Asset Price Volatility, Wealth Distribution and Spirit of Capitalism: The Role of Heterogeneity[*]

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Abstract

We are interested in the role of investors' heterogeneity on asset price volatility in a spirit-of-capitalism model. Our paper extends the asset pricing model developed by Lucas (1978) by introducing preferences for wealth and heterogeneity in preferences, income and initial wealth. Our model provides an explanation for a non-degenerate stationary wealth distribution and the occurrence of asset price fluctuations, driven by the volatility of agents' expectations. Investigating the role of heterogeneity, we show that heterogeneity in preferences, but also in income, can heighten social inequalities in the long run, and asset price volatility in the short run by promoting local indeterminacy.

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1 Introduction

In The Protestant Ethic and the Spirit of Capitalism, Max Weber (1905) argues that the spirit of capitalism according to which the private accumulation of wealth as an end in itself, and not for consumption purpose was the driver of Industrial Revolution in Europe. The continual desire for wealth accumulation promotes investments, and in the end progress which is synonymous with growth. We can find similar ideas in *The Wealth of Nations* by Adam Smith (1776), in *Capital* by Karl Marx (1867) and in *The Economic Consequences of the Peace* by John Maynard Keynes (1919). For the latter, this spirit of capitalism is a psychological aspect of a capitalist society. Introducing SOC hypothesis in standard optimal growth models through preferences for wealth, several contributions (see for instance Kurz, 1968; and Zou, 1994, 1995) confirm that such a hypothesis can explain long-term growth. Furthermore, some empirical studies support the the idea that agents have preferences for wealth, and underline their importance for explaining saving behavior (Carroll, 2000).

In the collective wisdom, the continual desire of wealth accumulation for its own sake by some agents (e.g. financial institutions, hedge funds, banks or traders) is often pointed out as one of the evils of our capitalist society in the times of financial crisis. For instance, Pope Françis denounced the love of money as responsible for both the recent financial crisis and current social inequalities in his *Evangelii Gaudium* in 2013. This is in accordance with Marx (1867) who argues that the perpetual lure of profits by the capitalists generates economic crises. Most financial crises are closely associated with episodes of excess volatility in asset prices. Through the promotion of savings, the spirit of capitalism is a potential source of such an asset price volatility. Several theoretical papers argue that wealth preferences in a standard asset pricing model explain the existence of a bubble on asset prices (Kamihigashi, 2008; Airaudo, 2012; Zhou, 2015), and excess asset price volatility (Bakshi and Chen, 1996; Boileau and Braeu, 2007; and Airaudo, 2012).

The present paper contributes to this literature about the effects of spirit of capitalism (henceforth, SOC) hypothesis in the standard asset pricing models, providing new insights on the role of heterogeneity among investors. The question addressed in this paper is the following:"Would a heterogeneous society, which consists of rich capitalists and poor workers, be more likely to experience social inequalities and financial crisis?" In particular, we aim to investigate the role of heterogeneity on the wealth distribution and the asset

price volatility.

To do this, we extend the continuous time version of infinite-horizon asset pricing model developed by Lucas (1978) to a heterogeneous agent framework with preferences for wealth. Investors trade a single consumption good and a financial asset generating dividends. Furthermore, we consider three sources of heterogeneity: heterogeneity in preferences for wealth, heterogeneity in initial wealth, and heterogeneity in income.

Following Zou (1994, 1995), we introduce SOC hypothesis through preferences for wealth, and consider a non-seperable utility function between consumption good and wealth holdings. Since financial wealth is often used as an index to rank individuals in a country, direct preferences for wealth could also be interpreted as preferences for social status.

Heterogeneity and wealth preferences generate a non-degenerate stationary wealth distribution, meaning that all investors hold financial assets at the steady state. In our paper, the spirit of capitalism encourage all agents to hold financial assets whatever the interest rate level and their endowments. This result contrasts with optimal growth models *à la* Becker (1980) with heterogeneous agents and borrowing constraints in which the most patient agents hold all the wealth of the economy in the steady state.

Preferences for wealth also explain the occurrence of asset price fluctuations, due to self-fulfilling expectations. Expectation-driven fluctuations are likely to occur when wealth and consumption are Edgeworth-substitutes i.e. when the marginal utility of consumption is decreasing in wealth. A similar result appears in the literature about Money-in-the-Utility-Function since money is a financial asset in these models, but provides no dividends. Assuming a Edgeworth substitutability between consumption and money is neither empirically plausible (Walsh, 2010) nor consistent with the idea that money serves as a medium exchange. However, a negative cross-derivative between wealth and consumption is coherent with the concept of frugality at the root of SOC hypothesis developed by Weber (1905). Furthermore, it is worth pointing out that housing wealth is a large component of households' wealth (see, Survey of Consumer Finances 2013 for U.S. data). Several studies shed light on the fact that housing and consumption are Edgeworth-substitutes (see Flavin and Nakagawa, 2008; Piazzesi, *et al.*, 2007 and Yogo, 2006). Therefore, a negative cross-derivative between consumption and wealth would be compatible with empirical evidences.

Investigating the role of heterogeneity, we show that heterogeneity in preferences matter for two reasons. First, heterogeneity in wealth preferences

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affects inequalities, asset price level and volatility. We show that a society which consists of different agents with respect to their wealth preferences (e.g. capitalist/workers) is characterized by higher social inequalities and a higher asset price level in the long run, and is more likely to experience fluctuations. Second, heterogeneity in income affects asset price level and dynamics only if preferences for wealth are heterogeneous. We show that if the rich are those with a stronger spirit of capitalism, inequality in income can heighten the asset price level in the long run, and promote the emergence of fluctuations. Therefore, a heterogeneous society which consists of rich capitalists and poor workers, for instance, is more likely to experience high social inequalities and financial crises.

Since we extend the asset pricing model developed by Lucas (1978) to a heterogeneous agent framework, our paper is also closely relalted to Kocherlakota (1992), Santos and Woodford (1997), Huang and Werner (2004), and more recently Le Van *et al.* (2015), except that these papers consider a framework with borrowing constraints and without SOC hypothesis. Furthermore these papers focus on the existence of a rational bubble on the financial asset. In contrast, in our paper we are interested in the occurrence of asset price fluctuations, driven by the volatility of agents expectations.

A recent contribution closely related to our paper underline the role of spirit of capitalism in the emergence of endogenous fluctuations. For instance, Airaudo (2012) proves the existence of endogenous periodic cycles and chaotic dynamics in Lucas (1978) asset pricing model with SOC hypothesis. However, Airaudo (2012) considers a representative agent framework. In our paper, we take into account the role of heterogeneity on the asset price dynamics, but also on the social inequalities.

The paper is organized as follows. In the next section, we present the model. Section 3 is devoted to the intertemporal equilibrium. In Section 4, we describe the mean-preserving method. Section 5 analyzes the existence and uniqueness of the steady state. In Section 6, we study local dynamics and the role of heterogeneity on dynamics. Concluding remarks are provided in Section 7, while computational details are gathered in Appendix.

2   The model

Our starting point is a modified continuous-time version of the exchange economy developed by Lucas (1978).We consider an exchange economy with

n infinitely-lived heterogeneous investors. There are three sources of heterogeneity: initial wealth, income stream, and preferences. Without loss of generality, we consider two types of households, labeled with $i = 0, 1$. More precisely, there are $n_i > 1$ agents of type i with $n_0 + n_1 = n$. To keep things as simple as possible, we assume that the size of each class of agents are identical.

Assumption 1 $n_0 = n_1 = n/2$.

Individuals derive utility both consumption from $c_i(t)$ and from financial wealth $w_i(t)$. Preferences for wealth capture the hypothesis of "spirit of capitalism. The utility function of an agent at time $t = 0$ is the discounted sum of instantaneous utilities

$$\int_0^{+\infty} e^{-\rho t} u_i \left(c_i(t), w_i(t) \right) dt \tag{1}$$

where $\rho > 0$ is the common subjective rate of time preference.

Following Smith (2001) and Boileau and Braeu (2007), preferences of a household of type i are summarized by the following non-separable utility function in consumption and wealth:

$$u_i \left(c_i(t), w_i(t) \right) = \begin{cases} \dfrac{[c_i(t)^\alpha w_i(t)^{\gamma_i}]^{1-\varepsilon} - 1}{1 - \varepsilon} & if\ \varepsilon > 0, \varepsilon \neq 1; \\[3mm] \alpha \log c_i(t) + \gamma_i \log w_i(t) & if\ \varepsilon = 1 \end{cases} \tag{2}$$

where $\varepsilon > 0$ and $\alpha \in (0, 1)$ are respectively the common relative risk aversion coefficient and the weight of consumption in the utility function. The parameter $\gamma_i > 0$ measures the strength of spirit of capitalism, and captures the heterogeneity in preferences, as long as $\gamma_1 \neq \gamma_0$. Without loss of generality, we rule out the case in which agents do not derive wealth preferences, and consider a particular distribution for γ_i. We assume that the agents of type 1 have a stronger spirit of capitalism than the agents of type 0.

Assumption 2 $0 < \gamma_0 \leq \gamma_1$.

To ensure the concavity of the utility function, we assume

Assumption 3 $1 - (\alpha + \gamma_i)(1 - \varepsilon) > 0$.

Given this utility function, both consumption and wealth are normal goods. Moreover, when $\varepsilon < 1$, wealth and consumption are Edgeworth-complements, meaning that marginal utility of consumption increases with wealth (i.e., $u_{icw}(c_i, w_i) > 0$), and Edgeworth-substitutes (i.e., $u_{icw}(c_i, w_i) < 0$) when $\varepsilon > 1$.

At the initial period $t = 0$, individuals are endowed with different shares of the initial stock $s_i(0)$. At time t, each investor i receives a constant dividend π per share and an exogenous income stream of $y_i > 0$ units of final good. They trade and buy new shares $s_i(t)$ at price $q(t)$, and consume $c_i(t)$ units of final good.

Even though there is no production side in our paper, we could interpret y_i as earnings coming from a labor activity. Heterogeneity in income y_i could depict heterogeneity in skills: If all agents face the same wage, a low-skilled agent has a lower income compared to a high-skilled. In contrast to heterogeneity in preferences, we do not impose restrictions neither on the distribution of income y_i, nor on the distribution of initial wealth $s_i(0)$. Since we do not deal with the transitional dynamics of the wealth distribution in this paper, we focus only on two configurations depending on the dispersion of income: $y_0 < y_1$ and $y_0 > y_1$.

In the first case (i.e. $\gamma_0 < \gamma_1$ and $y_0 < y_1$), investors 0 have both a lower spirit of capitalism and income, while investors 1 have both a stronger spirit of capitalism and income This situation is consistent with several empirical studies on U.S data which show that the individuals working in the financial sector belong to the top income earners (see Kaplan and Rauh, 2010). In the second case (i.e. $\gamma_0 < \gamma_1$ and $y_0 > y_1$), investors 1, who have a stronger spirit of capitalism, get the lowest income. This second case could illustrate a society in which the capitalist (an agent of type 1) would be a rentier, namely a person mainly living on capital income. Throughout the paper, we call agents of type 0, *workers*, and agents of type 1, *capitalists*.

Given an initial level of wealth $w_i(0)$, the investor i maximizes her utility function (1) with respect to $(c_i(t), w_i(t), s_i(t))$ under the following budget and stock constraints:

$$\dot{w}_i(t) \; = \; [\dot{q}(t) + \pi] \, s_i(t) + y_i - c_i(t) \tag{3}$$

$$w_i(t) \; = \; q(t)s_i(t) \tag{4}$$

Let $r(t)$ be the interest rate of the asset defined as follows:

$$r(t) = \frac{\dot{q}(t) + \pi}{q(t)}. \tag{5}$$

Under Assumptions 1-3, the optimal behavior of an individual i is summarized by the following Euler equation and the transversality condition:

$$\frac{\dot{c}_i(t)}{c_i(t)} = \frac{1}{1 + \alpha(\varepsilon - 1)}\left[r(t) + \frac{\gamma_i}{\alpha}\frac{c_i(t)}{w_i(t)} - \rho - \gamma_i(\varepsilon - 1)\frac{\dot{w}_i(t)}{w_i(t)}\right] \tag{6}$$

$$\lim_{t \to +\infty} e^{-\rho t} u_{ic}(c_i(t), w_i(t)) w_i(t) = 0 \tag{7}$$

Since all investors have direct preferences for wealth, and Inada conditions are satisfied both for consumption and wealth, then $s_i(t) > 0$ is the only solution satisfying the optimal behavior of an investor i.

When agents derive utility from wealth, the Euler equation (6) has two additional terms compared to the asset pricing model developed by Lucas (1978)[1]:

$$\frac{\gamma_i}{\alpha}\frac{c_i(t)}{w_i(t)} \quad \text{and} \quad -\gamma_i(\varepsilon - 1)\frac{\dot{w}_i(t)}{w_i(t)}$$

The first term corresponds to the marginal rate of substitution of consumption for wealth, through which the preferences for wealth increase the willingness to delay consumption for the future. Through the second term, this willingness to postpone consumption will be reinforced if wealth and consumption are Edgeworth-complements (i.e., $\varepsilon < 1$), or dampened if substitutes (i.e., $\varepsilon > 1$).

3   Intertemporal equilibrium

An intertemporal equilibrium is defined as follows:

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[1]In Lucas (1978), the Euler equation is given by $\dfrac{\dot{c}_i(t)}{c_i(t)} = \dfrac{r(t) - \rho}{1 + \alpha(\varepsilon - 1)}.$

Definition 1 *Under Assumptions* 1-3, *an equilibrium of the economy* $E = (n, \rho, \pi, (y_i, u_i, s_i(0))_{i=0}^1)$ *is an intertemporal path* $(q(t), (s_i(t), c_i(t))_{i=0}^1)_{t \geq 0}$ *satisfying the optimal behavior of agents* (3)-(7) *and the equilibrium condition on the asset market:*

$$n\frac{s_0(t) + s_1(t)}{2} = 1. \tag{8}$$

Let $\psi = 1 + \alpha(\varepsilon - 1)$ and $\theta_i = \gamma_i(1 - \varepsilon)$. From Definition 1, an intertemporal equilibrium is a path $(q(t), c_1(t), s_1(t))_{t=0}^{+\infty}$ satisfying the following three-dimensional dynamic system:

$$
\begin{cases}
-\psi\dfrac{\dot{c}_1(t)}{c_1(t)} + (1 + \theta_1)\dfrac{\dot{q}(t)}{q(t)} + \theta_1\dfrac{\dot{s}_1(t)}{s_1(t)} = \rho - \dfrac{\gamma_1}{\alpha}\dfrac{c_1(t)}{q(t)s_1(t)} - \dfrac{\pi}{q(t)} \tag{9} \\[2ex]
\psi\dfrac{n_1 c_1(t)}{\pi + ny - n_1 c_1(t)}\dfrac{\dot{c}_1(t)}{c_1(t)} + (1 + \theta_0)\dfrac{\dot{q}(t)}{q(t)} - \theta_0\dfrac{n_1 s_1(t)}{1 - n_1 s_1(t)}\dfrac{\dot{s}_1(t)}{s_1(t)} \\[2ex]
\qquad\qquad\qquad = \rho - \dfrac{\gamma_0}{\alpha}\dfrac{\pi + ny - n_1 c_1(t)}{q(t)(1 - n_1 s_1(t))} - \dfrac{\pi}{q(t)} \tag{10} \\[2ex]
\dfrac{\dot{s}_1(t)}{s_1(t)} = \dfrac{\pi}{q(t)} + \dfrac{y_1}{q(t)s_1(t)} - \dfrac{c_1(t)}{q(t)s_1(t)} \tag{11}
\end{cases}
$$

where $s_i(0) > 0$ is given. Note that there are one predetermined variable $s_1(t)$ and two non-predetermined variables $q(t)$ and $c_1(t)$.

We shall now study the existence and the uniqueness of the steady state, then local dynamic properties of the economy, while emphasizing the role of the heterogeneity both in preferences and in income.

In order to evaluate the effect of the heterogeneity on the economy, we apply the mean-preserving method. Before starting our analysis of the steady state, we present this method in the next section.

4 Mean-preserving approach to heterogeneity

To highlight and understand the role of heterogeneity in preferences and income on the stationary asset price level, wealth distribution, and local

dynamics, we impose a mean-preserving spread of distribution both on heterogeneity in preferences and in income. Thus, we fix the midpoints, and obtain under Assumption 1:

$$\gamma \equiv \frac{\gamma_0 + \gamma_1}{2} \quad \text{and} \quad y \equiv \frac{y_0 + y_1}{2}$$

and we define a measure for each source of heterogeneity:

$$\sigma_\gamma \equiv \sqrt{\frac{(\gamma_0 - \gamma)^2}{2} + \frac{(\gamma_1 - \gamma)^2}{2}}, \tag{12}$$

$$\sigma_y \equiv \sqrt{\frac{(y_0 - y)^2}{2} + \frac{(y_1 - y)^2}{2}}, \tag{13}$$

where σ_γ and σ_y are respectively the standard deviations of the distribution of weight of wealth in preferences and the one of the distribution of income.

To keep our analysis as simple as possible, we define two heterogeneity parameters, x and z, given by $x = \gamma_1 - \gamma$ and $z = y_1 - y$. Under Assumption 1, x is defined on $(0, \gamma)$. Since we do not impose any restrictions on the distribution of income, z is defined on $(-y, y)$. When $y_1 < y_0$, one has $z < 0$, and conversely, when $y_1 > y_0$, $z > 0$. The standard deviations rewrite as functions of x and z:

$$\sigma_\gamma = x, \ \forall \ x \in [0, \gamma) \tag{14}$$

$$\sigma_y = \begin{cases} -z, & \text{if } y_1 < y_0, \\ z, & \text{if } y_1 > y_0 \end{cases} \tag{15}$$

An increase in x depicts an increase in the dispersion of γ_i. A x close to γ means that individuals have very heterogeneous preferences for wealth. An increase in z in absolute value expresses a raise in the dispersion of income y_i. For instance, a $z < 0$ close to $-y$ indicates that a worker is very rich compared to a capitalist. Conversely, a $z > 0$ close to y means that a capitalist is very rich compared to a worker.

5 Steady state analysis

A steady state is an equilibrium where $\dot{s}_1(t) = 0$, $\dot{c}_1(t) = 0$, $\dot{q}(t) = 0$, and $r(t) = r$ for all t.

From (5) and (8)-(11), we deduce that a steady state satisfies the following equations:

$$r = \rho - \frac{\gamma_1}{\alpha}\frac{\pi s_1 + y_1}{qs_1} \tag{16}$$

$$r = \rho - \frac{\gamma_0}{\alpha}\frac{\pi s_0 + y_0}{qs_0} \tag{17}$$

$$r = \frac{\pi}{q} \tag{18}$$

We recall that the second term on the right-hand side of equations (16) and (17) are respectively the marginal rate of substitution of consumption for wealth of an individual 1 and of an individual 0.

As discussed in Section 2, all agents in the economy hold positive shares of stock because of preferences for wealth. This implies that their marginal rates of substitution between wealth and consumption are equal at the steady state. From (8), (16) and (17), we shall get the stationary distribution of wealth and the asset price level, while the interest interest rate will be given by the dividend-price ratio (see (18)).

Therefore, a steady state is a solution (s_1^*, q^*) with $s_1^* \in (0, 2/n)$ and $q^* > 0$ satisfying the following system:

$$\gamma_1 \frac{\pi s_1 + y_1}{s_1} = \gamma_0 \frac{\pi(1 - n_1 s_1) + n_0 y_0}{1 - n_1 s_1} \tag{19}$$

$$q = \frac{\pi}{r(q, s_1)} \tag{20}$$

$$\text{with } r(q, s_1) = \rho - \frac{\gamma_1}{\alpha}\frac{\pi s_1 + y_1}{qs_1} \tag{21}$$

The next proposition proves the existence of an unique steady state, bringing the heterogeneity parameters (x and z) out.[2]

Proposition 1 *Let $\bar{q} = \frac{\pi}{\rho} + \frac{\gamma}{\alpha\rho}(\pi + ny)$. Under Assumption 1-3, there exists a unique steady state (s_1^*, q^*) such that $s_1^* = s_1^*(x, z) \in (0, 2/n)$ and $q^* = q^*(x, z) > 0$.*

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[2]In our paper, the uniqueness of steady state is a direct consequence of the class of preferences we consider, namely homothetic preferences. However, we can show that Greenwood-Hercowitz-Huffman preferences $u(c_i(t) + G_i(w_i(t))$, with $G_i'(.) > 0$ and $G''(.) < 0$, ensures a unique steady state.

Proof. See Appendix 8.1.

The expressions of $s_1^*(x, z)$ and $q^*(x, z)$ are given in Appendix 8.1. Proposition 1 indicates that the stationary asset price level q^* and the distribution of wealth given by s_1^* ($s_0^* = 2/n - s_1^*$) are affected both by the dispersion of income (z) and the dispersion of preferences (x). The asset price consists of two components. The first term corresponds to stationary asset price level found in the representative agent framework, while heterogeneity affects price through the second term. Proposition 1 shows that if two economies differ with respect to x and z, then they could experience different levels of inequalities, and the price of their financial assets could differ as well.

In the following, we first describe the stationary asset price level, and the role of heterogeneity on the latter, then we characterize the steady-state wealth distribution.

5.1 Stationary asset price level

Equation (18) indicates that the stationary asset price level is equal to dividends per share deflated by the stationary interest level r^*, which is equivalent to

$$\frac{\pi}{r^*} = \pi \int_t^{+\infty} e^{-r^*(s-t)} ds \tag{22}$$

The right-hand side of equation (22) corresponds to the definition of the fundamental value of an asset, namely the present discounted value of future dividends. The following proposition characterizes the asset price level at the steady state.

Proposition 2 *Let* $\underline{x} \equiv -\gamma n z \dfrac{2\pi + ny + n\sqrt{(y-z)(y+z)}}{4\pi^2 + 4\pi n y + (nz)^2}$. *Under Assumptions 1-3, the following holds at the steady state*[3]*:*

1. There is no bubble at the steady state;

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[3]When $y_1 < y_0$, we are unable to provide a result for the case $x < \underline{x}$, analytically. However, we could provide a numerical analysis. For this exercise, we just need to provide values for γ satisfying Assumption 2, y and d, then let varying x on $(0, \gamma)$ and z on $(-y, y)$. Several numerical examples hint that the asset price level is decreasing with x when $x < \underline{x}$ and increasing when $x > \underline{x}$.

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2. *The asset price q^* does not depend on σ_y when $x = 0$, is decreasing with σ_y when $x > 0$ and $y_1 < y_0$, and is increasing with σ_y when $x > 0$ and $y_1 > y_0$;*

3. *For $x > \underline{x}$, the asset price q^* is increasing with σ_γ.*

Proof. See Appendix 8.2.

Proposition 1 shows the non-existence of bubbles at the steady state. The presence of positive dividends explains this result. Indeed, Kamihigashi (2008) and Airaudo (2012) obtain the same result in a representative agent framework with preferences for wealth. In these two papers, the financial asset generates dividends. In contrast, Zhou (2015) proves that a bubble on an asset providing no dividends can exist at the steady state. Since we restrict our attention on the occurrence of expectation-driven fluctuations in the neighborhood of a steady sate, our economy does not exhibit bubble.

When agents face same preferences ($x = 0$), heterogeneity in income does not affect the stationary asset price level (Proposition 2.2). We can show from (16) and (18) that the asset price herein is equal to $\bar{q} = \pi/\rho + (\pi + ny)\gamma/(\alpha\rho)$, which corresponds to the stationary asset price level found in the representative agent framework. This result relies on the homothetic property of our preferences. Chatterjee (1994) shows that when preferences are homothetic or quasi-homothetic and agents are only heterogeneous in initial endowments, the aggregate dynamics are exactly the same as in the standard optimal growth model with representative agent. Caselli and Ventura (2000) extend this result to heterogeneity in skills and preferences for public goods.

Interestingly, Propositions 2.2 and 2.3 show that heterogeneity in preferences matters in our framework, and heterogeneity in income matters only if preferences are heterogeneous. Our explanation relies on the fact that we consider preferences for wealth and not for public good. When preferences are heterogenous ($x > 0$), the stationary asset price level decreases with the dispersion of income distribution when capitalists (agents 1) have a lower income than workers (agents 0), and increases with the dispersion of income otherwise (Proposition 2.2).

Economic intuition behind Proposition 2.2. Suppose that capitalists have a lower income than workers (i.e., $y_1 < y_0$). An increase in the dispersion in income distribution (i.e, y_0 raises and y_1 decreases in the same proportions) urges workers to accumulate more wealth, and capitalist less,

since wealth is a normal good. However, the increase in asset demand of workers is not sufficient to counteract the decrease in asset demand of capitalists. Thus, the asset price level declines following an increase in σ_y. We can provide the same rationale for the case $y_1 > y_0$ by considering the reversed mechanism.

As shown by Proposition 2.3, the critical value $\underline{x}$ is determinant in the role of preference heterogeneity for the stationary asset price level. When capitalists have a greater income than workers (i.e., $y_1 > y_0$), we get $\underline{x} < 0$, implying that the stationary asset price level increases with the dispersion of γ_i distribution. When capitalists have a lower income than workers (i.e., $y_1 < y_0$), $\underline{x}$ is now positive. The stationary asset price level increases with the dispersion of γ_i distribution if capitalists have a sufficiently strong spirit of capitalism than workers (i.e., $x > \underline{x}$).[4]

Economic intuition behind Proposition 2.3. When $y_1 > y_0$, capitalists have a higher income compared to workers. An increase in the dispersion of γ_i (higher γ_1 and lower γ_0) urges capitalists to accumulate more wealth, and workers less. The increase in asset demand of capitalists, sufficient to counteract the decrease in asset demand of workers, generates a rise in the asset price level. If capitalists are the poor (i.e., $y_1 < y_0$), but their willingness for wealth accumulation is sufficiently high compared to workers ($x > \underline{x}$), the previous mechanism prevails as well.

5.2   Stationary wealth and total income distributions

Financial wealth and total income are naturally used to rank individuals in a society, and thus provide some insights about social inequalities. For this reason, this subsection aims to characterize the stationary distributions in wealth and total income, and the role of heterogeneity on these distributions.

In our framework, we define the stationary wealth of an agent i as the real value of assets she holds, namely $w_i^*(x, z) = q^*(x, z)s_i^*(x, z)$, whereas her total income is given by $R_i^*(x, z) = \pi s_i^*(x, z) + y_i$. The next proposition characterizes the distributions of wealth and total income within the economy at the steady state.

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[4]Note that $x > \underline{x}$ is equivalent to $\gamma_1 > 2\underline{x} + \gamma_0$.

Proposition 3 *Let $\tilde{x} = -\frac{\gamma nz}{\pi + ny}$ and $\bar{x} = -\frac{\gamma zn}{\pi}$. Under Assumptions 1-3, the following holds at the steady state[5]:*

1. *The wealth distribution is non-degenerate meaning that capitalists and workers hold capital $s_i^*(x, z) > 0$;*

2. *A capitalist holds a greater stock share than a worker (i.e., $s_1^*(x, z) > s_0^*(x, z)$) if and only if she has sufficiently strong spirit of capitalism compared to the worker (i.e., $x > \tilde{x}$);*

3. *If capitalists have a lower income than workers and the income gap is high (i.e.; $y_1 < y_0$ and $z = y_1 - y_0 < -\pi$) or if capitalists receive a slightly lower income than workers, but they have a not too high spirit of capitalist relatively to workers ($-\pi < z < 0$ and $x < \bar{x}$), then the capitalists is the poorest in terms of total income (i.e., $R_1^* < R_0^*$). If capitalists have a higher income than workers (i.e., $y_1 > y_0$) or if capitalists receive a lower income than workers, but have a sufficiently strong spirit of capitalist compared to workers ($-\pi < z < 0$ and $x > \bar{x}$), then the capitalist is the richest in terms of total income (i.e., $R_1^* > R_0^*$).*

Proof. See Appendix 8.3.

In an optimal growth framework without wealth preferences, Becker (1980) proves that when the rate of time preference differs across agents, the wealth distribution is degenerate, meaning that the most patient agent holds all the financial wealth. In our framework, preferences for wealth encourage all agents to accumulate wealth. Our result about the non-degenerate distribution of wealth will be hold true with difference rate of time preference across agents.[6]

Proposition 3 explains some stylized facts on the saving behavior, namely why the rich accumulate more wealth (see Dynan, Skinner, and Zeldes, 2004). This result is also in accordance with Carroll (2000) who claims that the spirit of capitalism can explain the saving choices of the rich.[7]

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[5]For simplicity, the arguments of the functions are omitted

[6]Suen (2014) obtains also a non-degenerate distributions of capital in a model with time preference heterogeneity and direct preferences for wealth.

[7]Our result partially replicate U.S. data in the sense that a part of american households do not hold financial wealth (see, Survey of Consumer Finances 2013). We can overcome this issue by adding a third class of agents who do not have preferences for wealth. At the

Let us turn now to the effect of a change in agents' heterogeneity on wealth and total income inequality. After ranking the agents i in $(0, n)$ according to their increasing wealth or total income, we define the Gini coefficients associated with wealth distribution G_w^* and with total income distribution G_R^* as follows[8]:

$$G_w = 1 - 2\frac{\int_0^n W(i)di}{W(n)n} \text{ and } G_R = 1 - 2\frac{\int_0^1 \Gamma(i)di}{\Gamma(n)n} \tag{23}$$

For the definition of Gini coefficients, we suppose that workers are the poor in the economy:

Assumption 4 $y_0 < y_1$.

Assumption 4 ensures that $w_1^*(x, z) > w_0^*(x, z)$ and $R_1^*(x, z) > R_0^*(x, z)$. The stationary aggregate wealth $n_i w_i^*(x, z)$ and aggregate total income $n_i R_i^*(x, z)$ of agents of type i are respectively given by $n_i w_i^*(x, z) = n_i q^*(x, z) s_i^*(x, z)$ and $n_i R_i^*(x, z) = n_i(\pi s_i^*(x, z) + y_i)$. Under Assumptions $1 - 4$, we obtain:

$$W(i) = \begin{cases} i w_0^*(x, z), & \text{if } 0 \leq i \leq n_0, \\ \\ n_0 w_0^*(x, z) + (i - n_0) w_1^*(x, z), & \text{if } n_0 < i \leq n \end{cases} \tag{24}$$

$$\Gamma(i) = \begin{cases} i R_0^*, & \text{if } 0 \leq i \leq n_0, \\ \\ R_0^*(x, z) + (i - n_0) R_1^*(x, z), & \text{if } n_0 < i \leq n \end{cases} \tag{25}$$

Under Assumptions $1 - 4$, we get two following Gini coefficients evaluated at the steady state:

$$G_w^*(x, z) = \frac{1}{2}\left(s_1^*(x, z) - \frac{1}{n}\right) \tag{26}$$

$$G_R^*(x, z) = \frac{n}{2}\frac{\pi\left(s_1^*(x, z) - 1/n\right) + z}{\pi + ny} \tag{27}$$

with $s_1^*(x, z)$ given in Appendix 8.1.

Proposition 4 *Under Assumptions 1-4, $G_w^*(x, z)$ and $G_R^*(x, z)$ are both increasing with σ_γ and σ_y.*

Proof. See Appendix 8.4

Since both Gini coefficients are positively correlated, we find that they goes in the same direction when there is a change in preference heterogeneity or in income. Therefore, we can restrict our attention only on one coefficient when we deal with social inequality.

Economic intuition. A rise in the dispersion of γ_i distribution means that the spirit of capitalism among capitalists deepens, and the one of workers reduces. A higher heterogeneity in wealth preferences urges capitalists to save more, and thus to become richer, and workers, to save less. Social inequality increases. The same argument applies for a rise in income inequality. Under Assumption 4, a rise in the dispersion of income distribution forces capitalists who are initially rich to save more, and workers who are poor to save less. Social inequality increases.

In the next section, we shall highlight the role of heterogeneity on the occurrence of asset price fluctuations, and connect with the level of social inequalities

6 Heterogeneity and Volatility

In this section, we address the following question: "Would a very heterogeneous society be more likely to experience volatility in asset prices, and thus financial crisis, or the opposite?" In other words, we aim to investigate the role of heterogeneity on the existence of expectation-driven fluctuations in the neighborhood of the steady state. Our results are twofold. First, heterogeneity in income plays a role on the asset price volatility only when agents face different preferences. Second, heterogeneity in preferences can destabilize the economy by enlarging the range of parameter values for which fluctuations due to self-fulfilling expectations are likely to occur.

To do this, we analyze the local dynamic properties of our model, and refer to local indeterminacy concept for the existence of expectation-driven fluctuations. Local indeterminacy means that there exist multiple equilibria with the same initial condition which converges to a steady state. Local indeterminacy is a sufficient condition for the occurrence of fluctuations driven

by the volatility of agents' expectations, without requiring shock on the fundamentals i.e. preferences and/or dividends in our model.

From the log-linearization of the 3-dimensional dynamic system (9)-(11) around the steady state (q^*, s_1^*), we obtain the characteristic polynomial. As shown in Appendix 8.5., we can derive the trace $T(\varepsilon)$, the sum of the second order principal minor $S(\varepsilon)$ and the determinant $D(\varepsilon)$ of the associated Jacobian matrix as functions of ε. The characteristic polynomial of this economy is given by:

$$P(\lambda) = \lambda^3 - T(\varepsilon)\lambda^2 + S(\varepsilon)\lambda - D(\varepsilon) \tag{28}$$

Local indeterminacy occurs when the stable manifold has dimension greater than the number of predetermined variables. Since $s_1(t)$ is the only predetermined, the steady state will be locally determinate when the Jacobian matrix has zero or one eigenvalue with negative real part, and locally indeterminate when it has at least two eigenvalues with negative real part.

The next proposition provide the conditions on ε for which local indeterminacy occurs.

Proposition 5 *Let $\underline{\varepsilon}(x,z) \equiv 1 + \frac{\pi + ny}{c_1^*(x,z)} \frac{s_1^*(x,z)}{\gamma + x} > 1$. Under Assumptions 1-3, the following holds:*

1. *If $\varepsilon \in (0, \underline{\varepsilon}(x,z))$, the steady state is locally determinate.*

2. *If $\varepsilon > \underline{\varepsilon}(x,z)$, the steady state is locally indeterminate.*

Proof. See Appendix 8.5.

Proposition 5 shows that expectation-driven fluctuations are likely to occur when the coefficient of relative risk aversion ε is sufficiently high, in particular greater than 1. Hence, local indeterminacy occurs only if wealth and consumption are Edgeworth-substitutes (i.e., $u_{cw} < 0$), otherwise the steady state is always determinate.

A similar result appears in the literature about Money-in-the-Utility-Function. A necessary condition for local indeterminacy in this kind of model is a negative cross-derivatives of the utility function between consumption and money.[9] Nevertheless, a negative cross-derivative is neither empirically

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[9]For an overview about the link between money-in-the-utility function and indeterminacy, the reader could refer to Obstfeld (1984) and Matsuyama (1990).

plausible (Walsh, 2010) nor consistent with the idea that money serves as a medium exchange. In contrast, assuming a negative cross-derivative between wealth and consumption is coherent with the concept of frugality at the root of "spirit of capitalism" hypothesis developed by Weber (1905). Furthermore, several studies shed light on the fact that housing and consumption are Edgeworth-substitutes (see Flavin and Nakagawa, 2008; Piazzesi, *et al.*, 2007 and Yono, 2006). Since housing wealth is a large component of households' wealth (see, Survey of Consumer Finances 2013 for U.S. data), a negative cross-derivative between wealth and consumption would be empirically consistent.

More interestingly, Proposition 5 also indicates that the critical value $\underline{\varepsilon}$, for which fluctuations are likely to occur, is a function both of preferences and income heterogeneity (x and z). This means that heterogeneity plays a role in the emergence of expectation-driven fluctuations. In our paper, heterogeneity promotes the occurrence of volatility as soon as it enlarges the range of parameter values for which local indeterminacy occurs. If heterogeneity reduces the range of parameter values, then the heterogeneity has stabilizing virtues.

Before assessing the effect of heterogeneity both in preferences and income, we provide the mechanisms through which expectation-driven fluctuations, and show how heterogeneity modifies these mechanism. Since aggregate consumption is constant along an equilibrium path, and the economy remains near the steady state, by combining equations (9) and (10) we obtain

$$\frac{n_0}{c(t)} \left[\frac{\gamma_1}{\alpha} \frac{c_1(t)}{q(t)s_1(t)} c_1(t) + \frac{\gamma_0}{\alpha} \frac{c_0(t)}{q(t)s_0(t)} c_0(t) \right] = \rho - \frac{\dot{q}(t) + \pi}{q(t)}$$
$$- \frac{n_0}{c(t)} \left\{ c_1(t) \left[\gamma_1(1 - \varepsilon) \right] + c_0(t) \left[\gamma_0(1 - \varepsilon) \right] \right\} \frac{\dot{q}(t)}{q(t)} \tag{29}$$

with $c(t)$ the aggregate consumption, i.e. $c(t) = n_1 c_1(t) + n_0 c_0(t)$.

Equation (29) indicates that the aggregate marginal rate of substitution of consumption for wealth should equal the opportunity cost of wealth holding. We can see that a change in asset price level have an ambiguous effect through the opportunity cost, when $\varepsilon > 1$. $\varepsilon > \underline{\varepsilon}(x, z)$ is equivalent to the following inequality.

$$c_1(t) \left[1 + \gamma_1(1 - \varepsilon) \right] + c_0(t) \left[1 + \gamma_0(1 - \varepsilon) \right] < 0 \tag{30}$$

Suppose that $\varepsilon > \underline{\varepsilon}(x, z)$. A small drop in asset price from the stationary level q^* lowers the opportunity cost, and (29) can be satisfied only if the

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marginal rate of substitution decreases. This could occur only if the asset price increases. After a small deviation of asset price from its stationary level, the economy will converge monotonically toward its steady state.

Corollary 1 *Under Assumptions 1-3, when preferences for wealth are homogeneous ($x = 0$), heterogeneity in income has no impact on the conditions for the existence of local indeterminacy.*

When preferences are homogeneous, inequality (30) is equivalent to $1 + \gamma(1 - \varepsilon) < 0$. The critical value $\underline{\varepsilon}$ is given by $1/\gamma$. Heterogeneity in income plays, therefore, no role in the emergence of local indeterminacy. As discussed in Section 4, this is due to the homothetic properties of preferences.

As $\gamma_1 \geq \gamma_0$ under Assumption 3, inequality (30) is satisfied only if $\varepsilon > 1$ and $[1 + \gamma_1(1 - \varepsilon)] < 0$. If $[1 + \gamma_1(1 - \varepsilon)] < 0$, inequality (30) is equivalent to

$$|c_1(t) [1 + \gamma_1(1 - \varepsilon)]| > |c_0(t) [1 + \gamma_0(1 - \varepsilon)]| \qquad (31)$$

Inequality (31) means that the effect on the opportunity cost stemming from a change in behavior of capitalists dominates.

Corollary 2 *Under Assumptions 1-3, the following holds when $x > 0$:*

1. *When $y_1 < y_0$, an increase in income heterogeneity (a higher σ_y) stabilizes, by reducing the range of parameter values for which local indeterminacy occurs;*

2. *When $y_1 > y_0$, an increase in income heterogeneity (a higher σ_y) destabilizes, by enlarging the range of parameter value for which local indeterminacy occurs.*

Proof. See Appendix 8.6.

Economic intuition. When $y_1 < y_0$, a rise in the dispersion of income distribution prevents from the occurrence fluctuations. We have shown that indeterminacy are likely to occur only when the effect stemming from a change in behavior of capitalist dominates. However, when $y_1 < y_0$, this effect is dampened by a rise in the dispersion of income distribution. The reverse argument holds when $y_1 > y_0$.

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Since we restrict our attention on the dynamics near the steady state, we can claim that the effect of income heterogeneity on the total income distribution along an equilibrium path is similar to the effect at steady state. Thus, we indirectly link the distribution of total income with the occurrence of fluctuations. We have shown that Gini coefficient associated with total income distribution is positively correlated with σ_y when $y_1 > y_0$. Therefore, we conclude that an increase in total income inequality destabilizes the economy, when capitalists are also the rich in the society.

Corollary 3 *Under Assumptions 1-3, a rise in preference heterogeneity destabilizes by enlarging the range of parameter values for which local indeterminacy occurs for $x > \underline{x}$.*

Proof. See Appendix 8.6.

The critical value $\underline{x}$ is also determinant in the role of preference heterogeneity on the occurrence of endogenous fluctuations. When capitalists have a greater income than workers (i.e., $y_1 > y_0$), the latter is negative ($\underline{x} < 0$), implying that a rise in the dispersion of γ_i distribution promotes the existence of expectation-driven fluctuations. When capitalists have a lower income than workers (i.e., $y_1 < y_0$), $\underline{x}$ is now positive. A rise in the dispersion of γ_i distribution promotes the existence of expectation-driven fluctuations if capitalists have a sufficiently strong spirit of capitalism than workers ($x > \underline{x}$).

Economic intuition. A rise in the dispersion of γ_i boosts the willingness of capitalists to accumulate wealth, and thus reinforces the effect on the opportunity stemming from capitalists necessary for indeterminacy. When the rich are also the capitalists, an increase in heterogeneity of preferences destabilizes the economy. If capitalists are the poor, but their willingness for wealth accumulation is sufficiently high compared to workers ($x > \underline{x}$), the previous mechanism prevails as well.

From an economic point of view, Corollary 3 claims that a society, in which all agents would have same preferences, would be better from a stabilizing perspective to a society, in which there would be two social classes with the rich capitalists, on one hand, and the poor workers, on the other hands.

To answer our question addresses at the beginning of the section, a heterogeneous society, which consists of rich capitalists and poor workers, is more likely to experience asset price volatility, and thus financial crisis.

7 Concluding remarks

Our model adds two ingredients to the well-known asset pricing model developed by Lucas (1978) to inspect the role of investors heterogeneity on asset price volatility and social inequalities. The first ingredient is heterogeneity: heterogeneity in preferences, income stream and in initial wealth. The second ingredient is preferences for wealth, which captures the spirit of capitalism hypothesis originated from Max Weber (1905). These two novelties generate a non-degenerate stationary wealth distribution, meaning that all investors hold financial assets at the steady state.

Heterogeneous spirit of capitalism preferences matter for the occurrence of asset price fluctuations driven by the volatility of agents expectations. Investigating the role of investors heterogeneity, our paper shows that more heterogeneity in preferences, but also in income, can accentuate social inequalities in the long run, and reinforce mechanisms behind asset price volatility in the short run by promoting local indeterminacy.

By providing new insights about the role of heterogeneity on asset price volatility and wealth inequality, our paper can be used to investigate how a redistribution policy, as a capital income taxation, should be implemented to both reduce social inequalities and stabilize the economy. Since our paper is a purely theoretical analysis, it would be also convenient to provide an empirical assessment of our model. These two extensions are left for future research.

8 Appendix

8.1 Proof of Proposition 1

Let us prove Proposition 1.

A steady state (s_1^*, q^*) is a solution of $q_1(s_1) = q_0(s_1)$, with:

$$
\begin{cases}
q_1(s_1) = \dfrac{\gamma_1}{\alpha\rho} \dfrac{\pi s_1 + y_1}{s_1} + \dfrac{\pi}{\rho} & (32) \\[2ex]
q_0(s_1) = \dfrac{\gamma_0}{\alpha\rho} \dfrac{\pi(1 - n_1 s_1) + n_0 y_0}{1 - n_1 s_1} + \dfrac{\pi}{\rho} & (33)
\end{cases}
$$

There exists at least one value $s_1^* \in (0, 2/n)$ such that $q_1(s_1^*) = q_0(s_1^*)$. As $q_1(s_1) > 0 \ \forall \ s_1 \in (0, 2/n)$, we deduce that $q^* = q_1(s_1^*) > 0$. In particular, we get:

$$s_1^* = \frac{x\pi - \gamma yn/2 - xz/2}{x\pi n}$$
$$+\frac{\sqrt{(x\pi - \gamma yn/2 - xzn/2)^2 + (\gamma + x)(y + z)\pi xn}}{nx\pi} \equiv s_1^*(x, z) \tag{34}$$

$$q^* = \bar{q} + \frac{1}{\alpha\rho}\frac{[\gamma(1 - ns_1^*(x, z)) + x][y(1 - ns_1^*(x, z)) + z]}{2s_1^*(x, z)(1 - ns_1^*(x, z)/2)} \equiv q^*(x, z) \tag{35}$$

Since $q_1(s_1)$ is strictly decreasing on $(0, 2/n)$ and $q_0(s_1)$ is strictly increasing on $(0, 2/n)$, the solution (q^*, s_1^*) is unique. ∎

8.2 Proof of Proposition 2

We first prove Proposition 2.1 claiming that the stationary asset price is equal to its fundamental value.

Let $r(t)$ be an interest rate, $q(t)$ the asset price in terms of consumption good at time t and π the dividend in consumption good units generated by the asset. The no-arbitrage condition that governs the evolution of the asset price is given by:
$$q(t) = \frac{\dot{q}(t) + \pi}{r(t)} \tag{36}$$

Solving equation (36) by iterating forward, we obtain:
$$q(t) = \int_t^{+\infty} e^{\int_t^s -r(i)di}\pi ds + e^{\int_t^{+\infty} -r(i)di}q(+\infty) \tag{37}$$

The first term depicts the fundamental value of the asset $v(t)$, while the second term is the definition of a bubble $b(t)$:
$$v(t) = \int_t^{+\infty} e^{\int_t^s -r(i)di}\pi ds \tag{38}$$
$$b(t) = e^{\int_t^{+\infty} -r(i)di}q(+\infty) \tag{39}$$

At the steady state, $q(t) = q^*$ and $r(t) = r^*$. Therefore, from (38), we have
$$v(t) = \pi \int_t^{+\infty} e^{-r^*(s-t)} = \frac{\pi}{r^*} \equiv v^* \tag{40}$$

Combining (36) evaluated at the steady state with (40), one has

$$q^* = \frac{\pi}{r^*} = v^* \tag{41}$$

The asset price is equal to its fundamental component at the steady state.

We know prove Propositions 2.2 and 2.3 which discuss the effect of heterogeneity on the stationary asset price level q^*.

We recall that $\sigma_\gamma = x$, $\sigma_y = -z$ when $y_1 \leq y_0$, and $\sigma_y = z$ when $y_1 \geq y_0$. Hence, $\partial z / \partial \sigma_y \leq 0$ when $y_1 \leq y_0$, and $\partial z / \partial \sigma_y \geq 0$ when $y_1 \geq y_0$. We shall compute the derivatives of $q^*(x, z)$ with respect to σ_y and x, and analyze their signs. We start with $\partial q^* / \partial \sigma_y$:

$$\frac{\partial q^*(x, z)}{\partial \sigma_y} = \frac{\partial q^*(x, z)}{\partial z} \frac{\partial z}{\partial \sigma_y}, \text{ with} \tag{42}$$

$$\frac{\partial q^*(x, z)}{\partial z} = xn^3\pi \frac{\gamma + x}{\alpha\rho} \frac{g_1(x, z) - g_2(x, z)}{d(x, z)^2 \pi \sqrt{\Delta(x, z)}} \tag{43}$$

where

$$g_1(x, z) \equiv n\left(\frac{n\gamma y}{2}\right)^2 + n(\pi x)^2 + xyn^2\left(-\frac{\gamma y n}{2} - \gamma\pi + \pi x\right)$$
$$+ xz\frac{n^2}{2}\left[(\gamma - x)(\pi + ny) + \pi(\gamma + x)\right] \tag{44}$$

$$g_2(x, z) \equiv n\left(ny\frac{\gamma - x}{2} - \pi x\right)\sqrt{\Delta(x, z)}, \text{ with} \tag{45}$$

$$d(x, z) = x\pi - \frac{n\gamma y}{2} - \frac{nxz}{2} + \sqrt{(x\pi - n\gamma y/2 - nxz/2)^2 + (\gamma + x)(y + z)\pi xn} \tag{46}$$

$$\Delta(x, z) \equiv \left(\frac{\gamma y n}{2}\right)^2 + \left(\frac{nxz}{2}\right)^2 + (\pi x)^2 + \frac{\gamma n^2 xyz}{2} - \gamma\pi nxy + \gamma\pi nxy$$
$$+ \gamma\pi nxz - \pi nx^2 z + \pi nx^2 y + \pi nx^2 z \tag{47}$$

When $x = 0$; $\partial q^* / \partial z = 0$ (see (43)). We analyze now the sign of (43) when $x \in (0, \gamma)$. First of all, we can note that the denominator of (43) is positive $\forall \ x \in (0, \gamma)$ and $z \in (-y, y)$. As a consequence, the sign of (43) is given by its numerator, i.e. $g_1(x, z) - g_2(x, z)$.

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Note that $g_1(x,z) > 0 \; \forall \; x \in (0,\gamma)$ and $y \in (-y, y)$. Since $x \in (0, \gamma)$, $g_1(x,z)$ is increasing with $z \in (-y, y)$. Hence,

$$
\begin{aligned}
g_1(x,y) \;>\; & n\left(\frac{n\gamma y}{2}\right)^2 + n(\pi x)^2 + xy\left(-\frac{\gamma y n^3}{4} - \frac{\gamma \pi n^2}{2} + \pi x n^2\right) \\
& -\frac{n^2 xy}{4}\left[(\gamma - x)(\pi + ny) + \pi(\gamma + x)\right] \\
= & \; n\left[\left(\frac{n\gamma y}{2}\right)^2 + (\pi x)^2 + \left(\frac{xyn}{2}\right)^2 + \pi x^2 yn - \gamma n^2 y^2 x - \gamma nyx\pi\right] \\
= & \; n\left[\frac{n}{2}y(\gamma - x) - \pi x\right]^2 > 0 \qquad\qquad (48)
\end{aligned}
$$

Two cases appears when we study the sign of $g_2(x,z)$: case (a) $\dfrac{ny}{2}(\gamma - x) - \pi x < 0$ and case (b) $\dfrac{ny}{2}(\gamma - x) - \pi x > 0$.

Case (a) $\dfrac{ny}{2}(\gamma - x) - \pi x < 0.$

In Case (a), we have $g_2(x,y) < 0$. Therefore, we get $g_1(x,z) - g_2(x,z) > 0$. We can deduce that $\partial q^*(x,z)/\partial z > 0$ in the case (a).

Case (b) $\dfrac{ny}{2}(\gamma - x) - \pi x > 0.$

In Case (b), we have $g_2(x,y) > 0$. As a consequence, $\partial q^*(x,z)/\partial z > 0$ if and only if $g_1(x,z) > g_2(x,z)$.

As $g_1(x,y)$ and $g_2(x,y)$ are both positive, $g_1(x,z) > g_2(x,z)$ is equivalent to

$$
g_1(x,z)^2 \;>\; g_2(x,z)^2 \qquad\qquad (49)
$$

After some algebra, we can show that the inequality (49) is equivalent to

$$
(\gamma - x)(\gamma + x) > 0
$$

Since $x \in (0, \gamma)$, the inequality (49) holds true. Hence, we can conclude $g_1(x,z) - g_2(x,z) > 0 \; \forall \; x \in (0, \gamma)$ and $y \in (-y, y)$. Therefore, $\partial q^*/\partial z > 0$ when $x \in (0, \gamma)$ and $\frac{ny}{2}(\gamma - x) - \pi x > 0$.

From Case (a) and Case (b), we deduce that $\partial q^*/\partial z > 0$ when $x \in (0, \gamma)$. As $\partial z/\partial\sigma_y < 0$ when $y_1 < y_0$ and $\partial z/\partial\sigma_y > 0$ when $y_1 > y_0$, Proposition 2.2

follows.

Let prove Proposition 2.3. We analyze now the sign of the $\partial q^*(x, z)/\partial\sigma_\gamma$. We have

$$\frac{\partial q^*(x, z)}{\partial\sigma_\gamma} = \frac{\partial q^*(x, z)}{\partial x}\frac{\partial x}{\partial\sigma_\gamma}, \text{ with} \tag{50}$$

$$\frac{\partial q^*(x, z)}{\partial x} = \frac{1}{\alpha\rho}\frac{\tilde{g}(x, z)}{d(x, z)^2\sqrt{\Delta(x, z)}} \tag{51}$$

where

$$\tilde{g}(x, z) \equiv \tilde{g}_1(z)x^3 + \left[\tilde{g}_2(z) + \tilde{g}_3(z)\sqrt{\Delta(x, z)}\right]x^2 + \left[\tilde{g}_4(z) + \tilde{g}_5(z)\sqrt{\Delta(x, z)}\right]x$$
$$+ \quad \tilde{g}_6(z) + \tilde{g}_7(z)\sqrt{\Delta(x, z)}, \text{ with}$$
$$\tag{52}$$

$$\tilde{g}_1(z) = n^3yz^2 + 4\pi n^2y^2 + 2\pi n^2z^2 + 12\pi^2ny + 8\pi^3 \tag{53}$$
$$\tilde{g}_2(z) = 3\gamma n^3y^2z - 4\gamma\pi n^2y^2 + 10\gamma\pi n^2yz + 2\gamma\pi n^2z^2 - 4\gamma\pi^2ny + 8\gamma\pi^2nz$$
$$\tag{54}$$
$$\tilde{g}_3(z) = -n^2yz + 4\pi ny + 4\pi^2 \tag{55}$$
$$\tilde{g}_4(z) = 2\gamma^2n^3y^3 + \gamma^2n^3yz^2 + 2\gamma^2\pi n^2y^2 - 2\gamma^2\pi n^2yz + 2\gamma^2\pi n^2z^2 \tag{56}$$
$$\tilde{g}_5(z) = -2\gamma(ny)^2 - 2\gamma\pi n(y - z) \tag{57}$$
$$\tilde{g}_6(z) = \gamma^3n^3y^2z \tag{58}$$
$$\tilde{g}_7(z) = -\gamma^2n^2yz \tag{59}$$

As the denominator of (51) is positive, the sign of $\partial q^*/\partial x$ will be given by the sign of $\tilde{g}(x, z)$. Since the study of function $\tilde{g}(x, z)$ is not so trivial, we resort to the mathematical software Maple to provide a conclusion.

First of all, the function $\tilde{g}(x, z)$ is defined on $x \in [0, +\infty)$, and $\tilde{g}(0, z) = 0$. Furthermore, one has:

$$\lim_{x\to+\infty}\tilde{g}(x, z) = \lim_{x\to+\infty}x^3(\tilde{g}_1 + \tilde{g}_2\frac{\Delta(x, z)}{x}) \tag{60}$$
$$= \left[16\pi^3 + 20\pi^2ny + 2n^2(2y^2 - yz + z^2)\pi + n^3yz^2\right]x^3 > 0,$$
$$\forall \ z \in (-y, y)$$
$$\tag{61}$$

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Therefore, $\tilde{g}(x, z)$ tends towards ∞ when x goes to $+\infty$.

Maple finds that the equation $\tilde{g}(x, z) = 0$ has two solutions in x:

$$x_1 = -zn\gamma \frac{yn + 2\pi - n\sqrt{(y-z)(y+z)}}{(nz)^2 + 4\pi ny + 4\pi^2} \tag{62}$$

$$x_2 = -zn\gamma \frac{yn + 2\pi + n\sqrt{(y-z)(y+z)}}{(nz)^2 + 4\pi ny + 4\pi^2} \tag{63}$$

$$\tag{64}$$

When $z < 0$, one has $0 < x_1 < x_2$, $x_1 = x_2 = 0$ when $z = 0$, and $0 > x_1 > x_2$ when $z > 0$. Therefore, we assert that $\partial q^*/\partial x > 0$ when $z \geq 0$ and for $x > x_2 \equiv \underline{x}$ (in Proposition 2) when $z < 0$.

Analytically, we are not able to conclude on the sign of $\partial q^*/\partial x$ when $z < 0$, and in particular for the case where $x \in (0, \underline{x})$. A numerical analysis is required. For this numerical exercise, we just need to fix the values for γ satisfying Assumption 2, y and π, then let varying x on $(0, \gamma)$ and z on $(-y, y)$.[10] Several numerical examples hint that the asset price level is decreasing with x when $x < \underline{x}$ and increasing when $x > \underline{x}$. ■

8.3 Proof of Proposition 3

Proposition 3.1 is a direct consequence of Proposition 1.

Let prove Proposition 3.2, then Proposition 3.3.[11] Note that $s_1^* > s_0^*$ is equivalent to $s_1^* > 1/n$. As $q_1'(s_1) < 0$, $q_0'(s_1) > 0$ and $q_1(s_1^*) = q_0(s_1^*)$, where $q_1(s_1)$ and $q_0(s_1)$ are respectively given by (32) and (33), $s_1^* > 1/n$ if and only if $q_1(1/n) > q_0(1/n)$. This inequality is equivalent to $x > -\gamma nz/(\pi + ny) \equiv \tilde{x}$.

$R_1^* > R_0^*$ is equivalent to

$$s_1^* > (1/n) - z/\pi \tag{65}$$

If $z < -\pi/n$, then $1/n - z/\pi > 2/n$. As $s_1^* < 2/n$, the inequality (65) cannot hold. Hence, if $z < -\pi/n$, then $R_1^* < R_0^*$. If $z > \pi/n$, then we have $s_1^* > 0 > 1/n - z/\pi$. As a result, when $z > \pi/n$, we get $R_1^* > R_0^*$.

If $z \in (-\pi/n, \pi/n)$, then $2/n > 1/n - z/\pi > 0$. As a consequence, we should analyze under which conditions the inequality (65) holds.

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[10]There exist few estimations in the literature for the parameter γ measuring the weight of wealth in preferences. To match U.S. data, Airaudo (2012) sets γ to 0.68, whereas Karnizova (2010) to 0.83.

[11]For simplicity, the arguments of the functions are omitted.

As $q_1'(s_1) < 0$, $q_0'(s_1) > 0$ and $q_1(s_1^*) = q_0(s_1^*)$, $s_1^* > 1/n - z/\pi$ if and only if $q_1(1/n - z/\pi) > q_0(1/n - z/\pi)$ which is equivalent to $x > -\gamma zn/\pi \equiv \bar{x}$.

Note that for $z > 0$, $\bar{x} < 0$. Therefore, Proposition 3.3 follows. ∎

8.4 Proof of Proposition 4

First of all, we observe that $G_R^*(x, z)$ is an increasing function of $G_w^*(x, z)$

$$G_R^*(x, z) = \frac{\pi}{\pi + ny} G_w^*(x, z) + \frac{nz/2}{\pi + y} \tag{66}$$

As $G_w^*(x, z)$ is a function of $s_1^*(x, z)$, itself function of x and z, we first compute the derivatives of $s_1^*(x, z)$ with respect to x and z, then the derivative of $G_w^*(x, z)$ and $G_R^*(x, z)$ with respect to x and z. We have

$$\frac{\partial s_1^*(x, z)}{\partial x} = n\gamma \frac{y\sqrt{\Delta(x, z)} - (\gamma y^2 n/2 + xyzn/2 + 2\pi xy/2 + \pi xz - \pi xyn)}{\pi x^2 n \sqrt{\Delta(x, z)}} \tag{67}$$

where $\Delta(x, z)$ is given by (47).

Note that if and only if $\gamma y^2 n_0 n + xyzn_1 n + 2\pi xyn_1 + 2\pi n_1 xz - \pi xyn < 0$, then $\partial s_1^*(x, z)/\partial x > 0$. If $\gamma y^2 n_0 n + xyzn_1 n + 2\pi xyn_1 + 2\pi n_1 xz - \pi xyn > 0$, we should study the sign of the numerator of (67). The numerator is positive if and only if

$$y\sqrt{\Delta(x, z)} > \gamma y^2 n/2 + xyzn/2 + \pi xy + \pi xz - \pi xy \tag{68}$$

As both sides of (68) are positive, we can show after some algebra that inequality (68) is equivalent to

$$(y + z)(y - z) > 0 \tag{69}$$

Since $z \in (-y, y)$, the inequality (68) is always satisfied. Therefore, $\partial s_1^*(x, z)/\partial x > 0 \ \forall \ x \in (0, \gamma)$.

Applying the chain rule, we get:

$$\frac{\partial G_w^*(x, z)}{\partial \sigma_x} = n_1 \frac{\partial s_1^*(x, z)}{\partial x} \frac{\partial x}{\partial \sigma_x} \tag{70}$$

$$\frac{\partial G_R^*(x, z)}{\partial \sigma_x} = \frac{\pi}{\pi + ny} \frac{\partial G_w^*(x, z)}{\partial \sigma_x} \tag{71}$$

As $\partial x/\partial \sigma_x > 0 \; \forall \; x \in (0, \gamma)$, Proposition 4.2 follows.

Furthermore,

$$\frac{\partial s_1^*(x, z)}{\partial z} = \frac{1}{2\pi} \frac{\gamma y n/2 + xzn/2 + \pi(\gamma + x)/2 + \pi(\gamma - x)/2 - \sqrt{\Delta(x, z)}}{\sqrt{\Delta(x, z)}}$$

(72)

where $\Delta(x, z)$ is given by (47). Note that numerator of (72) is positive if and only if

$$\gamma y n/2 + xzn/2 + \pi(\gamma + x)/2 + \pi(\gamma - x)/2 > \sqrt{\Delta(x, z)} \qquad (73)$$

As $x \in (0, \gamma)$ and $z > -y$, both sides of inequality (73) are positive. We can show that inequality (73) is equivalent to

$$(\gamma + x)(\gamma - x) > 0 \qquad (74)$$

Since $x \in (0, \gamma)$, the inequality (73) is always satisfied, and the numerator of (72) is always positive. Therefore, $\partial s_1^*(x, z)/\partial z > 0 \; \forall \; z \in (-y, y)$.

Applying the chain rule, we get:

$$\frac{\partial G_w^*(x, z)}{\partial \sigma_y} = \frac{n}{2} \frac{\partial s_1^*(x, z)}{\partial z} \frac{\partial z}{\partial \sigma_y} \qquad (75)$$

$$\frac{\partial G_R^*(x, z)}{\partial \sigma_y} = \frac{1}{\pi + ny} \left(\pi \frac{\partial s_1^*(x, z)}{\partial z} + \frac{n}{2} \right) \frac{\partial z}{\partial \sigma_y} \qquad (76)$$

As $\partial z/\partial \sigma_y < 0$ when $y_1 < y_0$ and $\partial z/\partial \sigma_y > 0$ when $y_1 > y_0$, Proposition 4.2 follows. ∎

8.5 Proof of Proposition 5

8.5.1 Linearized dynamic system

To conduct our analysis, we log-linearize the dynamic system (9)-(11) around the steady state (s_1^*, q^*) with respect to (s_{1t}, q_t, c_{1t}), and define $\hat{x} = log(x/x^*)$. Let $\psi = 1 + \alpha(\varepsilon - 1)$ and $\theta_i = \gamma_i(1 - \varepsilon)$, we obtain[12]:

$$\begin{pmatrix} -\psi & 1 + \theta_1 & \theta_1 \\ \psi c_1^*/c_0^* & 1 + \theta_0 & -\theta_1 c_1^*/c_0^* \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \dot{\hat{c}}_1 \\ \dot{\hat{q}} \\ \dot{\hat{s}}_1 \end{pmatrix}$$

[12]For simplicity, the arguments of the functions.

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$$
= \begin{pmatrix} -(\rho - \pi/q^*) & \rho & (\rho - \pi/q^*) \\ (\rho - \pi/q^*)c_1^*/c_0^* & \rho & -(\rho - \pi/q^*)\gamma_1 c_1^*/(\gamma_0 c_0^*) \\ -(\rho - \pi/q^*)\alpha/\gamma_1 & 0 & \pi/q^* \end{pmatrix} \times \begin{pmatrix} \hat{c}_1 \\ \hat{q} \\ \hat{s}_1 \end{pmatrix}
$$

with $c_1^* = \pi s_1^* + y + z$ and $c_0^* = \pi(2/n - s_1^*) + y - z$.

8.5.2 The Characteristic Polynomial $P(\lambda)$

The characteristic polynomial of this economy is given by:

$$
P(\lambda) = \lambda^3 - T(\varepsilon)\lambda^2 + S(\varepsilon)\lambda - D(\varepsilon) \tag{77}
$$

where

$$
T(\varepsilon) = \rho \frac{\varepsilon - \bar{\varepsilon}}{\varepsilon - \underline{\varepsilon}} \tag{78}
$$

$$
D(\varepsilon) = \frac{D_1(\varepsilon)}{\varepsilon - \underline{\varepsilon}} \tag{79}
$$

$$
D(\varepsilon) - S(\varepsilon)T(\varepsilon) = \frac{\delta_0(\varepsilon)}{(\varepsilon - \underline{\varepsilon})^2} [\delta_1(\bar{\varepsilon} - \underline{\varepsilon}) + \delta_2(1 - \varepsilon)(\bar{\varepsilon} - \varepsilon) - \delta_3(\bar{\varepsilon} - \varepsilon)] \tag{80}
$$

where under Assumptions 1-3,

$$
\underline{\varepsilon} = 1 + \frac{c}{c_1^*} \frac{s_1^*}{\gamma_1} > 1 \tag{81}
$$

$$
\bar{\varepsilon} = 1 + 2\frac{c}{c_1^*} \frac{s_1^*}{\gamma_1} > \underline{\varepsilon} \tag{82}
$$

$$
D_1 = \frac{\rho}{1 - \alpha(1 - \varepsilon)} \frac{1}{\alpha q^*} \left(\tilde{c}_1^* \frac{y_0}{q^* s_0^*} + \tilde{c}_0^* \frac{y_1}{q^* s_1^*} \right) > 0, \ \forall \ \varepsilon > 0 \tag{83}
$$

$$
\delta_0(\varepsilon) = \rho \frac{\rho - \pi/q^*}{1 - \alpha(1 - \varepsilon)} \frac{1}{\gamma_1 \gamma_0} \frac{s_1^*}{2\gamma_1 c_1^*} > 0 \ \forall \ \varepsilon > 0 \tag{84}
$$

$$
\delta_1 = \gamma_1 \gamma_0 \left(c_1^* \frac{y_0}{q^* s_0^*} + c_0^* \frac{y_1}{q^* s_1^*} \right) > 0 \tag{85}
$$

$$
\delta_2 = \gamma_1 \gamma_0 \left(\gamma_1 c_1^* \frac{y_0}{q^* s_0^*} + \gamma_0 c_0^* \frac{y_1}{q^* s_1^*} \right) > 0 \tag{86}
$$

$$
\delta_3 = \rho^3 \frac{c}{c_1^*} \frac{s_1^*}{\gamma_1} > 0 \tag{87}
$$

with $c = (c_1^* + c_0^*)n/2 = \pi + ny$.

8.5.3   Proof of Proposition 5

We know that

- For $T(\varepsilon) < 0$, if $D(\varepsilon) < 0$ and $D(\varepsilon) > S(\varepsilon)T(\varepsilon)$, there are three eigenvalues with negative real parts;

- For $T(\varepsilon) < 0$ and $D(\varepsilon) > 0$ or for $T(\varepsilon) > 0$, $D(\varepsilon) > 0$ and $D(\varepsilon) > S(\varepsilon)T(\varepsilon)$, there are two eigenvalues with negative real parts;

- For $T(\varepsilon) < 0$, if $D(\varepsilon) < 0$ and $D(\varepsilon) < S(\varepsilon)T(\varepsilon)$ or, for $T(\varepsilon) > 0$, if $D(\varepsilon) < 0$, there is one eigenvalue with negative real part;

- for $T(\varepsilon) > 0$, if $D(\varepsilon) > 0$ and $D(\varepsilon) < S(\varepsilon)T(\varepsilon)$, there is no eigenvalue with negative real part.

By analyzing $(78) - (80)$, we obtain the following results:

- If $\varepsilon < \underline{\varepsilon}$, then $T(\varepsilon) > 0$ and $D(\varepsilon) < 0$, thus there is one eigenvalue with negative real part.

- If $\varepsilon \in (\underline{\varepsilon}, \bar{\varepsilon})$, then $T(\varepsilon) < 0$ and $D(\varepsilon) > 0$, thus there are two eigenvalues with negative real part.

- If $\varepsilon > \bar{\varepsilon}$, then $T(\varepsilon) > 0$, $D(\varepsilon) > 0$ and $D(\varepsilon) > S(\varepsilon)T(\varepsilon)$, thus there are two eigenvalues with negative real part.

Following Blanchard-Kahn (1980) conditions, we get the following

- Local determinacy when there are zero or one eigenvalue with negative real part;

- Local indeterminacy when there are at least two eigenvalues with negative real part.

■

8.6 Proofs of Corollaries 2 and 3

We have

$$q^* = \frac{\gamma + x}{\alpha\rho}\frac{c_1^*}{s_1^*} + \frac{\pi}{\rho} \tag{88}$$

$$\underline{\varepsilon} = 1 + \frac{\pi + ny}{c_1^*}\frac{s_1^*}{\gamma + x} \tag{89}$$

From (88) and (89), we deduce that

$$\text{sign }\frac{\partial\underline{\varepsilon}}{\partial x} = \text{sign }-\frac{\partial q^*}{\partial x} \tag{90}$$

$$\text{sign }\frac{\partial\underline{\varepsilon}}{\partial z} = \text{sign }-\frac{\partial q^*}{\partial z} \tag{91}$$

Corollaries 2 and 3 follows Proposition 2. ∎

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