We consider an overlapping generations model à la Diamond (1965) with two additional ingredients: altruism and an asset (or land) bringing non-stationary positive dividends (or fruits). We study the global dynamics of capital stocks and asset values as well as the interplay between them. Asset price bubbles are also investigated.

1. Introduction

According to the literature on pure rational bubbles (asset without dividend) à la Tirole (1985), a bubble may coexist with physical capital because (1) agents want to buy the asset at any date (the young buys the bubble from the old) and (2) the real interest rate of the economy without bubble asset is lower than the population growth rate (the economy experiences capital overaccumulation or low interest rate). Although this literature is huge, very few papers have tackled the issue of bubble when dividends are positive. Many unaddressed questions on bubbles with positive dividend remain. Why do these bubbles arise? What are their dynamic properties? How do the capital and financial asset values interfere over time? What is the difference between bubbles of assets with and without dividends?

Our goal is to address these open issues. In addition, we generalize Tirole (1985) with a kind of altruism. Altruism matters affecting the offspring’s saving and the portfolio composition. Therefore, the novelty of the paper is twofold and rests on the introduction of forward (or descending) altruism and a financial asset (or land) bringing non-stationary positive dividends (or fruits) in the overlapping generations (OLG) benchmark à la Diamond (1965).

First, we prove that standard Inada condition ensures the existence of an interior intertemporal equilibrium. We do so in two steps: (1) proving the existence in finite-horizon cases, and (2) passing to the limit, we get an equilibrium for the infinite-horizon case. Notice that, without Inada condition, this existence result may fail. Indeed, in a low productivity situation, households prefer to invest in financial asset instead of physical capital, which may lead to zero aggregate capital (this is possible because households can consume dividends).

Results on equilibrium existence are complemented by a global analysis of equilibrium including the case of bubbly equilibria. As in the standard literature (Tirole, 1982; Kocherlakota, 1992; Santos and Woodford, 1997; Huang and Werner, 2000), we say that a bubble exists at an equilibrium if the equilibrium price of financial asset exceeds the present discounted value of its dividends, that is its fundamental value. In short, we call the bubble the difference between the asset price and the fundamental value. This equals the value at infinity of one unit of asset. In particular, when dividend is zero at any date, the asset is called bubble by Tirole (1985) or fiat money by other authors (Bewley, 1980; Weil, 1987).

We firstly prove that, if there is no bubbly equilibrium, then the economy has a unique equilibrium. Hence, the main part of our analysis focuses on multiple equilibria where bubbles may appear.

One of our main results is that a bubble exists only if the sum over time of ratios of dividend to production is finite. By consequence, in a bounded economy, a bubble exists only if the sum over time of dividends is finite. This entails a number of implications. For instance, when dividends are strictly positive, there does not exist a steady state associated with a bubble in the
asset; this property holds whatever the level of interest rate. By contrast, as proved by Tirole (1985), a pure bubble may arise at the steady state: this is the very difference between bubbles in assets with and without dividend. A particular case of our setup is Weil (1990) who provided an example of bubble where dividends may be positive but become zero after a finite number of periods.

We also show that, in a bounded economy with high interest rate (i.e., the interest rate at the steady state of the economy without financial asset is strictly higher than the population growth rate), there does not exist asset bubble. This result is independent of the level of asset dividends and, in this respect, quintessential. Of course, it covers Tirole (1985), where dividends are zero at any date, and rests on the following intuition. As seen above, in a bounded economy, bubbles are excluded when dividends do not converge to zero. When dividends converge to zero, we can prove that in the long run (1) the capital stock is bounded from above by that at the steady state of the economy without financial asset and (2) the asset value converges to zero. Combining these properties and the high interest rate condition, the discounted value of one unit of asset converges to zero, which means that there is no bubble.

Summing up, we obtain two necessary conditions for bounded economies, under which bubble may arise: (1) a low interest rate and (2) a finite sum of dividends. Interestingly, we prove that along a bubbly equilibrium, capital stocks converge either to the steady state of the economy without financial asset or to the level at which the interest rate equals the rate of population growth. This implies in turn that asset values must converge along a bubbly equilibrium.

Our above general findings are complemented by analyses in special cases. More precisely, in the case of Cobb–Douglas and linear technologies, we obtain a continuum of bubbly equilibria. Closed forms are also computed under some specifications. We find that a higher degree of forward altruism lowers the interest rate in the economy without financial asset. In this respect, we can say that descendant altruism promotes bubbles. To the best of our knowledge, these examples are the first ones dealing with bubble in a production economy with concave technology.

In the last part of the paper, we revisit the connection between bubble, interest rate and asset price. The seminal article by Tirole (1985) finds out that existence of pure bubbles requires a low interest rate. Such conclusion rests on the boundedness of aggregate output, including asset dividends. Indeed, in the case of high interest rate, if a bubble exists, the asset values grow to infinity and the equilibrium feasibility is violated. However, we argue that, in the case of unbounded growth (of the capital-free side of production), incomes of households are high enough to cover the value of asset with bubble (that agents may buy) even if this asset value grows to infinity (because of high interest rate). Moreover, in such an economy, dividends are no longer required to be bounded. This is also an added value of our paper.

At a first sight, we may be convinced that asset prices increase in time along a bubbly equilibrium. However, we provide a counterexample of bubbly equilibrium along which asset prices may increase, decrease or even fluctuate in time. This means that there is no robust causal link between bubble existence and monotonicity of asset prices.

The rest of the paper is organized as follows. Section 2 introduces the economic fundamentals. Sections 3 and 4 present some equilibrium properties and a formal definition of bubble. Section 5 provides general results on equilibrium transition for bubbles and capital. Section 6 and Section 7 focus on particular cases and global dynamics. All the technical proofs are gathered in Appendices.

2. Model

We consider a two-period OLG model of rational bubbles in the spirit of Diamond (1965), Tirole (1985) and Weil (1987). Time is discrete \( t = 0, 1, 2, \ldots \).

**Production.** At each date, there is a representative firm with the production function \( F(K, L) \) where \( K \) and \( L \) are the aggregate capital and the labor forces. We require standard assumptions.

**Assumption 1.** \( F \) is constant returns to scale, concave, strictly increasing and in \( C^2 \).

Let \( R_t \) and \( w_t \) represent the return on capital and the wage rate. Profit maximization under complete capital depreciation implies

\[
R_t = R(k_t) \equiv f'(k_t) \quad \text{and} \quad w_t = w(k_t) \equiv f(k_t) - k_t f'(k_t)
\]

where \( k_t = K_t/L_t \) denotes the capital intensity, \( f(k_t) \equiv F(k_t, 1) \).

**Generations.** Assume that there are \( N_t \) new individuals entering the economy at time \( t \). The growth factor of population is supposed to be constant: \( n = N_{t+1}/N_t \).

**Households.** Each young agent lives for two periods and supplies one unit of labor. Assume that preferences of households are rationalized by an additively separable utility function

\[
U(c_t, d_{t+1}) \equiv u(c_t) + \beta u(d_{t+1})
\]

where \( \beta \) represents the degree of patience, while \( c_t \) and \( d_{t+1} \) denote the consumption demands at time \( t \) and \( t+1 \) of a household born at time \( t \).

**Assumption 2.** \( u \) is in \( C^2 \), \( u'(c) > 0 > u''(c) \), \( u'(0) = \infty \).

Agent born at date \( t \) saves through a portfolio \((a_t, s_t)\) of financial asset and physical capital. Consumption prices are normalized to one. \( q_t \) and \( \delta_t \geq 0 \) denote the asset price and the dividend in consumption units, while

\[
b_t \equiv q_t a_t \quad \text{and} \quad \xi_t \equiv \delta_t a_t
\]

the values of asset and dividend respectively. The sequence of dividends \((\xi_t)\) is assumed to be exogenous.

Once households buy the asset \( a_t \), they will be able to resell it tomorrow and perceive dividends (in terms of consumption good). This asset can also be interpreted as a Lucas’ tree or land, or stock as in Kocherlakota (1992).

Budget constraints of household born at date \( t \) are written

\[
c_t + s_t + q_t a_t \leq u_t + s_t \quad \text{(2)}
\]

\[
d_{t+1} + n g_{t+1} \leq R_{t+1} s_{t+1} + (q_{t+1} + \delta_{t+1}) a_t
\]

\[
x_{t+1} \leq n g_{t+1} \quad \text{(4)}
\]

where \( g_{t+1} \) represents the bequests from parents to offspring and \( x \) is the degree of forward (or descending) altruism.

There are two theoretical approaches to bequests. (1) In the case of selfish preferences, households leave only unintended bequests due to lifespan uncertainty (Davies, 1981) or leave bequests to receive care in the old age and give more to the child who provides more care. (2) In the case of altruistic preferences, households leave bequests to offspring even if children provide no care and give more to the child with greater needs (Becker, 1981).

Empirical studies show that bequests matter. Kotlikoff and Summers (1981) calculate the share of intergenerational transfers in total households’ wealth in the United States and find a range between 46% and 81% according to the method used. Other studies show lower shares. About two-thirds of the studies using U.S. data support the altruism model while those using French data support the selfish exchange model (Laferrière and Wolff, 2006).
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