A Quantitative Theory of Heterogeneous Returns to Wealth*

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January 2025

Abstract

Recent empirical evidence documents that different individuals systematically earn different rates of return on their wealth, even after controlling for portfolio composition. We propose a general equilibrium theory of residual heterogeneity in rates of return on wealth by embedding a financial market with search frictions into an otherwise standard incomplete-market model. We show that the distribution of rates of return offered in the financial market is endogenous and depends on the marginal product of capital, the return on fiat money, and the joint distribution of households across wealth and financial human capital. When calibrated, the model succeeds in reproducing the extent of residual dispersion in returns to wealth across individuals, and the relationship between wealth and returns. We use the calibrated model to study different policies and counterfactuals, with a particular focus on the effect of inflation.

JEL Codes: D83, D52, D31

Keywords: Search frictions, Financial frictions, Incomplete markets, Wealth inequality, Inflation.

1 Introduction

Recent empirical evidence documents that different individuals earn very different rates of return on their wealth (Fagereng, Guiso, Malacrino and Pistaferri 2020). Part of the heterogeneity in the rates of return is due to differences in the riskiness of the investment portfolio held by different individuals. Part of the heterogeneity is due to ex-post differences in the rates of return of investments that, ex-ante, have similar return and risk. Yet, even after controlling for portfolio composition and averaging out for more than 10 years,

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there is still a sizeable amount of residual variation in the rates of return earned by different individuals. These systematic differences in rates of return are positively correlated with the wealth level of different individuals. The fact that richer individuals earn systematically higher rates of returns, controlling for risk, is obviously of great consequence for understanding the extent and causes of wealth inequality (see, e.g., Benhabib, Bisin and Luo 2019).

On its own, the empirical observation that different individuals earn systematically different rates of return on their wealth is of limited use for macroeconomic analysis, since the distribution of returns and the correlation between returns and wealth is an endogenous object that is likely to respond to changes in fundamentals, such as technological shocks and policy changes. In order to usefully incorporate the empirical observation in Fagereng, Guiso, Malacrino and Pistaferri (2020) in a macroeconomic model, we need a theory that explains how investment opportunities with different rates of return can coexist in the market even though they have the same degree of risk, why different individuals end up earning systematically different rates of return, and why the individuals that end up earning higher rates tend to be richer.

The goal of this paper is to propose a theory of persistent heterogeneity in individual rates of return that are positively correlated with wealth. At the core of our theory lies the recognition that heterogeneity in rates of return for investment opportunities with similar risk is just one more example of the failure of the Law of One Price. Since the textbook explanation for the failure of the Law of One Price is the search-theory of Butters (1977), Varian (1980), and Burdett and Judd (1983), our theory posits that the market where households supply savings and firms seek capital is subject to search frictions. As in Butters (1977), Varian (1980), and Burdett and Judd (1983), the equilibrium of the market is such that firms operating the same technology choose to offer different rates of returns. Households differ in their ability to search the capital market and, for this reason, they earn systematically different rates of return. We interpret differences in ability to search the capital market as financial human capital, which we think of as a form of knowledge in which households can invest. Since the benefit from earning higher rates of return is increasing in wealth, richer households invest more in financial human capital and, for this reason, earn higher rates on their wealth than poorer households.

In the first part of the paper, we embed our theory of heterogeneous returns to wealth in the general equilibrium incomplete-markets model of Aiyagari (1994), Bewley (1983), and Huggett (1996). As in Aiyagari (1994), Bewley (1983) and Huggett (1996), households face an idiosyncratic labor income risk for which there is no insurance market. Households need to self-insure against their labor income risk by accumulating wealth, which they can invest in either fiat money or capital. Departing from Aiyagari (1994), Bewley (1983), and Huggett (1996), the market where households supply savings and firms demand capital is subject to search frictions. Specifically, a household cannot lend to any firm in the capital market, but only to the discrete subset of them with which it comes into contact.

The average number of firms with which a household comes into contact depends on its financial human capital, a stock of knowledge that the household can accumulate by investing some of its resources.

The equilibrium of the capital market features dispersion in the rates of return offered by firms in the capital market is non-degenerate. As in Butters (1977), Varian (1980), and Burdett and Judd (1983), there is dispersion in the rates of return offered by firms because some households come into contact with a single firm and other households come into contact with multiple firms. Firms are indifferent between offering different returns. Firms that offer high rates of return raise more capital, but they enjoy a lower profit margin on each unit of capital. Firms that offer lower rates of return raise less capital, but enjoy a higher profit margin on each unit of capital. The distribution of rates of return offered by firms depends on the rate of return on money, which is the household's investment option outside of the capital market, the marginal product of capital, which is the firm's return on raising an additional unit of capital, and on the joint distribution of households across financial human capital and wealth, which determines the elasticity of the capital supply curve facing firms.

The equilibrium of the capital market features a positive correlation between wealth and rates of return. This property of equilibrium is intuitive. Households with more financial human capital are able to contact more firms and, since the distribution of rates of return offered by firms is dispersed, they earn higher returns. Households with more wealth benefit more from earning a higher return, and, for this reason, they are willing to accumulate more financial human capital. From the above observations, it follows that wealth and rates of return are positively correlated. Naturally, the strength of this correlation depends on the persistence of the accumulation process of financial human capital and on the dispersion in rates of return offered by firms.

In the second part of the paper, we calibrate the model to match the extent of heterogeneity in returns to wealth documented by Fagereng, Guiso, Malacrino and Pistaferri (2020). Specifically, we calibrate the model to match the persistence and innovation of labor earnings, the average rate of return on wealth, and the distribution of individual fixed-effects in rates of return on wealth after controlling for portfolio composition. The model reproduces well the targeted moments. The model also generates a strong, positive relationship between wealth and rates of return. The model generates a significant amount of wealth inequality, albeit not as much as in the data. This shortcoming is not surprising given that, in the model, there are no entrepreneurs.

In the last part of the paper, we use the calibrated model to run some counterfactual experiments, which highlight the importance of making the households' distribution of rates of returns endogenous. In the first experiment, we measure the effect of inflation. Inflation lowers the rate of return on both money and capital. Inflation directly lowers the rate of return on money. Inflation also lowers the distribution of rates of return on capital offered by firms, because it lowers the rate of return that household earn outside

of the capital market and against which firms have to compete. The negative effect of inflation on the distribution of rates of return on capital is strongest at the bottom of the distribution, where firms are more likely to be competing against money. Inflation steepens the relationship between wealth and rates of return. Poor households have lower financial human capital and, for this reason, they are more likely to hold their savings in money or to invest them in firms that offer relatively low rates. Rich households have more financial human capital and, for this reason, they are more likely to invest their savings in firms that offer relatively high rates of return. Since inflation lowers the return on money and the relatively low returns on capital, it steepens the relationship between wealth and rates of return. In turn, since the relationship between wealth and rates of return becomes steeper, wealth inequality increases.

An increase in inflation from 2% to 10% lowers welfare by the equivalent of 2% of consumption. Poorer households benefit from the increase in inflation, since these households have no wealth and, hence, do not suffer from the decline in rates of return, but they do benefit from the revenues from seignorage. Middle-class households suffer the most from the increase in inflation, since the decline in rates of return hinders their ability to accumulate wealth. Richer households suffer from inflation only marginally, as inflation has a negligible effect on the relatively high rates of return on capital.

In the second experiment, we measure the effect of a technological or a regulatory change in the environment that allows firms to offer different rates of return to households with different financial human capital. When price discrimination in the capital market is feasible, firms offer lower rates of return to households with less financial human capital, since these households cannot benefit from the pro-competitive search activity of more knowledgeable individuals. Conversely, when price discrimination in the capital market is feasible, firms offer higher rates of return to households with more financial human capital. Since households with less financial human capital tend to be poorer than households with more financial human capital, the relationship between wealth and rates of return becomes stronger, leading to an increase in wealth inequality.

In the last experiment, we measure the effect of a financial literacy program that provides all households with a minimum investment in financial human capital. The financial literacy program increases the amount of financial human capital held by all households and, for this reason, it increases the competitiveness of the capital market and it induces firms to offer higher rates of return. The financial literacy program increases especially the financial human capital of poorer households and, in doing so, it weakens the relationship between wealth and rates of return and, in turn, it reduces wealth inequality. A financial literacy program worth 1% of output increases welfare by the equivalent of 2% of consumption. The welfare of the poorest households actually declines, because these households have no wealth and, hence, cannot benefit from free financial education, but they do bear the cost of the program. The welfare of middle-class households increases the most, because these households have their investment in financial human capital

subsidized by the government and they earn higher returns on their wealth. The welfare of the richest households also increases, but less than for the middle class, since these households enjoy smaller increases in their rates of return.

The paper relates to the literature on failures of the Law of One Price. Failures of the Law of One Price have been extensively documented in the retail market (see, e.g., Kaplan and Menzio 2015) and in the labor market (see, e.g., Postel-Vinay and Robin 2002). The leading explanation for the failure of the Law of One Price is the existence of search frictions (see, e.g., Butters 1977, Burdett and Judd 1983, Burdett and Mortensen 1998, Postel-Vinay and Robin 2002). We follow this literature by interpreting persistent differences in the rate of return of wealth as a violation of the Law of One Price in the context of financial markets and by rationalizing this violation as the equilibrium of a market with search frictions.

The paper relates to the literature on uninsured idiosyncratic risk in macroeconomics (see, e.g., Aiyagari 1994, Krusell and Smith 1998, Kaplan and Violante 2014). Relative to this literature, we introduce search frictions in the market where households supply savings and firms demand capital. Search frictions in the capital market allow us to make sense of the evidence reported in Fagereng, Guiso, Malacrino and Pistaferri (2020). Search frictions in the capital market imply that households face not only idiosyncratic risk about their labor earnings, but also about the rate of return on their wealth. The paper complements recent work that extends the incomplete-market macroeconomic framework in the consumption good market (see, e.g., Pytka 2018 and Nord 2023).

The paper relates to the literature on the effect of trend inflation (see, e.g., Lucas 2000, Lagos and Wright 2005). In our model, money demand comes from households that did not find any investment opportunities in the capital market and still want to postpone their consumption. By lowering the rate of return on money, inflation lowers the value of the households' outside option in the capital market and, for this reason, it lowers the equilibrium distribution of rates of returns on capital offered by firms. The paper measures the impact of inflation through this novel outside option channel. The idea that inflation affects real outcomes by impacting the equilibrium outcomes in a market where money is not used is reminiscent of Lagos and Zhang (2022).

2 Environment and Equilibrium

2.1 Environment

The economy is populated by households, firms and a government. There is a measure h of households per firm. Households maximize the expected sum of current and future periodical payoffs $u(c)$ discounted at the factor $\beta \in (0,1)$, where $u(c)$ is a strictly increasing and strictly concave function of consumption. Households are ex-post heterogeneous with respect to the endowment of efficiency units of labor $z \in \mathcal{Z}$, financial wealth $a \in \mathcal{A}$,

and financial human capital $\lambda \in \Lambda$, with $\mathcal{Z} = \mathbb{R}_+$, $\mathcal{A} = \mathbb{R}_+$, and $\Lambda = \{\lambda_1, \lambda_2, ...\lambda_I\}$. The efficiency units of labor of a household follow a stochastic process denoted by the probability function $\phi_z(\hat{z}|z)$, where $\hat{z}$ denotes the household's efficiency units in the next period and z denotes the efficiency units in the current period. The financial human capital of a household follows a stochastic process denoted by the probability function $\phi_\lambda(\hat{\lambda}|\lambda, e)$, where $\hat{\lambda}$ is the household's financial human capital in the next period, λ is the financial human capital in the current period, and $e \in \mathbb{R}_+$ denotes the household's investment in human capital in the current period. The financial wealth a of a household evolves according to its consumption and investment decisions.

There is a measure 1 of firms. Firms operate a constant returns to scale technology that turns $k \in \mathbb{R}_+$ capital and $\ell \in R_+$ efficiency units of labor into $y(k, \ell) + (1 - \delta_k)k$ units of output, where $y(k, \ell)$ is a constant return to scale function that is strictly increasing and strictly concave in K and Z, and $\delta_k \in [0, 1]$ is the depreciation rate of capital. For the sake of concreteness, we will specialize the production function $y(k, \ell)$ to have a Cobb-Douglas form $Ak^\alpha \ell^{1-\alpha}$ Firms are owned by the households. Since, as we shall see, the firm's problem is static, firms maximize periodical profits.

Firms rent capital from households in a frictional capital market. On one side of the market, a firm chooses what interest rate to offer its lenders. On the other side of the market, a household searches for borrowers and comes into contact with a discrete number of randomly-selected firms. The number of firms with which a household comes into contact depends, stochastically, on the financial human capital of the household. Specifically, a household with financial human capital λ_i comes into contact with n firms, where n is distributed as a Poisson with coefficient λ_i. The household observes the interest rate offered by the n contacted firms and decides whether and where to invest its wealth. Once the capital market is closed, firms hire labor from households in a perfectly competitive market, where both firms and households take as given the wage w.

If the household does not lend its wealth to a firm in the frictional capital market, it can either store the consumption good or hold fiat money. If the household stores the consumption good, it enjoys a real interest rate equal to $1 - \delta_c$, where $\delta_c \in [0, 1]$ is the depreciation rate of consumption when stored across periods. If the household holds fiat money, it enjoys a real rate equal to $\hat{\phi}/\phi$, where $\hat{\phi}$ is the value of a unit of fiat money in terms of the consumption good tomorrow and ϕ is the value of a unit of firat money in terms of the consumption good today. Obviously, the real interest rate $\underline{r}$ enjoyed by a household that does not lend its savings to a firm is the maximum between the return on storage $1 - \delta_c$ and the return on money $\hat{\phi}/\phi$.

There is a government that issues fiat money and levies labor taxes. The government supplies a quantity $M\gamma$ of new fiat money in every period. The government levies taxes τ on labor earnings. The government balances the budget in every period. Hence, if money growth is positive, i.e. $\gamma > 0$, the government subsidizes labor, i.e. $\tau < 0$. If money growth is negative, i.e. $\gamma < 0$, the government taxes labor, i.e. $\tau > 0$.

The environment described above is a version of the incomplete market model of Ayiagari (1994), Bewley (1983) and Huggett (1996), in which the market where households lend and where firms lend is frictional. Specifically, we assume that households cannot lend to just any borrower in the market, but only to a discrete subset of them. The assumption is meant to capture the view that households have limited ability to locate investment opportunities, and they have limited capacity to understand the investments offered by different borrowers. As a result, households are able and willing to lend to a limited subset of the borrowers in the market. We assume that the size of the choice set of a household is a random variable whose average, λ, depends on the household's financial human capital—a measure of the household's general knowledge about the market and of its ability to understand different investment opportunities.

As in the product market models of Butters (1977), Varian (1980) and Burdett and Judd (1983), the fact that some households have access to a single investment opportunity guarantees the borrowers offer interest rates that are lower than the marginal product of capital. Secondly, the fact that some households have access to a single investment opportunity and others have access to multiple investment opportunities guarantees that the distribution of interest rates offered by lenders is non-degenerate. The dispersion in interest rates does not reflect compensation for risk, but it is a genuine departure from the law of one price. Lastly, the gap between the interest rates offered by borrowers and the marginal product of capital, a measure of the extent to which the market is imperfectly competitive, depends on the average size of the households' choice sets. The market is imperfectly competitive, and the extent of imperfect competition is endogenous.

In order to focus on the role of imperfect competition in the market where households invest, we make several simplifying assumptions. First, we abstract from heterogeneity in the return and riskiness of different investments. In particular, we assume that all firms operate the same non-stochastic production function. Extending the model to allow for heterogeneity and randomness in the production function would be fairly easy, but outside of the scope of this paper. Second, we abstract from intermediation. In particular, we assume that households directly lend capital to firms. Introducing intermediaries that collects savings from households and deliver them to firms would not affect the structure of equilibrium, as long as households have limited information about intermediaries. Third, we abstract from long-term relationships between households and firms. Specifically, we assume that households lend capital to firms for only one period and, more importantly, that a firm remains in the choice set of a household for only one period. Allowing for long-term relationships between households and firms would significantly complicate the model by creating persistent heterogeneity not only in the size, but also in the content of the choice set of different households. Lastly, we assume that households are not allowed to trade shares of the firms.

2.2 Problem of the firm

We now want to derive the equilibrium conditions. In this subsection, we formulate the problem of the firm in the labor and capital markets. In subsection 2.3, we formulate the problem of the household. In subsection 2.4, we deal with the clearning conditions in the labor, capital and money market. In subsection 2.5, we describe some of the key properties of equilibrium. Throughout the paper, we are going to restrict attention to steady-state equilibria. For this reason, we omit the dependance of the value functions from the aggegate state of the economy.

Consider a firm that rented k units of capital at the gross interest rate r in the capital market. The firm's problem in the labor market is

$$\max_{\ell \geq 0} Ak^{\alpha}\ell^{1-\alpha} + (1-\delta_k)k - w\ell - rk. \tag{2.1}$$

The firm's revenues are given by the revenues from selling the output $Ak^{\alpha}\ell^{1-\alpha}$ and the revenues from selling the undepreciated capital $(1-\delta_k)k$. The firm's costs are given by the wage bill $w\ell$ and the capital bill rk. The firm chooses how many efficiency units of labor ℓ to hire in order to maximize its profit, which is given by the difference between revenues and costs.

The optimality condition for the firm's problem in the labor market is given by

$$(1-\alpha)Ak^{\alpha}\ell^{-\alpha} = w. \tag{2.2}$$

Solving the optimality condition (2.2) with respect to ℓ yields

$$\ell = \left[\frac{(1-\alpha)A}{w}\right]^{\frac{1}{\alpha}} k. \tag{2.3}$$

The above expressions are easy to understand. The firm finds it optimal to hire a quantity of labor ℓ such that the marginal productivity of labor, the left-hand side of (2.2), is equal to the wage w, the right-hand side of (2.2). Since the firm's production function features constant returns to scale in labor and capital, the marginal productivity of labor only depends on the labor/capital ratio and, hence, the optimal quantity of labor is proportional to the firm's capital k.

Substituting (2.3) into the firm's profit function (2.1) yields

$$\begin{aligned} & A\left[\frac{(1-\alpha)A}{w}\right]^{\frac{1-\alpha}{\alpha}} k + (1-\delta_k)k - w\left[\frac{(1-\alpha)A}{w}\right]^{\frac{1}{\alpha}} k - rk \\ = \;& \alpha A\left[\frac{(1-\alpha)A}{w}\right]^{\frac{1-\alpha}{\alpha}} k + (1-\delta_k)k - rk \\ = \;& (r^* - r)\, k, \end{aligned} \tag{2.4}$$

where r^* denotes the marginal productivity of capital given that the firm hires the optimal

quantity of labor, and r^* is given by

$$r^* = \alpha A \left[\frac{(1-\alpha)A}{w} \right]^{\frac{1-\alpha}{\alpha}} + 1 - \delta_k. \tag{2.5}$$

The last line in (2.4) states that the maximized profit for a firm that has rented k units of capital at the gross interest rate r is equal to k times the difference between the marginal productivity of capital r^* and r. If the firm's gross interest rate r is equal to the marginal productivity of capital r^*, as it is in a perfectly competitive capital market, the firm's profit is zero. If the firm's gross interest rate r is strictly smaller than the marginal productivity of capital r^*, as it is in an imperfectly competitive capital market, the firm's profit is strictly positive and proportional to its capital.

Next, we turn to the problem of a firm in the capital market. To formulate the problem of the firm, we need to introduce some notation. Specifically, we let $F(r)$ denote the fraction of firms that offer an interest rate smaller or equal to r, we let $F(r-)$ denote the fraction of firms that offer an interest rate strictly smaller than r, and we let $\zeta(r)$ denote the measure of firms that offer an interest rate equal to r. Moreover, we let h_i denote the measure of households with financial human capital λ_i, and we let $H_i(s)$ denote the fraction of these households with savings that are smaller or equal to s.

Consider a firm offering the interest rate $r \geq \underline{r}$. The profit of the firm is given by

$$\pi(r) = \sum_{i=1}^{I} \left[\sum_{n=0}^{\infty} \int h_{i,n} \omega_{i,n}(r) \left(r^* - r\right) s dH_i(s) \right], \tag{2.6}$$

where

$$h_{i,n} = h_i \frac{e^{-\lambda_i} \lambda_i^{n+1}}{(n+1)!} (n+1), \tag{2.7}$$

and

$$\omega_{i,n}(r) = F(r-)^n + \sum_{j=1}^{n} \binom{n}{j} \frac{F(r-)^{n-j} \zeta(r)^j}{j+1}. \tag{2.8}$$

Let us explain the expressions above. The firm meets a measure $h_{i,n}$ of households with financial human capital h_i that are in contact with n other borrowers. The measure $h_{i,n}$ of households is given by the measure of firms with human capital λ_i, h_i, times the probability that one of these households is in contact with a total of $n+1$ borrowers, $\exp(-\lambda_i)\lambda_i^{n+1}/(n+1)!$, times the number of borrowers contacted by each of these households, $n+1$. The probability $\omega_{i,n}(r)$ that one of these households lends its savings to the firm is given by the sum of the probability of two events. The first event is such that all the other n contacts of the household offer an interest rate strictly smaller than r. The second event is such that j of the other n contacts of the household offer an interest rate equal to r, the remaining $n-j$ contacts of the firm offer an interest rate strictly smaller than r, and the household randomly chooses to lend to the firm. If the firm borrows from the household, it enjoys a profit of $(r^* - r)s$, where s are the household's savings.

The interest rate distribution F is consistent with firm's profit maximization if and only if (2.6) is maximized at every r on the support of F. Using this condition for the optimality of F, it is easy to show that F does not have any mass points (Lemma 1 in Menzio 2024). If F had a mass point at some interest rate $r_0 < r^*$, the firm's profit would be strictly greater at $r_0 + \epsilon$ than at r_0, for some $\epsilon > 0$ and small enough. Indeed, by offering $r_0 + \epsilon$, the firm trades with all of the $h_{i,n}$ households that are in contact with j additional borrowers offering r_0 and with $n - j$ additional borrowers offering less than r_0. By offering r_0, the firm trades only with a fraction $1/(j+1)$ of the $h_{i,n}$ households that are in contact with j additional borrowers offering r_0 and with $n - j$ borrowers offering less than r_0. Hence, the firm raises discretely more capital by offering $r_0 + \epsilon$ and, in doing so, it loses an arbitrarily small ϵ of profit per unit of capital raised. If F had a mass point at r^*, the firm's profit would be strictly greater at $\underline{r}$ than at r^*. Indeed, by offering $\underline{r}$, the firm trades with all of the $h_{i,0}$ households that are not in contact with any other borrower, and makes a strictly positive profit on each unit of capital raised from them. By offering r^*, the firm makes no profits.

Since F does not have any mass points, we can rewrite (2.6) as

$$\begin{aligned}\pi(r) &= \textstyle\sum_{i=1}^{I}\left[\sum_{n=0}^{\infty}\int h_i \frac{e^{-\lambda_i}\lambda_i^{n+1}}{n!}F(r)^n\,(r^*-r)\,s dH_i(s)\right]\\ &= \textstyle\sum_{i=1}^{I}\left[\left(e^{-\lambda_i(1-F(r))}\lambda_i\sum_{n=0}^{\infty}\frac{e^{-\lambda_i F(r)}\lambda_i^n F(r)^n}{n!}\right)\int h_i\,(r^*-r)\,s dH_i(s)\right]\\ &= \textstyle\sum_{i=1}^{I} e^{-\lambda_i(1-F(r))}\lambda_i S_i\,(r^*-r).\end{aligned} \tag{2.9}$$

The first line in (2.9) is obtained by substituting $h_{i,n}$ and $\omega_{i,n}(r)$ and by noting that $\chi(R) = 0$. The second line is obtained by collecting terms. The last line is obtained by defining as S_i the total savings of households with financial human capital h_i, i.e. $S_i = h_i \int s dH_i(s)$, and by noting that the summation over n equals 1.

The interest rate distribution F is consistent with firm's profit maximization if and only if (2.9) is maximized at every r on the support of F. Using this condition for the optimality of F, it is easy to show that the support of F is an interval $[r_\ell, r_h]$, with $r_\ell = \underline{r}$ (Lemma 2 in Menzio 2024). If the support of F had a gap between r_0 and r_1, with $r_0 < r_1$, the profit of the firm would be strictly greater at r_0 than at r_1. Indeed, the firm would raise the same amount of capital by offering r_0 and r_1, since $F(r_0) = F(r_1)$. The firm, however, would enjoy a strictly higher profit per unit of capital raised by offering r_0 rather than r_1. Therefore, the support of F must be an interval $[r_\ell, r_h]$. A similar argument can be used to show that the lowest interest rate on the support of F must be $\underline{r}$.

Since $\underline{r}$ is on the support of the interest rate distribution F, the firm attains its maximized profit, π^*, by offering $\underline{r}$. Since $\underline{r}$ is the lowest interest rate on the support of F, $F(\underline{r}) = 0$. These observations imply that

$$\pi^* = \sum\nolimits_{i=1}^{I} \lambda_i e^{-\lambda_i} S_i (r^* - \underline{r}). \tag{2.10}$$

Since r is on the support of the interest rate distribution F, the firm attains its maximized profit, Π^*, by offering any $r \in [r_\ell, r_h]$. This observation implies that

$$\pi^* = \sum\nolimits_{i=1}^{I} \lambda_i e^{-\lambda_i(1-F(r))} S_i(r^* - r). \tag{2.11}$$

Combining (2.10) and (2.11) yields

$$\sum\nolimits_{i=1}^{I} \lambda_i e^{-\lambda_i} S_i(r^* - \underline{r}) = \sum\nolimits_{i=1}^{I} \lambda_i e^{-\lambda_i(1-F(r))} S_i(r^* - r). \tag{2.12}$$

The expression in (2.12) is an equal-profit condition that uniquely pins down the equilibrium interest rate distribution F.

2.3 Problem of the household

Consider a household with financial wealth a, efficiency units of labor z, and financial human capital λ. The household's maximized lifetime utility $V(a, z, \lambda)$ is such that

$$\begin{aligned} & V(a, z, \lambda) \\ = \; & \max_{(c,e,s)\in\mathbb{R}^3_+} u(c) + \beta \mathbb{E}_{\hat{z}|z} \left\{ \sum_{\hat{\imath}=1}^{I} \phi_\lambda(\hat{\lambda}|\lambda, e) \left[\sum_{n=0}^{\infty} \frac{e^{-\lambda}\lambda^n}{n!} \int V(sr, \hat{z}, \hat{\lambda}) dF_n(r) \right] \right\}, \\ & \text{s.t. } c + e + s \leq a + w(1-\tau)z + \pi^*. \end{aligned} \tag{2.13}$$

In the current period, the household earns $w(1-\tau)z$ in labor income, and π^* in profits from the firms. The household chooses how to allocate its earnings $w(1-\tau)z + \pi^*$ and its wealth a into consumption c, investment in financial human capital e, and savings s. Following the literature on incomplete markets, we assume that the household's choice of savings is constrained to be positive. The household then meets n randomly-selected firms in the capital market with probability $\exp(-\lambda)\lambda^n/n!$. For $n = 1, 2, \ldots$, the household's interest rate r is a draw from the cumulative distribution $F_n(r)$, where $F_n(r) = F(r)^n$ is the distribution of the highest of n draws from the distribution $F(r)$ of interest rates offered by firms. For $n = 0$, the household's interest rate r is a draw from $F_0(r)$, where $F_0(r)$ denotes a distribution that is degenerate at $\underline{r}$. In the next period, the household's financial wealth is sr. The household's efficiency units of labor are $\hat{z}$ with probability $\phi_z(\hat{z}|z)$. The household's financial human capital is $\hat{\lambda}$ with probability $\phi_\lambda(\hat{\lambda}|\lambda, e)$.

2.4 Market clearing

The clearing condition for the capital market is

$$\sum\nolimits_{i=1}^{I} (1 - e^{-\lambda_i}) S_i = K. \tag{2.14}$$

The left-hand side of (2.14) is the capital that is lent by households to firms, which is given by the savings S_i of households with financial human capital λ_i multiplied by the

fraction $1 - \exp(-\lambda_i)$ of these households that meet at least one firm. The right-hand side of (2.14) denotes the amount of capital borrowed by firms from households.

The clearing condition for the labor market is

$$L = \left[\frac{(1-\alpha)A}{w}\right]^{\frac{1}{\alpha}} K. \tag{2.15}$$

The left-hand side of (2.15) is the amount of efficiency units of labor supplied by households, which we denote as L. The right-hand side of (2.15) is the amount of efficiency units of labor hired by firms, which is equal to the amount of capital borrowed by firms multiplied by $[(1-\alpha)A/w]^{1/\alpha}$.

The balanced-budget condition for the government is

$$M\gamma\phi + Lw\tau = 0. \tag{2.16}$$

The first-term on the left-hand side of (2.16) is the real value of the new money issued by the government in a given period. The second term on the left-hand side of (2.16) is the real value of labor taxes (if τ is positive) or labor subsidies (if τ is negative) collected or dispensed by the government in a given period. The sum of the two terms must be equal to zero.

The clearing condition for the money market depends on whether we are in a monetary equilibrium—a stationary equilibrium in which money has value—or in a non-monetary equilibrium—a stationary equilibrium in which money has no value.

For a monetary equilibrium to exist, it has to be the case that households prefer holding money than storing goods or, equivalently, $\phi/\phi > 1 - \delta_c$. In this case, the clearing condition for the money market is

$$\sum\nolimits_{i=1}^{I} S_i e^{-\lambda_i} = M\phi. \tag{2.17}$$

The left-hand side of (2.17) is the real money demand by households, which is given by the savings S_i of households with financial human capital λ_i multiplied by the fraction $\exp(-\lambda_i)$ of these households that do not meet any firms. The right-hand side of (2.17) is the real value of the money supplied by the government.

We can then use the clearing condition for the money market in the next period to recover the real return on money. The clearing condition for the money market in the next period is

$$\sum\nolimits_{i=1}^{I} S_i e^{-\lambda_i} = M(1+\gamma)\hat{\phi}. \tag{2.18}$$

The demand for money from the households in the next period is the same as in the current period. The supply of money from the government increases by the factor γ, but the value of a unit of money is $\hat{\phi}$ rather than ϕ.

Equating the right-hand sides of (2.17) and (2.18) yields

$$\frac{\hat{\phi}}{\phi} = \frac{1}{1+\gamma}. \tag{2.19}$$

The real return on money is the inverse of the gross growth rate of the quantity of money in the economy or, equivalently, the inverse of the gross growth rate of the price of consumption in units of money (the inverse of the inflation rate). The expression in (2.19) implies that a monetary equilibrium exists only if $1/(1+\gamma) > 1-\delta_c$.

In a non-monetary equilibrium, money has no value. In a non-monetary equilibrium, households prefer storing goods than holding money. When households prefer storing goods than holding money, the clearing conditions for the money market imply $\phi = 0$ and $\hat{\phi} = 0$. Hence, a non-monetary equilibrium always exists. In what follows, we shall assume that the economy is a monetary equilibrium whenever the condition $1/(1+\gamma) > 1-\delta_c$ holds.

2.5 Properties of equilibrium

Let us first discuss some properties of the distribution F of interest rates offered by firms to households. Denote as $r(x)$ the interest rate offered by a firm at the x-th quantile of F. From (2.12), it follows that $r(x)$ is given by

$$r(x) = r^* - \frac{\sum_{i=1}^{I} \lambda_i e^{-\lambda_i} S_i}{\sum_{i=1}^{I} \lambda_i e^{-\lambda_i (1-x)} S_i} (r^* - \underline{r}). \tag{2.20}$$

The expression above shows that the interest rates offered by firms are strictly smaller than the marginal product of capital r^*. Since some households come into contact with only one firm, it must be the case that the equilibrium profits of a firm are strictly positive and, hence, the firms must offer interest rates that are strictly smaller than r^*. The expression above also shows that the distribution of interest rates offered by firms is non-degenerate. Since some households come into contact with multiple firms, an individual firm would have an incentive to outbid the competition if all the other firms offered the same interest rate. Lastly, the expression above shows that the interest rates offered by firms are greater than the interest rate $\underline{r}$ that households can earn by either holding money or storing goods. Since all households can obtain the return $\underline{r}$, firms always need to compete against the storage option and, as a result, they must offer interest rates greater than $\underline{r}$. The firm at the bottom of the distribution F, i.e. the firm at the $x = 0$ quantile, offers an interest rate equal to $\underline{r}$, since such a firm will only raise capital from households that have not contacted any other firm in the market and, hence, it is only competing against the interest rate that households can earn outside of the capital market.

The interest rate distribution F depends on the marginal product of capital, r^*. Specifically, an increase in the marginal product of capital r^* increases the interest rate $r(x)$

offered by firms at the x-th quantile of the F distribution. The rate at which an increase in r^* is passed through to $r(x)$ is less than one-for-one and depends on x. Specifically, the pass-through of r^* is zero at $x = 0$, it is strictly increasing in x, and it is smaller than 1 at $x = 1$. Intuitively, an increase in r^* increases the profit that a firm enjoys on every unit of capital borrowed from a household and, for this reason, it induces firms to increase their interest rates. The increase in the interest rate offered by firms is smallest at the bottom of the F distribution, where firms' profit margins are large and less sensitive to changes in r^*. The increase in the interest rate is largest at the top of the F distribution, where firms' profit margins are small and most sensitive to changes in r^*.

Using (2.20), it is easy to compute the average interest rate $\overline{r}_n$ enjoyed by a household that comes into contact with n firms in the capital market. Specifically, $\overline{r}_n$ is given by

$$\begin{aligned} \overline{r}_n &= \textstyle\int_{r_\ell}^{r_h} r n F(r)^{n-1} F'(r) dr \\ &= \textstyle\int_0^1 r(x) n F(r(x))^{n-1} F'(r(x)) r'(x) dx \\ &= \textstyle\int_0^1 r(x) n x^{n-1} dx. \end{aligned} \tag{2.21}$$

The first line in (2.21) makes use of the fact that the maximum interest rate among n random draws from F is distributed according to the distribution $F(r)^n$, which has density $nF(r)^{n-1}F'(r)$. The second line is obtained by changing the variable of integration from r to x. The last line makes use of the fact that $F(r(x)) = x$ and, hence, $F'(r()x)r'(x) = 1$. Since $dr(x)/dr^*$ is strictly increasing in x and the cumulative distribution function x^n is increasing in n (in the sense of first-order stochastic dominance), the expression in the last line of (2.21) implies that the households that gain the most from an increase in the marginal product of capital are the households that come into contact with a larger number of firms, which tend to be the households with higher financial human capital.

The interest rate distribution F depends on the rate of return $\underline{r}$ that households can obtain outside of the capital market. Specifically, an increase in $\underline{r}$ increases the interest rate $r(x)$ offered by firms at the x-th quantile of the F distribution. The rate at which an increase in $\underline{r}$ passes through to $r(x)$ is less than one-for-one and depends on x. Specifically, the pass-through of $\underline{r}$ is 1 for $x = 0$, it is strictly decreasing in x, and it is greater than 0 at $x = 1$. Intuitively, an increase in $\underline{r}$ forces the firm at the bottom of the distribution F to increase its interest rate one-for-one, since $\underline{r}$ is the best alternative rate of return for all of its lenders. The increase in the interest rate offered by the firm at the bottom of the distribution pushes firms that are further up the distribution to increase their interest rates, since these firms are sometimes competing with the firm at the bottom. The increase in $\underline{r}$ trickles up the distribution, but the effect becomes weaker and weaker. Since $dr(x)/d\underline{r}$ is strictly decreasing in x, (2.21) implies that the households that gain the most from an increase in the interest rate on storage are the households that contact a small number n of firms in the capital market, which tend to be households with low financial human capital.

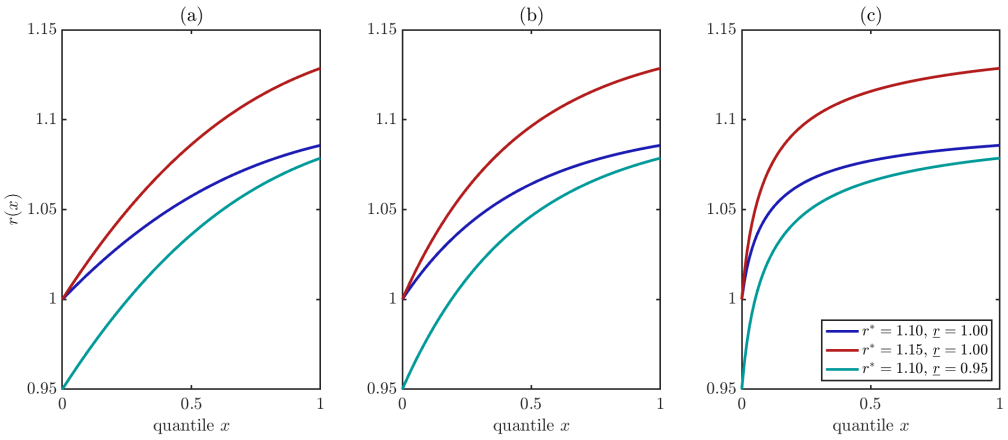


Figure 1: Panel (a): Distribution of rates of return on capital offered by firms. Panels (b) and (c): Distribution of rates of return on capital earned by household with low and high λ for different r^* and $\underline{r}$.

The interest rate distribution F depends on the distribution of savings across households with different financial human capital. Specifically, moving savings S from households with relatively low financial human capital, i.e. households with a relatively low λ, to households with relatively high financial human capital, i.e. households with a relatively high λ, leads to an increase in the interest rates offered by firms. The finding is intuitive. If a larger fraction of savings is in the hands of households with high financial human capital, which are household that are able to contact more firms, the competition in the capital market intensifies and the interest rates increase. An increase in the fraction of savings in the hands of households with high financial human capital can be caused by either an increase in the fraction of financially educated households, or by an increase in the savings that each one of these households has.

Figure 1 illustrates the findings above. The figure plots the interest rate $r(x)$ offered by a firm at the x-th quantile of the F distribution (panel a), the distribution of interest rates received by households with low financial human capital (panel b), and with high financial human capital (panel c) for different values of the marginal product of capital r^* and for different rates of return $\underline{r}$ that households can obtain outside the capital market.

Next, let us discuss the saving behavior of households. The optimality condition for savings $s > 0$ is given by

$$\begin{aligned} & u'(a + wz(1-\tau) - e - s) \\ \geq \quad & \beta \mathbb{E}_{\hat{z}|z} \left\{ \sum_{\hat{\imath}=1}^{I} \phi_\lambda(\hat{\lambda}|\lambda, e) \left[\sum_{n=0}^{\infty} \frac{e^{-\lambda}\lambda^n}{n!} \int r \frac{\partial V_{\hat{\imath}}(sr, \hat{z}, \hat{\lambda})}{\partial a} dF_n(r) \right] \right\}, \end{aligned} \tag{2.22}$$

and $s \geq 0$, where the two inequalities hold with complementary slackness. The left-hand side of (2.22) is the marginal cost of increasing s, which is given by the marginal utility of consumption in the current period. The right-hand side of (2.22) is the marginal benefit of increasing s, which is given by the expected marginal value of r additional units of

wealth in the next period. Condition (2.22) states that the marginal cost of increasing savings must be equal to the marginal benefit, as long as $s > 0$. If $s = 0$, the marginal cost of increasing savings must be greater or equal to the marginal benefit.

The optimal choice of s depends on the household's current wealth a and on the household's current efficiency units of labor z, as it would in a standard incomplete markets models in the style of Ayiagari (1994), Bewley (1983), and Hugget (1996). In contrast to standard incomplete markets models, the optimal choice of s also depends on the household's financial human capital λ. Panel (a) in Figure 2 plots the household's optimal savings as a function of its current wealth a, for different levels of financial human capital. As expected, the household's optimal savings are strictly increasing in the household's wealth a, since higher a lowers the marginal cost of savings s. The household's optimal savings are increasing in the household's financial human capital, since financial human capital allows the household to contact more firms and obtain a higher interest rate which, in turn, tends to increase the marginal benefit of savings.

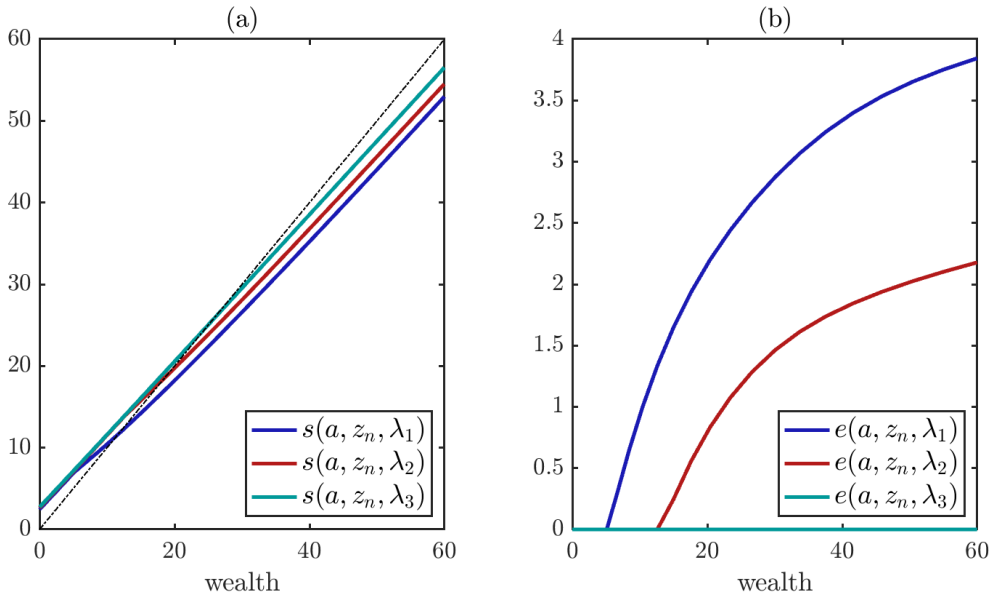


Figure 2: Panel (a): Savings as a function of a for different λs. Panel (b): Investment in financial human capital as a function of a for different λs.

Lastly, let us discuss the household's investment in financial human capital. The optimality condition for e is given by

$$\begin{aligned} & u'(a + wz(1-\tau) - e - s) \\ \geq \quad & \beta \mathbb{E}_{\hat{z}|z} \left\{ \sum_{i=1}^{I} \frac{\partial \phi_\lambda(\hat{\lambda}|\lambda, e)}{\partial e} \left[\sum_{n=0}^{\infty} \frac{e^{-\lambda}\lambda^n}{n!} \int V(sr, \hat{z}, \hat{\lambda}) dF_n(r) \right] \right\}, \end{aligned} \tag{2.23}$$

and $e \geq 0$, where the two inequalities hold with complementary slackness. The left-hand side of (2.23) is the marginal cost of increasing e, which is given by the marginal

utility of consumption in the current period. The right-hand side of (2.23) is the marginal benefit of increasing e, which is given by the marginal change in the probability of having financial human capital $\hat{\lambda}$ in the next period multiplied by the expected continuation value conditional on $\hat{\lambda}$. The household's continuation value is increasing in $\hat{\lambda}$ because a household with more financial human capital contacts from firms and obtains higher interest rates. Condition (2.23) states that the marginal cost of investing more in financial human capital must be equal to the marginal benefit, as long as $e > 0$. If $e = 0$, the marginal cost of investing more in financial human capital must be greater or equal to the marginal benefit.

The optimal choice of e depends on the household's current wealth a and on the household's current efficiency units of labor z. Figure 2 plots the household's optimal investment in financial human capital as a function of its current wealth a. The household's optimal investment e is increasing in the household's wealth a, since higher a lowers the marginal cost of e and increases the marginal benefit of e. Panel (b) in Figure 2 plots the household's optimal investment in financial human capital for different levels of financial human capital. The relationship between e and λ depends on the return to details of the stochastic process relating e and λ to $\hat{\lambda}$. In the case illustrated by Figure 2, households with higher financial human capital choose lower e.

3 Calibration

3.1 Calibration targets

Before describing the targets of the calibration, let us review the parameters of the model. The preferences of the household are described by the utility function $u(c) = c^{1-\nu}/(1-\nu)$, where ν is the coefficient of relative risk aversion, and by the discount factor β. The real interest rate that the household can achieve without lending to a firm is $\underline{r}$, which is the maximum between $1/(1+\gamma)$, the real interest rate on holding cash, $1-\delta_c$, the complement to 1 of the depreciation rate on consumption goods. The technology of the firm is described by the Cobb-Douglas function $y(k, \ell) = Ak^{\alpha}\ell^{1-\alpha}$, where α is the elasticity of output with respect to capital, $1 - \alpha$ is the elasticity of output with respect to labor, and A is a parameter describing total factor productivity, and by the depreciation rate of capital δ_k.

We specialize the stochastic process $\phi_z(\hat{z}|z)$ for the evolution of the efficiency units of labor to be $\log \hat{z} = \rho \log z + \epsilon$, where $\hat{z}$ denotes the household's efficiency units of labor in the next period, z denotes the household's efficiency units of labor in the current period, ρ is an autocorrelation parameter, and ϵ is a random variable that is normally distributed with mean 0 and standard deviation σ. The realization of ϵ is independent across households and across time. The stochastic process is discretized and then normalized so that the aggregate measure of efficiency units L equals 1.

We specialize the stochastic process for financial human capital as a process of climb-

ing up and down a ladder. We choose the set of financial human capitals to be $\Lambda = \{\lambda_1, \lambda_2, \lambda_3\}$, with $\lambda_1 < \lambda_2 < \lambda_3$. The stochastic process for the evolution of the household's human capital is $\phi_\lambda(\lambda_i|\lambda_i, e)$, where λ_i denotes the financial human capital of the household in the next period, λ_i denotes the financial human capital of the household in the current period, and e denotes the household's investment in human capital in the current period. For $\lambda_i = \lambda_2$ or λ_3, we set $\phi_\lambda(\lambda_{i-1}|\lambda_i, e) = \delta_\lambda$, where δ_λ is a parameter that captures depreciation of financial human capital. For $\lambda_i = \lambda_1$ or λ_2, we set $\phi_\lambda(\lambda_{i+1}|\lambda_i, e) = \max(1 - \delta_\lambda, 1 - \exp(-\eta e))$, where η is a parameter than controls the effect of investment on the accumulation of financial human capital. For any λ_i, we set $\phi_\lambda(\lambda_i|\lambda_i, e)$ to be $1 - \phi_\lambda(\lambda_{i-1}|\lambda_i, e) - \phi_\lambda(\lambda_{i+1}|\lambda_i, e)$.

We set the length of a period to be 1 year. We set the coefficient ν of relative risk aversion in the household's preferences function to be 1.5, a common choice in the incomplete market literature. We normalize the total factor productivity A to 1. We set the elasticity α of output with respect to capital to match a 36% capital share and a 64% labor share, which are typical measures of capital and labor shares for the US. We set the depreciation rate of capital δ_k to be 8%, which is a typical measure of capital depreciation. Following Auclert et al. (2021), we set the autocorrelation coefficient ρ in the stochastic process for efficiency units of labor to 0.87, and the standard deviation σ of the innovation to 0.47.

The remaining parameters are the steps in the financial human capital ladder (λ_1, λ_2, λ_3), the depreciation factor of financial human capital δ_λ, the coefficient η that controls the return to investment in financial human capital, the real interest rate $\underline{r} = \max\{1/(1+\gamma), 1-\delta_c\}$ that households can obtain outside of the financial market, and the household's discount factor β. These are the parameters that shape the extent of frictions in the financial market.

We target properties of the distribution of returns to net worth documented by Fagereng, Guiso, Malacrino and Pistaferri (2020). The average return to net worth is 3.6% and the standard deviation is 7.8%. Returns vary systematically across individuals, even after controlling for portfolio composition and wealth. Regressing individual returns on portfolio composition and wealth yields residuals that have different 11-year averages (fixed-effects) for different individuals. An individual at the 25th percentile of the distribution of fixed-effects has a return that is 1.58 percentage point lower than average. An individual at the 75th percentile of the distribution of fixed-effects has a return that is 1.86 percentage points higher than average. Returns vary with wealth. A shift from the 10th the 90th percentile of the wealth distribution increases the average return by 8 percentage points. A shift from the 10th to the 90th percentile of the wealth distribution increases the individual fixed-effect by 3.5 percentage points. Since the model abstracts from differences in risk across assets, we are going to target properties of the distribution of fixed-effects.

We also target properties of the composition of portfolios documented by Fagereng, Guiso, Malacrino and Pistaferri (2020). Individuals between the 10th and the 20th per-

Assigned		
ν	1.5	CRRA
A	1	TFP
α	0.36	capital elasticty
δ_k	0.08	depreciation rate for capital
ρ	0.87	AR(1) $\log z$
σ	0.47	std. dev. $\log z$ shocks
$\underline{r}$	0.98	return on money
Calibrated		
β	0.894	discount factor
λ_1	0.719	low financial h.c.
λ_2	1.917	intermediate financial h.c.
λ_3	3.250	high financial h.c.
η	0.291	scale parameter for investment e
δ_λ	0.011	depreciation rate financial h.c.

Table 1: Calibrated parameter values

centile of the wealth distribution hold 75% of their wealth in money (cash or bank deposits). Individuals between the 20th and the 50th percentile of the wealth distribution hold 30% of their gross wealth in either cash or bank deposits. Individuals between the 50th and the 90th percentile of the wealth distribution hold 10% of their gross wealth in either cash or bank deposits. Additionally, We target the fraction of aggregate money holdings, measured as M2, over output, measured as GDP. Finally, we target an inflation rate of 2% per year, and assume that the real rate of return on holding money exceeds the rate of return on storing the consumption good.

3.2 Properties of the calibrated model

Table 1 reports the calibrated parameter values. Table 2 displays the distribution of wealth in the calibrated model. The wealth distribution is highly concentrated. The households with wealth below the median (i.e., the poorest 50%) have less than 5% of the aggregate wealth. The households with wealth between the 50th and the 90th percentile have about 40% of the aggregate wealth. The richest 10% of households have more than half of the aggregate wealth, with the richest 1% holding 10% of it. In the data, the poorest 50% of households have 2% of the aggregate wealth. Households between the 50th and the 90th percentile have 30%. The richest 10% of households have 65% of aggregate wealth, with the top 1% holding about 25% of it. Overall, the model generates a highly concentrated wealth distribution in which a majority of households owns very little wealth. The model, however, understates the wealth share of the top 1%. This is not entirely surprising in a model that abstracts from entrepreneurship and its risky returns.

Figure 3 plots the distribution of interest rates offered by firms. The marginal pro-

Targeted moments	Data	Model
FE distribution		
10th percentile	-3.430	-3.000
25th percentile	-1.580	-1.787
75th percentile	1.860	1.644
90th percentile	4.280	3.943
$\mathbb{E}(r)$	1.036	1.037
M/Y	0.511	0.546
Untargeted moments		
Wealth shares (%)		
bottom 50%	3.176	1.067
50-90%	34.821	37.983
90-99%	35.914	45.856
top 1%	26.088	15.094

Table 2: Model fit. Fixed-effect distribution and average rate of return from Fagereng et al. (2020). M2/GDP is the US average over 1984-2006 from FRED. Wealth shares are US averages over 1990-2006 from Fed Board.

ductivity of capital is 13.54%. The lower bound of the distribution is −2%, which is the negative of the rate of inflation. The upper bound of the distribution is 11.32%, which is lower than the marginal product of capital because of search frictions. Figure 4 plots the distribution of interest rates earned by households, in the aggregate and conditional on their financial human capital. Households with higher financial human capital earn higher interest rates both because they are more likely to contact a firm in the financial market and because, conditional on meeting at least one firm, they contact more firms. The aggregate distribution is closest to the distribution conditional on λ_1 because, in equilibrium, the majority of households have the lowest level of financial human capital.

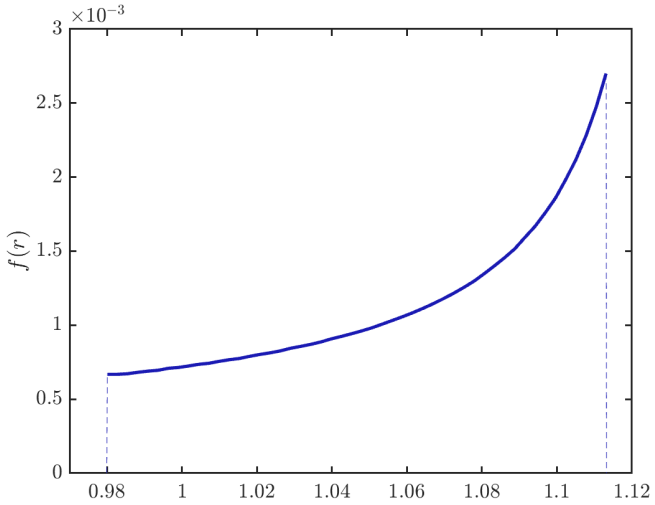


Figure 3: Distribution F of rates of return on capital.

The left panel in Figure 5 plots the distribution of individual fixed-effects in returns, where the fixed-effect of an individual is defined as his average return over a 11-year period (as in Fagereng, Guiso, Malacrino and Pistaferri 2020). The model reproduces quite well the extent of persistent dispersion in interest rates across individuals. In the model, even though households have to search the financial market in every period, individual interest rates are persistent because of the persistence of financial human capital. The right panel in Figure 5 plots the relationship between wealth percentile and interest rate. The model reproduces successfully the positive relationship between wealth and interest rate. In the model, households with higher earnings have an incentive to invest in both financial assets and financial human capital, which generates a positive correlation between the two variables and, in turn, a positive correlation between financial wealth and interest rates.

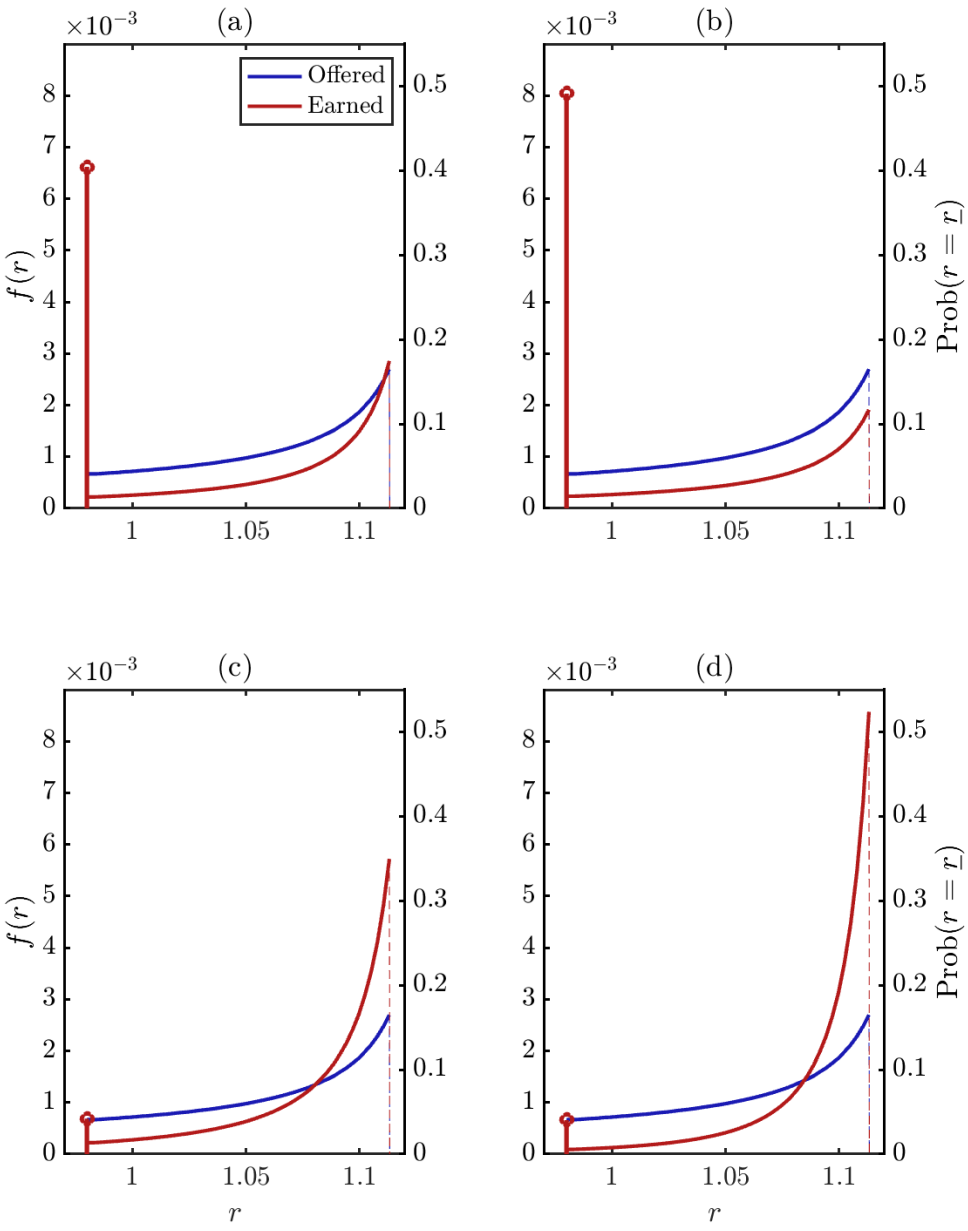


Figure 4: Panel (a): Distribution F of rates of return on capital (blue), and distribution of rates of return on wealth (red) for the whole population; Panel (b): Distribution of rates of return on wealth for lowest λ; Panel (c): Distribution of rates of return on wealth for intermediate λ; Panel (d): Distribution for highest λ. Red dot denotes fraction of households earning $\underline{r}$ and is measured on the right scale.

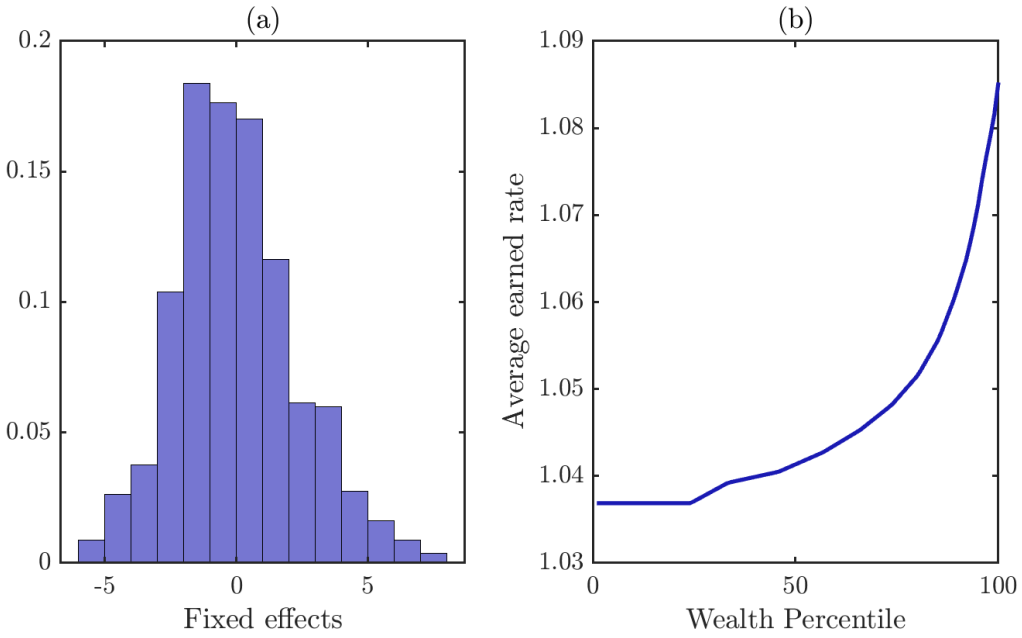


Figure 5: Panel (a): Distribution of fixed-effects in rates of return. Panel (b): Rates of return by wealth.

4 Measurement, Counterfactuals and Policy

4.1 Inflation

Using the calibrated model, we measure the equilibrium and welfare effects of inflation. In particular, we ask how equilibrium outcomes—such as the distribution of rates of returns offered by firms, the distribution of financial wealth across households, the distribution of financial human capital across households, and aggregate capital—and welfare outcomes—such as the welfare of households at different quantiles of the wealth distribution and aggregate welfare—change when inflation increases because of an increase in the growth rate gamma of the money supply.

Inflation lowers the real rate of return on money. Since money is an investment opportunity that is available to all households and against which all firms need to compete, inflation allows firms to offer lower real rate of returns on capital. As explained in subsection 2.5, the effect of inflation on the rates offered by firms is strongest at the bottom of the distribution F, and is weakest at the top of the distribution F. Therefore, inflation not only lowers the distribution of real interest rates offered by firms, but it also stretches the distribution out.

The households' investment in financial human capital responds to the changes in the rate of return on money and capital induced by inflation. The households' incentives to invest in financial human capital become stronger because inflation lowers the rate of return on money more than the rate of return on capital, and financial human capital lowers the chances that a household is forced to keep its savings in cash. The households' incentives to invest in human capital become stronger also because inflation increases the

dispersion of rates of return on capital offered by different firms, and financial human capital allows households to sample more firms. Both the change in the rate of return on money and the change in the distribution of the rates of return on capital induce households to accumulate more financial knowledge.

The increase in the financial knowledge of households affects equilibrium outcomes through two channels. First, financial knowledge increases the average number of firms that households contact in the capital market. For this reason, financial knowledge forces firms to offer higher rates of return. This partly offsets the direct negative effect of inflation on the distribution F. Second, financial knowledge lowers the fraction of households that have to keep their savings in cash. For this reason, the increase in financial knowledge leads to a shift in the households' portfolio from money to capital.

The households' saving behavior also responds to the changes in the rates of return on money and capital induced by inflation. In particular, households tend to save less because inflation lowers both the rate of return on money and the rate of return on capital. For this reason, inflation lowers aggregate wealth. Whether the decline in aggregate wealth leads to a decline in aggregate capital depends on the effect of inflation on the composition of the households' portfolio. If inflation causes a relatively large shift in the portfolio composition away from money and towards capital, aggregate wealth declines but aggregate capital increases. If inflation causes a relatively small shift in the portfolio composition, both aggregate wealth and aggregate capital decline.

Let us first look at the effect of increasing inflation from its baseline of 2% to 10%. Figure 6 plots the distribution of rates of return offered by firms. The average real rate of return falls from 6.11% to 4.14%. The rate of return at the 10th percentile of the distribution F falls from 0.28 to -6.20%. The rate of return at the 90th percentile of the distribution F increases from 10.71% to 11.2% percent. The increase in the rate of return at the top of the distribution is due to the fact that inflation lowers the aggregate stock of capital and, hence, increases the marginal product of capital. The increase in inflation lowers the average rate of return on capital and increases the dispersion of the rates of return on capital.

Figure 7 plots the distribution of rates of return earned by households with different levels of financial human capital when the inflation rate is 2% and 10%. For households with the lowest level of financial human capital, the average rate of return falls from 2.61% to -1.90%. For households with the intermediate level of financial human capital, the average rate of return falls from 7.76% to 6.88%. For households with the highest level of financial human capital, the average rate of return falls from 8.49 to 8.26%. The increase in inflation reduces the rates of return on all households, but especially on households with lower financial human capital—which are the households who are more likely to have to keep their savings in cash or to lend their savings to firms at the bottom of the F distribution.

Figure 8 panel (a) plots the fraction of households with different levels of financial

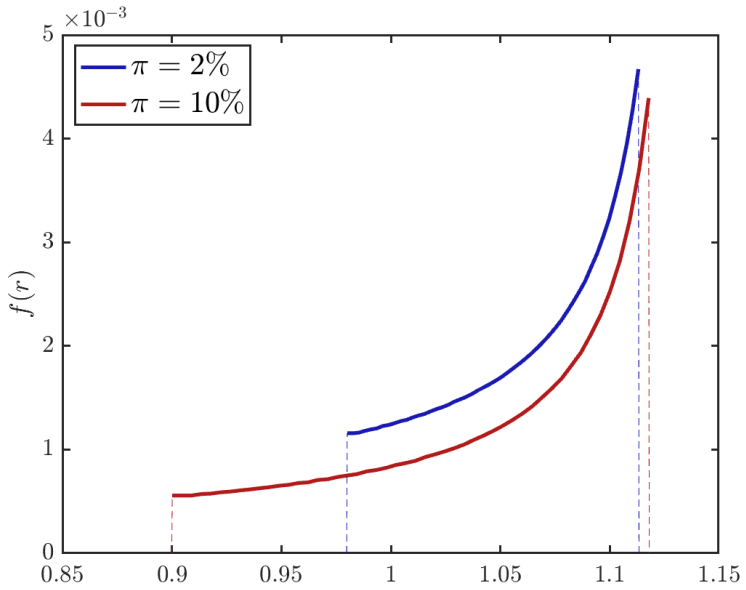


Figure 6: Distribution F of rates of return on capital at 2 and 10% inflation.

human capital as a function of the inflation rate. When the inflation rate is 2%, the fraction of households at λ_1 is 77%, the fraction of households at λ_2 is 17%, and the fraction of households at λ_3 is 6%. When the inflation rate is 10%, the fraction of households at λ_1 is 63%, the fraction of households at λ_2 is 23%, and the fraction of households at λ_3 is 15%. Inflation forces households to invest more in understanding the financial market.

Figure 8 panel (b) plots the aggregate stock of wealth, the real value of the aggregate stock of money, and the aggregate stock of capital as functions of the inflation rate. The aggregate stock of wealth declines by 14% as inflation goes from 2 to 10%. The real value of the aggregate stock of money is about 52% lower when the inflation rate is 10% rather than 2%. The aggregate stock of capital is slightly lower (-1%) when the inflation rate is 10% rather than 2%. Inflation induces households to accumulate less wealth and to reallocate their wealth from money to capital.

Figure 9 plots the Lorenz curves of the wealth distribution at different inflation rates. As one can see, the Lorenz curve is lower when the inflation rate is 10% rather than 2%, meaning that the increase in inflation leads to an increase in wealth inequality. More specifically, the share of wealth in the hands of the wealthiest 1% of the population grows from 15 to 18%. The share of wealth in the hands of the wealthiest 10% of the population grows from 61% to 67%. Conversely, the share of wealth in the hands of the poorest 50% of the population falls from 1.1 to 0.3%. Inflation increases wealth inequality because it lowers the rates of return for households with low financial human capital much more than the rates of return for households with high financial human capital. Since households with low financial human capital tend to be poorer and households with high financial human capital tend to be richer, inflation tends to make the rich richer and the poor

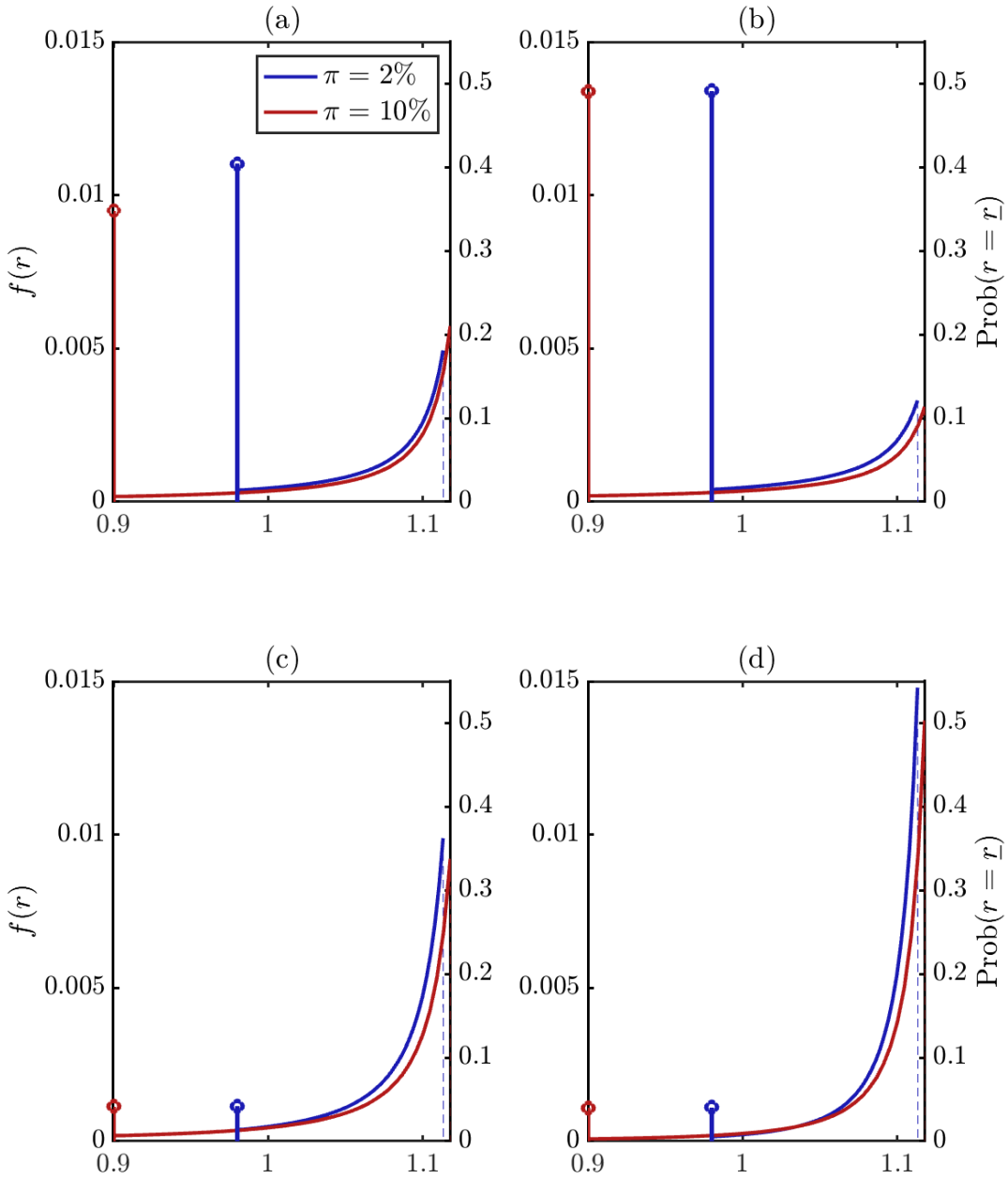


Figure 7: Rates of return on wealth for the whole population (panel a), lowest (panel b), intermediate (panel c), and highest (panel d) financial human capital households.

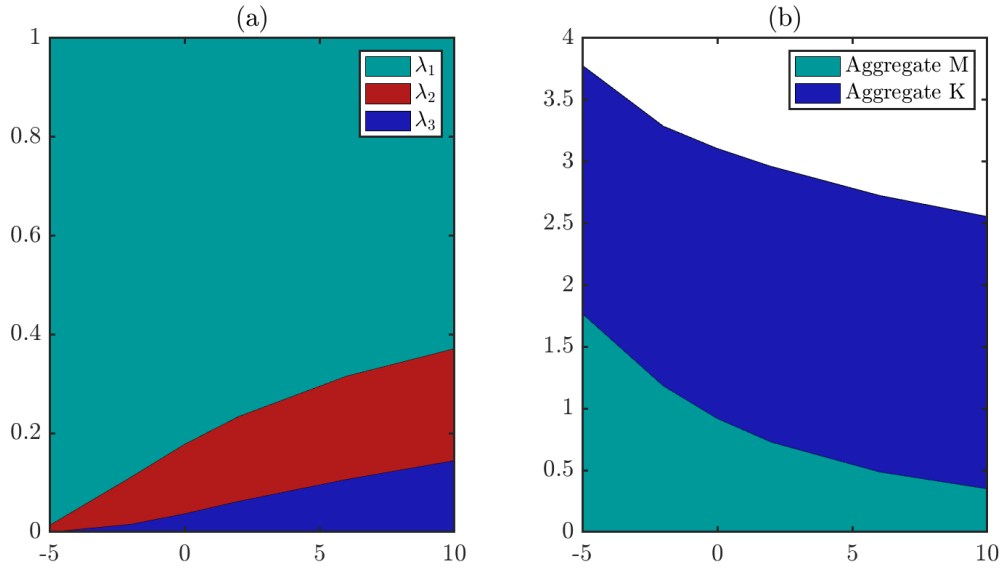


Figure 8: Panel (a): Distribution of financial human capital as a function of inflation; Panel (b): Aggregate wealth, capital and money as a function of inflation.

poorer.

In the paragraphs above, we discussed the equilibrium effects of a permanent increase in the inflation rate from 2 to 10%. These effects are generally monotonic in inflation over the interval of rates between 2 and 10%. Namely, real interest rates on capital are decreasing in inflation, the dispersion of real interest rates across households with different levels of financial knowledge is increasing in inflation; aggregate wealth, aggregate money, and aggregate capital are decreasing in inflation; wealth inequality is increasing in inflation.

Naturally, we can also examine what happens when we lower inflation and move towards the Friedman rule. Let us focus on the effect of lowering inflation from 2% to -5%. Figure 9 show that an inflation rate of -5% increases and compresses the distribution of real interest rates on capital. Indeed, an inflation rate of -5% means that households can guarantee themselves a 5% real return by simply holding their savings in cash. The return on money forces firms to offer higher rates of return on capital. The return on money pushes up the return on capital at the bottom of the distribution F more than at the top and, for this reason, it compresses the distribution. Since the return on money increases more than the return on capital and the distribution of returns on capital becomes more compressed, households accumulate less financial knowledge, as shown in Figure 8. Up to this point, the effect of lowering inflation below 2% is simply the opposite of the effect of raising inflation above 2%, but, as we are about to show momentarily, this is not always the case.

Figure 8 shows that aggregate wealth and the aggregate stock of money are monotonically decreasing in inflation. The aggregate stock of capital is hump-shaped in inflation.

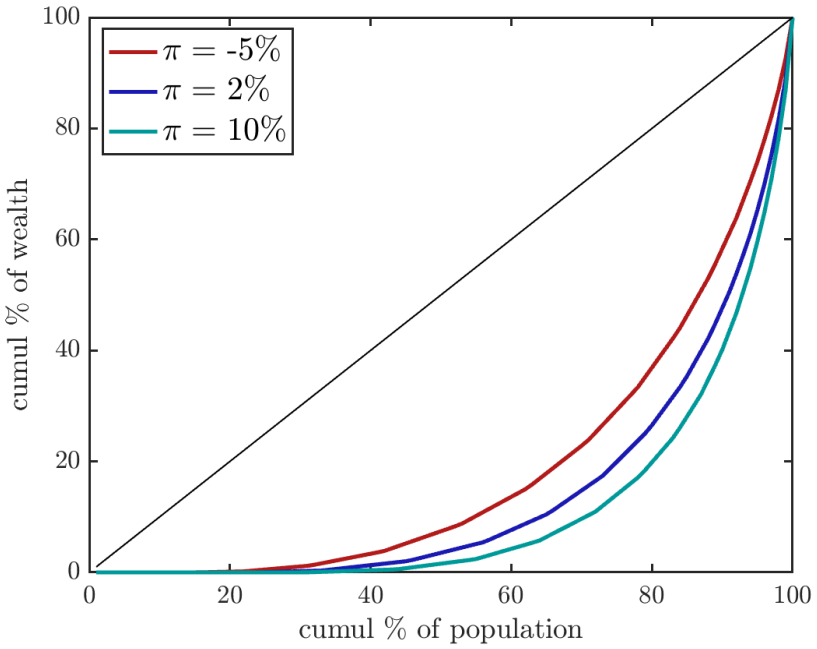


Figure 9: Wealth inequality for different inflation rates.

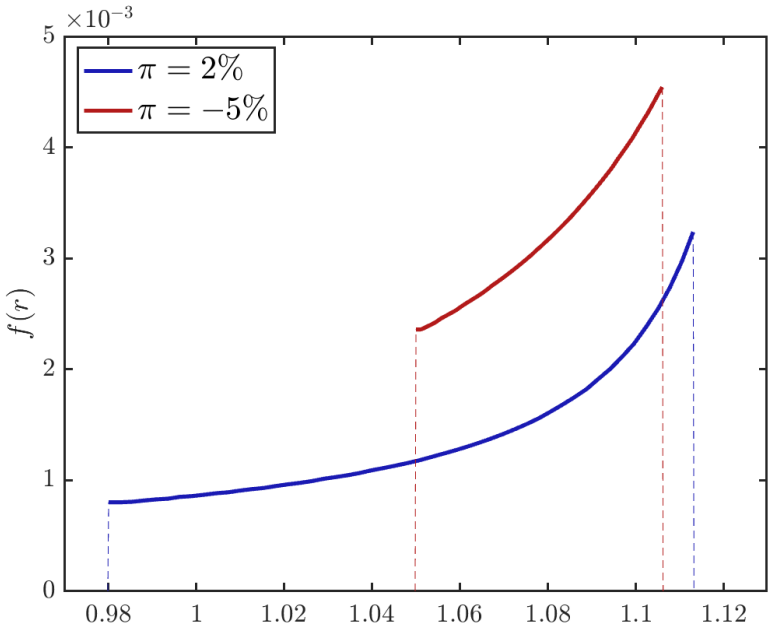


Figure 10: Distribution F of rates of return on capital at 2% and -5% inflation.

Indeed, the aggregate stock of capital declines precipitously as inflation approaches the Friedman rule. When the rate of return on money approaches the marginal product of capital, the household's incentives to acquire financial knowledge vanish and, as a result, the fraction of the households' wealth that ends up in the hands of the firms becomes smaller and smaller causing the capital stock to shrink. Following an inflation rate close to the Friedman rule makes money such a good substitute for capital that households do not spend any resources to access the capital market.

Let us now turn to the welfare effects of inflation. Inflation increases the dispersion in the real rates faced by the households and, for this reason, it tends to increase risk and lower welfare. Inflation increases the gap between the real rates faced by the households and the marginal product of capital and, for this reason, it tends to distort wealth accumulation and lower welfare. Inflation affects the portfolio allocation of households away from money and towards capital, which tends to increase welfare.

Figure 11 plots welfare as a function of inflation. Following Lucas (2000), we measure welfare as the percentage change in consumption that would make households indifferent between living in an economy with an inflation rate of 2% and living in an economy with a different inflation rate. These welfare calculations are subject to the caveat of comparing steady states and, for this reason, they need to be taken with a grain of salt. For an inflation rate of -5%, welfare is 1.75% higher than in the baseline because households earn higher and less uncertain rates of return on wealth. For an inflation rate of -5%, welfare is higher than in the baseline even though the capital stock is lower and output is 3% lower. For an inflation rate of 10%, welfare is 2.26% lower than in the baseline because households face earn lower and more uncertain rates of return on wealth.

Figure 11 also plots welfare for poor and rich households. Even though inflation increases wealth inequality and risk in rates of return, the poorest 20% of households benefits the most from inflation. These households have very little wealth and the distortions created by inflation in the capital market do not affect them, while the revenues generated by seignorage increase their after-tax labor earnings. The middle class suffers the most from inflation as they have some wealth that now earns lower and more uncertain returns. The richest 1% benefits from inflation, as they tend to be so financially educated to be able to avoid the distortionary effects of inflation.

4.2 Price discrimination

In the baseline model, firms cannot discriminate households in the capital market—in the sense that they cannot tailor the interest rate that they offer to the lenders' characteristics, such as their financial human capital or their wealth, or to the lenders' circumstances, such as the number or quality of their alternative investment opportunities. The underlying assumption is that firms are either unable or forbidden from discriminating lenders. In this subsection, we want to use the calibrated model to measure the equilibrium and welfare

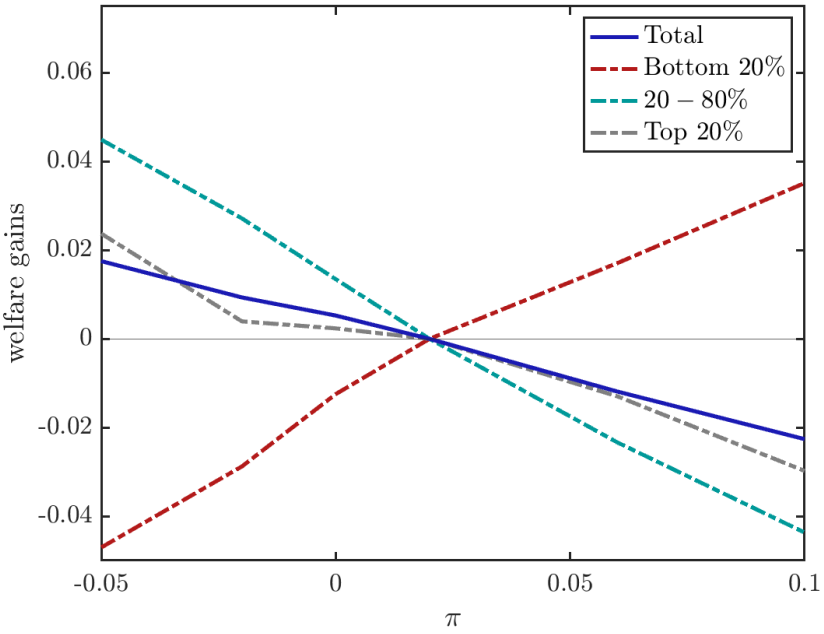


Figure 11: Welfare effect of moving inflation from 2%.

effects of legal reforms or technological innovations that allow firms to discriminate lenders based on their financial human capital.

If firms can discriminate lenders based on their financial human capital, each firm can offer a potentially different interest rate to different types of household. A firm that offers the interest rate $r \geq \underline{r}$ to households with financial human capital λ_i enjoys the profit

$$\pi_i(r) = \lambda_i e^{-\lambda_i(1-F_i(r))} S_i(r^* - r). \tag{4.1}$$

In the expression above, F_i denotes the distribution of interest rates offered to households of type i. As in Section 2, it is easy to establish that the distribution F_i does not have any mass points, and that the support of the distribution F_i is some interval $[r_{i,\ell}, r_{i,h}]$, with $r_{i,\ell} = \underline{r}$.

The firm's profit (4.1) must attain its maximum at every interest rate r on the interval $[r_{i,\ell}, r_{i,h}]$. This observation implies that

$$e^{-\lambda_i}(r^* - \underline{r}) = e^{-\lambda_i(1-F_i(r))}(r^* - r). \tag{4.2}$$

From (4.2), it follows that a firm at the x-th quantile of the distribution F_i offers the interest rate

$$r_i(x) = r^* - \frac{e^{-\lambda_i}}{e^{-\lambda_i(1-x)}}(r^* - \underline{r}). \tag{4.3}$$

Since the right-hand side of (4.3) is strictly increasing in λ_i and $\lambda_{i+1} > \lambda_i$, it follows that $r_{i+1}(x) > r_i(x)$. The distribution of interest rates that firms offer to households with higher financial human capital first-order stochastically dominates the distribution of interest rates that firms offer to households with lower financial human capital. This

finding is intuitive. Since households with more financial human capital are able to locate more investment opportunities, firms have to compete more intensely for them, and they offer them higher interest rates.

If firms cannot discriminate lenders, a firm at the x-th quantile of the distribution F offers the interest rate

$$r(x) = r^* - \frac{\sum_{i=1}^{I} \lambda_i e^{-\lambda_i} S_i}{\sum_{i=1}^{I} \lambda_i e^{-\lambda_i (1-x)} S_i} (r^* - \underline{r}). \tag{4.4}$$

A comparison between (4.4) and (4.3) reveals that households with relatively high financial human capital are offered higher interest rates when firms can discriminate. Conversely, households with relatively low financial human capital are offered lower interest rates when firms can discriminate. The finding is intuitive. When firms cannot price discriminate, the extent of competition in the market is determined by the average financial human capital of all the households. When firms can discriminate lenders, the markets where households with high and low financial human capital search are segmented. The market populated by households with relatively high financial human capital is more competitive than average, and firms offer higher interest rates. The market populated by households with relatively low financial human capital is less competitive than average, and firms offer lower interest rates. Note that, since households with relatively high financial human capital tend to be richer and households with relatively low financial human capital tend to be poorer, discrimination tends to increase inequality.

Discrimination affects the households' savings decision of households. The optimality condition for savings s is given by

$$\begin{aligned} & u'(a + wz(1-\tau) - e - s) \\ \geq \quad & \beta \mathbb{E}_{\hat{z}|z} \left\{ \sum_{\hat{i}=1}^{I} \phi_\lambda(\hat{\lambda}|\lambda, e) \left[\sum_{n=0}^{\infty} \frac{e^{-\lambda} \lambda^n}{n!} \int r \frac{\partial V_{\hat{i}}(sr, \hat{z}, \hat{\lambda})}{\partial a} dF_{i,n}(r) \right] \right\}, \end{aligned} \tag{4.5}$$

and $s \geq 0$, where the two inequalities hold with complementary slackness. In the above expression, $F_{i,n}(r)$ denotes the distribution of the highest interest rate offered to a household that has financial human capital λ_i and comes into contact with n firms in the capital market. For households with relatively high financial human capital, the distribution of the highest of n interest rates is higher when firms can discriminate. Therefore, households with relatively high financial human capital tend to save more when firms can discriminate. In contrast, for households with relatively low financial human capital, the distribution of the highest of n interest rates is lower when firms can discriminate. Therefore, households with relatively low financial human capital tend to save less when firms can discriminate. Again, discrimination tends to increase inequality.

Discrimination also affects the households' investment decision in financial human

capital. The optimality condition for investment in financial human capital e is given by

$$\begin{aligned} & u'(a + wz(1-\tau) - e - s) \\ \geq \quad & \beta \mathbb{E}_{\hat{z}|z} \left\{ \sum_{i=1}^{I} \frac{\partial \phi_\lambda(\hat{\lambda}|\lambda, e)}{\partial e} \left[\sum_{n=0}^{\infty} \frac{e^{-\lambda}\lambda^n}{n!} \int V(sr, \hat{z}, \hat{\lambda}) dF_{i,n}(r) \right] \right\}, \end{aligned} \tag{4.6}$$

and $e \geq 0$, where the two inequalities hold with complementary slackness. When firms cannot discriminate lenders, the benefit to the household from investing in financial human capital is given by the value of sampling more firms. When firms can discriminate lenders, the benefit to the household from investing in financial human capital is given by the value of sampling more firms and the value of being offered higher interest rates. Therefore, when firms can discriminate lenders, households tend to invest more in financial human capital.

Figure 12 plots the distribution of interest rates offered to households with different financial human capital. The median interest rate offered to households with the lowest financial human capital is 1.60%, the 10th percentile interest rate is -1.19%, and the 90th percentile is 3.78%. The median interest rate offered to households with the highest financial human capital is 7.71%, the 10th percentile interest rate is 1.41%, and the 90th percentile interest rate is 9.64%. Figure 12 also plots the distribution of interest rates offered to households when firms cannot discriminate. The median interest rate is 6.88%, the 10th percentile interest rate is 0.28%, and the 90th percentile interest rate is 10.71%. Discrimination leads to a significant decline in the interest rates offered to households with low financial human capital.

	Baseline	Discrimination	Literacy Program
Wealth shares (%)			
bottom 50%	1.07	1.01	1.45
50-90%	37.98	37.60	40.24
90-99%	45.86	46.33	44.30
top 1%	15.09	15.06	14.01
Human Capital shares (%)			
% λ_1	76.57	62.91	59.39
% λ_2	17.16	19.65	28.13
% λ_3	6.27	17.45	12.48
Aggregate Measures			
Wealth	2.96	3.39	3.18
Capital	2.23	2.88	2.50
Capital/Wealth	0.75	0.85	0.79

Table 3: Effects of price discrimination and financial literacy.

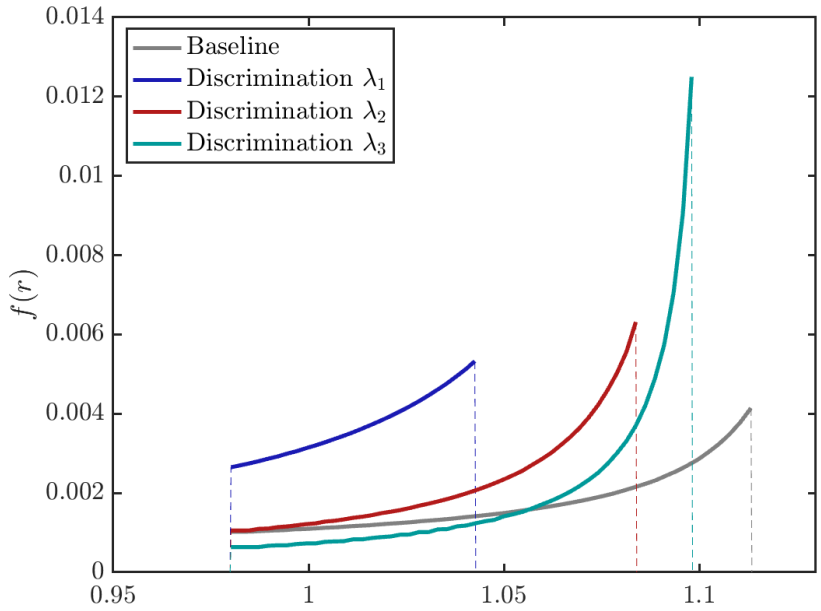


Figure 12: Distribution F of rates of return with and without price discrimination.

Table 3 displays the distribution of financial human capital among households. The fraction of households with the lowest financial human capital is 63%, the fraction of households with the intermediate financial human capital is 20%, and the fraction of households with the highest human capital is 17%. When firms cannot discriminate, the fraction of households with the lowest financial human capital is 77%, the fraction of households with the intermediate financial human capital is 17%, and the fraction of households with the highest human capital is 6%. Discrimination induces households to accumulate more financial knowledge. Discrimination also tends to increase wealth inequality, although the effect is mostly offset by the increase in financial knowledge.

Table 4 shows the welfare consequences of discrimination in the capital market for households at different deciles of the wealth distribution. The welfare of the poorest 50% of households decreases significantly, since discrimination forces these households to either earn lower rates of return or to invest in financial human capital. The welfare of the richest 50% of households increases significantly, since discrimination allows these households to earn higher rates of return. The welfare effect is strongest for the richest 10% of households. The overall effect of price discrimination of welfare is close to zero, but the effect on welfare inequality is large.

	Discrimination	Literacy Program
Aggregate	0.49	1.90
bottom 15%	-3.82	-1.15
15-30%	-2.71	2.96
30-50%	-0.28	1.57
50-90%	3.17	3.51
90-99%	12.65	0.96
top 1%	9.38	-6.10

Table 4: Welfare effect of price discrimination and financial literacy.

4.3 Financial literacy

When a household decides to invest in its financial human capital, it creates a positive externality on other households. From the perspective a household, the benefit of investing in financial human capital is an increase in the number of firms contacted in the capital market and, in turn, an increase in the rate of return on savings. From the perspective of other households, the benefit of a household investing in financial human capital is an increase in the competitiveness of the capital market and, in turn, an increase in the rates of return offered by firms. The positive externality that households create on others when investing in financial human capital means that the stock of financial knowledge is inefficiently low.

We use the calibrated model to quantify the effects of introducing a financial literacy program. The program is such that households receive $\underline{e}$ units of investment in financial human capital for free from the government. The program is financed by adjusting the tax rate on labor earnings so as to maintain a balanced budget. Specifically, we consider a program in which the cost of the program is equal to $1\% of output$.

Table 3 shows the distribution of financial human capital among households. The fraction of households with the lowest level of financial human capital falls from 77 to 59%. The fraction of households with the intermediate level of financial human capital increases from 17 to 28%. The fraction of households with the highest level of financial human capital increases from 6 to 12%. Obviously, a program that provides a subsidy to households in the form of free financial education increases the stock of financial human capital in the population.

Figure 13, panel (a), shows the distribution of interest rates offered to households. The median interest rate is 6.60%, the 10th percentile interest rate is 0.28%, and the 90th percentile is 10.71%. In comparison, without the financial literacy program, the median interest rate is 6.88%, the 10th percentile interest rate is 0.28%, and the 90th percentile interest rate is 10.71%. It appears that the financial literacy program decreases rates of return. However, this is just a by-product of a higher capital stock. Panel b of Figure 13 shows the distribution of markdowns that firms extract under the financial literacy

program.

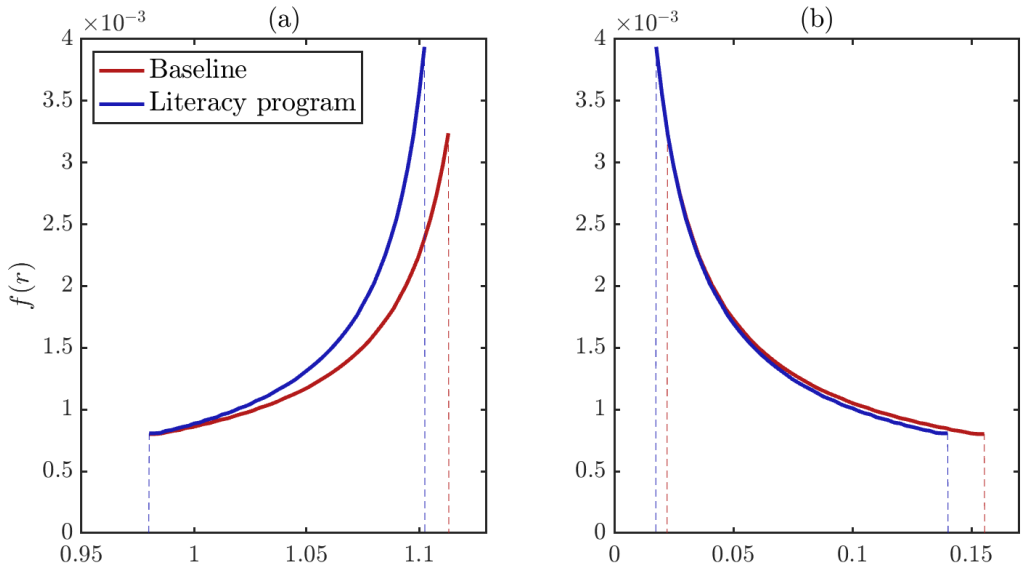


Figure 13: Panel (a): Distribution of rates of return on capital; Panel (b): Distribution of markdowns on rates of return on capital.

By increasing financial knowledge, the financial literacy program induces households to accumulate more wealth. The aggregate stock of wealth increases by 7.4%. By increasing financial knowledge, the financial literacy program leads to a reallocation of the households' wealth composition away from money and into capital. Indeed, the fraction of the households' wealth invested in money falls from 25 to 21%, while the fraction of wealth invested in capital increases from 75 to 79%. Since wealth and the fraction of wealth invested in capital both increase, the aggregate capital stock increases as well.

Table 3 displays the wealth distribution. The fraction of wealth in the hands of the poorest 50% is 0.4 percentage point higher with the financial literacy program in place. In contrast, the fraction of wealth in the hands of the richest 10% is 2.6 percentage points lower. Similarly, the fraction of wealth in the hands of the richest 1% is 1.1 percentage points lower. The financial literacy program is effective at reducing wealth inequality by weakening the relationship between wealth and rates of return on wealth.

Table 4 shows the welfare consequences of the financial literacy program. The welfare of the poorest 15% of households declines, since these households pay for the financial literacy program by facing higher labor income taxes, but receive no benefit from the program because they have essentially no wealth. The welfare of the middle class increases substantially, since these households benefit from the subsidy to their financial human capital. The welfare of the very rich declines, as the marginal product of capital falls. Overall, this fully-funded financial literacy program can increase welfare by almost 2%.

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