

Concentrated Ownership and Equilibrium Asset Prices ^{*}

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Abstract

Investors can choose to hold diversified or levered, concentrated portfolios of risky assets. This paper studies the dynamics of asset prices in an economy in which both investment styles coexist in equilibrium even though all agents are ex-ante identical. I capture the tradeoff between risk sharing and productivity gains by introducing what I call “active capital.” People who participate in such investments are restricted in their outside opportunities but receive extra compensation for the productivity gains they bring to the corresponding enterprises. I show that fluctuations in the quantity of active capital increase the volatility of asset prices relative to a standard economy. Not all shocks shift the distribution of ownership: risk considerations determine the willingness to provide active capital, whereas current and expected future economic activity do not play a role. Therefore, active capital fluctuates jointly with risk premia, amplifying their variations. As a consequence, the price of volatility risk exposure can be large, and return volatility is mainly induced by fluctuations in future expected returns. These results are particularly strong when fundamental volatility is low, because at such times, a large number of concentrated owners are likely to exit their positions and sell off their assets.

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1 Introduction

This paper characterizes the behavior of asset prices in an economy in which diversified and concentrated, levered investment coexist even though no ex ante heterogeneity is present. What determines the aggregate fraction of capital held by concentrated investors? How does the presence of concentrated investors affect the determination of asset prices? I show these two questions are intimately linked. When deciding whether to concentrate their holdings in particular projects to increase their productivity, agents compare the induced wealth risk to that of a diversified portfolio. Therefore, they respond to price dynamics. Conversely, as assets change hands among categories of investors, prices fluctuate. This two-sided relation between concentrated ownership and asset prices has rich implications for the equilibrium dynamics of prices.

Concentrated, levered ownership is ubiquitous in the economy. A number of economic activities can run more efficiently if some agents invest a significant fraction of their wealth in the enterprise. The benefits of such positions are one of the reasons advanced for stock-based compensation of executives and for why entrepreneurs keep a large equity stake in their businesses. The gains from concentrated, levered ownership can also come from investors outside the firm, typically financial institutions, exerting direct control or monitoring insiders.¹ As assets change hands between different types of investors and agents switch activity, we typically observe changes in aggregate asset prices.² The financial crisis of 2007-2009 is such an episode: business creation dropped and many leveraged financial institutions largely reduced or ceased completely their activities as asset prices dipped across markets.³ This paper sheds light on how, in aggregate, the organization of ownership between concentrated and diversified investors is determined jointly with asset prices.

I present a dynamic general equilibrium model with a role for concentrated investment. Agents are allowed to pick what I call “active capital” as an alternative form of asset ownership. Active investors constrain themselves to a concentrated risky po-

¹Venture capitalists and private equity funds exemplify this type of behavior, but one can also think of the activity of investment banks and hedge funds.

²For instance, broker-dealers (Adrian et al., 2010), buyout funds (Haddad et al., 2011), and venture capitalists (Gompers et al., 2008) diminish their activities in periods of high risk premium.

³Between December 2007 and March 2009, the hedge fund industry equity went from \$1975bn to \$973bn according to the Barclay Hedge database. For broker-dealers, He et al. (2010) estimate a change of trading assets from \$2601bn to \$1810bn using balance sheets of three pure broker-dealers. Private equity activity was also largely impaired for an extended period of time: the CityUK report on global private equity reports a drop in funds raised from \$480bn in 2007 to \$140bn in 2009.

sition in a firm, which makes the firm more productive. I represent this activity by a constraint on the portfolio shares in risky assets for active agents. This constraint reproduces the high portfolio leverage typical of these investors and is close to the optimal contract as a solution of a moral hazard problem.⁴ This framework allows me to study the joint determination of the quantity of active capital and asset prices in a variety of stochastic structures. I show the effects of active capital on asset prices and the real economy crucially depend on the nature of fundamental risk in the economy.

Active capital affects asset prices through two channels: *distorted risk sharing* and *deleveraging risk*. The static effect of active capital is a distortion of the risk-sharing arrangement in the economy. Active agents hold a disproportionate fraction of the risky assets. Therefore, the passive agents bear less risk in equilibrium. Consequently, they require a lower risk premium for the asset. This channel tells us risks that active agents bear will tend to have a lower price than those with no active ownership. Diverging from the standard perfect risk sharing is optimal in this framework because it improves the productivity of firms. I show, however, that a competitive market yields an excess amount of active capital. Taxing firms that use this source of capital raises the welfare of all agents by improving risk sharing.

The second channel, *deleveraging risk*, is driven by the dependence of the quantity of active capital on economic fundamentals. For instance, if fundamental risk increases, the quantity of active capital decreases. We observe a deleveraging episode: some active investors switch back to passive investments. This switch requires selling assets to reduce their excess risky portfolio holdings. Existing passive agents have to absorb these assets arriving on the market, which tends to lower prices further than the direct impact of the increase in risk. In this sense, active capital amplifies the fundamental volatility risk. Ex ante, this effect will tend to increase the price of this risk. The general finding is that shocks that affect the supply or demand of active capital are amplified and command a higher price of risk.

The determination of the quantity of active capital is key to understanding characteristics of these two effects. Equilibrium in the active capital market equates the quantity of active capital firms demand with the number of investors willing to accept this particular portfolio. Firms demand active owners because they increase cash flow. They trade off these productivity gains with the extra cost of active capital. I assume the gains per fraction of active capital are independent of the state of the economy.

⁴See Holmstrom (1979) for the original derivation and Holmstrom and Tirole (1997) for a general equilibrium application.

Therefore, the demand curve for active capital is constant over time. On the other hand, the supply of active capital is endogenously determined. Because all agents are ex-ante identical, the extra returns paid to active capital must exactly compensate active agents for the extra risk they bear. The required compensation (cost of active capital) depends positively on risk aversion, the riskiness of the asset, and the size of the deviation from the optimal portfolio. This result points at two important shocks that shift the amount of active capital: volatility and risk-aversion shocks. But not all shocks do impact asset prices and the economy: shocks to the level of output, in the style of TFP shocks, do not yield changes in the composition of ownership, and therefore are not amplified. Such distinction points at an explanation why not all recessions occur jointly with financial crises: the active sector is resilient to technological recession, but much less so to periods of economic uncertainty.

In general equilibrium, asset prices change with different levels of active capital. Market clearing implies that with more active agents, passive agents hold a smaller quantity of risky assets. For this condition to be consistent with optimization by passive agents, the asset must be more expensive. Therefore, the portfolio of active agents becomes more costly and they ask for more compensation for their activity. This feedback of activity on risk sharing makes the supply of active capital an increasing function of its price. Because deleveraging risk plays a role through variations in the quantity and not the price of active capital, the effects are more dramatic when the demand and supply are more elastic and when supply is more responsive to economic conditions. In particular, the deleveraging risk is large in periods with important quantities of active capital.

The main contribution of this paper is to provide an equilibrium model of investor heterogeneity resulting from choices of agents. To my knowledge, this paper is the first to provide such an approach to asset-pricing theory with heterogeneous agents. The rest of this large literature has focused on heterogeneous investment behavior resulting from exogenous differences in preferences or ability. I show this distinction is meaningful, affecting not only the dynamics of asset prices but also real dynamics as well as response to policy interventions. Related, an important contribution is the characterization of the equilibrium dynamics of asset prices. I argue the behavior of prices in the model echoes a number of asset pricing-facts. In particular, the model generates a negative link between the quantity of active capital and the aggregate risk premium. Further, the presence of active capital increases the volatility of asset prices through fluctuations in expected returns, unrelated to fluctuations in the current level of the economy or growth prospects. Finally, a third contribution of the paper is to provide a tractable model

with meaningful investor heterogeneity. I show that for arbitrary Markov dynamics, solving the model with or without heterogenous agents has the same complexity. The two problems share the same difficulty, a partial differential equation in the number of exogenous state variables characterizing the price function. All other quantities admit simple closed-form expressions.

After discussing related work, section 2 presents a simple case of the model showing how equilibrium in the active capital market is determined, illustrating the two main mechanisms. I detail the general model in section 3. Section 4 focuses on the pricing implications of the presence of active capital in an economy with changes in aggregate uncertainty and growth prospects. In particular it helps draw a comparison between level and volatility shocks. Finally, I discuss the role of variation in financial constraints and firm-level uncertainty as well as the effect of policy actions in section 5.

Related Literature

This paper fits in the literature studying asset prices in the presence of heterogeneous investors. In particular, it is closely related to the work on heterogeneity resulting from financial frictions.⁵

I focus on the role of equity constraints on agents linked to particular firms for asset-pricing dynamics. Closest to my paper are Brunnermeier and Sannikov (2013), and He and Krishnamurthy (2013). They both study the dynamics of asset prices in models with an equity constraint. Related is Danielsson et al. (2009), who study volatility dynamics in the presence of a Value At Risk constraint. My approach differs from these papers because all agents in the economy choose between being levered or not, rather than having two predetermined categories of agent. As a consequence, they focus on the net worth of each category of agents rather than the incentives to be active rather than passive. I further detail in section 4 how this distinction affects asset pricing predictions across the two types of models.

Other sources of heterogeneity in the behavior of agents have been pointed to as potential sources of fluctuations in risk premia. For instance, Dumas (1989) shows that even with i.i.d. dynamics, heterogeneity in risk aversion can generate fluctuations in expected returns. Basak and Cuoco (1998) study an economy with participation constraints. Gennaioli et al. (2011) study the implications of neglected risks for deleveraging and asset prices. Geanakoplos (2009) focuses on how belief heterogeneity interacts with margins. Again, a key difference in my paper is that the heterogeneity is always

⁵Brunnermeier et al. (2010) survey extensively this literature.

predetermined.

Finally, a number of papers study how traders with large stakes affect firm dynamics. DeMarzo and Urošević (2006) study the trading behavior of a large investor that can influence the firm. Basak and Pavlova (2013) study pricing in an economy where an investor can affect aggregate prices. In my economy, investors hold concentrated stakes in individual firms but are atomistic at the scale of the economy; therefore individual decisions do not feed back directly on the equilibrium.

2 Basic Model

In this section, I present a case of my model with constant economic conditions to illustrate how the quantity of concentrated capital and asset prices are jointly determined in equilibrium. I study an infinite-horizon, continuous-time economy. I first explain how I model the role of concentrated positions in increasing productivity. Then I move on to determining the equilibrium of the model, and emphasize properties of prices in my economy that will drive the results in the general model with time-varying conditions.

I depart from the standard framework by relaxing the assumption that the production outcomes of firms are independent of their ownership structure. In a Walrasian equilibrium, ownership is determined only by concerns about consumption smoothing across time and states of the world; having agents that influence the production of the firm own it provides no benefit. Many (e.g., Berle and Means (1932)) have argued the development of larger firms and financial markets causing more diffuse ownership, has led this model to be an increasingly accurate representation of the world. However, this argument is at odds with the data. Holderness et al. (1999) find the mean percentage of common stock held by a firm's officers and directors for exchange-listed firms actually increased from 13% in 1935 to 21% in 1995. Additionally, private firms still represent a large fraction of the economy, and most of their equity is owned by their workers. I capture the particular role of concentrated ownership by introducing the notion of active investors: agents that concentrate their asset holdings in a given firm increase its productivity.

I do not explicitly model the labor and production decisions, but rather focus on the implications of an exogenously specified constraint for asset allocation. Specifically, each firm can choose to pay some agents to actively invest in it. Firms thereby trade off the cost of hiring these agents with the additional productivity they provide. The additional productivity is proportional to the fraction of capital active investors own,

where the marginal return λ is exogenously specified. Agents, on the other hand, choose whether to allocate their wealth optimally without focusing on any precise firm or investing actively in a given firm. An agent investing actively must allocate a fraction $\bar{\theta} > 1$ exogenously specified of his wealth in claims to the output of the firm, financing this position by taking up risk-free debt. The motive for concentrating holdings is that the firm in which an agent invests actively will compensate him in addition to the regular asset returns.

Similar to these assumptions is the decision of inside ownership by firms. They can choose whether to provide their employees with fixed or stock-based compensation. Conversely, people can choose “safe” career paths that do not link their labor decisions⁶ to their wealth-allocation decisions, or to concentrate their wealth in one firm where its evolution depends on the enterprise’s performance. However, note that many other forms of active investment exist. For instance, entrepreneurs usually keep a large stake in the firms they create. Active investment also does not need to come from agents working directly inside the firm. Holmstrom and Tirole (1997) emphasize that outside investors can affect a firm’s outcomes through their monitoring activity. Typical of such activity are private equity funds and venture capitalists, whether they fund new projects or buy out firms, but one can also think of the investment activities of a number of hedge funds or investment banks.

2.1 The hiring decision of firms

I assume a continuum of identical firms indexed by $j \in [0, 1]$. Firms can go on the occupation market and hire the services of active investors in order to increase their productivity. Let m_t^j be the fraction of total firm value held by active agents at time t . The evolution of the firm cash flow D_t^j is given by

$$(2.1) \quad \frac{dD_t^j}{D_t^j} = (\mu_D + \lambda m_t^j)dt + \sigma_D dZ_t.$$

The parameters μ_D and σ_D control the fundamental drift and volatility of cash-flow growth, and $\{Z_t\}$ is a univariate Brownian motion. Active investment increases cash-flow growth, with a marginal return λ . Such an effect is similar to the effect of investment in a standard q-theory framework. For instance, active investors can help the firm make better decisions or work harder, thereby increasing productivity while they are at the firm and permanently increasing the scale of production.

⁶I focus only on the active capital friction. In particular, I assume the wealth of all other agents is perfectly liquid and tradable at all times.

Firms have to pay active investors for their services. I assume the payment takes the form of a fee $f_t dt$ per unit of capital. This fee is determined by the competitive equilibrium of the occupation market, and the firm takes it as given. Denoting P_t^j as the market value of the firm, the total payment to active investors at time t is $f_t m_t^j P_t^j dt$. Equivalent to a direct payment, f_t can be thought of as a rate of share issuance: for each unit of capital they provide, active investors receive $f_t dt$ extra shares. Because this payment is infinitesimal, whether investors receive it before or after the resolution of uncertainty is irrelevant. Another equivalent interpretation of this payment is an issuance of new shares paid to the active investors.

The firm chooses how many investors, as a fraction of its capital, it hires to maximize its share value. The firm takes the process for the stochastic discount factor $\{S_\tau\}$ and the fee $\{f_\tau\}$ as given. As in the standard investment theory, the firm faces a static tradeoff between productivity increase and the fee payment. The marginal benefit of increasing m_t^j is a gain in scale generating a value $\lambda P_t^j dt$, whereas the marginal cost is the payment $f_t P_t^j dt$. Because neither the marginal benefit nor the cost depends on m_t^j , we obtain a perfectly elastic demand for active capital from the firm:

$$\begin{cases} m_t^j = 1 & \text{if } \lambda > f_t, \\ m_t^j \in [0, 1] & \text{if } \lambda = f_t, \\ m_t^j = 0 & \text{if } \lambda < f_t. \end{cases}$$

In the case of an interior equilibrium, $\lambda = f_t$, cost and benefit exactly cancel each other out. Firms are indifferent between any level of active capital. Their valuation does not depend on the level they choose; that is, the valuation is the same as that of a firm without active capital. In section 3, I provide a more complete derivation of this result and justify the time consistency of the policy function, even though the cost depends on the value the firm is optimizing.

2.2 The occupation decision of agents

I assume a continuum of ex-ante identical agents indexed by $i \in [0, 1]$. They value risky consumption plans with the standard power utility function:

$$\mathcal{U}(\{C_\tau\}_{\tau=t}^\infty) = \mathbb{E}_t \left[\int_0^\infty e^{-\beta\tau} \frac{C_{t+\tau}^\gamma}{\gamma} d\tau \right],$$

where β is the rate of time discount and $\Gamma = 1 - \gamma$ is the relative risk aversion. Agents are all endowed with an equal fraction of all firms at time 0. Let W_t^i be their wealth

at time t . At each point in time, agents can choose to be either passive or active investors. If they decide to be passive, they can also choose their portfolios. They make this decision in order to maximize their lifetime utility, taking asset returns and the fee for active capital as given.

Practically, most forms of active investment have some degree of illiquidity. Compensation contracts often involve some long-term relation, at least at the yearly frequency with the annual payment of bonuses. Similarly, entrepreneurs cannot always liquidate their firms on short notice. My model does not feature this long-run illiquidity, but captures the idea that at any point in time, some agents decide to take on or leave active investments. Indeed, we observe a lot of mobility in the workforce, and the landscape of firms is constantly changing.⁷

Passive investors are standard neoclassical agents. Let this (endogenous) subset of investors at time t be \mathcal{P}_t^* . They have unrestricted access to the asset markets: they can buy and sell claims to any payoff. I note θ_t^{i,j^*} as the number of shares of firm j bought by agent i , and $\mu_{R,t}^j$ and $\sigma_{R,t}^j$ as the drift and volatility of these shares' returns. The wealth evolution for a passive agent is then

$$(2.2) \quad dW_t^i = \left(W_t^i \left(\int_0^1 \theta_t^{i,j^*} (\mu_{R,t}^j - r_{f,t}) dj + r_{f,t} \right) - C_t \right) dt + W_t^i \left(\int_0^1 \theta_t^{i,j^*} \sigma_{R,t}^j dj \right) dZ_t.$$

Active investors (set $\mathcal{A}_t^{j^*}$ for firm j and \mathcal{A}_t^* in aggregate) focus on a single firm j and help increase its productivity. I assume a fraction $\bar{\theta} > 1$ of shares of firm i financed by risk-free borrowing must comprise the investors' portfolios. The assumption that $\bar{\theta} > 1$ implies aggregate risk is concentrated in the hands of active investors.⁸ As a compensation for focusing on firm j , they receive an extra return f_t per unit of investment. The wealth evolution for an active agent investing in firm j is therefore

$$(2.3) \quad dW_t^i = \left(W_t^i (\bar{\theta} (\mu_{R,t}^j - r_{f,t}) + r_{f,t} + \bar{\theta} f_t) - C_t \right) dt + W_t^i \bar{\theta} \sigma_{R,t}^j dZ_t.$$

This constraint departs from the standard optimal contract in the presence of moral hazard (Holmstrom, 1979) in three ways: no benchmarking of aggregate risk, contract on market price rather than actual output, and constraint proportional to wealth.⁹

⁷Puri and Zarutskie (2011) find that about 3 million firms are created in any five-year period between 1981 and 2005.

⁸It is easy to check that an inequality constraint of $\theta \geq \bar{\theta}$ would always bind. If $\bar{\theta} \leq 1$ with an inequality constraint, the constraint would always be slack.

⁹The first two are common assumptions of the literature on the macroeconomic role of financial constraints and are present in Bernanke et al. (1999), He and Krishnamurthy (2012), and Brunnermeier and Sannikov (2013). Di Tella (2013) offers a rationalization of this property.

The standard theory predicts the contract should only take into account a measure of the idiosyncratic part of cash flow, not an overall stock position. However, in practice, equity-based compensation is widely used and little evidence points to relative-performance evaluation.¹⁰ The concentrated positions even seem to make agents bear an excessive amount of aggregate risk.¹¹ One could argue agents can go on markets and choose whether to hedge any excess exposure to aggregate risk. To my knowledge of the literature, little evidence supports that agents engage in such shorting of aggregate risk. This lack of hedging might be due to a limited ability to take short positions. My results still hold if agents cannot hedge as much as they would like to. In this case, $\bar{\theta}$ becomes the loading on risk after all possible hedging is done. Whether compensation should be commensurate with changes in stock prices or proportional to the percentage change is ambiguous from the theoretical point of view. Empirically, percentage-percentage measures appear to give more sensible results and are more stable across firms.¹²

When choosing his occupation, an agent faces a tradeoff between optimizing his portfolio and receiving the fee f_t . Because passive agents are unconstrained, without the fee, the utility of a passive investor would be smaller than that of an active investor. Concentrating a portfolio on a levered position in one firm would serve no purpose.

To solve for the optimal decision of an agent, we can make a few simplifying remarks. First note that because all firms are identical, they all have the same return and volatility, $\mu_{R,t}^j$ and $\sigma_{R,t}^j$, so I drop the superscript j and note θ_t^{i*} as the optimal risky position of agent i if he is passive. Also note the opportunity set of agents is linear in their wealth and independent of their past occupation, preferences are homogenous of degree γ , and the opportunity set of a firm is linear in its current size. The model is therefore stationary, and no endogenous state variable is present. In particular, the utility level of each agent as a function of wealth does not depend on i and t . It is given by

$$U_t^i = \frac{(W_t^i)^\gamma}{\gamma} G$$

for some endogenous constant G .

¹⁰Janakiraman et al. (1992) and Aggarwal and Samwick (1999) do not find significant evidence in favor of relative performance evaluation for firms' executives.

¹¹Moreira (2009) finds small-business owners' income loads excessively on aggregate risk.

¹²The seminal paper of Jensen and Murphy (1990) finds an apparently small dollar-dollar sensitivity of 0.3% for CEOs. Edmans et al. (2009) propose a model predicting percentage-percentage pay. They find empirically this measure is 9 on average and is stable across different sizes of firms.

We can then focus on the Hamilton-Jacobi-Bellman equation, determining the utility of an agent starting with one unit of wealth:

$$\begin{cases} 0 = \max\{\text{HJB}_P, \text{HJB}_A\} \\ \text{HJB}_A = \sup_c c^\gamma - \beta G + \gamma G(\bar{\theta}(\mu_R - r_f) + r_f + \bar{\theta}f_t - c) + \frac{1}{2}\gamma(\gamma - 1)G\bar{\theta}^2\sigma_R^2 \\ \text{HJB}_P = \sup_{c,\theta} c^\gamma - \beta G + \gamma G(\theta(\mu_R - r_f) + r_f - c) + \frac{1}{2}\gamma(\gamma - 1)G\theta^2\sigma_R^2, \end{cases}$$

where the first maximization corresponds to the occupation choice and the next two correspond to the consumption and portfolio choices of an agent in each occupation. The first-order condition with respect to consumption is the same for both occupations. It tells us that if both occupations occur in equilibrium, the consumption-wealth ratio of all agents will be the same, equal to

$$c = G^{\frac{1}{\gamma-1}}.$$

The other first-order condition is the portfolio choice of a passive investor. Because a passive investor is just a regular investor with power utility, we obtain the standard Merton formula:

$$\theta^* = \frac{\mu_R - r_f}{(1 - \gamma)\sigma_R^2}.$$

The two HJB are the same linear-quadratic function of the portfolio share, with the exception of the fee $\bar{\theta}f$. Depending on whether the fee exceeds the quadratic cost of deviating from the optimal portfolio, agents will choose one or the other activity. Agents are indifferent between occupations if:

$$(2.4) \quad \bar{\theta}f = \frac{1}{2}(1 - \gamma)(\bar{\theta} - \theta^*)^2\sigma_R^2.$$

If the left-hand side is larger than the right-hand side, all agents are active; if the right-hand side is larger, all agents are passive. The supply of active capital, taking asset prices as given, is therefore perfectly elastic.

The cost of deviating from the optimal portfolio is proportional to relative risk aversion $(1 - \gamma)$, return volatility σ_R^2 , and the distance between the active portfolio and the optimal one. Note this cost is not a measure of the absolute excessive risk taken by an active investor, but rather of how far his portfolio is from that of the optimal one in terms of risk.

2.3 Equilibrium

We can now turn to the determination of the equilibrium. To do so, I add market-clearing conditions to the problems of agents and firms. I generalize the standard

Walrasian equilibrium by adding a market for active investment where firms and agents are price takers. This market structure represents the idea that firms compete for hiring active investors, and investors compete for the active positions.

Definition 2.1. Given $\bar{\theta}_A$ and λ , an equilibrium constitutes $\theta_t^{i,j}$, c_t^i , a partition \mathcal{A}_t^{j*} and \mathcal{P}_t^* , m_t^j , S_t , and f_t for $i, j \in [0, 1]$ and $t \in [0, \infty)$ such that

(i) The portfolio choices of active investors satisfy the equity constraint:

$$\forall t \in [0, \infty), \forall j \in [0, 1], \forall i \in \mathcal{A}_t^{j*}, \theta_t^{i,j} = \bar{\theta} \text{ and } \forall j' \neq j, \theta_t^{i,j'} = 0.$$

(ii) Occupation $\mathcal{O}_t(A_j$ if $i \in \mathcal{A}_t^{j*}$, P if $i \in \mathcal{P}_t^*$) portfolio, and consumption choices are feasible and maximize utility given aggregate prices, the active fee f , and the wealth evolutions (2.2) and (2.3):

$$\begin{aligned} & \max_{\mathcal{O}_t, C_t, \{\theta^{i,j}\}_t} \mathbb{E}_t \left[\int_0^\infty e^{-\beta\tau} \frac{C_{t+\tau}^\gamma}{\gamma} d\tau \right] \text{ such that} \\ & dW_t^i = \left(W_t^i \left(\int_0^1 \theta_t^{i,j*} (\mu_{R,t}^j - r_{f,t}) dj + r_{f,t} \right) - C_t \right) dt \\ & \quad + W_t^i \left(\int_0^1 \theta_t^{i,j*} \sigma_{R,t}^j dj \right) dZ_t \quad \text{if } \mathcal{O}_t = P \\ & dW_t^i = (W_t^i (\bar{\theta} (\mu_{R,t}^j - r_{f,t}) + r_{f,t} + \bar{\theta} f_t) - C_t) dt \\ & \quad + W_t^i \bar{\theta} \sigma_{R,t}^j dZ_t \quad \text{if } \mathcal{O}_t = A_j \\ & W_t, C_t \geq 0, \quad \forall t. \end{aligned}$$

(iii) Levels of active investment maximize firm value:

$$\forall t \in [0, \infty), \forall j \in [0, 1],$$

$$\{m_\tau^j\} \in \arg \max_{\{m_\tau\}} P_t = \arg \max_{\{m_\tau\}} \mathbb{E}_t \left[\int \frac{S_{t+\tau}}{S_t} D_{t+\tau} - f_{t+\tau} m_{t+\tau} P_{t+\tau} d\tau \right]$$

given the cash-flow evolution (2.1).

(iv) The occupation market clears:

$$\forall j \in [0, 1], m_t^j P_t^j = \int_{\mathcal{A}_t^{j*}} \theta_t^{i,j} W_t^i di.$$

(v) The market for assets clears:

$$\forall j \in [0, 1], P_t^j = \int_0^1 \theta_t^{i,j} W_t^i di.$$

(vi) *The market for goods clears:*

$$\int_0^1 C_t^i di = \int_0^1 D_t^j dj.$$

Some of the integrals in the definition above are a slight abuse of notation in order to keep clarity. Indeed, individual passive investors' stock positions in a given firm will typically be negligible compared to those of active investors. These problems disappear once we aggregate across firms. To do so, let $P_t = \int_0^1 P_t^j dj$ be the price of the aggregate endowment. It is equal to the aggregate wealth $W_t = \int_0^1 W_t^i di$. We can note the aggregate fraction of active capital as $M_t = \int_0^1 m_t^j P_t^j / P_t dj$. Finally, let θ_t^* be the portfolio of a passive agent, as we saw they all make the same choice. Combining the market-clearing conditions for the occupation and the asset markets, we obtain the following market-clearing condition:

$$(2.5) \quad \frac{M_t}{\bar{\theta}} + \frac{1 - M_t}{\theta_t^*} = 1.$$

This condition is summarized in Figure 1. All wealth is owned either by active investors, who have in total a fraction M_t of risky assets by each taking a position $\bar{\theta}$, or passive investors, who have in total a fraction $1 - M_t$ of risky assets by taking a position θ_t^* .

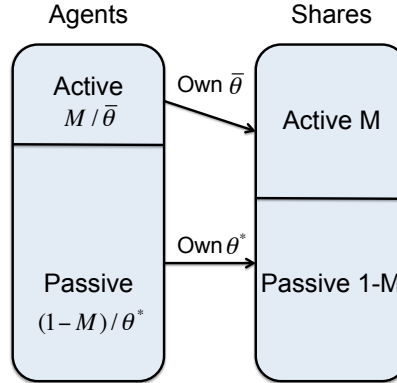


Figure 1: **Market-clearing condition**

This market-clearing condition, combined with the individual supply of active capital (2.4), determines the aggregate supply of active capital. This function, linking the quantity M to the price f , is increasing. Indeed, as M increases, the fraction of risky assets owned by active investors increases. The market-clearing condition (2.5)

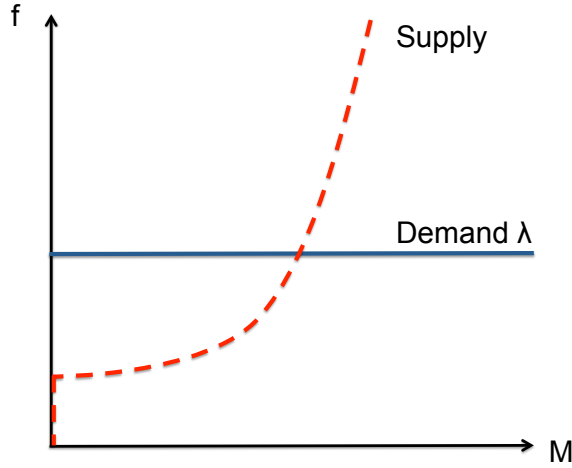


Figure 2: **Equilibrium of the active capital market**

shows that as passive agents have to sell risky assets to the new active investors, their portfolio share θ^* decreases. This change in positions increases the distance between the active and passive portfolios and, as shown by the individual supply (2.4), increases the fee required by agents to invest actively.

To determine the equilibrium of the active capital market, it suffices to equate the aggregate supply to the perfectly elastic demand of firms at the fee level λ . Figure 2 illustrates this equilibrium, which corresponds to the quantity M such that

$$\lambda = \frac{\frac{1}{2}(1 - \gamma)(\bar{\theta} - \theta^*)^2 \sigma_R^2}{\bar{\theta}}.$$

This equilibrium pins down the portfolio share θ^* of passive agents and therefore the level of active capital. We obtain directly the following comparative statics:

Proposition 2.2. *The portfolio share of passive agents θ^* and the fraction of passive capital $1 - M$ are*

- (i) *increasing in return volatility σ_D and,*
- (ii) *increasing in relative risk aversion $1 - \gamma$.*

2.4 Asset prices

Let us turn to the behavior of asset prices. Because of the absence of state variables, we can start by noticing the price–cash-flow ratio is constant. This result implies the

volatility of return will exactly equal the volatility of cash-flow σ_D . The active capital market does not affect price volatility in this setting. The price–cash-flow ratio satisfies the standard Gordon growth formula:

$$V = (r_f + \sigma_D rp - \mu_D)^{-1},$$

where rp is the risk price of the innovation dZ of cash flow and r_f is the risk-free rate. To determine these quantities, note that passive investors are standard investors à la Merton. Therefore, the stochastic discount factor in the economy corresponds to the marginal utility of these agents. In particular, using the first-order condition of the portfolio decision, we obtain the risk price:

$$rp = (1 - \gamma)\sigma_D\theta^*.$$

This formula helps us detail the two main effects of the active capital market: distorted risk sharing and deleveraging risk.

Distorted risk sharing. Because $\theta^* < 1$, we can conclude the risk price is lower than in an economy without active capital (which corresponds to $\theta^* = 1$). Active investors hold a disproportionate share of the aggregate risk of the economy; therefore, in equilibrium, passive investors have to bear less risk. The risk active investors take does not affect the risk price. Indeed, though investors take asset prices into account in their occupation choice, active investors are not marginal in the asset market: their portfolio is constrained to take the value $\bar{\theta}$. Of course, they are compensated for taking this risk by the fee f ¹³. The importance of the distortion in risk sharing is clearly linked to the fraction M of active investors. As Proposition 2.2 shows, risk prices will be relatively lower in economies with low fundamental volatility and populated by agents with low risk aversion.

Deleveraging risk. This dependency with respect to risk conditions yields the second main effect of active capital: deleveraging risk. Because the quantity of active capital is sensitive to risk, fluctuations in risks will generate large fluctuations in prices and risk premium. I illustrate this effect here as a comparative static. I detail it in a completely dynamic model in the following sections. Figure 3 represents the equilibrium changes after an increase in fundamental volatility σ_D . First, on the right panel, we see the

¹³The fee f cannot exactly be interpreted as a different expected return incentivizing active agents to take on a portfolio $\bar{\theta}$. One can prove active agents, even in the presence of the fee, would always choose a lower share of risky assets if relieved of the constraint.

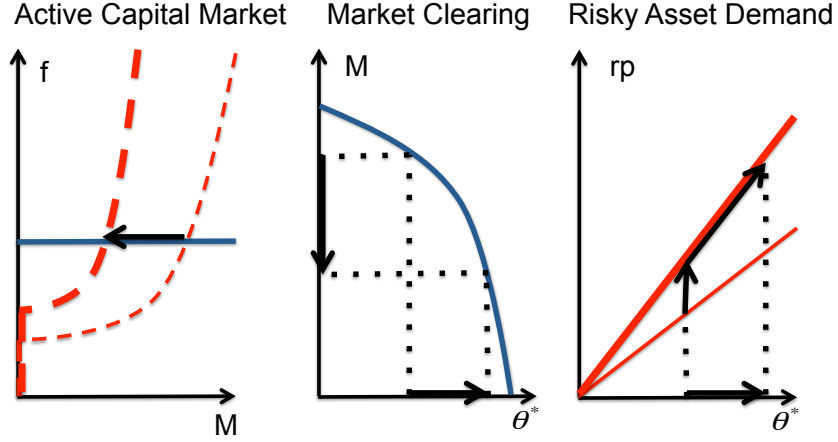


Figure 3: **Deleveraging following an increase in volatility**

demand for risky assets decreases: passive agents ask a higher risk price. This effect is standard in an economy without active capital. To hold the same quantity of a more risky asset, agents demand a larger compensation. Therefore, we move vertically from the initial demand curve to the new one. But this change is not the only one: the relative cost of providing active capital increases. We can see this increase on the first panel: the supply curve for active capital shifts left. Because the demand is perfectly elastic, this shift results in a lower quantity M of active capital. Active agents sell off their assets, and passive agents have to hold more risky assets. The middle panel shows this move along the market-clearing condition. Finally, returning to the right panel, we move along the demand curve of passive agents having to hold more risky assets and therefore, asking for a larger risk price.

Another way to look at this phenomenon is to consider the elasticity of the risk price with respect to volatility or relative risk aversion; the results are the same. In the standard model without active capital, the risk price is proportional to volatility and therefore the elasticity is 1. With active capital, as the amount of risk as well as the quantity of risky assets held by passive agents increase, this elasticity is larger than 1:

$$\begin{aligned} \frac{\partial \log(rp)}{\partial \log(\sigma_D)} &= 1 + \frac{\partial \log(\theta^*)}{\partial \log(\sigma_D)} > 1 \\ &= 1 + \frac{\bar{\theta} - \theta^*}{\theta^*}. \end{aligned}$$

This elasticity indicates the determinant of the magnitude of the deleveraging effect. The deleveraging effect is proportional to the leverage of the active investors' risky

position relative to that of passive investors. For instance, if $\bar{\theta} > 2$, this effect is always more important than the standard quantity of risk effect. When the quantity of active capital in the economy is large, the price of risk is more sensitive to volatility, as θ^* gets smaller.

On the other hand, no such deleveraging occurs following shocks to the level of cash flow, as shown by the constant equilibrium fraction of active capital M . As a comparative static, changes in future expected cash flow, created by a change in fundamental growth rate μ_D , also do not yield any change in the fraction of active capital. These results point to the key idea that shocks to uncertainty or risk aversion interact strongly with the fraction of active capital, whereas shocks to the level of present or future cash flow do not. This difference confers a particular importance of changes in volatility and expected returns to explain asset price volatility and expected returns once we turn to the fully dynamic model.

3 General Model

I now turn to the general case of the model. I characterize Markov equilibria in the general case of Duffie-Epstein-Zin preferences and an arbitrary Markov diffusion for cash-flow growth. I then explain how to obtain all quantities of the model from the solution of a single partial differential equation. Finally, I compare the structure of my model with endogenous activity choices to that of models with intrinsic heterogeneity.

3.1 Firms

The aggregation results regarding firms derived in the previous section still hold as I maintain linear dynamics in the size of firms for cash flow. Therefore, I focus on a representative firm. The evolution of its cash flow is given by

$$\frac{dD_t}{D_t} = (\mu_D(s_t) + \lambda m_t)dt + \sigma_D(s_t)dZ_t,$$

where $\{Z_t\}$ is now a multivariate Brownian motion of dimension K . Aggregate conditions are characterized by $\{s_t\}$, a set of S state variables following a Markov diffusion:

$$ds_t = \mu_s(s_t) + \sigma_s(s_t)dZ_t.$$

As before, firms choose their fraction of active capital m_t dynamically, taking the process for the active fee $\{f_t\}$ and the stochastic discount factor $\{S_t\}$ as given. The

firms maximize the net present value P_t of their payoffs after payment of the active fee. This decision corresponds to the following problem:

$$P_t = \sup_{\{m_{t+\tau}\}_{0 \leq \tau < \infty}} \mathbb{E}_t \left[\int_0^\infty \frac{S_{t+\tau}}{S_t} (D_{t+\tau} - f_{t+\tau} m_{t+\tau} P_{t+\tau}) d\tau \right]$$

$$\text{s.t. } \frac{dD_{t+\tau}}{D_{t+\tau}} = (\mu_D(s_{t+\tau}) + \lambda m_{t+\tau}) dt + \sigma_D(s_{t+\tau}) dZ_{t+\tau}.$$

The linearity of both the objective function and the dynamics in the current level of cash flow implies the value function is linear in the level of cash flow and the optimal policy does not depend on this level. In other words, P_t/D_t and m_t^* are deterministic functions of s_t . By abuse of notation, $P/D(s_t) = V(s_t)$ and $m(s_t)$, respectively, in the remainder of the paper.

The recursive structure of the problem guarantees time consistency of the optimal policy. Further it allows us to write the problem in the form of a Hamilton-Jacobi-Bellman equation, as can be seen in appendix A.1. As is standard for this type of investment model, the choice of optimal active capital turns out to be static. The first-order condition to have an interior optimum is, as it was for the stationary case,

$$\lambda = f_t.$$

This condition pins down the fee paid to active capital but not individual policies. The indeterminacy can generate ex-post heterogeneity in the size of firms. However, because the dynamics of cash flow are linear in the current level, and the way m^j aggregates to M , one can see aggregate dynamics are invariant to the distribution of individual firms' policies.

Another implication of this first-order condition, also derived in appendix, is that the price of the firm is the same as that of an identical firm without active capital:

$$P_t = \mathbb{E}_t \left[\int_0^\infty \frac{S_{t+\tau}}{S_t} D_{t+\tau} d\tau \right]$$

$$\text{s.t. } \frac{dD_{t+\tau}}{D_{t+\tau}} = \mu_D(s_{t+\tau}) dt + \sigma_D(s_{t+\tau}) dZ_{t+\tau}.$$

In particular, any difference in the price of the firm compared to an economy without active capital must come from different processes for the stochastic discount factor. In this sense, my model emphasizes that fluctuations in the quantity of active capital, even if they do not affect the payoffs to passive investors, affect asset prices through the changes in the valuation of this cash flow.

3.2 Asset markets

Because some passive agents that are marginal in complete asset markets are always present, we know no arbitrage opportunities are available. Therefore, a stochastic discount factor exists. It follows a diffusion given by

$$\frac{dS_t}{S_t} = -r_{f,t}dt - rp_t dZ_t,$$

where r_f is the risk-free rate and rp is the vector of risk prices of the K shocks.

Without loss of generality, I assume a set of K assets are available to investors. The first one is a share of any of the firms. As noted previously, they all have the same price and cash-flow evolution, so their shares have the same returns. The other $K - 1$ asset returns are in zero net supply, have unit variance, and complete the market. Their expected excess returns can directly be inferred from the stochastic discount factor $\{S_t\}$, because they correspond to the risk prices. I note $\mu_{R,t}$ as the vector of expected returns and $\sigma_{R,t}$ as the vector of volatility of these assets. The risk-free asset is in zero net supply. In equilibrium, all these quantities are deterministic functions of the state s_t of the economy.

3.3 Agents

Agents now rank consumption streams according to the stochastic differential utility of Duffie and Epstein (1992). It is a continuous-time version of the recursive preferences of Epstein and Zin (1989). Let \mathcal{U}_t be the utility of the agent at time t , and let $f(C, \mathcal{U})$ be the aggregator. The utility value \mathcal{U}_t is defined recursively by:

$$\mathcal{U}_t = \mathbb{E}_t \left[\int_t^\infty g(C_s, \mathcal{U}_s) ds \right].$$

For the aggregator g , I use the standard function:

$$g(C, \mathcal{U}) = \beta \frac{\gamma}{\rho} \mathcal{U} \left[\frac{C^\rho}{\gamma^\frac{\rho}{\gamma} \mathcal{U}^\frac{\rho}{\gamma}} - 1 \right].$$

β is the rate of time preference. $\Gamma = 1 - \gamma$ is the relative risk aversion (RRA) of the agent. $\psi = \frac{1}{1-\rho}$ is the intertemporal elasticity of substitution (IES). When $\Gamma = \frac{1}{\psi}$, or, equivalently, $\gamma = \rho$, the utility function reduces to the standard power utility specification of section 2. This utility function is homogenous of degree γ and therefore preferences are homothetic. An important motivation for using these preferences, in

addition to the fact that they have proven useful in obtaining good quantitative results for asset-pricing models, is that they generate a volatility risk premium.

Agents can choose whether they are active or passive investors. Let \mathcal{A}_t^* and \mathcal{P}_t^* be these sets of investors at each time. Agents can move freely between occupations. They can choose their consumption C_t without any constraint.

Passive investors choose freely their portfolio $\boldsymbol{\theta}_t^*$ across all assets. Their wealth evolution is then

$$dW_t^i = (W_t^i(\boldsymbol{\theta}^{*'}(\mu_{R,t} - r_{f,t}) + r_{f,t}) - C_t) dt + W_t^i \boldsymbol{\theta}^{*'} \sigma_R dZ_t.$$

Active investors are constrained to choose a portfolio $\bar{\boldsymbol{\theta}} = [\bar{\theta}, 0, \dots, 0]$ that only consists of a position in shares of the firm. Again, I assume $\bar{\theta} > 1$. This assumption constrains them to hold more of the asset than anybody would hold in a world without active investors. Additionally, they cannot hedge the risk coming from changes in the state variables. As a compensation for accepting this constraint, they receive the fee $f_t dt$ for each unit of capital of the firm in which they invest. The evolution of their wealth is driven by

$$dW_t^i = \left(W_t^i(\bar{\boldsymbol{\theta}}'(\mu_{R,t} - r_{f,t}) + r_{f,t} + \bar{\theta} f_t) - C_t \right) dt + W_t^i \bar{\boldsymbol{\theta}}' \sigma_R dZ_t.$$

Because all these dynamics are linear in wealth and the homogeneity of utility functions, one can see all agents will face the same tradeoff, irrespective of their current wealth, when choosing their occupations. Additionally, agents in each occupation will all have the same consumption-wealth ratio, written as $c_t^i = C_t^i/W_t^i$. To have an interior equilibrium for the level of active capital, agents, given their wealth, have to be indifferent between activities at each point in time. Let G_t/γ be the utility of an agent with wealth 1 at date t . The utility of an agent with wealth W_t^i is then

$$\mathcal{U}_t = \frac{(W_t^i)^\gamma}{\gamma} G_t,$$

where G_t is a deterministic function of the state variables I note as $G(s_t)$. In particular, $G(\cdot)$ must be the value function of an agent being active or passive for some interval of time. The following proposition formalizes this idea.

Proposition 3.1. *The fee f_t is such that the value function per unit of wealth $G(s_t)$ solves the Hamilton-Jacobi-Bellman problems:*

(i) **Passive investor:**

$$0 = \max_{c \geq 0, \boldsymbol{\theta} \in \mathbb{R}^K} g(\gamma^{1/\gamma} c, G) + \frac{\mathbb{E}[d(W^\gamma G)]}{W^\gamma dt}$$

$$s.t. dW_t = (W_t(\boldsymbol{\theta}'(\mu_{R,t} - r_{f,t}) + r_{f,t}) - C_t) dt + W_t \boldsymbol{\theta}' \sigma_R dZ_t.$$

(ii) **Active investor:**

$$0 = \max_{c \geq 0} g(\gamma^{1/\gamma} c, G) + \frac{\mathbb{E}[d(W^\gamma G)]}{W^\gamma dt}$$

$$s.t. \quad dW_t = \left(W_t(\bar{\theta}'(\mu_{R,t} - r_{f,t}) + r_{f,t} + \bar{\theta}f_t) - C_t \right) dt + W_t \bar{\theta}' \sigma_R dZ_t.$$

I derive these problems in appendix A.2.1. This proposition helps us sidestep an issue with the continuous-time model: a few of the agents switch often. The aggregate level of active capital is a function of the state variables. As they follow a diffusion, the fraction of active agents will also follow a diffusion. For instance, one can prove all agents cannot possibly follow stopping-time strategies to change their activities. This problem is not present in the discrete-time version of the model. Proposition 3.1 holds in the limit of the discrete-time case, because it characterizes agents' indifference, not their actual occupation trajectory.

Examining the problems of Proposition 3.1, we can derive the consumptions and portfolios of agents as well as the activity fee:

Proposition 3.2. *At equilibrium:*

(i) *All agents (active and passive) have the same consumption-wealth ratio, determined by*

$$c = \beta^{\frac{-1}{(\rho-1)}} G^{\frac{\rho}{(\rho-1)\gamma}}.$$

(ii) *The portfolio θ^* of passive agents is*

$$\theta^* = \frac{1}{1-\gamma} (\sigma_R \sigma'_R)^{-1} (\mu_R - r_f) + \frac{1}{1-\gamma} (\sigma_R \sigma'_R)^{-1} \sigma_R \sigma'_s G_s.$$

(iii) *The activity fee f is given by*

$$\bar{\theta}f = \frac{1}{2}(1-\gamma) (\bar{\theta} - \theta^*)' \sigma_R \sigma'_R (\bar{\theta} - \theta^*).$$

The proof is in appendix A.2.2. Points (i) and (ii) are the standard portfolio results for a passive agent with recursive preferences. Note that active agents do not choose a consumption policy distinct from that of passive agents, because the only determinant of consumption is the marginal utility of wealth. The consumption policy has to be the same, active or passive, because agents are indifferent between occupations at all levels of wealth.

The formula for the fee f_t is similar to the stationary case, proportional to relative risk aversion and the volatility of the portfolio $\bar{\theta} - \theta^*$. One can note that it is purely a

compensation for risk taken as a departure from the optimal portfolio. In particular, it does not depend on the covariance of returns with the state variables, because in a diffusion framework, hedging demands are linear in the amount of risk. Therefore, the already larger equilibrium returns from the levered position exactly offset the additional loading on the state variables the agent has to take. Another way to state this result is to notice that, if active agents would be allowed to hedge some risk, they would be indifferent as to which source of risk they lower to get closer to their optimal portfolio.

3.4 Equilibrium

As in the stationary model, the demand of active capital from firms pins down the fee to be constant, equal to the marginal productivity: $f(s_t) = \lambda$. Note that because hedging assets are in zero net supply and all passive investors take the same position, this position has to be zero. The optimal portfolio takes the form $\boldsymbol{\theta}^* = [\theta^*, 0, \dots, 0]$ in equilibrium. We can therefore simplify the supply of active capital to obtain

$$(3.1) \quad \lambda = \frac{1}{2\bar{\theta}}(1 - \gamma)(\bar{\theta} - \theta^*)^2 \sigma_{R,1}^2.$$

In the stationary model, this condition was sufficient to pin down the equilibrium portfolio θ^* , because the volatility of returns corresponded to the fundamental volatility σ_D . Now, because time-varying conditions are present, this quantity is endogenous and depends on the quantity of active capital. To see this result, first apply Ito's lemma to the asset returns:

$$(3.2) \quad \frac{dR}{R} = \frac{D_t}{P_t} dt + \frac{dD_t}{D_t} + \frac{dV_t}{V_t} + \frac{\langle dD_t, dV_t \rangle}{P_t}.$$

The volatility comes from fluctuations in cash-flow dD_t as well as fluctuations in the price-cash-flow ratio dV_t . Any changes in the properties of the stochastic discount factor or in expected future cash flow affect this valuation ratio. Fluctuation in the fraction of active investors amplifies these changes. To see this effect, consider, for instance, a change tomorrow in the volatility of cash flow. If we happen to be in a high-volatility state, the price will be lower than in a low-volatility state for three reasons. First, future cash flows are riskier and as such are discounted more. Second, because the environment is more riskier, the risk price for cash-flow shocks is larger. Finally, again because the environment is riskier, less active capital will be present; therefore, the risk price will be even larger as passive investors bear more of the risk. This third channel, present only with an active sector, creates additional price volatility.

Going back to equation (3.1), we can see, however, this endogenous channel creates an important self-limiting force on the development of the active investment sector. If the active sector is developed and is at risk of fluctuations, returns are more volatile. Therefore, agents are less willing to provide this large quantity of active capital in the first place.

Finally, the market-clearing conditions for the occupation and asset markets can be combined to pin down the fraction of active capital:

$$\frac{M}{\bar{\theta}} + \frac{1 - M}{\theta^*} = 1.$$

3.5 Summarizing the solution

Putting together all the previous results, we can narrow down the model to only one partial differential equation, characterizing the price–cash-flow ratio, equal to the wealth–consumption ratio. I assume σ_s to be diagonal to save space, the extension to correlated shocks is trivial.

Proposition 3.3. *The price–cash-flow ratio solves:*

$$\begin{aligned} 0 = & 1 + \mu_D \rho V - \beta V - \mu_s \cdot V_s + \frac{1}{2} \text{tr}(\sigma_s V_{ss} \sigma_s') \\ & - \frac{1}{2} V \sigma_D^2 \rho (1 - \gamma) (1 - (\theta^* - 1)^2) \\ & + \frac{1}{V} V_s \sigma_s \sigma_s' V_s \left(\frac{1}{2} \left(\frac{\gamma}{\rho} - 1 \right) + \frac{1}{2} \rho (1 - \gamma) (\theta^* - 1)^2 \right), \end{aligned}$$

where the optimal portfolio θ^* is the unique solution lower than 1 to

$$\lambda = \frac{1}{2\bar{\theta}} (1 - \gamma) (\bar{\theta} - \theta^*)^2 \left(\sigma_D^2 + \frac{V_s'}{V} \sigma_s' \sigma_s \frac{V_s}{V} \right).$$

This proposition shows clearly the tractability of the problem. The first partial differential equation (PDE) is similar to the case of an endowment economy. The only difference is changes in the risk adjustments (the last two lines of the equation) to account for the fact that marginal agents on asset markets do not hold the aggregate portfolio. In particular, when $\theta^* = 1$, we obtain the solution to the homogenous-agent endowment economy. This characterization of the solution actually extends beyond this model. As long as all agents in the economy have the same consumption–wealth ratio and the optimal portfolio is given by θ^* , this PDE determines the aggregate price of capital and the stochastic discount factor.

The second part of the proposition is more specific to the model of this paper. It reflects the economics of the markets for active capital. As emphasized before, even though the determination of the quantity of active capital is static, it depends on the equilibrium price and therefore the two equations have to be solved together. We can just plug in the explicit solution for θ^* in the PDE to obtain a standalone PDE. The dimension of the PDE is the number of state variables. In particular in the case of a unique state variable, the equation is an ordinary differential equation of degree 2.

Finally, in contrast to the standard heterogenous agent literature, this PDE does not rely on any additional state variables than those specified in the fundamental dynamics. Even if one adds fluctuations in the parameters governing the leveraged positions (e.g. $\bar{\theta}$ or λ), no endogenous state variable appears. Therefore the boundary conditions of this problem are the same as those of the corresponding endowment economy, essentially determined by exogenous fluctuations.

3.6 Comparison with models of intrinsic heterogeneity

Before studying in more detail the asset-pricing implications of the model, let us compare the approach of this paper to an approach of intrinsic heterogeneity. To do so, let us start by an example. One can ask why both butchers and bakers exist in our society. A first explanation is that having both bread and meat is useful. Therefore, even if everybody is identical ex ante, we should see some people become butchers and others bakers. Another explanation is that some people enjoy being bakers — or are better skilled at it — whereas other people enjoy being butchers. Both explanations have some truth in reality and have been considered, often jointly, for labor markets. In the study of the role of heterogeneity for asset pricing and macroeconomics, an important question is the role of agents taking different amounts of risk. Most of the literature has focused on the second type of explanation, where heterogeneity is intrinsic. This paper focuses on the first explanation. Beyond a conceptual difference, the two approaches are also distinct in their conclusions.

From a static point of view, both approaches are similar. The distorted risk-sharing effect is present regardless of the source of the heterogeneity. The relative weight of active versus passive investors determines the risk premium in the economy. When turning to the dynamics, similarities are also present, by the mere fact of the distorted risk-sharing effect. If, for whatever reason, the relative wealth of active versus passive investors changes, the risk premium changes. However, the essential difference between the two approaches is in the source of these fluctuations. In models with intrinsic

heterogeneity, all that matters is the evolution of relative wealth of various categories of agents. When a group endures larger losses than others, the wealth distribution is shifted. In my model, this effect does not necessarily happen. The only element that matters is incentives to take on one activity rather than the other. For instance, in the model of section 2, even though active and passive agents experience different wealth shocks, the composition of ownership stays constant. As I describe in more detail in the next section, the role of incentives to choose activity creates asymmetries in which shocks are amplified. First-moment shocks do not affect the ownership composition, whereas second-moment shocks do and are amplified.

The implications of this difference go beyond asset pricing. For instance, an object of interest is the wealth distribution. Typically in asset-pricing models with heterogeneous agent, the wealth distribution is fundamentally non-stationary. Less risk-averse (or more optimistic) agents accumulate more wealth on average and outweighs other agents in the long-run.¹⁴ My model, because agent types are not uniquely pinned down, does not feature a unique wealth distribution. In appendix A.3, I discuss various implementations of the equilibrium. I show that some simple implementations keep a stationary wealth distribution.

The effect of various policies will also be affected depending on the modeling approach. With exogenous heterogeneity, if the goal is to push asset prices up, an effective policy is to transfer wealth to natural risk takers. Indeed, such a policy increases the risk capacity of the economy and pushes the premium down. In an economy with investment, this policy can help stimulate the growth of the economy. In my model, such transfers are completely ineffective. Indeed, the equilibrium composition of ownership is determined by incentives rather than the wealth distribution. Providing more wealth to current active investors only results in some of them exiting their activity and switching back to passive. As such, my model is an important warning on the generality of the result of a necessary transfer to risk takers during crisis periods, even ex post. On the other hand, effective policies in my model are those shifting incentives to be active rather than passive. I discuss such an example in section 5.1.

¹⁴A notable exception to this general result is Borovicka (2013) for particular parameter combinations of Epstein-Zin preferences.

4 Asset-Pricing Implications with rich fundamental shocks

I now turn to the asset-pricing implications of the model. I present a particular case of the results of the previous section for a commonly studied long-run-risk economy. This framework allows me to study the interaction of distinct types of fundamental shocks with active capital provision. In particular, I focus on the consequences of fluctuations in the quantity of active capital for the volatility of returns and the price of various sources of risk. This allows me to illustrate how the deleveraging effect following increases in risk occurs along the equilibrium path and interacts with prices. Further, I show that the irrelevance of instantaneous cash-flow shocks extends to changes in the expected growth rate of the economy.

4.1 Setup

I study a continuous time version of the long-run risk model of Bansal and Yaron (2004), as in Hansen et al. (2007). Two state variables are present: $s_t = (X_t, \sigma_t^2)$. The dynamics of cash-flow growth are given by

$$\begin{aligned}\frac{dD_t}{D_t} &= (\mu_D + X_t + \lambda m_t)dt + \sigma_t dZ_t^D \\ dX_t &= -\kappa_X X_t dt + \phi \sigma_t dZ_t^X \\ d\sigma_t^2 &= -\kappa(\sigma_t^2 - \sigma_0^2)dt + \nu \sigma_t dZ_t^\sigma,\end{aligned}$$

where Z^D , Z^X , and Z^σ are independent Brownian motions. The variable X_t controls the persistent component of cash-flow growth, and σ_t controls the volatility of shocks. For σ_t^2 to stay positive, I impose the parameter restriction $2\kappa\sigma_0^2 > \nu^2$.

To illustrate the theoretical results, I follow the calibration of Bansal and Yaron (2004) I report in Table 1. All parameters are at the monthly frequency. An important feature of this calibration is that the intertemporal elasticity of substitution is larger than 1, making the price increasing in expected cash flow. For the active investment parameters, I use $\bar{\theta} = 1.2$ and $\lambda = \mu_D$.

I compare the solution of my model to the case of no active capital, which is equivalent to set $\theta^* = 1$ and $m = 0$ in all previous calculations. I call the latter model the baseline model.

Table 1: **Preferences and consumption dynamics**

Preferences			Consumption		State Variables			
β	RRA	IES	μ_D	σ_0	κ_X	κ_σ	ϕ_X	ν
0.0013	10	1.5	0.13%	0.79%	0.0212	0.0131	5.64	0.0003

4.2 Price–cash-flow ratio and quantity of active capital

First, note the price is always larger with active capital than without. Indeed, the first-order condition of passive agents for consumption tells us the utility level is increasing in the price. Agents in the economy can choose at any moment to use their shares of risky assets to finance the consumption plan they would have in an economy without active capital. Indeed, we proved the price of the risky asset is the same as that of a firm employing no active investors, which is the output consumed in the baseline case. The fact that agents choose not to do this trade tells us they are better off in this equilibrium.

I now look separately at the asset price and the quantity of active capital along changes in the two state variables.

4.2.1 Role of the fundamental growth rate

As shown in the stationary case, the cash-flow growth rate does not affect active capital, because the cash-flow growth rate does not affect the volatility of returns. This property still holds approximately in the long-run-risk model. Bansal and Yaron (2004) obtain this property exactly in their log-linear approximation, and the result is fairly robust in this parameter region. The reason changes in growth rate do not change the volatility is that the corresponding changes in the timing of risk are small.

The absence of an impact of the growth rate on return volatility translates into an absence of dependence on X_t of the portfolio of passive agents. Figure 4 confirms this result. This figure represents, for various levels of the volatility state, the portfolio of passive agents as a function of the growth rate X_t .

4.2.2 Role of the fundamental volatility

Fundamental volatility has a much more important impact on the active capital market. In figure 5, we see important variations in the portfolio of passive agents with changes

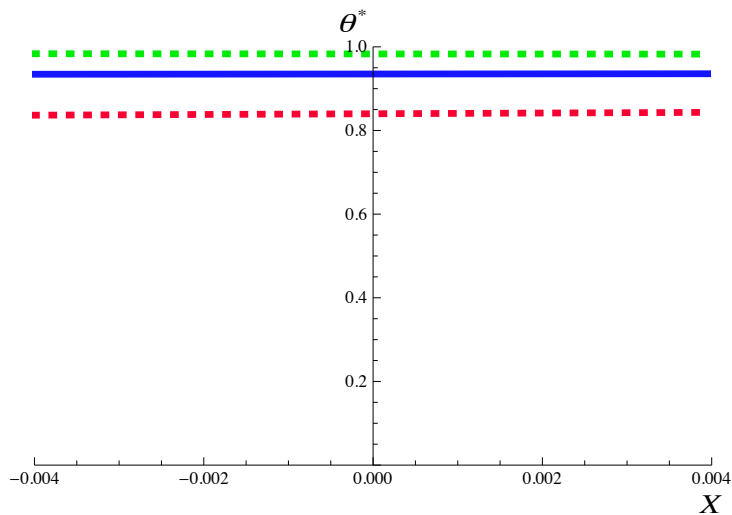


Figure 4: **Optimal portfolio of passive agents θ^* as a function of X** (*blue: σ_0^2 , green: $1.5\sigma_0^2$, red: $0.5\sigma_0^2$*)

in volatility. This result corresponds to the idea that fundamental volatility is reflected in the volatility of returns and subsequently in the supply of active capital. When volatility is low, agents are more willing to supply active capital relative to passive investment. These active agents buy a larger fraction of the assets, and the remaining agents are left holding less risky assets.

Interestingly, we observe that θ^* is a concave function of σ_t . The portfolio of passive agents changes more in response to a volatility change at lower levels of fundamental volatility than at higher levels. This result corresponds to the idea that the economy is more susceptible to large waves of deleveraging when large amounts of concentrated investments are present. Naturally, this deleveraging affects prices. Figure 6 shows the price–cash-flow ratio V as a function of fundamental volatility σ_t for the model and the baseline case. As volatility increases and active capital disappears, the price converges to the baseline case. Though risky allocations are the same in both models when θ^* reaches 1, the two prices are not equalized. Indeed, risky allocations will depart from each other when mean-reversion and shocks brings σ_t down. Corresponding to the concavity of θ^* , the price converges in a concave way to that in the baseline model. However, when reaching very low volatility states, because passive agents do not bear much risk, the price becomes less sensitive to changes in volatility.

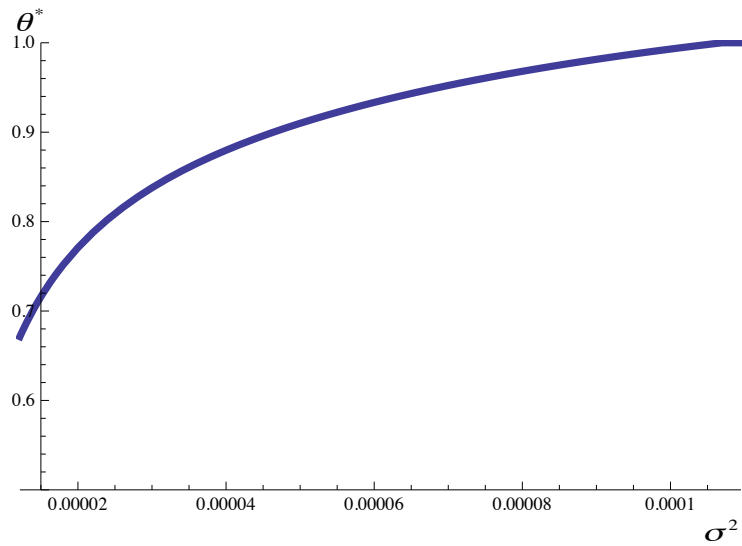


Figure 5: Optimal portfolio of passive agents θ^* as a function of σ^2 ($X = 0$)

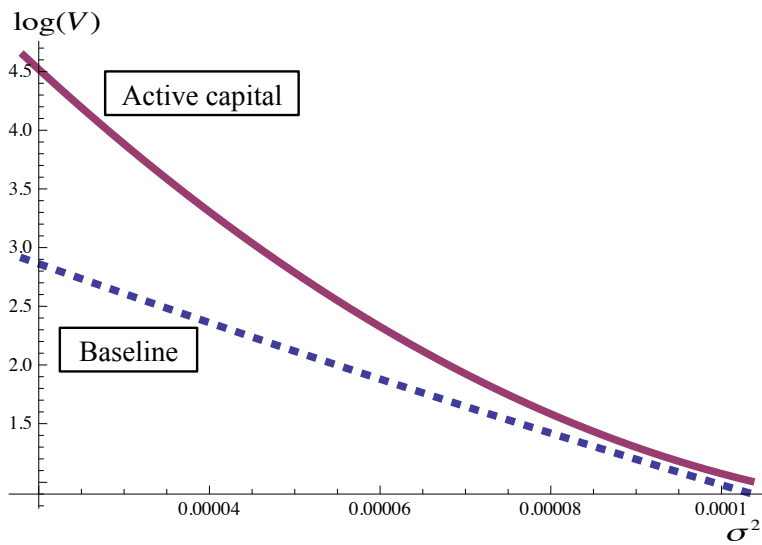


Figure 6: Price-cash-flow ratio as a function of volatility σ^2 ($X = 0$)

4.3 Return volatility and fundamental volatility

As fluctuations in active capital affect prices, they create additional volatility for the asset. The risky-asset returns dynamics are

$$\frac{dR_t}{R_t} = \mu_R(s_t)dt + \sigma_t dZ^D + \phi\sigma_t \frac{\partial \log V}{\partial X}(s_t) dZ_t^X + \nu\sigma_t \frac{\partial \log V}{\partial \sigma^2}(s_t) dZ^\sigma.$$

The volatility of returns comes from the three shocks affecting the economy: the instantaneous cash-flow shock dZ^D , the shock to expected cash-flow growth dZ^X , and the shock to uncertainty dZ^σ . First note that direct shocks to cash flow, as in the baseline model, are directly transmitted to returns. They do not affect the active capital market; therefore, their impact on prices is left unchanged. Similarly, because the sensitivity of the valuation ratio to the growth rate is unchanged, the volatility from changes in future expectations of cash flow is the same as in the baseline model.

Finally, the volatility shock now has a larger effect on prices: the sensitivity $\partial \log V / \partial \sigma^2$ is larger than in the baseline case. This larger volatility comes through the deleveraging effect. When volatility increases, the asset becomes less attractive to passive agents, and they must absorb the assets sold off by active agents who change occupations. From these results, we see active capital not only increases the volatility of returns but also changes the composition of its sources. In particular, it puts relatively less weight on cash-flow shocks than on volatility shocks. Figure 7 illustrates this effect. We can see the volatility shocks explain a larger part of returns variance. Additionally, as we noticed for the sensitivity of prices, this distortion of the composition of risk is larger in low-volatility states.

The source of return volatility has been a puzzle for the asset-pricing literature since Campbell and Shiller (1988). They point out the volatility of returns appears to be too large relative to the volatility of cash flow. The long-run-risk model of Bansal and Yaron (2004) explains this puzzle by the presence of small persistent shocks affecting consumption growth that have a large impact on the utility of agents with recursive preferences. However, Beeler and Campbell (2009) point out that the model still generates a counter-factual level of cash-flow predictability. In other words, it creates too tight a link between prices and expected cash flow. Volatility shocks do not affect the level of future cash flows but create variation in prices through variation in discount rates and therefore have the potential to explain return volatility. Bansal et al. (2007) present a calibration of the long-run-risk model in which volatility shocks are extremely persistent, and avoid the excess cash-flow predictability. My model offers an endogenous channel that gives more importance to volatility shocks. This effect

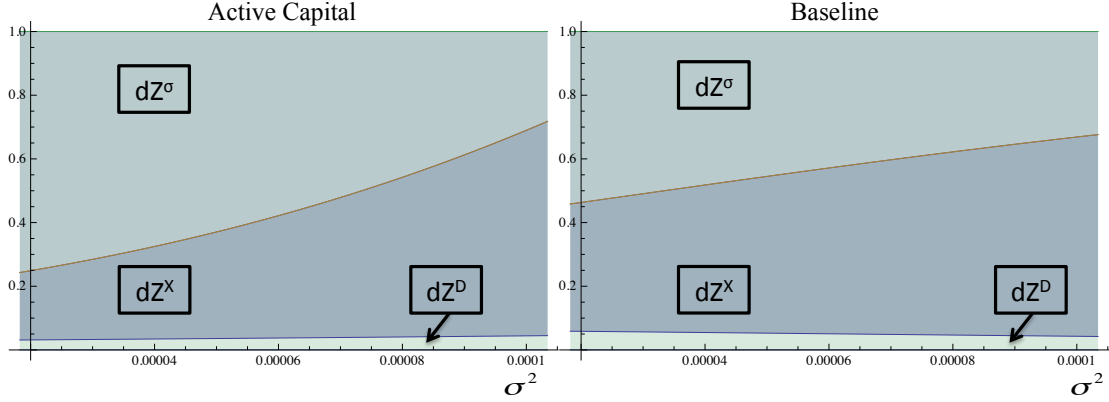


Figure 7: **Decomposition of the volatility of returns as a function of σ_t ($X = 0$; left panel: active capital; right panel: baseline case)**

comes through the endogenous variation in risk-sharing between active and passive investors. In particular, we should observe that variations in prices, due to changes in risk premia, coincide with variation in the quantity of active capital. In a similar vein, Adrian et al. (2010) find that intermediary leverage is negatively related to the macroeconomic risk premium. Also, Haddad et al. (2011) find the quantity of leveraged buyouts, a transaction concentrating ownership of risky assets, is strongly negatively correlated with a measure of the equity risk premium.

4.4 Price of risks

As we saw when examining the firm problem, the price of the risky asset is equal to that of a similar firm employing no active capital. Because active capital has no effect on payoff of the risky asset in equilibrium, all changes in valuation relative to the baseline model must come through changes in the stochastic discount factor, particularly risk prices. For these prices, the two effects described in section 2 play a role.

The risk prices for the three shocks are

$$\begin{cases} rp_D = (1 - \gamma)\theta^*\sigma_t \\ rp_X = \phi\sigma_t \frac{\partial \log V}{\partial X} [(1 - \gamma)\theta^* - \frac{\gamma\rho}{1-\rho}] \\ rp_\sigma = \nu\sigma_t \frac{\partial \log V}{\partial \sigma^2} [(1 - \gamma)\theta^* - \frac{\gamma\rho}{1-\rho}]. \end{cases}$$

The first effect is risk dampening. In equilibrium, passive agents hold fewer risky assets than in the baseline model: $\theta^* < 1$. Because agents hold less risk, they require a

lower compensation for marginal risk. The dampening is direct for the instantaneous shock price rp_D . For the other two shocks, the dampening is less important, because $\gamma\rho/(1-\rho) < 0$. The reason for this property is that with recursive preferences, the long-run impact of shocks on utility affects risk prices. The first term in brackets for rp_X and rp_σ comes from the instantaneous loading on risk. Passive agents instantaneously bear less risk than in the baseline case, causing dampening. However, at the next instant, all agents are identical again. Therefore, they all have the same value functions and all have to bear equally the long-run consequences of shocks. The long-run component of risk prices is not dampened.

The second effect is deleveraging risk. Shocks to fundamental volatility are riskier because they increase not only the riskiness of the asset, but also the fraction of risky assets passive agents hold. This extra risk corresponds to the larger sensitivity $\partial \log V / \partial \sigma^2$ relative to the baseline case. As for the volatility of returns, deleveraging only occurs with volatility shocks and as such this amplification only affects the risk price of volatility rp_σ . A consequence of this phenomenon is a change in the relative values of risk prices for the various sources of risk. Active capital affects not only the price of shocks, but also the nature of priced shocks. The volatility risk price becomes relatively more important than the other two risk prices.

These last results have implications for understanding the cross section of expected returns. Indeed, though I assume firms are identical, in reality, they have different loadings on the various sources of risk. If the volatility risk price is relatively large, exposure to volatility risk is likely to be an important determinant of the cross-section. Ang et al. (2006), or, in a more structural framework, Bansal et al. (2012) and Campbell et al. (2012), find exposure to shocks to aggregate volatility lines up with expected returns. Additionally, because conditional expected returns move in tandem with volatility in this model, measuring exposure to shocks to expected returns should provide a good proxy for exposure to this long-run volatility shock. Kozak and Santosh (2012) confirm this result using a model-free measure of expected returns: stocks that covary positively with aggregate expected returns earn lower average returns.

The specific prediction of this model is that the shocks to volatility correspond to changes in the quantity of levered investors. Larger exposure to measures of leveraged investment should correspond to larger expected returns. Adrian et al. (2011) measure covariance of returns with the leverage of broker-dealers and find this exposure is able to predict returns.

5 Extensions

In this section, I present a few extensions of the model. First I discuss the efficiency of the equilibrium. I show that taxing firms for the use of active capital increases welfare in a static framework. Then I discuss the effect of specific financial shocks, represented by changes in the productivity of active investment. To do so, I relax two assumptions: constant returns to scale and no dependence on the state variables. I also show how to incorporate firm-level uncertainty can also fuel financial crisis. Finally I discuss the real implications of changes in active ownership by adding investment in physical capital to the model.

5.1 Tax on active capital

One can wonder whether the equilibrium allocation of this model is efficient. Indeed, the presence of the portfolio constraint for active investors is a source of market incompleteness. In such frameworks, pecuniary externalities are generically sources of externality. Changing asset prices affects different agents differently and generate redistribution. Gromb and Vayanos (2002) study such welfare implications in an exogenously segmented market framework.

I focus on the following intervention: a tax on firms per unit of active capital, given back to them as a lump-sum payment. This intervention is equivalent to reducing the fee firms pay to active investors. An interesting aspect of this policy is that it does not affect the agents' side of the markets. In particular, agents in the two categories still have to be indifferent. This way, the policy will be unambiguously Pareto ranked with the market equilibrium. I only look at the first-order effect of an increase in tax from the market equilibrium. Additionally I focus on a small interval dt of the stationary model.

The tax affects the conditions of the agents' problem in three ways: a direct effect of reduction of the fee f and indirect effects on the relative valuation of risky and risk-free payoffs and on the cash flow of the firm through a different level M of active capital. This last effect has no first-order impact because in the market equilibrium, the fee f and the marginal productivity λ cancel each other out. The effect of the reduced fee is to increase the utility of passive investors and reduce that of active investors. To equate the two utilities again, the relative price of risky assets has to decrease. Indeed, passive agents, as sellers of risky assets, lose from this change, and active agents, as buyers of risky assets, gain. If markets were complete, as marginal rates of substitutions are

equalized across agents, the total first-order effect of all these changes would be exactly zero. Alternatively, this result can be seen as a direct consequence of the first welfare theorem.

In our incomplete market framework, as active agents are constrained to own more risky assets than they would desire, they value risky assets relatively less than passive agents. Thus the effect of a change in the fee relative to a change in the relative price of risky assets is larger for passive agents than active agents. The net effect is an increase in the utility level of both agents. The first unit of tax creates welfare; therefore, too much active capital is present in the market equilibrium.

This conclusion is specific to the stationary model in which no intertemporal link in the decision to provide active investment is present. In the general case, future changes in the level of active capital affects the present decision to enter active investment, potentially creating other inefficiencies. Another concern before taking this result as a policy implication is the exogeneity of the contract. Practically, policy interventions could affect the contracts offered on markets.

5.2 Financial shocks

Up until now, I restrained the analysis to fundamental shocks in order to isolate the endogenous effects of the presence of concentrated ownership. It is natural to assume that the “active” technology is not constant over time, and in particular the productivity of active capital could change over time. I study two sources for this variation: decreasing returns to scale and exogenously time-varying productivity.

5.2.1 Decreasing returns to active capital

Up until now, I have assumed active capital exhibits constant returns to scale. However, as the number of active investors increases, their quality could decrease, and the opportunities to create value are lower. A way to model this phenomenon is to assume decreasing returns to scale at the firm level. This approach complicates the resolution of the model because it creates surplus at the firm level: the residual payoff increases from the use of active capital.

To avoid this issue, we can use decreasing returns to scale at the aggregate level, but constant returns at the individual level. This approach corresponds to a decrease in the quality of active capital when more firms use it. Individual firms see no difference

in returns as a function of the individual quantity they use.¹⁵ This model corresponds to the following dynamics of cash flow:

$$\frac{dD_t}{D_t} = (\mu_D(s_t) + \lambda(M_t)m_t)dt + \sigma_D(s_t)dZ_t,$$

where $\lambda(\cdot)$ is a decreasing function. This specification leaves the individual demand of firms perfectly elastic, but makes the aggregate demand a decreasing function, given by the first-order condition of the individual firm problem:

$$\lambda(M_t) = f.$$

The decreasing aggregate demand mitigates deleveraging. When the supply of active capital is lowered, both a decrease in the quantity and an increase in the fee for active investment absorb this change. Fluctuations in the fee have no impact on risk sharing and therefore do not affect risk premia. Panels (a) and (b) of Figure 8 show the effect of an increase in volatility in the standard model and in the decreasing returns case, respectively. The more inelastic the aggregate demand for active capital is, the smaller the fluctuations in the quantity of active capital are. The limiting effect of productivity increase on the deleveraging decision can be seen, for instance, in the Q1:2009 letter to investors of Pershing Square Capital, a large activist hedge fund. They explain that they exited some of their positions due to their “inability to accurately forecast with confidence the duration and depth of the current recessionary environment.” However, they note, “The fact that a number of our competitors have closed their doors or withdrawn from an activist approach obviously makes for a less competitive environment for the surviving participants.[...] Judged by these standards, the ingredients for profitable shareholder activism are more present than ever before, and we continue to be highly capable of implementation.”

5.2.2 Dependence on state-variables

Alternatively, the productivity of active capital varies in and of its own or with economic conditions. It corresponds to assuming marginal productivity is a function $\lambda(s_t)$ of the state variables. This assumption does not affect the resolution of the model. If $\lambda(s_t)$ changes independently from other conditions, it corresponds to shifts in the demand for active capital. The fee is always equal to the marginal productivity, and quantity

¹⁵Empirically, the evidence is mixed. Some have argued the impact of active capital on firm value is hump shaped.

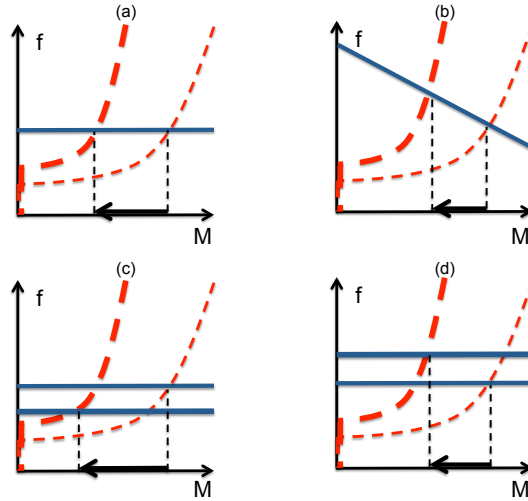


Figure 8: **Changes in active capital market equilibrium following an increase in volatility** (*a: standard model; b: decreasing returns; c: negative relation of λ and σ ; d: positive relation*)

changes along the supply curve clear the market. When the productivity increases, the fee and the fraction of active capital increase. When active capital becomes more productive, its quantity increases, more agents lever up, and risk prices decrease. Such fluctuations would be priced in equilibrium.

If $\lambda(s_t)$ is correlated with economic conditions, the corresponding demand shocks can amplify or dampen the endogenous fluctuations in supply. If $\lambda(s_t)$ is negatively related to fundamental volatility, deleveraging cycles are amplified. In times of high volatility, neither are agents willing to provide active capital nor do firms demand it. This case corresponds to panel (c) of Figure 8. However, if the relation is positive and active capital is more effective in volatile periods, deleveraging is dampened. If the productivity gains are large enough, they could suppress deleveraging altogether or even create more active capital in volatile times (panel (d) of Figure 8). Empirically, the sign of this correlation is an open question.

5.3 Idiosyncratic risk

Another important feature left out is idiosyncratic risk. Indeed, firms' output depends not only on aggregate conditions, but also on individual-level shocks. A simple way to modify the model is to introduce firm-specific shocks to cash-flow growth. This

assumption corresponds to changing the dynamics of the static model to

$$\frac{dD_t^j}{D_t^j} = (\mu_D + \lambda m_t)dt + \sigma_D dZ^D + \sigma_j dZ^j,$$

where Z^j is a Brownian motion specific to firm j , independent from all other shocks of the economy. Idiosyncratic shocks do not affect the price–cash-flow ratio; they are directly reflected into returns. The supply of active capital is then

$$\bar{\theta}f = \frac{1}{2}(1 - \gamma)(\bar{\theta} - \theta^*)^2(\sigma_D^2 + \sigma_j^2).$$

We see idiosyncratic risk causes agents to require a larger compensation than in the basic model. In equilibrium, the lower supply generates a decrease in the quantity of active capital. Because less active capital is present, and active capital is less sensitive to aggregate conditions at low levels, the excess sensibility to the level of volatility will be milder. However, empirically, idiosyncratic volatility correlates positively with aggregate volatility, as Campbell et al. (2001) and Bloom (2009) show. In this case, fluctuations in the two types of volatility concur and increase the magnitude of fluctuations in the level of active capital.

5.4 Physical investment

A last extension is to include physical investment in the model. Indeed, so far the variation in prices due to fluctuations in active capital did not translate to variations in quantities. In practice, firms respond to prices in deciding their investment policies. This mechanism is well-known, and I highlight here only a potential new dimension of it, the potential complementarity of active capital and physical capital. We can introduce physical investment without losing tractability of the model. To do so, I introduce a CES aggregator of active investment and physical investment in the cash-flow dynamic:

$$\begin{aligned} \frac{dD_t}{D_t} &= (\mu_D + \lambda(m_t, i_t)) dt + \sigma_D dZ_t^D \\ \lambda(m, i) &= \lambda_0(am^r + (1 - a)i^r)^{\frac{1}{r}}, \end{aligned}$$

where i_t is the level of physical investment. The investment i_t is directly taken out of the cash flow of the firm. The first-order conditions of the firm problem become:

$$\begin{cases} \frac{\partial \lambda}{\partial m}(m, i) = f \\ \frac{\partial \lambda}{\partial i}(m, i) = 1/V. \end{cases}$$

Because λ is homogenous of degree 1, these conditions pin down only the ratio of active capital to physical investment. Also, as in the standard model, this homogeneity implies all gains are used to pay for the two resources: active capital and investment goods. The price of the firm does not depend on the scale of its investment and all effects of active capital come through changes in the stochastic discount factor.

This model naturally generates comovement between active capital and physical investment. The elasticity of substitution between m and i is $1/(1-r)$. If they are complements, active investment and physical investment can both decrease in periods of high volatility. The decrease in physical investment now has two rationales. First, the standard q-theory rationale yields that in times of high uncertainty, valuations are low, investment is not valuable. This effect can be seen in the right-hand side of first-order condition for physical capital. Second, the novel rationale I introduce is that, in times of high uncertainty, little active investment is used and therefore physical investment is less valuable. This effect corresponds to the left-hand side of the first-order condition for physical capital. This extra complementarity could be an explanation for the depth of recessions following financial crisis.

6 Conclusion

In this paper, I introduced a tractable model of asset pricing in the presence of concentrated ownership. In particular, I showed the price of risky assets and the provision of active capital are strongly tied. Variations in risk premia affect the supply of active capital, thereby generating the documented negative relation between expected returns and the amount of active capital. The quantity of active capital feeds back into aggregate risk sharing. As active investors deleverage to get out of their positions in times of high volatility, passive investors must bear the risk exactly when they do not want to. This feedback is a source of amplification for shocks to risk premia. On the other hand, cash-flow shocks, because they are borne by active agents, are less costly for passive investors and command a lower risk premium. This mechanism can help us understand better why cash-flow shocks are not necessarily the key determinant of expected returns. On the other hand, fluctuations in risk premia might command a higher risk price than the standard model, due to their amplification because they cause variations in the quantity of active capital. Similarly, a large fraction of the volatility of asset prices might be due to fluctuations in fundamental volatility.

Importantly, these conclusions differ significantly from the standard models in which

heterogeneity is intrinsic rather than the result of agents' choices. Opposite to the rest of the literature, the model of this paper makes the different extreme assumption of complete flexibility in activity choice. Further, I showed differences extend from the behavior of asset prices to the evolution of the wealth distribution as well as the results of various policy interventions. These important qualitative distinctions in terms of predictions call for more theoretical and quantitative analysis of the dynamic properties of heterogenous-agent models. Just as for any other economic choices, understanding heterogeneity in practice will need a combination of intrinsic heterogeneity and agents' choices. Proposition 3.3 suggests the framework this paper introduces could help for this task. Indeed, I showed one can disentangle solving for prices given the equilibrium heterogeneity from the determination of this heterogeneity.

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A Proofs for the general model

A.1 Firm problem

The sequence problem for the valuation of the firm is:

$$P_t = \sup_{\{m_{t+\tau}\}_{0 \leq \tau < \infty}} \mathbb{E}_t \left[\int_0^\infty \frac{S_{t+\tau}}{S_t} (D_{t+\tau} - f_{t+\tau} m_{t+\tau} P_{t+\tau}) d\tau \right]$$

$$\text{s.t. } \frac{dD_{t+\tau}}{D_{t+\tau}} = (\mu_D(s_{t+\tau}) + \lambda m_{t+\tau}) dt + \sigma_D(s_{t+\tau}) dZ_{t+\tau}.$$

Time consistency Though the payments of the fee depend of current and future values of the price P_t , this problem is time consistent. To see this result, we can rewrite $\forall t < T$:

$$\frac{P_t}{D_t} = \sup_{\{m_{t+\tau}\}_{0 \leq \tau < T-t}} \mathbb{E}_t \left[\int_0^{T-t} \frac{S_{t+\tau}}{S_t} \left(\frac{D_{t+\tau}}{D_t} - f_{t+\tau} m_{t+\tau} \frac{P_{t+\tau}}{D_t} \right) d\tau + \frac{S_T}{S_t} \frac{D_T}{D_t} \tilde{V}_T \right]$$

$$\text{s.t. } \frac{dD_{t+\tau}}{D_{t+\tau}} = (\mu_D(s_{t+\tau}) + \lambda m_{t+\tau}) dt + \sigma_D(s_{t+\tau}) dZ_{t+\tau}, 0 \leq \tau \leq T-t$$

$$\tilde{V}_T = \sup_{\{m_{T+\tau}\}_{0 \leq \tau < \infty}} \mathbb{E}_T \left[\int_0^\infty \frac{S_{T+\tau}}{S_T} \left(\frac{D_{T+\tau}}{D_T} - f_{T+\tau} m_{T+\tau} \frac{\tilde{V}_{T+\tau}}{\tilde{V}_T} \right) d\tau \right]$$

$$\text{s.t. } \frac{dD_{T+\tau}}{D_{T+\tau}} = (\mu_D(s_{T+\tau}) + \lambda m_{T+\tau}) dt + \sigma_D(s_{T+\tau}) dZ_{T+\tau}, 0 \leq \tau < \infty,$$

where $\tilde{V}_{T+\tau}$ for $\tau > 0$ is defined similarly to \tilde{V}_T . Examining the problems for $\{\tilde{V}_{T+\tau}\}_{0 \leq \tau < \infty}$ shows it exactly corresponds to the problem for $\{P_{T+\tau}/D_{T+\tau}\}_{0 \leq \tau < \infty}$, which confirms time consistency.

Hamilton-Jacobi-Bellman problem Because of the homogeneity of the problem, the price-cash-flow ratio $V_t = P_t/D_t$ is just a function $V(s_t)$ of the state variables s_t . We can transform the sequence problem in a HJB equation. After dividing by $S_t D_t V_t$, we get:

$$0 = \max_m \frac{1}{V} - fm + \frac{\mathbb{E}[d(SDV)]}{SDV dt}.$$

Expanding, we obtain:

$$0 = \max_m \frac{1}{V} - fm + \frac{\mathbb{E}[dS]}{S dt} + \frac{\mathbb{E}[dD]}{D dt} + \frac{\mathbb{E}[dV]}{V dt}$$

$$+ \frac{\langle dS, dV \rangle}{[SV dt]} + \frac{\langle dS, dD \rangle}{[SD dt]} + \frac{\langle dD, dV \rangle}{[DV dt]}.$$

Optimal quantity of active capital The activity level only appears in the flow term $1/V - fm$ and the drift of the size of the firm $\mathbb{E}[dD]/D dt = \mu_D(s) + \lambda m$. The optimization in m is therefore linear. This linearity gives us two key implications in the case of an interior optimum. First the slope of the equation in m has to be 0; this relation links the equilibrium fee for active capital to its productivity:

$$(A.1) \quad f(s) = \lambda.$$

Irrelevance of active capital for pricing Second, has the slope is zero, all terms in m cancel out in the HJB. The equation determining V corresponds to:

$$0 = \max_m \frac{1}{V} + \frac{\mathbb{E}[dS]}{Sdt} + \frac{\mathbb{E}[d\tilde{D}]}{\tilde{D}dt} + \frac{\mathbb{E}[dV]}{Vdt} \\ + \frac{\langle dS, dV \rangle}{[SVdt]} + \frac{\langle dS, d\tilde{D} \rangle}{[S\tilde{D}dt]} + \frac{\langle d\tilde{D}, dV \rangle}{[\tilde{D}Vdt]},$$

where

$$\frac{d\tilde{D}_{t+\tau}}{\tilde{D}_{t+\tau}} = \mu_D(s_{t+\tau})dt + \sigma_D(s_{t+\tau})dZ_{t+\tau}.$$

This equation corresponds to the price of a firm that never uses any amount of active capital.

A.2 Agent problem

A.2.1 Rescaling the HJB

The HJB equation determining the value function of an agent in any equation is the standard formulation for recursive preferences:

$$0 = \max_{C \geq 0, \theta \in \Theta} g(C, \mathcal{U}) + \mathbb{E}(d\mathcal{U})/dt.$$

First, using the homogeneity of the utility function and the linearity of wealth dynamics, we can express \mathcal{U} as a separated function of wealth and the state variables:

$$\mathcal{U} = \frac{(W_t^i)^\gamma}{\gamma} G(s_t).$$

Then, using the homogeneity of the aggregator g , we simplify:

$$0 = \max_{c \geq 0, \theta \in \mathbb{R}^K} f(\gamma^{1/\gamma} c, F) \frac{W^\gamma}{\gamma} + \mathbb{E} \left[d \left(\frac{W^\gamma}{\gamma} F \right) \right] / dt.$$

Dividing, by W^γ gives directly the equations of Proposition 3.1.

A.2.2 Solving for consumption and the fee

First compute the various derivatives of the value function \mathcal{U} :

$$\mathcal{U} = \frac{W^\gamma}{\gamma} G, \quad \mathcal{U}_W = \gamma \frac{W^{\gamma-1}}{\gamma} G, \quad \mathcal{U}_{WW} = \gamma(\gamma-1) \frac{W^{\gamma-2}}{\gamma} G, \quad \text{and} \quad \mathcal{U}_{W_s} = \gamma \frac{W^{\gamma-1}}{\gamma} G_s.$$

Let us focus first on the HJB of the passive agent:

$$0 = \max_{C, \theta} g(C, \mathcal{U}) + \frac{\mathbb{E}[d\mathcal{U}]}{dt}.$$

Expanding gives:

$$0 = \max_{C, \theta} g(C, \mathcal{U}) + \mathcal{U}_W [W(\theta'(\mu_R - r_f) + r_f) - C] + \mathcal{U}'_s \mu_s \\ + \frac{1}{2} \mathcal{U}_{WW} W^2 \theta' \sigma_R \sigma'_R \theta + W \theta' \sigma_R \sigma'_s \mathcal{U}_{W_s} + \frac{1}{2} (\sigma'_s \sigma_s) * \mathcal{U}_{s_s},$$

where $*$ is the elementwise multiplication. The first-order condition for consumption is:

$$g_C(C, \mathcal{U}) = \mathcal{U}_W.$$

The first-order condition for the portfolio share is:

$$\boldsymbol{\theta}^* = -\frac{\mathcal{U}_W W}{\mathcal{U}_{WW} W^2} (\sigma_R \sigma'_R)^{-1} (\mu_R - r_f) - (\sigma_R \sigma'_R)^{-1} \sigma_R \sigma'_S \frac{\mathcal{U}_{W_s} W}{\mathcal{U}_{WW} W^2}.$$

Plugging in using the formulas for the derivatives, we get:

$$c = C/W = \beta^{\frac{-1}{(\rho-1)}} G^{\frac{\rho}{(\rho-1)\gamma}}$$

$$\boldsymbol{\theta}^* = \frac{1}{1-\gamma} (\sigma_R \sigma'_R)^{-1} (\mu_R - r_f) + \frac{1}{1-\gamma} (\sigma_R \sigma'_R)^{-1} \sigma_R \sigma'_s G_s.$$

These formulas are the first two points of Proposition 3.2. Now we can turn to the problem of the passive agent. It is:

$$0 = \max_C f(C, \mathcal{U}) + \mathcal{U}_W [W(\bar{\boldsymbol{\theta}}'(\mu_R - r_f) + r_f + \bar{\boldsymbol{\theta}}'f) - C] + \mathcal{U}'_s \mu_s$$

$$+ \frac{1}{2} \mathcal{U}_{WW} W^2 \bar{\boldsymbol{\theta}}' \sigma_R \sigma'_R \bar{\boldsymbol{\theta}} + W \bar{\boldsymbol{\theta}}' \sigma_R \sigma'_s \mathcal{U}_{W_s} + \frac{1}{2} (\sigma'_s \sigma_s) * \mathcal{U}_{ss}.$$

The first order condition for consumption is clearly the same as for the active agent which proves that they pick the same consumption wealth ratio. To solve for the fee, just subtract this HJB from that of the passive investor. It gives:

$$\mathcal{U}_W \bar{\boldsymbol{\theta}}' f = \left[\mathcal{U}_W W \boldsymbol{\theta}^{*'} (\mu_R - r_f) + \frac{1}{2} \mathcal{U}_{WW} W^2 \boldsymbol{\theta}^{*'} \sigma_R \sigma'_R \boldsymbol{\theta}^* + W \boldsymbol{\theta}^{*'} \sigma_R \sigma'_s \mathcal{U}_{W_s} \right]$$

$$- \left[\mathcal{U}_W W \bar{\boldsymbol{\theta}}' (\mu_R - r_f) + \frac{1}{2} \mathcal{U}_{WW} W^2 \bar{\boldsymbol{\theta}}' \sigma_R \sigma'_R \bar{\boldsymbol{\theta}} + W \bar{\boldsymbol{\theta}}' \sigma_R \sigma'_s \mathcal{U}_{W_s} \right].$$

The right-hand side is the difference of two values of an affine-quadratic form where one of the evaluation points is the optimum. It is therefore exactly quadratic, and equal to, after dividing by \mathcal{U}_W :

$$\bar{\boldsymbol{\theta}}' f = \frac{1}{2} (1-\gamma) (\boldsymbol{\theta}^* - \bar{\boldsymbol{\theta}})' \sigma_R \sigma'_R (\boldsymbol{\theta}^* - \bar{\boldsymbol{\theta}})$$

which concludes the proof.

A.3 Individual policies and the wealth distribution

Let us consider possible wealth distribution evolutions in the population. Let us first recapitulate properties of wealth trajectories and then examine a couple of possible implementations of the equilibrium.

At each point in time, active investors receive on average a higher wealth increase than passive investors. This difference comes through two channels: they take on more leverage and therefore receive extra asset returns, and they receive the fee. Active investors are also more exposed to shocks than passive investors. Therefore, when returns are good, active investors gain relatively more wealth; when returns are bad, active investors lose relatively more wealth. These differences in wealth

evolution will create dispersion in wealth across agents. However, because agents can choose their occupation at each point in time, and preferences are homothetic, this wealth heterogeneity does not create a related heterogeneity in behavior. The individual policies are not pinned down by the equilibrium conditions, and many occupation-choice trajectories are consistent with the evolution of aggregate quantities. To get a better idea of how much switching is necessary at equilibrium, consider two simple implementations.

Remember we have a continuum of agents indexed by i on $[0, 1]$, and note $w_t^i = W_t^i/W_t$ their fraction of total wealth at time t . A fraction $M(s_t)/\bar{\theta}$ must be in the active sector. A first implementation is that the agents with the lowest indices are active. To determine which agents are active, define implicitly the threshold I_t by

$$\int_0^{I_t} w_t^i di = \frac{M(s_t)}{\bar{\theta}}.$$

A unique solution to this equation always exists, as all individual wealth fractions w_t^i clearly stay strictly positive and integrate to 1, which is strictly larger than the right-hand side. Also, because all individual wealth fractions w_t^i and $M(s_t)$ follow a diffusion, I_t does as well. Using properties of diffusion processes, we can derive local properties of career dynamics in this implementation:

Proposition A.1. *At each point in time t :*

- (i) *For almost every agent i , $\varepsilon > 0$ almost surely exists such that i does not change occupation in $[t, t + \varepsilon)$,*
- (ii) *Agent I_t , for any interval $[t, t + \varepsilon)$, almost surely changes occupation an uncountable set of times, without isolated points.*

This proposition is a direct consequence of the properties of the zeros of the Brownian motion found, for instance, in Morters and Peres (2010). In other words, the proposition tells us most agents do not change jobs on any finite interval. Only the agents at the border will go back and forth an infinite number of times. Because these agent only represent an infinitesimal fraction of aggregate wealth, their back-and-forth do not affect aggregate dynamics. This implementation of the equilibrium has the undesirable effect of not allowing a stationary distribution of wealth. To see this result, consider the wealth of agent 0 relative to any other agents. Because he is always active, his wealth has a larger drift than that of any other agent; therefore, the ratio of his wealth relative to any other agent tends to increase, and in the limit diverges to infinity almost surely.

An alternative implementation that insures the wealth distribution does not diverge is to make the group of active agents change over time. For instance, given $\zeta > 0$, we can choose the subset $[\zeta t, \zeta t + I_t'] \bmod 1$, where I_t' is now defined by:

$$\int_{\zeta t}^{\zeta t + I_t'} w_t^{(i \bmod 1)} di = \frac{M(s_t)}{\bar{\theta}_A}.$$

As the group of active agents cycles through the population, no individual wealth can drift permanently over that of the rest of the population. Relative to proposition A.1, we now have two agents switching occupation at each point in time. Agent $\zeta t \bmod 1$ becomes passive, and agent $(\zeta t + I_t') \bmod 1$ switches an infinite number of times.

Finally, note that in both implementations considered here, neither the wealth distributions nor the threshold I_t are deterministic functions of the state s_t . Indeed, past shocks affect the relative

wealth evolutions of the two groups and modify the fraction of agents to include in order to obtain the equilibrium fraction of active capital.

B Solving the model of section 4

Stochastic discount factor

The stochastic discount factor evolution is given by

$$\frac{dS_t}{S_t} = -r_f(s_t) - rp_D(s_t)dZ_t^D - rp_X(s_t)dZ_t^X - rp_\sigma(s_t)dZ_t^\sigma.$$

Firm problem

The HJB determining the price-cash-flow ratio $V(s)$ is

$$0 = \frac{1}{V} + \frac{\mathbb{E}[d(SDV)]}{SDVdt}.$$

Expanding, we obtain:

$$\begin{aligned} -\frac{1}{V} &= \frac{\mathbb{E}[dS]}{Sdt} + \frac{\mathbb{E}[dD]}{Ddt} + \frac{\mathbb{E}[dV]}{Vdt} + \frac{\langle dS, dD \rangle}{SDdt} + \frac{\langle dS, dV \rangle}{SVdt} \\ &= -r_f + \mu_D - \kappa_X X_t \frac{V_X}{V} - \kappa_\sigma (\sigma_t^2 - \sigma_0^2) \frac{V_\sigma}{V} \\ &\quad + \frac{1}{2} \nu^2 \sigma_t^2 \frac{V_{\sigma\sigma}}{V} + \frac{1}{2} \phi^2 \sigma_t^2 \frac{V_{XX}}{V} \\ &\quad - rp_D \sigma_t - rp_X \phi \sigma_t \frac{V_X}{V} - rp_\sigma \nu \sigma_t \frac{V_\sigma}{V}. \end{aligned}$$

To obtain a single partial differential equation in V , we need to express the risk-free rate and all three risk prices as functions of V and the state variables. To do so, we first use the optimal portfolio of the passive agent

Stock return

The stock return for the firm's share is given by:

$$\begin{aligned} \frac{dR}{R} &= \left(\frac{1}{V} + \mu_D - \kappa_X \frac{V_X}{V} X_t - \kappa_\sigma \frac{V_\sigma}{V} (\sigma_t^2 - \sigma_0^2) + \frac{1}{2} \frac{V_{XX}}{V} \phi^2 \sigma_t^2 + \frac{1}{2} \frac{V_{\sigma\sigma}}{V} \nu^2 \sigma_t^2 \right) dt \\ &\quad + \sigma_t \left(dZ^D + \phi \frac{V_X}{V} dZ^X + \nu \frac{V_\sigma}{V} dZ^\sigma \right). \end{aligned}$$

The expected return is:

$$\begin{aligned} \mathbb{E}_t \left[\frac{dR}{Rdt} \right] &= \frac{1}{V} + \mu_D - \kappa_X \frac{V_X}{V} X_t - \kappa_\sigma \frac{V_\sigma}{V} (\sigma_t^2 - \sigma_0^2) + \frac{1}{2} \frac{V_{XX}}{V} \phi^2 \sigma_t^2 + \frac{1}{2} \frac{V_{\sigma\sigma}}{V} \nu^2 \sigma_t^2 \\ &= r_f + rp_D \sigma_t + rp_X \phi \sigma_t \frac{V_X}{V} + rp_\sigma \nu \sigma_t \frac{V_\sigma}{V}. \end{aligned}$$

Return dynamics for state variable insurance claims

The other two assets of the economy are zero-cost assets that pay off $rp_X dt + dZ^X$ and $rp_\sigma dt + dZ^\sigma$. We need to check that their price is indeed zero. For the volatility shock insurance this corresponds to

$$\begin{aligned}\mathbb{E}\left[\frac{S_{t+dt}}{S_t} X_{t+dt}\right] &= \mathbb{E}[X_{t+dt}] + \mathbb{E}\left[\frac{dS_t}{S_t} X_{t+dt}\right] \\ &= rp_\sigma dt - rp_\sigma dt = 0.\end{aligned}$$

Portfolio problem of a passive agent

We can directly replace by the results of the general model.

Consumption-wealth ratio c :

Market-clearing imposes the consumption-wealth ratio to equal the cash-flow-price ratio:

$$\frac{1}{V} = c = \beta^{\frac{-1}{\rho-1}} G^{\frac{\rho}{\gamma(\rho-1)}}.$$

Volatility insurance position θ_σ :

In equilibrium, agents do not take any position in the insurance claims.

$$\begin{aligned}0 &= \gamma rp_\sigma + \gamma(\gamma - 1)\theta^* \nu \frac{V_\sigma}{V} \sigma_t + \gamma \frac{G_\sigma}{G} \nu \sigma_t \\ rp_\sigma &= \nu \sigma_t \left[(1 - \gamma)\theta^* \frac{V_\sigma}{V} - \frac{G_\sigma}{G} \right] \\ &= \nu \sigma_t \frac{V_\sigma}{V} \left[(1 - \gamma)\theta^* - \frac{\gamma\rho}{1 - \rho} \right],\end{aligned}$$

where the last equality is obtained by using the market-clearing condition for consumption linking V and G .

Growth-rate insurance position θ_X :

Similarly, we obtain:

$$rp_X = \phi \sigma_t \frac{V_X}{V} \left[(1 - \gamma)\theta^* - \frac{\gamma\rho}{1 - \rho} \right].$$

Stock position θ^*

We invert the formula for the optimal position θ^* to find the risk price of the shock dZ^D .

$$0 = (\mu_R - r_f) + (\gamma - 1) \left[\theta^* \sigma_t^2 + \theta^* \nu^2 \left(\frac{V_\sigma}{V} \right) + \theta^* \phi^2 \left(\frac{V_X}{V} \right)^2 \sigma_t^2 \right] + \phi^2 \frac{G_X}{G} \frac{V_X}{V} \sigma_t^2 + \nu^2 \frac{G_\sigma}{G} \frac{V_\sigma}{V} \sigma_t^2.$$

Plugging in for $\mu_R - r_f$ as a function of risk premia and recognizing the formulas for the other risk prices, we obtain:

$$rp_D = (1 - \gamma)\theta^* \sigma_t.$$

Risk-free rate

The risk-free rate r_f is obtained by plugging in all the quantities just derived in the HJB of the passive agent.

At this stage, we have expressed all the risk prices and the risk-free rate as functions of $V(s_t)$ and the optimal portfolio $\theta^*(s_t)$. The equilibrium of the market for active capital provides us this last quantity.

Market clearing in the active capital market

From the firms' FOC, we know the fee f must equal the marginal productivity of active capital λ . Equating this with the indifference condition between agents of different occupations gives:

$$\bar{\theta}\lambda = \frac{1}{2}(1-\gamma)(\bar{\theta}-\theta^*)^2\sigma_t^2 \left[1 + \nu^2 \left(\frac{V_\sigma}{V} \right)^2 + \phi^2 \left(\frac{V_X}{V} \right)^2 \right]$$

The only unknown quantity is therefore $V(s_t)$. It is determined by the valuation equation of the firm.