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Macroeconomic implications of financial policy

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A B S T R A C T

This paper studies the effects of financial policy in a model with heterogeneous agents, incomplete markets and portfolio restrictions. For an economy calibrated to replicate key aspects of the U.S. wealth distribution, we find that the quantitative effects of financial policy are relatively small. The reason is that the households determining aggregate behavior are relatively well insured and can therefore offset the actions of the firm by modifying their portfolio allocations. However, financial policy has important effects on asset prices. Whereas a higher level of debt in the capital structure of the firm introduces more risk into the economy by increasing the volatility of the equity return, it enhances the liquidity of households by increasing the supply of bonds. In an economy with a substantial amount of heterogeneity, this last effect dominates and leverage leads to a decrease in the equity premium. This is in contrast to the findings in representative agent models, in which leverage unambiguously increases the premium through a higher equity return volatility.

1. Introduction

The Modigliani–Miller theorem (1958, 1963) on the irrelevance of the firm's financial policy has been shown to hold in a wide range of environments. In particular, Stiglitz (1969, 1974) extended the partial equilibrium argument developed by the previous authors to a multi-period general equilibrium setup with uncertainty, showing that financial policy is irrelevant for the equilibrium allocations and the value of firms. Moreover, DeMarzo (1988) and Gottardi (1995) showed that this result holds in a more general setting with incomplete financial markets. The previous studies, however, have maintained the convenient assumption of the absence of binding borrowing limits. Given this, they have abstracted from the possibility that financial policy has real effects due to the fact that agents are borrowing constrained.

The aim of this paper is to contribute towards filling this gap by providing a quantitative evaluation of the effects of the firm's financial policy in an environment with incomplete markets, substantial wealth heterogeneity and constraints on borrowing that are effectively binding in equilibrium. This is motivated by two main considerations. First, the friction we study is empirically relevant. The literature documents that there is a fairly high share of borrowing constrained households that ranges between 20% and 30% depending on the assets considered and the type of surveys (see e.g. Jappelli, 1990 or Budria et al., 2002). It is thus important to understand to what extent this interacts with the composition of the capital structure of the firms. For example, by determining the supply of assets though its financial policy, the firm could directly affect the share of households who are at the borrowing constraint.

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Second, the presence of binding borrowing limits breaks the traditional Modigliani–Miller result, which relies on the possibility that households can undo the financial policy of the firm by changing their portfolio allocations. Clearly, in an environment with borrowing constraints, households for whom the trading limits are binding will be restrained in their ability to change their portfolio following a change in financial policy. Given this, the effects of financial policy on the portfolio composition of households could have a fairly large effect on the allocations and macroeconomic aggregates. In addition, financial policy can also affect asset prices. For example, by issuing debt, firms could potentially enhance the liquidity of households by allowing them to accumulate bonds. In turn, this increase in liquidity could potentially offer better self-insurance for borrowing constrained households and decrease the market price of risk.

To investigate these conjectures, we analyze a model with incomplete markets and heterogeneous agents which closely matches the earning process and the distribution of asset holdings in the United States. Households face both idiosyncratic uncertainty and aggregate risk. Idiosyncratic uncertainty arises from a stochastic earnings process that matches the Gini coefficient of earning in the U.S., while aggregate risks arise from productivity shocks and unemployment fluctuations. Markets are assumed to be incomplete, since households can only partially self-insure against these risks by trading in risk free bonds and risky stocks, against which they cannot borrow. This type of incomplete markets economy was originally developed and analyzed by Krusell and Smith (1997) and it has become a standard workhorse for quantitatively analysis (see also Pijoan-Mas, 2007 and Cocco et al., 2005). However, the focus has been on the households' portfolio allocations and financial policy has been ignored. In the present paper, we model firms as dynamic entities by adopting the value maximization firm objective studied by Duffie and Shaffer (1986), DeMarzo (1988) and Carceles-Poveda and Coen-Pirani (2009). Further, we embed the financial policy of firms by assuming that they can raise external finance using two types of contracts: a risk free bond and risky equity. Even though the capital structure is determined exogenously by the leverage ratio, our approach constitutes a first step towards the study of the real effects of financial policy in models with heterogeneous shareholders.

Using the framework described above, the effects of financial policy are quantified by comparing environments with different levels of leverage. We first study the properties of a benchmark economy with a leverage ratio that is close to the one observed in the U.S. (see Rajan and Zingales, 1995). The benchmark model closely matches both the Gini of earnings and the share of households that are borrowing constrained in stocks, while it generates a high Gini coefficient for the risky asset holdings, as in the data. We then evaluate to what extent a change in firm financial policy modifies the macroeconomic properties and asset prices alongside with the wealth distribution and the portfolio allocations. Our main results can be summarized as follows.

First, we find that financial policy has important effects on asset prices. In particular, an increase in leverage has two opposite effects on the equity premium, which can be written as the product of the equity return standard deviation and the sharpe ratio. On the one hand, leverage makes equity riskier by increasing the spread between the payoffs in good and bad times and this tends to increase the premium. On the other hand, the sharpe ratio decreases with leverage in the presence of household heterogeneity and this tends to decrease the equity premium. Overall, the latter effect dominates when we move from an economy with no leverage to a leveraged economy, in which case we find that a higher level of leverage leads to a decrease in the premium. Further, the two effects seem to almost cancel with higher levels of leverage, in which case the premium is relatively constant. Interestingly, our findings are in contrast to the ones in representative agent economies such as the one studied by Jermann (1998). In this case, the latter effects on the sharpe ratio are not present, and the premium increases considerably with a higher level of leverage due to a higher volatility of stock returns. In sum, financial policy has important effects on asset prices in the presence of household heterogeneity through its effects on the degree of risk sharing.

Several important effects explain the decline in the sharpe ratio and the premium in the presence of household heterogeneity and borrowing constraints. On one hand, the introduction of leverage provides an additional way of smoothing consumption by allowing households to accumulate more risk free bonds.[1] Since households can reduce their exposure to risk thanks to the bonds issued by firms in a leveraged economy, they will then demand a lower compensation for holding risky assets. Moreover, the fact that a higher level of leverage has a similar effect to the one of loosening the borrowing constraints on debt implies that the risk free rate will increase with leverage. This has important consequences on the portfolio allocations and the wealth distribution. In particular, the agents that price in an economy with no leverage are mostly the ones with the highest labor market risk. However, following an increase in leverage, some of the households facing low risks will incorporate bonds to their portfolio and become pricing agents. This implies that the pool of pricing agents will incorporate people with relatively low consumption fluctuations and will loose people with relatively high consumption fluctuations following an increase in leverage.

Second, in spite of the effects of leverage on asset prices and the wealth distribution, we find that the Modigliani Miller irrelevance result approximately holds in this environment. In other words, the effects of firm leverage on the real allocations and the value of the firm are negligible, in spite of the fact that borrowing constraints are binding for a high share of the population. The key insight for this result is related to the approximate aggregation result found by Krusell and Smith (1997, 1998) in a similar model with no leverage. In this class of incomplete market models, the effective insurance achieved with only one asset is almost perfect in utility terms. Further, the marginal propensity to save of the well-insured

[1] To a certain extent, this result is similar to the effects of a higher government debt that is described in Aiyagari and McGrattan (1998), with the difference that these authors focus on long term stationary equilibria and therefore ignore the effects of more debt on asset price fluctuations.

individuals is very similar among agents and is close to the one of a representative agent, while the marginal propensity is only different for those agents that are at or close to the borrowing constraint on total wealth. These last agents, however, have a marginal effect on the aggregates due to the fact that their asset holdings are too low to contribute to the law of motion of aggregate wealth. In other words, only the rich and well insured agents with almost linear saving rules matter for determining the aggregates. The presence of leverage only reinforces this approximate aggregation argument, since it increases the supply of bonds and provides additional self-insurance. Changes in the portfolio composition and the wealth distribution induced by the financial policy of the firm have, therefore, little effect on the aggregate laws of motion.

To summarize, on the one hand, aggregate allocations are not affected by financial policy. As explained before, this is due to the fact that the behavior of the aggregates is essentially determined by agents that are relatively well insured and are not affected much by an increase in leverage. On the other hand, a higher leverage affects all households and in particular it enhances the liquidity of the relatively poor. Since these agents participate in financial markets to insure against risks, financial policy affects their wealth and portfolio allocations and as a consequence it has an effect on asset prices.

The rest of the paper is organized as follows. Section 2 presents the model and Section 3 presents the calibration and solution method. Further, Section 4 presents the numerical results and Section 5 summarizes and concludes.

2. The model

We consider an infinite horizon economy with aggregate uncertainty and idiosyncratic labor income risk. The economy is populated by a representative firm and by a continuum of infinitely lived households. Markets are incomplete, implying that households cannot write contracts whose payments are contingent on the realization of their idiosyncratic labor income shock. Thus, even though households are ex-ante identical, they differ in equilibrium due to their different labor shock realizations and accumulated wealth.[2]

2.1. Production technology

Each period t, the representative firm uses aggregate capital $K_t \in \mathbb{R}_+$ and aggregate labor $L_t \in \mathbb{R}_+$ to produce $y_t \in \mathbb{R}_+$ units of a single good with the aggregate technology $y_t = f(z_t, K_t, L_t)$, where z_t is an aggregate productivity shock. We assume that z_t can take a finite number of values in the set $Z \equiv \{z_1, z_2, \ldots, z_{N_z}\}$ and that it follows a stationary Markov process with transition function $\Pi_z(z, z') = \Pr(z_{t+1} = z' \mid z_t = z)$. Given z_t, the production function $f(z_t, \cdot, \cdot) : \mathbb{R}_+^2 \to \mathbb{R}_+$ is continuously differentiable on the interior of its domain, strictly increasing, strictly concave and homogeneous of degree one in K and L. We also assume that $\lim_{K\to 0} f_K = \infty$ and $\lim_{K\to\infty} f_K = 0$. Capital depreciates at the constant rate $\delta \in (0, 1)$ and it accumulates according to the standard equation:

$$K_{t+1} = I_t + (1 - \delta)K_t \tag{1}$$

where I_t denotes aggregate investment.

2.2. Preferences

Households are indexed by i and they have identical and additively time-separable preferences over sequences of consumption $c_i \equiv \{c_{i,t}\}_{t=0}^{\infty}$ of the form:

$$U(c_i) = E_0 \sum_{t=0}^{\infty} \beta^t u(c_{i,t}) \tag{2}$$

where $\beta \in (0, 1)$ is the subjective discount factor, E_t denotes the expectation conditional on information at time t, and u is the period utility function, assumed to be strictly increasing, strictly concave and twice continuously differentiable, with $\lim_{c\to 0} u'(c) = \infty$ and $\lim_{c\to\infty} u'(c) = 0$.

2.3. Idiosyncratic uncertainty

Each period, households are subject to idiosyncratic labor income risk that can be decomposed into two parts.[3] First, there is an employment possibility that depends on aggregate risk and is denoted by $e_t \in E \equiv \{0, 1\}$. When $e = 1$, we think of the agent as employed, while $e = 0$ denotes that the agent is unemployed. Conditional on z_t and z_{t+1}, we assume that the period $t + 1$ realization of the employment shock follows a Markov process with transition function

$$\Pi_e(z, z', e, e') = \Pr(e_{t+1} = e' \mid e_t = e,\ z_t = z,\ z_{t+1} = z').$$

---

[2] Results not reported here show that our qualitative and quantitative findings regarding the effects of financial policy are very similar in a model with only two agents.

[3] This structure of uncertainty has been used by Pijoan-Mas (2007) and it follows Krusell and Smith (1997, 1998).

Note that this particular structure for the law of motion of the idiosyncratic shock serves for two purposes. It allows for the labor market uncertainty to be correlated with the aggregate uncertainty, as suggested by Mankiw (1986). In addition, one can impose conditions on the previous transition matrix so that aggregate employment is only a function of the productivity shock by the law of large numbers. This implies that we do not need to include employment as an additional state variable.

Second, if an agent is employed, we assume that he is endowed with $l_t \in L \equiv \{l_1, l_2, \ldots, l\}$ efficiency labor units that will be supplied to the firm. The efficiency level is independent of the aggregate productivity shock l_t and it follows a stationary Markov process with transition function $\Pi_l(l, l') = \Pr(l_{t+1} = l' \mid l_t = l)$. With this process, we will capture important facts of the cross sectional earnings and wealth distributions. Since the average labor efficiency is constant by the law of large numbers, we can normalize its unconditional expectation to one without loss of generality. Finally, if an agent is unemployed, we assume that he receives an exogenous amount g of goods, which can be interpreted as home production or unemployment insurance. In what follows, we use u_g and u_b to denote the unemployment rates in good and bad times respectively.

2.4. Financial markets

In this economy, firms decide on the aggregate investment and they can raise external finance using two types of contracts. The first is a one period risk free bond that promises a fixed return to the owner. The second is risky equity that entitles the owner to be the residual claimant of the firms profits once the bonds have been paid. Both assets are freely traded in competitive financial markets.

As mentioned earlier, markets are assumed to be incomplete, in the sense that there are no markets for assets contingent on the realization of the individual shocks. This implies that households can only trade in the two different assets described above: one-period risk free claims to next period consumption units $b_{i,t+1} \in \mathbb{B} \equiv [\kappa_t^b, \infty)$ and equity claims on the representative firm's profits $s_{i,t+1} \in \mathbb{S} \equiv [\kappa_t^s, \infty)$. The lower bounds κ_t^s and κ_t^b on holdings of each type of asset may be imposed as some constraints on short selling or they may be set more loosely such as to avoid Ponzi schemes.[4]

2.5. The households' problem

Household i maximizes his expected lifetime utility subject to the following constraints:

$$c_{i,t} + s_{i,t+1} + b_{i,t+1} = \omega_{i,t}, \tag{3}$$

$$\omega_{i,t+1} = \begin{Bmatrix} w_{t+1} l_{i,t+1} + R_{t+1}^s s_{i,t+1} + R_{t+1}^b b_{i,t+1} & \text{if } e = 1 \\ g + R_{t+1}^s s_{i,t+1} + R_{t+1}^b b_{i,t+1} & \text{if } e = 0 \end{Bmatrix}, \tag{4}$$

$$(c_{i,t}, b_{i,t+1}, s_{i,t+1}) \geqslant \left(0, \kappa_{t+1}^b, \kappa_{t+1}^s\right). \tag{5}$$

In the previous equations, w is the aggregate wage rate paid by the firm and R_{t+1}^s and R_{t+1}^b denote the gross returns on equity and bond holdings respectively. Further, $\omega_{i,t}$ represents the individual vector of wealth at the beginning of the period, defined as the sum of labor earnings and asset income generated by the previous period investments. The law of motion of individual wealth is given by Eq. (4) and condition (5) are the individual feasibility constraints. As mentioned earlier, the asset holdings are subject to possibly state dependent trading constraints. The first order conditions from the previous maximization problem imply that, for each agent i:

$$1 \geqslant E_t\left\{\mathcal{M}_{i,t,t+1} R_{t+1}^s\right\} \quad \text{and} \quad s_{i,t+1} \geqslant \kappa_{t+1}^s,$$

$$1 \geqslant E_t\left\{\mathcal{M}_{i,t,t+1} R_{t+1}^b\right\} \quad \text{and} \quad b_{i,t+1} \geqslant \kappa_{t+1}^b$$

where $\mathcal{M}_{t,t+1}^i = \beta \frac{u_c(c_{i,t+j})}{u_c(c_{i,t})}$ represents the stochastic marginal rate of substitution of household i between periods t and $t+1$. As usual, the previous two conditions hold with equality for households for which the trading constraints are not binding. Let $q_{t,t+1}^s$ and $q_{t,t+1}^b$ the stochastic marginal rates of substitution corresponding to any household that is unconstrained at period t in the markets for shares and bonds respectively, that is,

$$q_{t,t+j}^x \equiv \left\{\mathcal{M}_{t,t+j}^i :\ x_{i,t+j} > \kappa_{t+j}^x \text{ for } x = s \text{ or } b\right\}. \tag{6}$$

Using this notation, we can rewrite the asset pricing equations as follows:

$$1 = E_t\left\{q_{t,t+1}^s R_{t+1}^s\right\}, \tag{7}$$

$$1 = E_t\left\{q_{t,t+1}^b R_{t+1}^b\right\}. \tag{8}$$

We will find useful to rewrite the household problem recursively. To do this, we drop the time subscripts and denote by prime the variables dated next period. In addition, instead of identifying households by their label i, we do it by their vector

[4] Carceles-Poveda (2006) shows that there exist endogenous borrowing limits under which financial policy is irrelevant. However, the Modigliani–Miller irrelevance result breaks under the limits studied in this paper.

of individual state variables. This vector is given by the agents' wealth $\omega \in \Omega = [\underline{\omega}, \infty)$ at the beginning of the period, by the employment opportunity e and by the efficiency units endowment l. Let μ be the probability measure over a σ-algebra generated by the set $\Omega \times E \times L$ and let $\mu' = \Gamma(\mu, z, z')$ be the transition function.[5] The aggregate state of the economy is then given by the aggregate shock z and by the distribution μ of agents over their individual state variables. Given prices and the choice of capital K' of the firm, the household problem in recursive form is then given by

$$v(\omega, e, l; z, \mu) = \max_{c,b',s'} \left\{ u(c) + \beta E_{e',l',z'|e,l,z}\left[v(\omega', e', l'; z', \mu') \right] \right\} \tag{9}$$

subject to

$$\begin{aligned} & c = \omega - b' - s', \\ & \omega' = \begin{Bmatrix} b'R^b(\mu, z) + s'R^s(\mu', z') + w(\mu', z')l' & \text{if } e = 1 \\ b'R^b(\mu, z) + s'R^s(\mu', z') + g & \text{if } e = 0 \end{Bmatrix}, \\ & L' = g^L(z') \quad \text{and} \quad \mu' = \Gamma(z, \mu, z'), \\ & c \geqslant 0, \quad b' \geqslant \kappa^b \quad \text{and} \quad s' \geqslant \kappa^s. \end{aligned} \tag{10}$$

The expression $E_{x'|x}$ is the operator for the mathematical expectation with respect the distribution of x' conditional on x and the laws of motion for e', l' and z' are therefore implicit in this operator. Further, g^L and Γ are the laws of motion that agents use to forecast the next period labor and the joint distribution of individual shocks and wealth. Finally, note that the gross return on bonds depends on today's aggregate state and it is therefore known at the time of taking decisions. In contrast, the return on shares and the aggregate wage depend on next period's realization of the aggregate shock.

2.6. The firm's problem

The firm owns the capital stock and decides on the aggregate investment level. As mentioned earlier, investment can be financed with retained earnings or through the issue of new securities. These include common stocks and risk free one period bonds, whose outstanding number at the end of period t is denoted by $S_{t+1} \in \mathbb{R}_{++}$ and $B_{t+1} \in \mathbb{R}_{++}$ respectively. The budget constraint for the firm is therefore given by

$$d_t^s S_t = N_t + p_t^s(S_{t+1} - S_t) + B_{t+1} - R_t^b B_t. \tag{11}$$

In the previous equation, $d_t^s S_t$ are the total dividends, d_t^s and p_t^s are the per share dividend and stock price respectively and $N_t = f(z_t, K_t, L_t) - w_t L_t - I_t$ is the firm's net cash flow. The previous equation implies that total dividends and investment are equal to the firm's profits and the net value from the two securities issued during period t, net of the interest payments to debt holders.

In what follows, we let $V_t = p_t^s S_{t+1} + B_{t+1}$ be the ex-dividend firm value and $\rho = \frac{B_{t+1}}{V_t}$ the leverage ratio, representing the fraction of the firm value accounted for by corporate debt. As we see, the leverage ratio fully determines the composition of the firm's capital structure, since $B_{t+1} = \rho V_t$ and $p_t^s S_{t+1} = (1 - \rho)V_t$. In the present paper, we assume that firms do not choose the optimal composition of capital between bonds and capital shares but instead take the exogenous leverage ratio $\rho \in [0, 1)$ as given when they decide on the level of investment. Clearly, the exogeneity of ρ is quite a strong assumption, but it suffices for our purpose of measuring how important are different levels of leverage for the individual and aggregate allocations. It is well known that, in a complete markets setting, leverage is irrelevant and firms are thus indifferent between different levels of ρ. However, this is not the case when markets are incomplete and households are subject to portfolio restrictions.

Unfortunately, the definition of an appropriate firm objective in the present setting is not straightforward, since the usual profit maximization objective is no longer well defined when markets are incomplete. This is due to the fact that the available markets do not provide sufficient information to value future profits unambiguously.[6] Following Carceles-Poveda and Coen-Pirani (2009), we adopt the value maximization approach proposed by DeMarzo (1988) and by Duffie and Shaffer (1986). In essence, this requires firms to discount cash flows according to some no present value price that does not allow for arbitrage opportunities. In the present setting, this objective can be defined as follows[7]:

$$E_t \sum_{j=0}^{\infty} \mathcal{M}_{t,t+j}^f N_{t+j} \tag{12}$$

where $\mathcal{M}_{t,t}^f = 1$, $\mathcal{M}_{t,t+j}^f = \mathcal{M}_{t,t+j-1}^f \mathcal{M}_{t+j-1,t+j}^f$ for $j \geqslant 1$ and $E_t \mathcal{M}_{t,t+1}^f = \frac{E_t q_{t,t+1}^s}{1 - \rho + \rho \frac{E_t q_{t,t+1}^s}{E_t q_{t,t+1}^b}}$.

[5] Since the process for the employment shock depends on z and z' so will the transition function for the distribution of agents over the individual state variables.

[6] See Dreze (1985) and Grossmann and Stiglitz (1977, 1980) for a review of the literature on this issue.

[7] As shown by Carceles-Poveda and Coen-Pirani (2009), this objective implies that the equilibrium allocations are the same as under the standard objective assumed by Krusell and Smith (1997, 1998), under which firms maximize period by period profits.

As reflected by the previous expression, the discount factor of the firm $\mathcal{M}^f_{t,t+j}$ under the objective we have postulated is a combination of the stochastic discount factors of the households that are unconstrained in the capital shares and the households that are unconstrained in the bonds.[8] Alternatively, if such a household exists, it corresponds to the discount factor of a household that has an interior portfolio solution. Note that, in the absence of leverage, $\mathcal{M}^f_{t,t+j} = q^s_{t,t+j}$ reduces to stochastic discount rate of the households that are unconstrained in equity shares. Similarly, in a representative agent economy, $\mathcal{M}^f_{t,t+j}$ reduces to the stochastic discount factor of the representative agent. The first order conditions from the firm's problem determine the aggregate wage rate and the aggregate capital stock and they imply that:

$$w_t = f_L(z_t, K_t, L_t), \tag{13}$$

$$1 = E_t\{\mathcal{M}^f_{t,t+1}[f_K(z_{t+1}, K_{t+1}, L_{t+1}) + 1 - \delta]\}. \tag{14}$$

In what follows, we establish a result regarding the capital choice of the firm that will be useful later on. The proof of Proposition 1 is relegated to Appendix A.

Proposition 1. *In equilibrium, the aggregate capital stock K_{t+1} chosen by the value maximizing and the ex-dividend firm value V_t are equal to the present discounted value of the firm's net cash flows*:

$$K_{t+1} = V_t = E_t\left\{\sum_{j=1}^{\infty} \mathcal{M}^f_{t,t+j}[f_K(z_{t+j}, K_{t+j}, L_{t+j})K_{t+j} - I_{t+j}]\right\}$$

where $\mathcal{M}^f_{t,t} = 1$, $\mathcal{M}^f_{t,t+j} = \mathcal{M}^f_{t,t+j-1}\mathcal{M}^f_{t+j-1,t+j}$ *for* $j \geqslant 1$ *and* $E_t\mathcal{M}_{t,t+1} = \frac{E_t q^s_{t,t+1}}{1-\rho+\rho\frac{E_t q^s_{t,t+1}}{E_t q^b_{t,t+1}}}$.

This proposition is very important, since it will allow us to eliminate the capital Euler condition from the equilibrium system of equations and use instead $K_{t+1} = V_t$. We are now ready to define a recursive competitive equilibrium.

2.7. Recursive competitive equilibrium

We consider a recursive competitive equilibrium definition given a certain leverage ratio ρ. First, the economy wide state vector is given by $(\omega, e, l; z, \mu)$. Further, we are looking household policy functions $c = g^c(\omega, e, l; z, \mu)$, $b' = g^b(\omega, e, l; z, \mu)$ and $s' = g^s(\omega, e, l; z, \mu)$ and for a policy function for the aggregate capital $K' = g^K(\omega, e, l; z, \mu)$.

Definition 1. A value maximizing recursive competitive equilibrium with respect to the leverage ratio ρ is defined by a law of motion Γ, a set of individual policy and value functions $\{v, g^c, g^s, g^b\}$, a policy function for the aggregate capital $\{g^K\}$, a set of pricing functions $\{w, R^b, R^s\}$ and a forecasting rule $\{g^L\}$ such that:

1. The policy function for aggregate capital g^K and the aggregate wage function w satisfy the firms' optimality conditions.
2. Given $\{w, R^b, R^s\}$, the law of motion Γ, the exogenous transition matrices $\{\Pi_z, \Pi_e, \Pi_l\}$, the forecasting rule $\{g^L\}$ and the capital policy rule $\{g^K\}$, the policy functions $\{g^c, g^b, g^s\}$ solve the household problem.
3. Labor, shares and bonds markets clear:

$$L = \int el\, d\mu,$$

$$\int g^s(\omega, e, l; z, \mu)\, d\mu = (1-\rho)K', \tag{15}$$

$$\int g^b(\omega, e, l; z, \mu)\, d\mu = \rho K'. \tag{16}$$

4. The law of motion $\Gamma(\mu, z, z')$ for μ is generated by the optimal decisions $\{g^c, g^b, g^s\}$, $\{g^K\}$ and by the transition matrices for the shocks. Further, the forecasting rule for aggregate labor is consistent with labor market clearing $g^L(z') = \int \epsilon' l\, d\mu$.

As usual, market clearing in the goods market is taken care of by Walras law. In particular, integrating Eqs. (3) and (4), one can verify that:

$$f(z, K, L) + (1-\delta)K = C + K'. \tag{17}$$

[8] Since market clearing implies that at least one household will be unconstrained in each asset market, the discount factor is well defined.

Table 1
Benchmark calibration.

Parameters	β	α	δ	σ	ρ	κ^s	κ^b
Values	0.9364	0.4	0.033	2	0.37	0	0

Note also that a value maximizing capital choice is consistent with the market clearing conditions for bonds and shares, since:

$$g^K(z,\mu) = \int g^s(\omega, e, l; z, \mu)\, d\mu + \int g^b(\omega, e, l, z, \mu)\, d\mu.$$

3. Calibration and solution method

3.1. Calibration

We calibrate the model to a quarterly frequency. The main aim of the calibration is to match some important aspects of the U.S. earnings and wealth distributions as well as key aggregate ratios for the U.S. economy.

3.1.1. Preferences, technology, leverage and trading constraints

The parameterization for preferences and technology is relatively standard. The utility is assumed to be of the constant relative risk aversion class and the risk aversion is set to $\sigma = 2$. The production function is Cobb Douglas, with a capital share α of 0.4, as in Cooley and Prescott (1995). The capital depreciation rate is set to $\delta = 0.033$ and the discount factor β is set to 0.9364. With the last two parameter values, the benchmark calibration matches a capital/output ratio of around 7 at the quarterly frequency.[9]

Three key parameters for our analysis are the leverage ratio and the trading constraints on equity and bonds. In the benchmark model, the leverage ratio is parameterized to match the fraction of households that are constrained in stocks in the U.S. This is equal to 42.5 percent and the model generates a fraction of 41.2 percent with a leverage ratio of $\rho = 0.37$. Note that this is closed to the observed leverage ratio in the United States. Rajan and Zingales (1995) calculate the leverage for non-financial firms using their consolidated balance sheet and different potential measures of leverage. In particular, one of the measures reported by the authors exactly corresponds to the leverage ratio in our model, since it is defined as the ratio of debt to capital, where capital corresponds to the sum of debt and equity of the firm. For this measure of leverage, the authors report a mean market value of around 0.3.

As to the trading constraints, they are set at $\kappa^s = 0$ and $\kappa^b = 0$ in the benchmark economy. Note that we purposedly choose tight borrowing constraints to give financial policy the highest chance of having real effects. Whereas the no short-selling constraint for equity is standard in the literature, the no borrowing constraint for bonds implies that households are not be able to trade in bonds in the absence of leverage ($\rho = 0$). The reason is that, in this later case, bonds are in zero net supply and no one can borrow. In contrast, the positive level of leverage in the benchmark economy implies that bonds are in positive supply and households will thus be able to trade in this asset in spite of facing a no borrowing constraint. Thus, the effect of leverage is similar to the effect of loosening the borrowing constraint on debt, since by allowing households to accumulate bonds it reduces the mass of agents at the borrowing constraint. Table 1 reports the benchmark parameter values.

3.1.2. Employment shocks and asset distribution

The response of individual and aggregate variables to changes in firm leverage crucially depends on both the fraction of households that are at the borrowing constraints and on the overall wealth distribution. Thus, another key aspect of the parameterization is to find a stylized process for wage income which is empirically relevant but also able to replicate some of the distributional facts in the U.S.

To do this, we follow the approach of Davila et al. (2007), Heathcote (2005) and Pijoan-Mas (2007). These authors show that it is possible to replicate some of the important cross sectional moments of the earnings distribution with a three state Markov chain for earnings, as long as the states are very different. We follow this strategy by distinguishing between three efficiency units for agents who are employed and we use the same calibration for productivity as Pijoan-Mas (2007), with $l \in \{30, 8, 1\}$ and[10]

$$\Pi_l = \begin{bmatrix} 0.9850 & 0.0100 & 0.0050 \\ 0.0025 & 0.9850 & 0.0125 \\ 0.0050 & 0.0100 & 0.9850 \end{bmatrix}.$$

[9] As illustrated by several authors (see e.g. Silos, 2007), the sum of capital and housing over GDP is around 3.4 annually, while the capital-to-output and the housing-to-output ratios are very similar and both around 1.74 annually, corresponding to a quarterly ratio of around 7. Since we exclude housing in the model, we have calibrated the economy to replicate the later ratio.

[10] The results are similar with the calibration for earnings used by Davila et al. (2007), who matches the Gini of earnings of 0.6.

Table 2
Distribution of earnings.

	Model	Data
Share of earnings of bottom 40%	4.6	3.8
Share of earnings of top 20%	62.2	60.2
Gini index of earnings	0.57	0.61

Table 3
Simulation targets for asset holdings.

	Model	Data
Share of borrowing constrained on stocks	41.2	42.5
Share of stocks of top 25%	96.8	98.2
Gini index of stocks	0.82	0.92

As the author shows, the process is able to replicate well some of the cross section and time series statistics of the U.S. earnings distribution. These are reported in Table 2. First, the process approximates relatively well the share of earnings of the bottom 40 percent, which is equal to 4.6 percent in the model against 3.8 percent in the data. In addition, it matches the share of earnings of the top 20 percent, which is equal to 62.2 percent in the model and 60.2 percent in the data. Second, the process yields a Gini coefficient of earnings of 0.57, which is fairly close to the coefficient of 0.61 in the U.S. data (see Budria et al., 2002). Last, as we will show later, with the benchmark level of leverage, the process also generates a relatively high Gini coefficient for equity.

Apart from the three different efficiency levels for the employed, we introduce an additional individual state of unemployment. This fourth state is meant to capture the interaction between aggregate risks and individual risks, and it has an important effect on the portfolio allocation between bonds and shares, as stressed by Mankiw (1986), Krusell and Smith (1997) and Pijoan-Mas (2007), who studies the effects of habit persistence on asset prices and the wealth distribution. In line with the latter two authors, we assume that labor supply is exogenous and that the aggregate unemployment rate is completely determined by the aggregate state of the economy. The unemployment duration is set to 1.5 quarters and 2.5 quarters in good times and bad times respectively. For the level of unemployment in good and bad times, we also use the same parameterization as Pijoan-Mas (2007), who targets the average and standard deviation of the unemployment rate as reported by the Bureau of Labor Statistics for the period 1948–2001. The author finds values for the unemployment rates in bad and good times equal to 0.0719 percent and 0.0417 percent respectively. Note that this parameterization seems to be more relevant than the one proposed initially by Krusell and Smith (1998), since the latter yields an unemployment volatility that is twice as high as the one found in the data, while it implies a countercyclical wage. As in Pijoan-Mas (2007), home production is calibrated to 5% of the average earnings.

The employment process, along with the choice of the leverage coefficient and the borrowing constraints, is able to match key targets of the U.S. wealth distribution. The main target of our parameterization is the distribution in stocks. We choose this target for the following reason. The first is to be able to compare the non-leverage economy and the economies with leverage in this dimension. Recall that, in the non-leverage economy, the riskless asset is in zero-net supply. This implies that the agents must invest all their wealth in stocks and the distribution over bonds is degenerate. Second, the changes in leverage will directly affect households who are borrowing constrained on stocks by providing an additional way of insurance through the riskfree asset. Since we are interested in the quantitative effects of changes in the firm's financial policy on the individual portfolio allocations and the macroeconomic aggregates when the borrowing constraints are binding, it is important to start from a benchmark economy with a distribution of stocks that is empirically relevant, particularly concerning the share of households that is borrowing constrained.[11]

Table 3 provides a comparison between the asset holding distribution observed in the data and in the model. The statistics from the data have been calculated using the Survey of Consumer Finance of 2004, while the distribution from the model has been calculated from a long simulation of 10,000 periods. As mentioned earlier, our model does a good job in matching the share of households who are borrowing constrained on stocks, which is equal to 41.2 percent in the simulations and 42.5 percent in the data. The model also provides a close match of the share of stocks held by the top 25 percent wealthiest people. This share is equal to 96.8 in the model against 98.2 in the data. The model does less well in terms of accounting for the Gini coefficient, which is lower in the model economy compared to the data. The reason is that

[11] To measure stocks, we use the category called equity in the SCF 2004. This includes the sum directly held stocks, investment in mutual funds and other managed assets as well as retirement accounts invested in stocks. To measure bonds, we use the category called bonds, which is defined as the sum of nontaxable bonds, mortgage bonds and corporate and foreign bonds. Note that we do not include the SCF category savings bonds, defined as government bonds, since government debt is absent from our model.

Table 4
Aggregate statistics of the benchmark economy.

$\rho = 0.37$	$\frac{K}{Y}$	Fraction with $s = 0$	Gini of equity	R^b	$E[R^s] - R^b$	Sharpe
Data	7.01	0.42	0.92	0.23	1.94	0.27
Economy	7.01	0.41	0.82	2.40	0.01	0.02

Source for asset pricing statistics: Ibbotson Associates.

we are not able to reproduce the substantial amount of stock holdings of the richest 1 percent of households, a problem that is common in the existing literature.[12] Additional details on the wealth distribution are reported later.

3.2. Solution method

As noted by other authors, solving this type of models is difficult due to the fact that the set of state variables contains the cross-sectional distribution of agents over the wealth and employment status. This is a time-varying infinite dimensional object in the presence of aggregate uncertainty. In this paper, we use the same approach as in Krusell and Smith (1997, 1998), who summarize the cross-sectional distribution with a finite set of moments, and approximate the transition for the aggregate laws of motion using a simulation procedure. However, rather than using Monte Carlo simulation to generate an updated cross-sectional distribution, we use a grid-based simulation procedure proposed by Young (forthcoming). This allows us to get rid of the cross-sectional sampling variation in the Monte Carlo simulation procedure. In particular, the procedure keeps track of the mass of agents at a fine grid of wealth levels.[13]

Since households can trade in both bonds and equity, we need to approximate both the law of motion of capital and the law of motion of the risk free return. The equilibrium laws of motion for K and R^b are as follows:

$$\log K' = a_0(z) + a_1(z) \log K,$$

$$R^b = b_0(z) + b_1(z) \log K$$

where the coefficients depend on the aggregate shock. We verify that only the mean of the aggregate capital matters for prices in this environment. Except for the simulation procedure, the algorithm follows Krusell and Smith (1997) and Pijoan-Mas (2007) and a more detailed description is provided in Appendix B.

4. Results

This section reports the findings from various model economies with different levels of firm leverage. We first discuss the benchmark economy with the benchmark level of leverage of $\rho = 0.37$. We then analyze the quantitative impact of changes in leverage on individual decisions and aggregate outcomes by comparing the benchmark economy to different alternative economies. The first one corresponds to an environment without any leverage ($\rho = 0$). This is defined as the non-leverage economy. The second one corresponds to an environment in which half of the capital structure of the firm is composed of debt ($\rho = 0.5$). This is defined as the high-leverage economy.

4.1. Benchmark economy

This section describes the main characteristics of the benchmark economy with $\rho = 0.37$. We first analyze the aggregate macroeconomic and financial indicators and we then analyze the optimal saving rules and the wealth distribution.

Table 4 presents some of the implied aggregate characteristics of the benchmark model, obtained from a long simulation of 10,000 periods, and their values in the data. Column 1 reports capital-output ratio and columns 2–3 report the share of households that are borrowing constrained in equity shares and the Gini coefficient of equity. Finally, columns 4–6 report the risk free rate, the mean equity premium and the Sharpe ratio (all in percent).

As mentioned earlier, the model is parameterized so that it matches the mean capital to output ratio in the data as well as the distribution in equity. The first three columns of Table 4 reflect that the model performs relatively well along these two dimensions. First, we match the capital output ratio. Second, we reproduce the share of households borrowing constrained in equity. Third, we obtain a fairly high Gini coefficient for equity that is equal to 0.82 percent. Finally, the last columns of the table reflect that our model performs very poorly regarding the main asset pricing facts in the U.S. data. This is reflected by a too high risk free rate, an almost zero equity premium and by a very small Sharpe ratio compared to

[12] Note that the Gini coefficient for stocks that we have calculated is higher than the traditional Gini coefficient for wealth of 0.78 reported by authors like Budria et al. (2002). The reason is that the latter authors focus on all assets instead of bonds and stocks, while their measure is net worth including debt.

[13] For more details on the procedure see Appendix B and Algan et al. (2008). The later authors compare different simulation procedures that imply no cross-sectional sampling variation, showing that the one used in the present paper is the easiest one.

its value in the data.[14] In essence, this shows that agents can self-insure very well with just two assets and it is consistent with the findings of Krusell and Smith (1997) and Pijoan-Mas (2007).

Fig. 1 displays the equilibrium decision rules for savings in bonds and equity, given each possible combination of household-specific productivity and employment status. The figures are drawn using the equilibrium aggregate capital stock when the economy is in the good aggregate state. Panels A to C illustrate the portfolio choice of the three types of employed workers, and Panel D illustrates the portfolio choice of a typical unemployed.

Looking at the figure, three important features show up. First, a large part of the unemployed agents hold bonds, whereas employed workers save mainly in equity shares. This result is consistent with earlier findings of Mankiw (1986), Krusell and Smith (1997) and Pijoan-Mas (2007). In the present framework, the unemployment rate and duration are counter-cyclical and the risky equity pays less when the variance of labor income risk is high. Thus, by borrowing as much as possible in equity and by holding bonds, unemployed workers choose a portfolio whose return is negatively correlated with their labor income risk. We also see that these agents are willing to hold equity shares only when their beginning of period wealth is relatively high. In contrast, employed workers save in equity shares for most of the wealth levels, since they can afford to trade-off a higher risk in exchange of a higher expected return.

Second, as long as employed workers are concerned, the higher their productivity, the lower their savings in equity shares. A comparison of Panels A and C illustrate that high productivity workers start to invest in equity shares for higher levels of wealth than low productivity workers. Even though this might seem counterfactual at first sight, it is a consequence of the fact that the probability of becoming unemployed is identical across efficiency states. In other words, the higher the efficiency, the greater the labor income risk relatively to the unemployment state. Given this, high productivity workers are willing to take less risk compared to low productivity workers. Third, as wealth increases, individuals save more in equity than in bonds. Since wealth–rich agents are better self-insured, they are willing to take more risk by holding equity in exchange of higher expected returns.

It is important to point out that the approximate aggregation result obtained by Krusell and Smith (1997, 1998) in economies with no leverage also holds in our benchmark economy with a positive level of leverage. This implies that the aggregates can be almost perfectly described as a function of the mean of aggregate capital and the aggregate productivity shock, as shown by the following equilibrium laws of motion:

$$\log K' = \underset{(9.0\times 10^{-5})}{0.0864} + \underset{(5.0\times 10^{-5})}{0.9545} \log K, \quad \text{with } R^2 = 99.9999,$$

$$R^b = \underset{(5.0\times 10^{-5})}{1.0853} - \underset{(3.0\times 10^{-5})}{0.0338} \log K, \quad \text{with } R^2 = 99.9646$$

in good times and

$$\log K' = \underset{(9.0\times 10^{-5})}{0.0610} + \underset{(5.0\times 10^{-5})}{0.9610} \log K, \quad \text{with } R^2 = 99.9999,$$

$$R^b = \underset{(4.0\times 10^{-5})}{1.0770} - \underset{(2.0\times 10^{-5})}{0.0317} \log K, \quad \text{with } R^2 = 99.9664$$

in bad times.

The key insight for this result is related to the properties of optimal saving behavior and high degree of self insurance obtained in these type of incomplete markets models. As shown by Krusell and Smith (1997, 1998), the effective insurance achieved with only one asset is already almost perfect in utility terms and adding a risk free asset only strengthens the aggregation result by enhancing self-insurance. In our model, the same happens with the introduction of leverage. It increases the possibility for self-insurance and thus goes in favor of the approximate aggregation result. To confirm this, Fig. 2 provides a complementary picture of the individual saving behavior of each type that displays the total investment in both assets as a function of individual wealth. The pictures are drawn again for a given value of the equilibrium aggregate capital stock when the economy is in the good aggregate state.

As we see, the marginal propensity to save is very similar across agents. In particular, as an agent's wealth increases, the slope of the savings function increases towards one and the decision rules become almost exactly linear, as in a representative agent framework. This is the essence of why approximate aggregation holds. The marginal propensity to save is only different for those agents that are at or close to the borrowing constraint on total wealth. However, these agents have relatively low asset holdings and do not contribute to the law of motion of aggregate wealth. In contrast, the agents who determine the aggregate capital stock are well-insured consumers with linear saving rules. Given this, the changes in the wealth distribution implied by the benchmark positive level of leverage have little effect on the aggregates.

Finally, Table 5 reports the portfolio choices by employment status that we will use to compare our model economies.

The table reflects that, among the employed, the high efficiency workers are the ones with a higher wealth and they also hold more equity shares and bonds than lower efficiency workers. As mentioned earlier, high efficiency workers have the highest income gap relatively to the unemployed, implying that they face the highest labor income risk among the workers and thus put more riskless bonds in their portfolio. About 55 percent of their total investment is made up of bonds against

[14] Note that the relatively low value for the discount factor is one of the key factors generating a too high risk free rate.

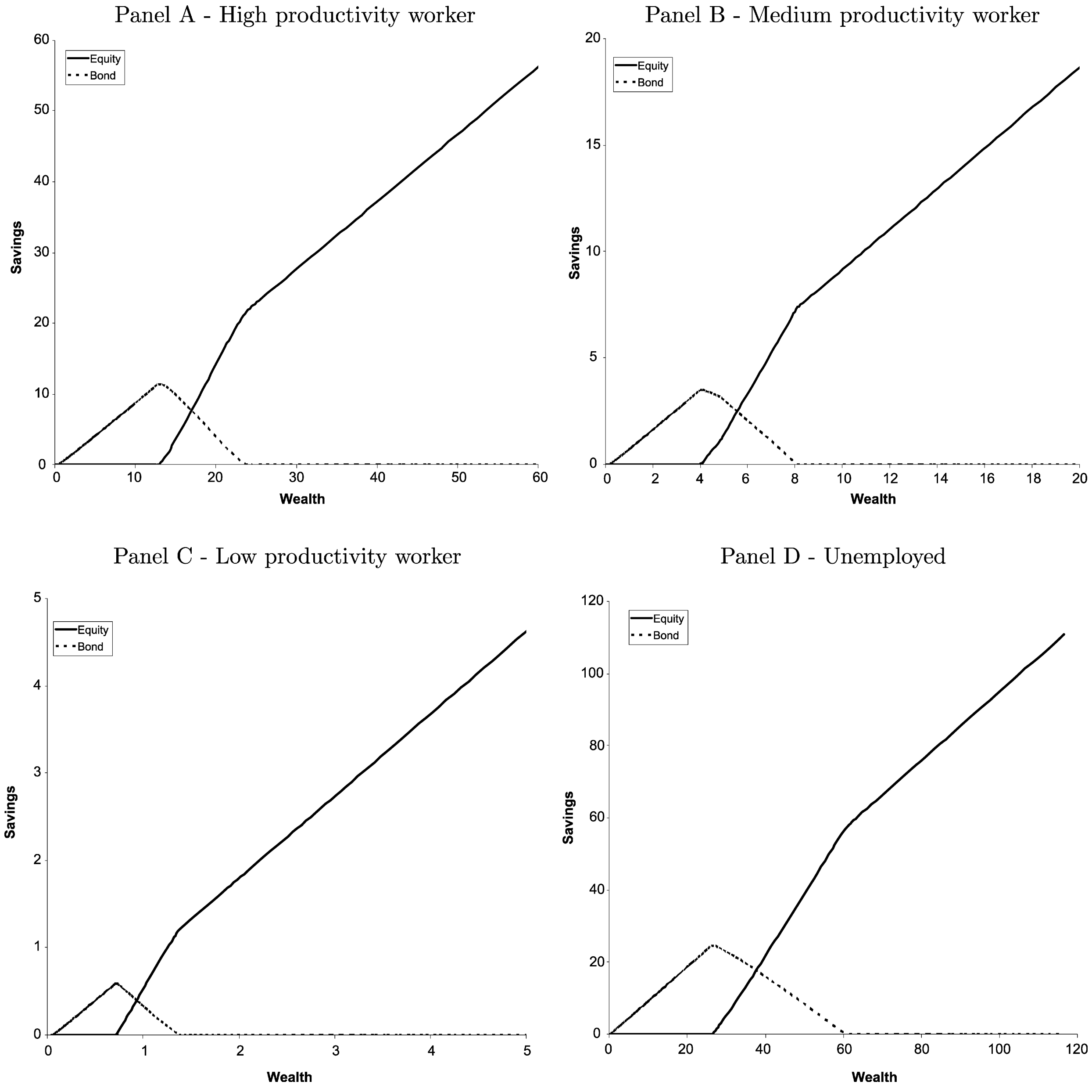

Fig. 1. Decision rules for savings – benchmark calibration with leverage = 0.37.

Table 5
Wealth distribution in the benchmark economy.

Model	Equity	Bonds	$\frac{\text{Bonds}}{\text{Total assets}}\%$	Data $\frac{\text{Bonds}}{\text{Total assets}}\%$
Mean	3.61	2.12	37.0	4.42
e_1	6.27	7.46	54.6	5.07
e_2	3.29	1.54	31.6	0.1
e_3	2.67	0.05	1.8	0.08
u	2.40	2.75	51.6	3.27

only 1.8 percent for the low efficiency workers. The same argument holds for the unemployed, who have a proportion of bonds of 51.6 percent over total savings.

For comparison, the last column of the table reports the share of bonds over total assets in the U.S. data based on the Survey of Consumer Finance 2004. To provide a relevant counter-part for our model, we have selected the sample of working aged people who are either employed or non-employed. The unconditional distribution of productivity levels in the

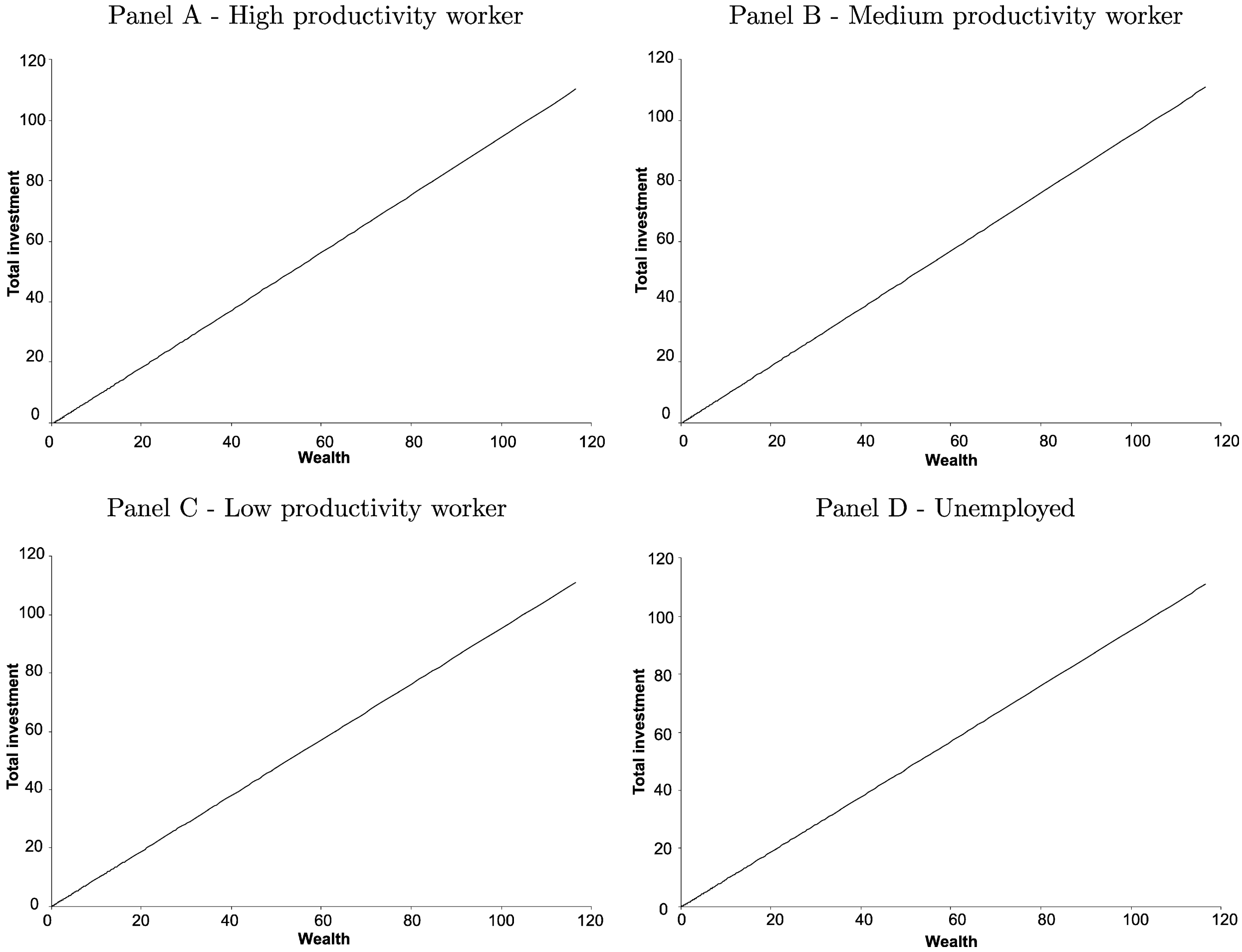

Fig. 2. Total savings – Benchmark calibration with leverage = 0.37.

model is 20 percent for the workers of type e_1, 40 percent for the workers of type e_2 and 40 percent for the workers of type e_3. To construct these groups, we put together the 80–100 percentile, the 40–80 percentile, and the 0–40 percentile of labor income of the employed workers in the data.

The table reflects that, qualitatively, the portfolio allocations by employment status predicted by the model are empirically relevant. In particular, the top 20 percent of the labor income distribution has the highest proportion of bonds in their portfolio. Further, the unemployed rank second, with a similar share of bonds as the high productivity workers, followed by the 40–80 percentile and 0–40 percentile in labor income. In other words, the model is able to match qualitatively an important feature of the U.S. portfolio composition between stocks and bonds by employment status and productivity level. Unfortunately, the share of bonds over total assets in the data is much lower than the one generated by the model. The main reason for this is that corporate bonds are the only risk free asset in our model, whereas very few households hold corporate bonds in the SCF database. In fact, most households hold savings bonds from the government, which are not present in our model.

4.2. Quantitative effects of firm leverage

This section analyzes the quantitative effects of the firm financing policy by comparing economies with different levels of leverage relatively to our benchmark model. The first economy corresponds to an environment without any leverage ($\rho = 0$). In this case, firms only issue equity shares. Further, there is no room for trade in bonds, since borrowing is not allowed by assumption $b' \geqslant 0$. The second economy corresponds to an environment in which half of the capital structure of the firm is made up of debt ($\rho = 0.5$). Except for the level of leverage, the different economies have exactly the same parameterization as the benchmark model economy.

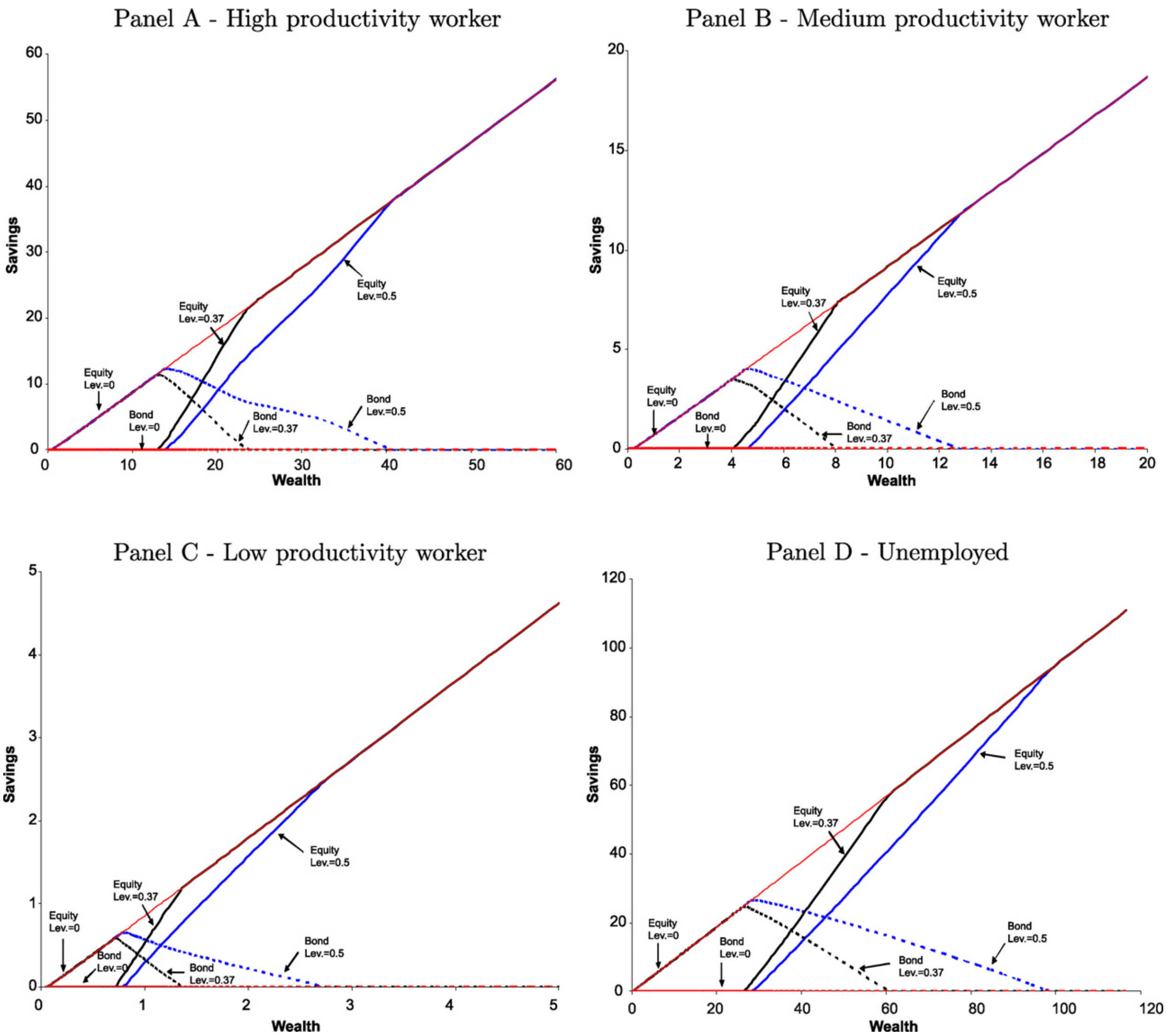

Fig. 3. Effect of leverage on savings.

4.2.1. Individual saving decisions

We start by discussing the effect of leverage on individual saving rules and then discuss some of the effects on the wealth distribution. Fig. 3 illustrates the decision rules as a function of leverage. Panels A to C illustrate the portfolio choice of the three types of employed workers, and Panel D illustrates the portfolio choice of a typical unemployed.

Two important observations are worth noting. First, the portfolio allocations of households in an economy without leverage $\rho = 0$ are very different to the ones in the benchmark case. In the absence of leverage, all agents are at the zero-bond borrowing constraint and no one is constrained in equity. This result is similar to the one found by Krusell and Smith (1997) in their portfolio model with no leverage and a tight borrowing constraint on stocks. Clearly, when no borrowing is allowed, there is no room for trade in bonds due to the fact that they are in zero net supply. Instead, all agents buy equity shares in order to self-insure. In contrast, if some borrowing was allowed, wealth–rich agents would borrow as much as possible in bonds and they would put all their savings in equity. In turn, this would enable wealth–poor agents to hold positive level of bonds and go short in equity.[15]

Second, the previous result implies that a positive level of leverage enhances the liquidity of households by providing an additional mean of smoothing consumption through risk-free bonds. The mechanism is thus similar to a loosening of

[15] The policy rules when some borrowing is allowed in our model are similar to the ones obtained by Krusell and Smith (1997). Note that the result according to which no one trades in bonds when the borrowing constraints are tight holds by the market clearing condition, whatever the employment process or the heterogeneity in preferences (see Krusell and Smith, 1997).

Table 6
Effects of leverage on the wealth distribution.

ρ	Fraction $s=0$	Fraction $b=0$	Fraction $s>0$, $b>0$	Gini s equity	Gini b bonds	Gini wealth
0	0.07	–	–	0.54	–	0.48
0.37	0.41	0.45	0.07	0.82	0.90	0.48
0.5	0.48	0.35	0.07	0.87	0.85	0.48

borrowing constraints, and is very similar to the effect of government debt stressed by Aiyagari and McGrattan (1998).[16] As we see, as leverage increases from $\rho = 0.37$ to $\rho = 0.5$, households hold more bonds and less equity. In particular, the debt issued by firms allows poor–wealth households to save in bonds in order to smooth their consumption. In addition, these households become constrained in equity shares and only start holding positive amounts of equity when their wealth is sufficiently high to allow for an almost perfect self-insurance. The figures reflect that this is uniform across all efficiency levels. Finally, when leverage is positive, we still observe the pattern that unemployed workers hold more bonds than employed workers, while high efficiency workers are the ones with a higher level of debt among the employed.

The policy rules above reflect that leverage has important effects on the portfolio choice of agents and it will therefore affect the number of agents that are constrained in each asset as well as the distribution of wealth. To get an intuition of the effects of leverage in this respect, it is instructive to analyze what the Modigliani–Miller theorem would imply for the portfolio choice of agents.

Suppose that financial policy was irrelevant[17] and firms reduced the level of leverage from ρ to some new level $\widetilde{\rho} < \rho$. The irrelevance of financial policy would imply that the aggregate capital K_{t+1}, the value of the firm V_t and the bond return R^b would be unchanged. Furthermore, following Stiglitz (1974) and Carceles-Poveda (2006), one can show that households would be able to achieve the same consumption allocation after the decrease in leverage by reducing their bond holdings and by increasing their equity holdings, $\Delta b_{i,t+1} < 0$ and $\Delta s_{i,t+1} > 0$. In other words, we should expect households to invest more in shares and less in the risk free bonds after a decrease in leverage. Similarly, we should expect to see more people constrained in bonds and less people constrained in equity when leverage is reduced. Clearly, all households would be able to offset the actions of the firm in a setting in which the borrowing limits are not effectively binding. However, some of the households are not able to do this in the present setting due to the presence of portfolio restrictions. For example, agents that are originally unconstrained in shares ($s_{i,t+1} > \kappa^s = 0$) but are at the limit on bonds ($b_{i,t+1} = \kappa^b = 0$) will not be able to further reduce his bond holdings after the firm decreases the level of leverage. As we will see later, however, these agents do not have a big effect on the aggregates, implying that financial policy is almost irrelevant in the present setting.

4.2.2. Wealth distribution

As we have seen, the level of leverage substantially affects the portfolio decisions of agents and it is likely to have important effects on the number of agents that are constrained and on the wealth distribution. Table 6 reports the percentage of agents that are constrained in each asset and the Gini coefficient of equity and bonds, depending on the leverage policy of the firm. For comparison, the statistics are also reported for the benchmark economy. As we see, an increase in leverage considerably modifies the Gini coefficient on capital and bonds. Moving from a non-leverage economy to an economy with leverage, the Gini on capital increases from 0.54 to 0.82. In addition, moving from the benchmark economy to an economy with a high leverage further rises the Gini for equity to 0.87 and decreases the Gini for bonds from 0.90 to 0.85 (the distribution is degenerate in a non-leverage economy).

Clearly, this pattern is mainly driven by the share of households who fall short in bonds and equity. As reflected by the table and the earlier discussion, when firms issue more debt, agents who face the highest risks in the economy are able to self-insure by buying more bonds and decreasing their equity shares. As a consequence, the share of households that is borrowing constrained in bonds decreases, while the share of household borrowing constrained in equity increases. With our parameterization, moving from a non-leverage economy to our benchmark model with $\rho = 0.37$ leads to a decrease in the share of people that are borrowing constrained in bonds from 100 percent to 45 percent and this decreases further to 10 percent with a high leverage. In contrast, 7 percent of the population is constrained in equity in the non leverage economy, and this percentage increases to 41 percent with the benchmark level of leverage and 48 percent with the high leverage.

Here, it is also important to note that the wealth Gini is not really sensitive to changes in the level of leverage, since only the composition between stocks and bonds changes after a change in leverage. The reason is again the fact that the Modigliani–Miller irrelevance proposition holds approximately in this environment. In other words, when firms change their

[16] These authors show that incomplete market models give a new role to government debt compared to standard models with complete markets. In the context with uninsurable risk, the government debt enhances the liquidity of households by providing an additional means of smoothing consumption in addition to claims to capital. The same argument holds here, but in a framework with two assets and aggregate risk.

[17] As shown by Stiglitz (1969, 1974) and DeMarzo (1988), financial policy is irrelevant in a setting with incomplete markets but no effectively binding borrowing constraints. In this setting, such a situation would arise if households were subject to the natural borrowing limit on total asset wealth, which is effectively never binding. Alternatively, one could assume endogenous limits as the ones characterized by Carceles-Poveda (2006), under which financial policy is also irrelevant.

Table 7
Leverage and macroeconomic quantities.

ρ	K	σ_K	C	σ_C
0	5.73	0.375	0.630	0.029
0.37	5.73	0.376	0.629	0.029
0.5	5.73	0.376	0.630	0.029

Table 8
Asset prices and leverage.

ρ	R^b	$E[R^s]-R^b$	$\sigma_{E[R^s]}$	Sharpe
0.00	2.0595	0.0371	0.2280	0.1635
0.01	2.3952	0.0094	0.2303	0.0405
0.37	2.4012	0.0064	0.3619	0.0176
0.5	2.4018	0.0075	0.4561	0.0165

financial policy, households are able to undo the actions of the firm and maintain the same level of wealth by altering their portfolio composition.

4.2.3. Macroeconomic aggregates

We now turn to the aggregate effects of the firm's financing policy. Table 7 reports the main macroeconomic statistics for different levels of leverage. The table reflects that the mean and standard deviation of the aggregate capital stock and aggregate consumption are almost identical across the different model economies, regardless of the level of leverage. This result states that the Modigliani–Miller approximately holds in our incomplete markets environment, even though the share of households that are borrowing constrained in equity or bonds is substantial.

The reason for this key result is similar to the reason for the approximate aggregation result found by Krusell and Smith (1997, 1998) explained above. In this class of models, individuals achieve almost perfect insurance with the two assets and their marginal propensity to consume is almostlinear. Thus, their saving behavior is close to that of a representative agent in a complete markets economy in which the Modigliani–Miller theorem holds exactly. In contrast, individuals who are close to the borrowing constraints and who have a non-linear savings behavior are precisely the wealth–poor agents, implying that their portfolio adjustments do not matter for determining the behavior of the aggregate capital stock. In fact, the only effect of leverage on aggregate wealth is to modify the distribution of equity and bonds. However, these changes do not matter in this economy, since aggregate quantities are not affected by changes in the distribution of wealth.

4.2.4. Asset prices

Whereas the level of leverage does not affect the aggregate quantities, it has important effects on the asset price statistics. Table 8 reports the average across simulations of the risk free rate, the equity premium, the sharpe ratio and the standard deviation of the equity return, which has been calculated as:

$$\sigma_{E[R^s]}=\left[\sum_{z'}\Pi_z(z,z')\big(R^s(\mu',z')-E\big[R^s(\mu',z')\big]\big)^2\right]^{1/2}.$$

Since the economy has a degenerate bond distribution with no leverage, we have also included the results with a level of leverage of $\rho=0.01$.

As leverage increases, the table reflects an increase in the risk free rate and a considerable increase in the standard deviation of the equity return. At the same time, there is a sharp decrease in the sharpe ratio, while the behavior of the equity premium is not monotone. In particular, the premium decreases when we move from an economy with no leverage to a leveraged economy, while it starts increasing with levels of leverage above the benchmark value.

To understand these results, note that the equity premium can be expressed as a product of the standard deviation of the conditional standard deviation of the equity return, $\sigma_{E[R^s]}$, and the sharpe ratio. This implies that, to increase the premium, one must increase the sharpe ratio and/or the volatility of the equity return. In the present setting, financial policy turns out to have two opposite effects. On the one hand, the sharpe ratio decreases with leverage. On the other hand $\sigma_{E[R^s]}$ increases with the leverage. The table reflects that the negative effect on the sharpe ratio seems to dominate when we move from an economy with no leverage to an economy with a leverage ratio below the benchmark value, leading to a decrease in the equity premium. However, there exists a value of ρ for which the positive effect on the equity return volatility dominates, leading to an increase in the premium. In what follows, we provide some intuition for these findings.

Consider first the standard deviation of the equity return. As stated above, one of the important observations from Table 8 is that equity becomes much riskier with leverage. In particular, $\sigma_{E[R^s]}$ is almost twice as high in the economy with $\rho=0.5$ compared to the economy with no leverage. In other words, the amount of risk in the economy increases with

Table 9
Effects of leverage on the portfolio allocations.

	$\rho = 0.00$			$\rho = 0.37$			$\rho = 0.5$		
Fractions	$s = 0$	$b = 0$	$\frac{b}{b+s}$	$s = 0$	$b = 0$	$\frac{b}{b+s}$	$s = 0$	$b = 0$	$\frac{b}{b+s}$
e_1	0.00	1.00	0.00	0.52	0.07	0.54	0.59	0.00	0.75
e_2	0.00	1.00	0.00	0.43	0.29	0.32	0.55	0.17	0.42
e_3	0.16	1.00	0.00	0.32	0.79	0.02	0.34	0.70	0.03
u	0.10	1.00	0.00	0.62	0.45	0.52	0.64	0.37	0.53
Pricing agents		0.0001			0.2321			0.2532	

leverage. This effect can be explained by looking at the expression for R^s_{t+1}. As shown in Appendix C, the equity return can be rewritten as:

$$R^s_{t+1} = \frac{[f_K(z_{t+1}, K_{t+1}, L_{t+1}) + 1 - \delta] - R^b_{t+1}\rho}{(1-\rho)}. \tag{18}$$

In the economy with no leverage, the equity return is equal to the marginal product of capital, which is high in good times and low in bad times. However, when leverage is introduced, the return has two components, a risk free component that depends on the bond return and a risky part that depends again on the marginal product of capital. The previous expression reflects that the risk free part is smaller than the bond return, while the risky component is magnified when leverage increases to $\rho = 0.5$ due to the fact that $1/(1-\rho) > 1$. In other words, leverage increases the volatility of the equity return. In turn, the fact that equity becomes riskier with leverage tends to increase the equity premium.

Consider now the sharpe ratio. Table 8 shows that moving from the economy with $\rho = 0$ to the benchmark leverage economy with $\rho = 0.37$ decreases the sharpe ratio from 0.16 to 0.017. To understand this result, recall that a key determinant of the Sharpe ratio is the variability in marginal utility of wealth of agents who hold both equities and bonds. In the economy with no leverage, these agents represent a very small subset of the total population, 0.01 percent, and they are all high efficiency workers. As discussed earlier, such agents are characterized by the highest risk, which implies a relatively high sharpe ratio. On the other hand, when the leverage ratio increases, households that were constrained in bonds before now incorporate bonds in their portfolio and become pricing agents. In particular, the low efficiency workers, who face the smallest risk in this economy, represent an increasing fraction of the pricing agents (12.46 percent and 16.59 percent in the economy with $\rho = 0.37$ and $\rho = 0.5$ respectively). Thus, as leverage ratio increases, the pool of pricing agents incorporates people with a less volatile marginal utility of wealth, resulting in a decrease in the sharpe ratio.

In addition to this, there are two other effects contributing to the decline in the sharpe ratio and the equity premium. Recall that, in the absence of leverage, there is no room for trade in bonds, since borrowing is not allowed and bonds are in zero net supply. On the other hand, leverage enhances the liquidity of households by allowing them to accumulate more bonds, providing them with an additional mean of smoothing consumption. This means that there will be fewer households at the borrowing constraint and in this sense an increase in leverage has a similar effect to the one of loosening the borrowing constraint on bonds. One of the important implications of this is that the risk free rate has to be lower in the absence of leverage to induce savers to reduce their bond holdings in equilibrium. This is confirmed by Table 8, showing that the risk free rate is 0.4 percent higher in the benchmark leverage economy compared to the non-leverage one. Furthermore, households modify their asset portfolios by buying more bonds, as it is documented in Table 9, which reports the fraction of constrained agents in each asset, and the bond/total investment ratio in each economy. Since they can reduce their exposure to risk *in* this way, households are then likely to demand a lower compensation for holding risky assets with leverage and this will tend to decrease the sharpe ratio.

Note that these last effects on the sharpe ratio are much stronger when we move from an economy with no leverage to a leveraged economy precisely due to the fact that households cannot trade in bonds in the absence of leverage. Given this, when we increase leverage from zero to $\rho = 0.01$, the dominating force is the decrease in the sharpe ratio, leading to a decrease in the premium. This is still true when we increase the leverage ratio to the benchmark value. On the other hand, the volatility of the equity return becomes stronger when we increase leverage beyond the benchmark, leading to a small but slight increase in the premium, as it shown when we go from the benchmark leveraged economy to a leverage economy with $\rho = 0.5$.

To summarize, a higher level of leverage leads to a riskier equity return. On the other hand, it also enhances risk sharing through the provision of an additional way of insuring against risk and it implies that the set of pricing agents face lower consumption fluctuations. This is particularly true when we move from an economy with no leverage to a leveraged economy, in which case the latter effects dominate and the equity premium decreases. On the other hand, the two effects seem to almost cancel out when we increase leverage beyond zero, in which case the premium only increases slightly. Interestingly, this is in sharp contrast to the findings of Jermann (1998), who finds that leverage considerably increases the equity premium in production economies with a representative agent. Note, however, that the only effect of leverage in this last case is to increase the volatility of dividends (or the riskiness of the equity return), implying that the representative household will demand a higher premium to trade in the risky asset.[18]

5. Conclusion

This paper has studied the effects of leverage in a model with substantial heterogeneity and borrowing constraints which are binding in equilibrium. This friction breaks the irrelevance of financial policy postulated by the traditional Modigliani–Miller proposition. We purposedly assume tight borrowing constraints so as to have a considerable amount of households at the borrowing limits and to give financial policy the highest chance for affecting the equilibrium allocations. Our results illustrate that financial policy does affect the asset prices. Whereas leverage introduces more risk into the economy by increasing the volatility of the equity return, it also enhances the liquidity of households by increasing the supply of bonds in the economy. In the presence of household heterogeneity, however, these two effects almost cancel out. In other words, changing the amount of debt in the capital structure of a leveraged firm does not have a big effect on the equity premium. We also find that leverage affects the portfolio allocations and the number of households that are at the borrowing constraints. However, the agents who determine the behavior of the aggregate laws of motion are relatively well insured and can therefore achieve a very similar consumption profile after the firm changes its financial policy. Given this, the Modigliani–Miller irrelevance proposition holds approximately in these type of economies.

It is important to point out that our approach assumes that leverage is taken as given by all agents in the economy, including the firms. It would therefore be interesting to extend the present setting so as to allow for an endogenous determination of the optimal financial policy of the firm. This is an important issue that we leave for further research.

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Appendix A. Proof of Proposition 1

To prove the proposition, we can first obtain an expression for the aggregate capital by multiplying the first-order condition of the firm with respect to K in (14) with K_{t+1} and by adding and subtracting K_{t+2} on the right-hand side:

$$K_{t+1} = E_t\left\{\mathcal{M}^f_{t,t+1}\left[f_K(z_{t+1}, K_{t+1}, L_{t+1})K_{t+1} - I_{t+1} + K_{t+2}\right]\right\}.$$

Substituting iteratively for K_{t+j} for $j \geqslant 2$ and using the fact that $\lim_{j\to\infty} E_t\mathcal{M}_{t,t+j}K_{t+j} = 0$ due to the absence of price bubbles in the present setting, the equation can be rewritten as[19]:

$$K_{t+1} = E_t\left\{\sum_{j=1}^{\infty}\mathcal{M}^f_{t,t+j}\left[f_K(z_{t+j}, K_{t+j}, L_{t+j})K_{t+j} - I_{t+j}\right]\right\}.$$

Second, we can obtain an expression for V_t by multiplying Eqs. (7) and (8) with S_{t+1} and B_{t+1} respectively, obtaining:

$$p^s_t S_{t+1} = E_t\left\{q^s_{t,t+1}\left[p^s_{t+1}S_{t+1} + d^s_{t+1}S_{t+1}\right]\right\},$$
$$B_{t+1} = E_t\left\{q^b_{t,t+1}R^b_{t+1}B_{t+1}\right\}.$$

Summing the previous two equations and using the accounting identity for the firm in (11), the ex-dividend firm value can be expressed as follows:

$$\begin{aligned} V_t &= E_t\left\{q^s_{t,t+1}\left[p^s_{t+1}S_{t+1} + d^s_{t+1}S_{t+1}\right]\right\} + E_t\left\{q^b_{t,t+1}R^b_{t+1}B_{t+1}\right\} \\ &= E_t\left\{q^s_{t,t+1}[N_{t+1} + V_{t+1}]\right\} - E_t\left\{q^s_{t,t+1}R^b_{t+1}\rho V_t\right\} + E_t\left\{q^b_{t,t+1}R^b_{t+1}\rho V_t\right\}. \end{aligned}$$

Rearranging terms and using the bond pricing equation (8), V_t can then be expressed as:

$$V_t = E_t\left\{\mathcal{M}^f_{t,t+1}[N_{t+1} + V_{t+1}]\right\}$$

[18] To see if the main result of the paper (i.e. irrelevance of financial policy) is due to the fact that stocks exhibit very low volatility, we have introduced depreciation shocks into the model. While these shocks make stocks more volatile and increase the premium, the main qualitative results of the paper are unchanged. These results can be provided by the authors upon request.

[19] See Santos and Woodford (1997) for an analysis of price bubbles in exchange economies and Carceles-Poveda and Coen-Pirani (2009) for an analysis of bubbles in the present setup.

where $\mathcal{M}^f_{t,t+1} = \frac{q^s_{t,t+1}}{1-\rho+\rho\frac{E_t q^s_{t,t+1}}{E_t q^b_{t,t+1}}}$. Finally, substituting iteratively for V_{t+j} with $j \geqslant 2$, we obtain:

$$V_t = E_t \sum_{j=1}^{\infty} \{ \mathcal{M}^f_{t,t+j} [f_K(z_{t+j}, K_{t+j}, L_{t+j}) K_{t+j} - I_{t+j}] \}$$

where we have again used the fact that $\lim_{j\to\infty} E_t \mathcal{M}^f_{t,t+j} V_{t+j} = 0$ and $\mathcal{M}^f_{t,t+j}$ is defined as before.

Appendix B. Numerical algorithm

The algorithm used to obtain the solution of the model is as follows.

1. Given a law of motion for capital and risk-free rate, solve the household's problem given by Eqs. (9)–(10).
2. Simulate the economy to approximate the equilibrium laws of motion for K and R^b. Rather than using Monte Carlo simulation to generate an updated cross-sectional distribution, as in Krusell and Smith (1998), we use a grid-based simulation procedure proposed by Young (forthcoming). This procedure keeps track of the mass of agents at a fine grid of wealth levels. In particular, given a fixed fine grid of N_{grid} wealth levels[20]:
   (a) Set an initial wealth distribution μ for each employment-efficiency type that provides the mass of agents with wealth ω_i at the ith wealth grid point for $i = 1, \dots, N_{\text{grid}}$ and an initial value for z.
   (b) Find the risk-free rate that achieves market clearing in shares and bonds. In particular, given Eqs. (15), (16) and (18), we iterate on R^b until the following condition is satisfied:

$$(1-\rho)\int g^b(\omega, e, l; z, K, R^b)\, d\mu - \rho \int g^s(\omega, e, l; z, K, R^b)\, d\mu = 0$$

   where $g^b(\omega, e, l; z, K, R^b)$, and $g^s(\omega, e, l; z, K, R^b)$ are the policy functions for bonds and shares that solve the following household's problem:

$$\tilde{v}(\omega, e, l; z, K, R^b) = \max_{c, b', s'} \{ u(c) + \beta E_{e', l', z' | e, l, z} [v(\omega', e', l'; z', \mu')] \}$$

   Note that the value function v is the solution obtained in step 1. Further, the resulting policy functions depend explicitly on the value of R^b.
   (c) Find the next period's wealth/employment-efficiency distribution using the decision rules $g^c(\omega, e, l; z, K, R^b)$, $g^b(\omega, e, l; z, K, R^b)$, and $g^s(\omega, e, l; z, K, R^b)$, and drawing a new value for z. In particular, for each wealth grid point calculate next period wealth given the decision rules, and locate it within the grid. Specifically, find the index I such that $\omega'(\omega_i, e, l; z, K, R^b)$ lies in $[\omega_I, \omega_{I+1}]$. Then, redistribute the current mass to the grid points ω_I and ω_{I+1} taking into account the employment-efficiency flows given z and z'. In particular, if $p_t^{i,e,l}$ stands for the mass of agents of type e and efficiency l at the ith grid points, let

$$p_{t+1}^{I,e',l'} = p_{t+1}^{I,e',l'} + g_{ee',ll',zz'} \frac{\omega_{I+1} - \omega'(\omega_i, e, l; z, K, R^b)}{\omega_{I+1} - \omega_I} p_t^{i,e,l}$$

   and let

$$p_{t+1}^{I+1,e',l'} = p_{t+1}^{I+1,e',l'} + g_{ee',ll',zz'} \frac{\omega'(\omega_i, e, l; z, K, R^b) - \omega_I}{\omega_{I+1} - \omega_I} p_t^{i,e,l}$$

   where $g_{ee',ll',zz'}$ stands for the mass of agents with employment status e and efficiency status l that will have employment status e' and efficiency status l' next period, conditional on the values of z and z'.
   (d) Repeat steps (b) and (c) and obtain a long time series for K and R^b, of which the first part is discarded.
3. Use the time series obtained in step 2 to regress $\log K'$, and R^b on constants and on the $\log K$ for each value of z to get the new equilibrium laws of motion for K and R^b.
4. Compare the new equilibrium laws of motion for K and R^b with those used in step 1. If they are similar, stop. Otherwise, update the coefficients of the laws of motion, and go to step 1.

[20] Here, we use an equidistant set of $N_{\text{grid}} = 1001$ points, with the lowest wealth level being the home production level ($\omega_1 = g$), and the highest being $\omega_{N_{\text{grid}}} = \overline{EAR}.\mathit{eff}_1 + k_{\max} * R^s_{\max}$, where $\overline{EAR}$, eff_1, $k_{\max}$ and $R^s_{\max}$ stand for the average earnings, the normalized level of efficiency units of the most efficient agent, the upper limit for capital ($k_{\max} = 110$), and the maximum level of equity return given that the lower limit for aggregate capital is equal to 5.73, respectively.

Appendix C. Derivation of the equity return

The results of Proposition 1 allow us to establish the following relationship between the gross returns on equity and bonds:

$$R^s_{t+1} = \frac{1}{1-\rho}\big(f_K(z_{t+1}, K_{t+1}, L_{t+1}) + 1 - \delta\big) - \frac{\rho}{1-\rho} R^b_{t+1}.$$

To see that this is the case, note first that the definition of the gross return on equity implies:

$$R^s_{t+1} = \frac{d^s_{t+1} + p^s_{t+1}}{p^s_t} = \frac{d^s_{t+1} S_{t+1} + p^s_{t+1} S_{t+1}}{p^s_t S_{t+1}}.$$

Using the budget constraint of the firm and the homogeneity of the production function, which implies that $f = f_K K + f_L L$, the equity gross return can be rewritten as:

$$R^s_{t+1} = \frac{[f_K(z_{t+1}, K_{t+1}, L_{t+1}) + 1 - \delta]K_{t+1} - K_{t+2} + p^s_{t+1} S_{t+2} + B_{t+2} - R^b_{t+1} B_{t+1}}{p^s_t S_{t+1}}.$$

Finally, using Proposition 1, which implies that $K_{t+2} = V_{t+1} = p^s_{t+1} S_{t+1} + B_{t+1}$, and the fact that $p^s_t S_{t+1} = (1-\rho)K_{t+1}$ and $B_{t+1} = \rho K_{t+1}$, we obtain:

$$R^s_{t+1} = \frac{[f_K(z_{t+1}, K_{t+1}, L_{t+1}) + 1 - \delta] - R^b_{t+1}\rho}{(1-\rho)}.$$

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