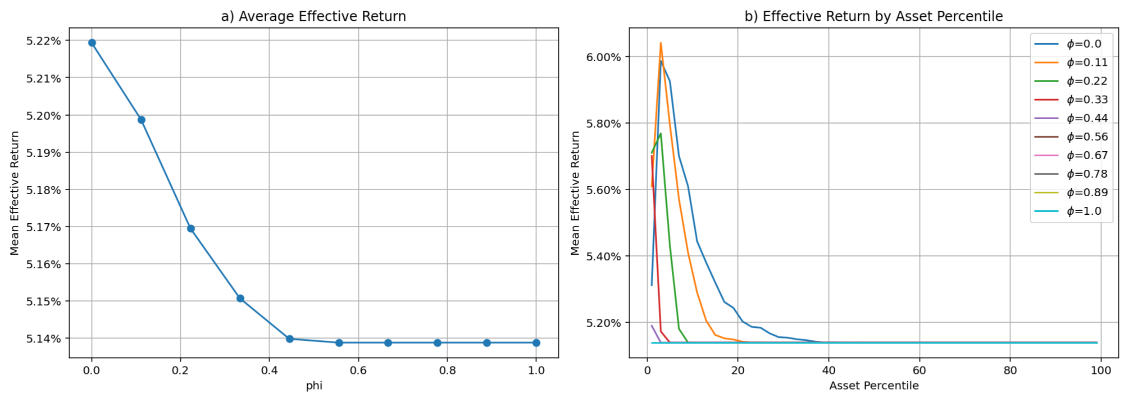

The effects of $\phi$ are more nuanced because they operate both through borrowing constraints and through intertemporal incentives. From equation 14, a reduction in $\phi$ lowers the revenue that financial intermediaries can recover when farmers decide to renege on their contract. This tightens the borrowing constraint and restricts access to external finance. As a consequence, adoption of modern inputs declines, reducing productivity and income. Up to this point, the mechanism is analogous to a decline in $D$: weaker financial enforcement reduces borrowing capacity and depresses farm income. In addition, $\phi$ affects the Euler equation (see equation 13). By altering $\partial_a y(a, z)$, financial development changes the effective return on savings: $R^{eff} = R + \partial_a y(a, z)$. An decrease in $\phi$ raises the marginal productivity of assets and therefore increases the effective intertemporal return. Even holding prices fixed, this shifts the intertemporal price of consumption and strengthens the incentive to accumulate assets. Agents optimally reallocate consumption toward the future in response to the higher effective return. Thus, changes in $\phi$ affect household behavior through three distinct mechanisms: Firstly, their intratemporal borrowing capacity, secondly production decisions and income and thirdly intertemporal consumption–savings trade-offs via the effective return. The last channel is quantitatively important in the model, as it can induce substantial increases in savings and corresponding reductions in current consumption, even when general equilibrium price adjustments are held fixed. Figure 4 shows that the impact of $\phi$ on modern farms is quantitatively low. While average agricultural income as well as modern agricultural income does not change significantly we see a marginal decrease in average income from traditional farmers associated with rising financial conditions. This is explained by the fact that more high productivity traditional farmers sort into modern farmers once they are able to borrow, thereby lowering agricultural productivity of traditional farmers. Figure 4 b) shows that the share of modern farms increases by roughly 1 percentage point. More notable is that under the current calibration once $\phi$ reaches 0.5 there is no change to the aggregate statistics anymore, due to the fact that the borrowing constraint becomes relaxed for farmers who prefer to operate a traditional technology in any case. This analysis is confirmed by plot d) which shows that the share of constrained modern farmers drops to virtually 0 afterward.

Figure 4: The effect of financial frictions on modern farmers



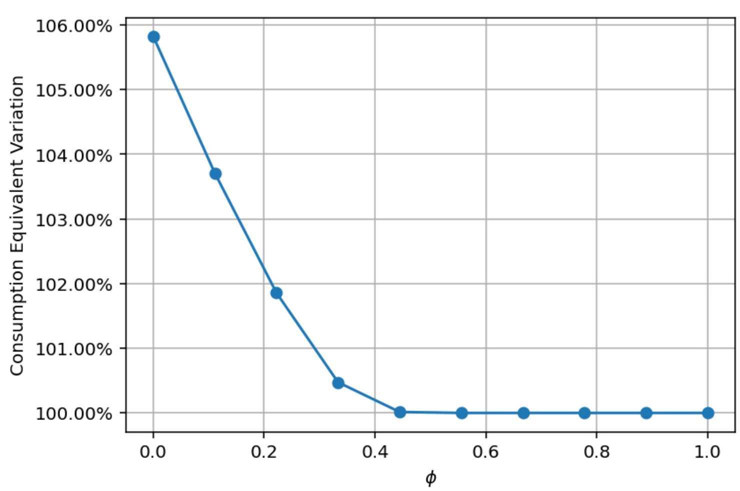

Let me now turn towards the effective interest rate $R^{eff}$. I evaluate the distribution weighted effective interest rate for different levels of $\phi$ in Figure a). Two things become immediately apparent. First, the graph follows the pattern already observed in figure 4 showing that the effects of $\phi$ fades out at roughly 0.5. Second, the average effective interest rate rises markedly. The mechanism is that a tightening of the collateral constraint increases the marginal value of assets, since additional wealth expands feasible borrowing and input choices. This raises the shadow return to savings above the market rate, thereby increasing the mean effective return across households. Figure 5 b) shows the average rate of return sorted according to the percentile distribution of assets. It is evident that the increase in mean $R^{eff}$ is driven by households at the lower end of the distribution, whereas for wealthier households the effective interest rate coincides with the market one. This mechanism will have important implications for savings and consumption decision of households.

Figure 5: Average effective interest rate faced by farmers




Lastly, I examine the partial equilibrium welfare effect of $\phi$. I fix prices and compute the consumption equivalent variation (CEV) of farmers relative to the frictionless case ($\phi = 1$). Figure 6 shows that the mean CEV is highest when financial frictions are most severe, which may appear counterintuitive at first.

Figure 6: Consumption Equivalent Variation in partial equilibrium




This pattern arises from two opposing effects. First, a lower $\phi$ slightly reduces the average income of households, making them worse off in the short run, yet we have already seen that this effect is quantitatively very limited. Second, the reduction in $\phi$ increases the effective return on savings for households who are constrained or have low consumption, i.e., those with higher marginal utility. This effect induces these households to save more, which enhances their long-run steady-state consumption.

Formally, the Euler equation can be written as:

$$\begin{aligned} u'(c_t) &= \beta\, \mathbb{E}[R^{\text{eff}}\, u'(c_{t+1})] \\ &= \beta\Big(\mathbb{E}[R^{\text{eff}}]\, \mathbb{E}[u'(c_{t+1})] + \text{Cov}(R^{\text{eff}}, u'(c_{t+1}))\Big). \end{aligned}$$

A positive covariance term implies that higher effective returns are realized by households with higher marginal utility, i.e., households that are relatively consumption-poor. As we have seen, these households tend to face the highest effective returns, which encourages additional savings and, in turn, higher long-run consumption. This mechanism explains why the mean CEV can be largest when financial frictions are most severe.

This result can be interpreted in the spirit of the Ramsey growth model. In the standard Ramsey framework, household impatience typically leads to under-saving, which lowers the long-run capital stock and causes steady-state consumption to fall short of the Golden Rule level.

In our model, the borrowing constraint effectively creates a situation where households face an additional marginal return to savings, captured by $R^{\text{eff}}$. Poorer households, who are more constrained, experience higher effective returns, which provides a stronger incentive to save. This increased saving pushes their future asset holdings closer to a more efficient long-run allocation, thereby raising their steady-state consumption.

In other words, the constraint paradoxically improves welfare by generating a channel through which households accumulate assets when marginal utility is high, moving them toward a "golden-rule"-like consumption level in the long run.

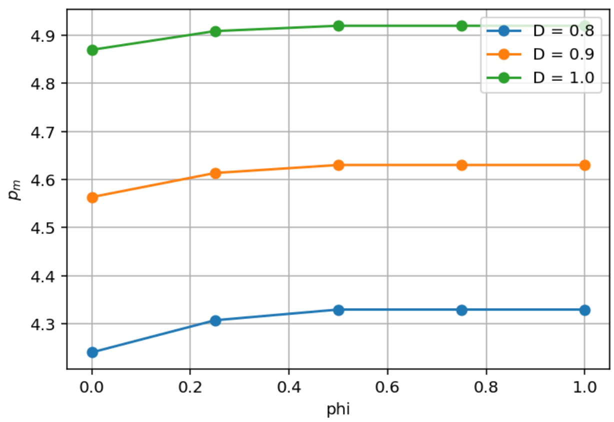
## 4.2 General Equilibrium Mechanisms: Relative price effects and Amplification

Having characterized the partial equilibrium results, I now turn to price adjustments and the general equilibrium implications of the model. To this end, I solve for steady states across three levels of climate-induced land damage, $D$, and five levels of financial frictions, $\phi$, resulting in 15 distinct steady-state equilibria.

As a first step, I examine the price dynamics shown in Figure 7. The figure plots the relative price of the manufacturing good, $p_m$, against varying levels of financial frictions, $\phi$. Since the agricultural good serves as the numeraire, movements in $p_m$ reflect changes in relative prices: an increase in $p_m$ implies that the agricultural good becomes relatively more expensive in terms of manufacturing goods. Consequently, any movement in prices can cause distributional shifts, modern farmers benefit from a drop in prices $p_m$ as inputs become cheaper and their financing constraint possibly relaxes, whereas traditional farmers experience a loss in purchasing power. Separate graphs are presented for each level of climate-induced land damage, $D$.

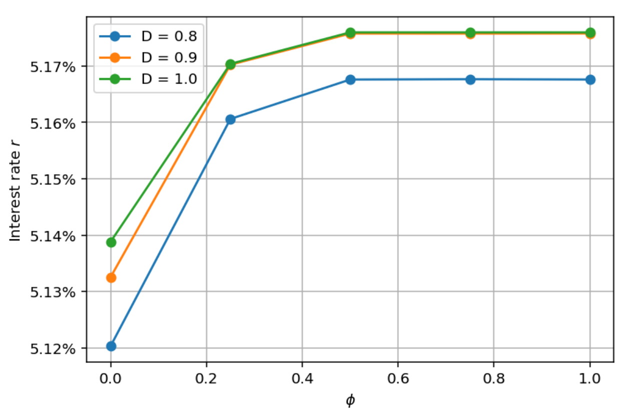
Across all specifications, $p_m$ increases weakly monotonic in both $D$ and $\phi$. The price is increasing in financial frictions due to the increased demand of of intermediary inputs, hence the curve flattens after the effect of financial frictions wears off. The price increases in $D$ for the same reason as the marginal product of intermediary goods grows. Notably, the decline in prices is more pronounced in economies with higher climate damage, indicating that environmental degradation and financial frictions interact to reduce input demand. ($\Delta p_m(D = 1) = 0.05$ vs $\Delta p_m(D = 0.8) = 0.09$).

Figure 7: Equilibrium price of the intermediary good



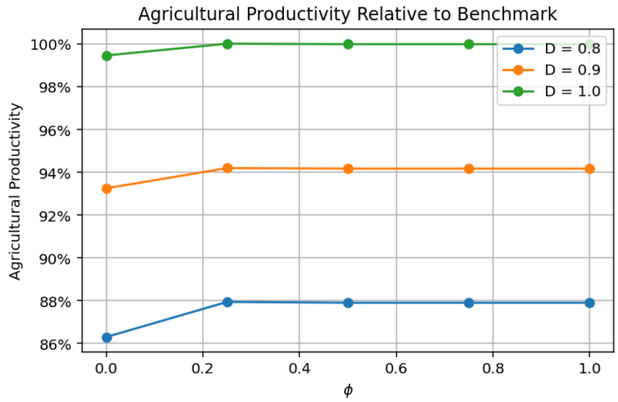

Next we take a look at the interest rate in figure 8, where we observe a similar pattern to the movement in manufacturing prices $p_m$. Interest rates increase weakly monotonic in both $D$ and $\phi$. The effect in the direction of $\phi$ wears out as soon as a change in $\phi$ no longer affects agents. Also note that there is virtually no effect on the interest rate when the productivity of land drops by 10%, only after a further drop of 10 percentage point we see a decrease in the interest rate. Moreover, we see that the effect of $\phi$ on the interest rate $r$ is enhanced when there are climatic damages. Hence, we find a similar interaction effect on the interest rate that already existed with $p_m$. The increase in $r$ has ambiguous effects on the distribution, since on the one hand it harms modern farmers by inceasing their financing cost, whereas on the other hand the wealthier farmers who are typically modern farmers earn a higher return on their assets.

Figure 8: Equilibrium interest rate




Before turning to the welfare implications in general equilibrium I examine the development of agricultural productivity in response to climate damages and financial frictions. I define agricultural productivity as average agricultural output per farmer. To quantify the results in relation to each other, I again take the scenario with no financial frictions and no climate damages as the benchmark. Figure 9 shows the result. Under the current parametrization, $\phi$ has little impact on agricultural productivity. Only for very low values we find a significant drop, which is more when damages harm land productivity. Consequently, agricultural output drops more when climate damages hit an economy which is characterized by weaker financial institutions, due to a tightening in borrowing constraints and less adoption of modern inputs.

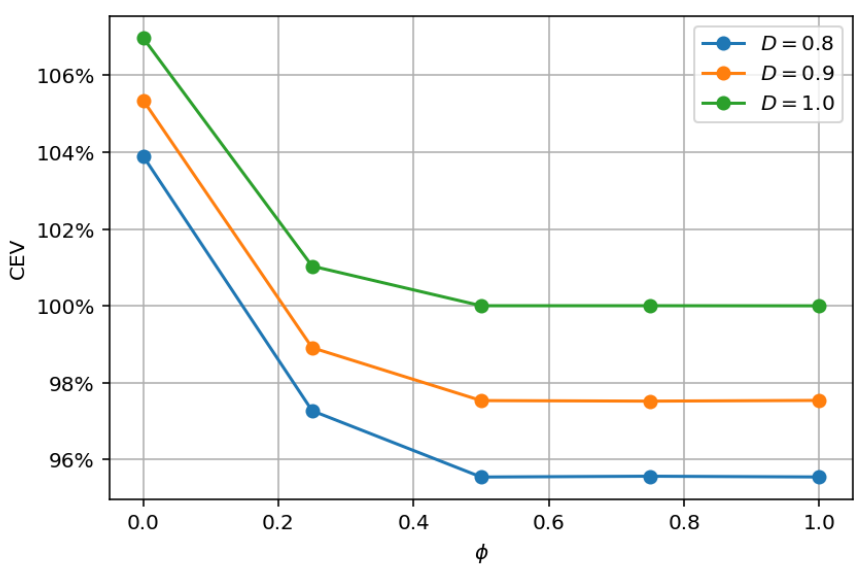
Figure 9: Agricultural productivity




As in the previous case welfare comparisons for farmers across these economies are summarized using consumption-equivalent variation (CEV), with the frictionless and undamaged economy ($\phi = 1$, $D = 1$) serving as the benchmark.

Figure 11 shows that welfare declines monotonically as climate damage increases, reflecting the direct negative effect of lower land productivity. Financial frictions tend to increase welfare. In particular, welfare remains relatively flat for high levels of financial development and only increases markedly once $\phi$ falls below 0.5. This pattern reflects the fact that financial constraints bind only for a small fraction of agents when borrowing conditions are relatively loose. This mirrors our findings from the partial equilibrium results in the previous section. Financial frictions raise the marginal productivity of assets and thus the effective intertemporal return. Under our calibration, this induces a strong reallocation of consumption toward the future. The resulting distortion in intertemporal prices can reduce lifetime utility despite the improvement in financial access. The negative effect of a decreasing agricultural output and productivity is outweighed by the positive effect of a higher steady state consumption.

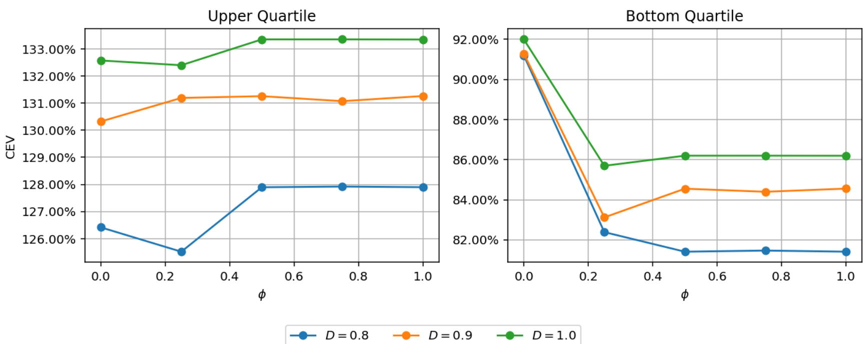
Figure 10: Consumption-equivalent variation across climate damage and financial frictions



We have shown that climate damage and financial frictions affect occupations asymmetrically through their impact on prices, borrowing constraints, and input use. To make this heterogeneity explicit, we examine the consumption-equivalent variation (CEV) separately for the bottom and top wealth quartiles. The benchmark CEV is defined relative to the mean welfare in the baseline economy with $D = 1$ and $\phi = 1$.

Two patterns emerge clearly. First, the top quartile attains a substantially higher consumption-equivalent level than the population mean, reflecting its stronger asset position and better access to modern production technologies. Second, welfare responses differ sharply across the distribution: changes in climate damage and financial frictions move the CEV of the top and bottom quartiles in opposite directions. Shocks or policies that raise welfare for wealthier agents tend to reduce welfare for poorer households, underscoring the distributional consequences of financial frictions and environmental damage.

Figure 11: Consumption-equivalent variation across climate damage and financial frictions




# 5 Conclusion

This paper developed a two-sector heterogeneous-agent model to study how climate-induced declines in land productivity interact with financial frictions in shaping agricultural productivity, technology adoption, and welfare. Climate damage reduces output not only directly through lower land productivity, but also indirectly by tightening endogenous borrowing constraints and triggering occupational reallocation away from modern production. These mechanisms generate amplification effects that operate through input demand, effective returns to savings, and general equilibrium price adjustments. Financial frictions distort the allocation of intermediary inputs and limit the adoption of modern technology, thereby lowering productivity. At the same time, they alter intertemporal incentives by raising the marginal value of assets for constrained households. In partial equilibrium, this channel can induce higher savings among poorer farmers and higher steady state consumption. In general equilibrium climate damages lead to clear welfare declines, while the aggregate amplification through financial frictions remains quantitatively modest under the baseline parametrization. Overall, the analysis shows that climate change and financial market imperfections interact through endogenous credit constraints and relative prices. Even when aggregate amplification is limited, financial frictions shape the composition of production, the distribution of returns, and the persistence of productivity losses.

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