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Endogenous Real Risk-Free Rate, the Central Bank, and Stock Market Bubbles

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Abstract

The central bank acts as a social planner, and adjusts the real risk-free rate of return to correct any mispricing in the stock market so that the emergence of positive or negative bubbles is avoided. The flip side is that if the real risk-free rate is fixed, it incorporates inefficiency into the financial market. Setting a zero bound for the risk-free rate constrains the adjustment in the case of negative bubbles, and the fixed negative risk-free rate in the market not only prevents the adjustment of possible positive bubbles but may also lead to rampant instability in the market. The paper also points out the limits of manageable control of mispricing. In addition, the analysis indicates that the central bank should intervene in the stock market even if it does not have perfect information about the bubble.

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1 Introduction

What should be the role of the central banks in the context of stock market bubbles? For example, Bernanke and Gertler (2001), Greenspan (2004), and Posen (2006) argue that the central bank should concentrate on inflation targeting and stable growth, while Bordo & Jeanne (2002), Bean (2004), and Roubini (2006) claim that the central bank should also burst stock market bubbles. Yellen (2010) supports the latter view by stating that the central bank should intervene in stock market pricing, if the bubble gets dangerous.

Concerning the means of intervention, Conlon (2015) suggest that the central bank should use its informational advantage, and intervene by warning the investors about noticeable bubbles. Thus, inaction of the central bank implicitly means that the stock prices can rise. Furthermore, the intervention by the central bank may make things even worse if it does not have private information about the bubble. Fischer (2016) takes another view by arguing that, in the case of economy-wide bubbles, the central bank should intervene by monetary policy.

Gali (2014) confronts the commonly accepted “leaning against the wind” type monetary policy of lifting the risk-free rate in order to de-inflate the bubble. Such a policy may actually make the bubble inflate further, because the fundamental component of an asset price corresponds to the discounted stream of payoffs, but the bubble component has no payoffs to discount. Thus, the latter component grows at the rate of interest, at least in expectation.

Inspired by the above argumentations, we present a simple financial market model, where the central bank is in charge of the adjustment of stock market bubbles. The adjustment is achieved by controlling the market real return of risk-free assets via monetary policy. The maneuverability of bubbles is studied both with and without perfect information about efficient stock market pricing and thus about the existence of bubbles. The model yields a "leaning against the wind" rule for monitoring and correcting any mispricing, and stabilizing the financial market.

In the model, the key building block is the possibility of bubbles. The seminal efficiency argument by Samuelson (1973) is that, with perfectly rational risk-neutral investors, the equilibrium stock price (P_t) is equal to the expected discounted dividends to the shareholder, that is the fundamental value (V_t). Tirole (1982) shows that $P_t = V_t$ holds also in the rational expectations equilibrium with long-lived risk averse investors so that infinite bubbles are impossible, while Tirole (1985) argues that, in an overlapping generations model with short lived investors and infinitely lived assets bubbles are possible so that $P_t \neq V_t$ may occasionally happen. Santos & Woodward (1997) indicates that bubbles are impossible in rational markets only in the long run, but that there is a possibility of $P_t \neq V_t$ in the short run.

The overlapping generations model is here interpreted so that rational investors have a short-term investing horizon. For example Shleifer and Vishny (1997) argue that the short-lived-investor assumption can be motivated so that the majority of investors in the market are professional wealth managers who handle other people's money with performance monitoring in short intervals. Delong et al. (1990), Froot et al. (1992), Campbell and Kyle (1993), Kyle and Xiong (2001), Shiller (2014), and Ilomäki (2016) argue that, if there are informed and uninformed short-term (that is short-lived) investors in the market, $P_t \neq V_t$ exists because of the asymmetry and correlated behavior of the uniformed investors. Furthermore, Allen et al. (2006), and Bacchetta & Van Wincoop (2008) show that $P_t \neq V_t$ occurs in the case of short-lived investors, because their noisy private information incorporates rational higher-order beliefs into the equilibrium. Cespa & Vives (2015) also uses a model of short-lived investors with asymmetric information, and ends to two extreme equilibriums: a high information equilibrium $P_t = V_t$ with low volatility and high liquidity, and a low information equilibrium $P_t \neq V_t$ with high volatility and low liquidity.

Therefore, our model builds on the assumption of asymmetric information among the investors, and on the argument of Loewenstein and Willard (2006) that an endogenous risk-free rate of return assures that $P_t = V_t$. Originally, the latter point derives from the property that the limited supply of risk-free assets pulls together the equilibrium price and the fundamental value, implying that $P_t \neq V_t$ is impossible regardless of the investors' behavior. In our model, the central bank intervenes the market by controlling the supply of risk-free assets.

In the context of endogenous risk-free rates of return, the question about zero or negative risk-free rates becomes particularly interesting. As a matter of fact, risk-free rates that are very close to zero or even negative have recently been witnessed in many developed countries, including the Euro area, Japan, USA, UK, Switzerland, Denmark, and Sweden. This begs important policy related questions about possible implications in the financial market, particularly if it is acknowledged that the central bank is solely able also to set a zero bound on the risk-free rate, or to fix it negative.

The zero bound means that the short nominal (or real) risk-free rate is kept non-negative. Buiter and Panigirtzoglou (2003) show that a zero bound may cause the Keynesian liquidity trap, where monetary policy cannot stimulate aggregate demand. Their argument, which goes back to Gesell (1949), is that the trap can be avoided by allowing negative nominal interest rates. On the other hand, Bean (2016) warns that a prolonged lowness of the risk-free rate can inflate an unstable bubble in the economy. We show that setting a zero bound on the real risk-free rate incorporates inefficiency into the financial markets, because it hampers the adjustment of negative bubbles. Likewise, we show that a fixed negative real risk-free rate makes the market adjustment impossible in the case of positive bubbles, and that it may even lead to a super bubble. Finally, the analysis shows that the central bank should intervene even if it is imperfectly informed about the bubble.

The paper proceeds as follows. Section 2 defines the basic model with informed and uninformed investors. Section 3 presents the analysis of the equilibrium in the financial market, and describes the interventions needed from the central bank to stabilize the financial market. Section 4 discusses the findings.

2 The model

The model follows Ilomäki (2016) with the extension of an endogenously determined real risk-free rate of return. The real rate is corrected for inflation so that where the gross inflation is determined as $1+\pi_t \equiv \frac{p_t}{p_{t-1}}$, where p is the general price level in the economy. The economy consists of an infinite set of rational constant absolute risk-averse (CARA) investors, who have asymmetric information so that $0<\mu<1$ of them are informed, and $1-\mu$ of them are uninformed in every period. The atomistic investors live for two periods, investing in the first period, and consuming in the second period.

There is an infinitely lived risky asset (share of firm F), and a risk-free alternative with time-varying real risk-free rate of return r_t^f. The investors allocate their investments between risk-free and risky assets. The portfolio choice is simplified, because the assumption of two-period lived CARA investors omits the possibility of hedging against changes in expected returns, and because the assumption of an infinitely lived risky asset constitutes limits for arbitrage in the overlapping generations model (Shleifer and Vishny, 1997).

There are four types of rational investors in every period *t*: young informed and uninformed investors who open their positions (the demand side), and old informed and uninformed investors who close their positions (the supply side). For simplicity, excess returns are normally distributed, the time-varying risk premium is common to all investors, and there are neither transaction costs nor taxes. The budget constraint comes from the assumption that all young investors at time *t* have the same individual endowment w_t^y.

The natural logarithm of the dividend D_t on firm F's stock follows random walk so that $\ln D_t = \ln D_{t-1} + e_t^d$, where $e_t^d \sim WN\ (0, \sigma_d^2)$. This means that the change in the dividend at *t* is permanent. In period *t*, the dividends are paid to old investors.

In period *t*, information common to all informed and uninformed investors consists of the history of equilibrium real prices $(...P_{t-3}, P_{t-2}, P_{t-1})$, and the current value of the time varying real risk-free rate (r_t^f). Moreover, all investors observe current real dividends (D_t), but the young informed investors have also private information on D_{t+1}.

Assume that, in any period *t*, the central bank acts as a social planner with the aim to stabilize the financial markets by adjusting the real risk-free rate of return. The central bank may have perfect or imperfect information on the financial market. In any case, the current value of the real risk-free rate of return r_t^f is determined by the adjustment to possible mispricing so that it is constant with zero variance from period t to period $t+1$. Supposing that the supply of the risk-free asset is in sole control of the central bank, the market clearing condition for the risk-free asset reads $\int_y a_y - \int_{cb} b_{cb} = 0$, where a_y is the total demand by the young investors, and b_{cb} is the total supply by the central bank in every period.

Furthermore, assume exogenous noise traders with the distribution $e_t^{nt} \sim N(0, \sigma_{nt}^2)$ in the stock market. Thus, the market clearing condition for the risky asset reads $\int_y x_y - \int_o s_o + e_t^{nt} = 0$, where x_y refers to total demand of the stock by the young investors, and s_o is the total supply of the stock by the old investors. The optimal demand decisions produce the equilibrium price in period t thus fulfilling the market clearing condition. This happens because the old investors have to close their position to consume in the second period.

Rational investors care also about the risk of the investment. LeRoy (1973) shows that if the risk-free rate of return is time-varying, and if all investors are risk averse, the proper discount rate includes the risk-free rate and a risk premium. Starting from Markowitz (1952) and Sharpe (1964), risk is defined as the variance of returns.

A rational young investor maximizes individual utility by allocating the initial endowment between risky and risk-free assets. The maximization problem reads

$$
\begin{aligned}
&Max[E(-e^{-\nu c_{t+1}} \mid \theta_t^y, w_t^y)] \\
&s.t. \\
&c_{t+1} = x^f(1+r_t^f) + x^r E_t(R_{t+1}) \\
&w_t^y = x^f + x^r,
\end{aligned}
\tag{1}
$$

where θ_t^y is the information set, $v > 0$ is the coefficient of risk aversion, c_{t+1} is consumption when old, w_t^y is the endowment, and x^f and x^r denote the amount of money invested in risk-free and risky assets, respectively. The expected excess real return on a risky share is

$$E_t(R_{t+1}) = \frac{P_{t+1} + D_{t+1} - (1+r_t^f)P_t}{P_t}. \tag{2}$$

Assuming normally distributed consumption, and plugging the consumption constraint into the utility function yields

$$E_t[U(c_{t+1})] = -e^{-\nu x^f(1+r_t^f) - \nu x^r E_t(R_{t+1}) + \frac{\nu^2}{2} x^{r^2} \sigma_r^2}, \tag{3}$$

where σ_r^2 is the variance of excess returns. Note that, since the investors observe r_t^f, its variance is zero. Maximize (3) with respect to x^f and x^r, and use equation (2) to write the first order pricing condition for the risky asset,

$$P_t = \frac{P_{t+1} + D_{t+1}}{1 + r_t^f + x_t^r \nu \sigma_r^2}. \tag{4}$$

Manipulation of (4) results in the optimal investment decision, saying that the stock demand of a rational young investor reads $x_t^r = \frac{(P_{t+1} + D_{t+1})/P_t - (1+r_t^f)}{\nu\sigma_r^2}$. In equation (4), the required net real rate of return is $r_t^n = r_t^f + x_t^r \nu \sigma_r^2$, where

$$x_t^r \nu \sigma_r^2 = \frac{P_{t+1} + D_{t+1}}{P_t} - (1+r_t^f) = \omega_t \tag{5}$$

denotes the time-varying risk premium. In any period *t*, the informed investors know it, but the uninformed investors know only the history of it, and anticipate the change by $\omega_t = (1 + r_t^f)\omega_{t-1}$.

3 The financial market equilibrium

In the model, all informed investors have the best possible information, and old/young investors recognize that young/old investors observe this. Recalling that the properties of random walk say that the change in the dividend at time t is permanent, the rational choice represented by equation (4) results over time in the perpetuity model, $P_t = \frac{D_{t+1}}{r_t^n} = V_t$. Therefore, it can be concluded that equation (4) reflects the fundamental value of the risky asset, and that the informed investors follow the Samuelsonian pricing pattern,

$$P_t^i = V_t. \tag{6}$$

The uninformed investors observe the current real dividend D_t, and the current value of the endogenous real risk-free rate r_t^f. Furthermore, they know the past equilibrium real price P_{t-1}, and the past actualized risk premium ω_{t-1}. The information set of the uninformed investors makes them operate as technical traders, and set prices according to past prices. Manipulating equation (4), and taking one step backwards yields

$$P_t^u = (1 + r_t^f + \omega_{t-1})P_{t-1} - D_t, \tag{7}$$

where $\omega_{t-1} = \frac{\omega_t}{1 + r_t^f}$.

Using equations (6) and (7), and recalling that μ is the share of the informed investors, and 1-μ is the share of the uninformed investors, the aggregate pricing rule in the financial market reads

$$P_t = \mu V_t + (1-\mu)\left[(1+r_t^f + \frac{\omega_t}{1+r_t^f})P_{t-1} - D_t\right]. \qquad (8)$$

The market real price given by equation (8) results from the asymmetry of information among the investors. This means that the shares of the informed and uninformed investors of the total demand depend on how the aggregate pricing rule suits them.

Dividing both sides of equation (8) by P_{t-1} and (1-μ) yields, after manipulation,

$$1+r_t^f + \frac{\omega_t}{1+r_t^f} = A_t\,, \qquad (9)$$

where

$$A_t = \frac{P_t + D_t - \mu(V_t + D_t)}{(1-\mu)P_{t-1}}$$

denotes the weighted spread between the equilibrium real price return and the real fundamental value return.

Equation (9) constitutes the non-bubble condition in the economy saying that there does not exist a bubble, if the required gross real yield (on the left-hand side) equals the weighted spread (on the right-hand side). Yet, because of the presence of uninformed investors ($0<\mu<1$), positive or negative bubbles are plausible so that $A_t > 1+r_t^f + \omega_t/(1+r_t^f)$ describes a positive bubble, and $A_t < 1+r_t^f + \omega_t/(1+r_t^f)$ describes a negative bubble in the stock market. Therefore, the task of the central bank is to eliminate any bubbles in the financial market by using monetary policy to adjust the real risk-free rate of return.

Proposition 1: *The emergence of a positive/negative bubble necessitates that the central bank should make the real risk-free rate rise/fall thus reducing/increasing the attraction of risky investments by the uninformed investors. The demand of the informed investors stays the same in terms of money invested in the risky asset.*

Proof: Multiply both sides of Equation (9) by ($1+r_t^f$), use $\omega_t = v\sigma_r^2 x_t^u$, differentiate, and manipulate to get

$$\frac{dr_t^f}{dA_t} = \frac{1+r_t^f}{2(1+r_t^f)-A_t}, \tag{10}$$

and

$$\frac{dr_t^f}{dx_t^u} = \frac{-v\sigma_r^2}{2(1+r_t^f)-A_t}, \tag{11}$$

where x_t^u is the demand of the uninformed investors in terms of money invested in the risky asset. In fact, by observing Equation (7) and D_{t+1} and ω_t, the central bank controls the demand of the uninformed investors in terms of money invested in the risky asset. Thus, by Equations (10) and (11), starting from a non-bubble equilibrium and assuming that $2(1+r_t^f) > A_t$, a marginal emergence of a positive bubble ($dA_t > 0$) necessitates a rise in the real risk-free rate thus reallocating the investments of the uninformed investors from risky to risk-free positions. Likewise, a marginal emergence of a negative bubble ($dA_t < 0$) necessitates a fall in the real risk-free rate thus reallocating the investments of the uninformed investors towards the risky alternative. Concerning the informed investors, the total stock demand in terms of money invested (x_t^i) stays the same, but the rational estimation of the real price per share $P_t = \frac{D_{t+1}}{r_t^f + \nu\sigma_r^2 x_t^i} = V_t$ falls/rises as the real risk-free rate rises/falls. Thus, a change in the risk-free rate changes their required rate of return ($r_t^n = r_t^f + \nu\sigma_r^2 x_t^i$) to hold risky assets. The central bank adjusts the real risk-free rate it until Equation (9) holds. In a corner solution, the real risk-free rate is set so high that the demand of the uninformed investors becomes zero, and $P_t = V_t$.

Q.E.D.

Corollary 1. *The adjustment of the real risk-free rate of return is effective, provided that the risk premium is lower than the square of the gross risk-free market yield.*

Proof: Examine the condition $A_t < 2(1+r_t^f)$ in the close neighborhood of the non-bubble optimum. Using equation (9), the result reads $\omega_t < (1+r_t^f)^2$. This is reasonably unrestrictive.

Q.E.D.

Corollary 2. *The range of the adjustment of the real risk-free rate resides within a bounded set.*

Proof: Substitute the breaking point $A_t = 2(1+r_t^f)$ in equation (9), and write $r_t^{f\,2} + 2r_t^f + (1-\omega_t) = 0$. Since $\omega_t > 0$, the solution includes two real roots, $r_t^f = -1 \pm \frac{\sqrt{4\omega_t}}{2}$.

Q.E.D.

Corollary 3. *A zero bound on the real risk-free rate restricts the adjustment to negative bubbles.*

Proof: By the proof of Corollary 2, r_t^f has at least one negative real root saying that the risk-free rate of return must be adjustable in the negative area. *Q.E.D.*

Corollary 4. *Fixed negative real risk-free rates restrain the adjustment of positive bubbles.*

Proof: Assume that there is an initial equilibrium at $r_t^f < 0$, and that a marginal positive bubble develops. Then, by equation (10), the real risk-free rate must be able to adjust to the positive direction in order to level out the bubble. *Q.E.D.*

Corollary 5. *A prolonged lowness of the real risk-free rate can inflate an unstable super bubble.*

Proof: Assume that, say, $r_t^f < 0$ is fixed and that a positive bubble develops meaning that A_t starts to grow. Without the adjustment facilitated by the real risk-free rate it eventually hits the breaking point $A_t = 2(1+r_t^f)$, after which the market is profoundly unstable. *Q.E.D.*

By the assumption that the central bank possesses perfect information about the stock market, the market stabilizing real risk-free rate, calculated from Equation (9) reads

$$r_t^f = \frac{P_t + D_t - \mu(V_t + D_t)}{(1-\mu)P_{t-1}} - (1+\omega_{t-1}) . \qquad (12)$$

However, the things are a bit different if the central bank does not possess perfect information about asset pricing and thus not about bubbles. Assume that the central bank has the same imperfect information as the uniformed investors, knowing only D_t, and anticipating that $P_t = P_{t-1}$ and $V_t = V_{t-1}$. Thus, Equation (12) becomes

$$r_t^{f'} = \frac{P_{t-1} + D_t - \mu(V_{t-1} + D_t)}{(1-\mu)P_{t-1}} - (1 + \omega_{t-1}). \tag{12'}$$

Proposition 2. *The central bank should intervene in the stock market even if it does not have private information about it.*

Proof: Subtract Equation (12') from Equation (12), and write

$$r_t^f - r_t^{f'} = \frac{(P_t - P_{t-1}) - \mu(V_t - V_{t-1})}{(1-\mu)P_{t-1}}. \tag{13}$$

By Equation (13), the difference of the real risk-free rates that are set with perfect and imperfect information equals the weighted difference between the real price change and the real fundamental value change. The left-hand side of Equation (13) is stationary, if the right-hand side is stationary. The first component on the right-hand side is stationary, since the central bank obeys Equation (12), and the second component is stationary by the assumption that $\ln D_t = \ln D_{t-1} + e_t^d$. The stationarity of the difference between the two real risk-free rates implies that Corollaries 1-5 apply also if the central bank possesses imperfect information on the stock market. *Q.E.D.*

4 Conclusions

The paper presents an overlapping generations model of rational investors with asymmetric information. The overlapping generations model is interpreted so that the wealth managers control people's money, monitored in short-term intervals. In the model, possible short-term bubbles are described by the disparity of the required real gross yield on the investment and the weighted spread between the equilibrium real price return and the real fundamental value return. In other words, in a non-bubble equilibrium, the weighted spread should equal the required real gross return, including the risk premium. The central bank, as a social planner, aims to dampen possible mispricing in the stock market by adjusting the real risk-free rate of return. The active role of the central bank is justified because uninformed investors make mistakes on pricing. By preventing bubbles to inflate the central bank avoids social losses caused by the development and eventual bursting of a super bubble.

The analysis shows that the central bank responds to a marginal emergence of a positive bubble by using its available means to make the real risk-free rate rise thus reallocating the investments of uninformed investors from risky to risk-free assets. Likewise, a negative bubble is dampened by making the real risk-free rate fall thus directing the investments of uninformed investors from risk-free to risky assets. In effect, the adjustment of the real risk-free rate of return levels out any bubbles. In fact, the central bank controls the demand of uninformed investors by adjusting the real risk-free rate, whereas the demand of informed investors stays the same, because the adjustment concerns them in the discounting of future dividends. The method is effective even if the central bank has no private information about bubbles.

The analysis also shows that there is a certain breaking point for mispricing, beyond which the above actions of the central bank are not only ineffective but make things even worse. The adjustment process is efficient, provided that the weighted spread is smaller than twice the real gross yield of the risk-free assets. In other words, the net risk premium must be lower than squared real gross risk-free yield. Otherwise, the real equilibrium price and the real fundamental value can drift apart forever, because further widening of the spread turns the linkage between the spread and the real risk-free rate from positive to negative. Thus, with very badly flawed pricing, that is in the case of a super bubble, the adjustment turns the other way round thus boosting the bubble (cf. Gali, 2014).

However, as the incidence of the breaking point is reasonably unlikely in normal market conditions, the above provision rather supports than questions the generality of the effectiveness of market adjustment. A more important implication of the analysis is that the adjustment of the real risk-free rate should range also to negative values. For example, setting a zero bound on the real risk-free rate of return would incorporate inefficiency into the stock market, because it restricts the adjustment to negative bubbles. Second, in an efficient market, a negative real risk-free rate can result only from the adjustment to a negative bubble. Thus, fixing a negative real risk-free rate would also incorporate inefficiency, since it restrains the adjustment to positive bubbles, and because it can thus end to profound instability in the financial markets.

The latter implications are important especially in the present context, where the liquidity trap is a relevant issue in monetary policy, and where the stock market is booming in spite of the common problems in the real economy. The liquidity trap, the stock market boom, and negative real interest rates constitute a toxic concoction.

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