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Endogenous fluctuations in a three-period OLG model with credit market imperfection

Mariko Tanaka
Graduate School of Economics, University of Tokyo

Abstract

This paper studies the effects of credit market imperfection on economic growth by focusing on intergenerational transactions in an overlapping generations model. We show that credit cycles of the wage growth factor emerge in moderately developed economies. We also show that there is a nonlinear relation between economic stability and a degree of credit market imperfection.

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Contact: Mariko Tanaka - tana68@nifty.com.

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1. Introduction

Some of previous studies have showed that economic fluctuations tend to emerge at an intermediate level of financial development. The literature has found several factors to explain why improving the level of financial development does not necessarily stabilize the economy. For example, Aghion et al. (2004) have focused on capital flows which finance booms and an increase in the price of the country-specific factor of production which reduces creditworthiness under credit market imperfection in a dynamic open economy model. Orgiazzi (2008) has extended Aghion et al. (2004) by incorporating the labor share and modifying their assumption that wages are paid before production takes place. Kunieda and Shibata (2011) have employed the Schumpeterian endogenous growth model in which agents in a generation are heterogeneous in terms of their productivity in creating capital goods for an R&D sector. Hirano and Yanagawa (2010) have constructed an endogenous growth model in which each entrepreneur faces an investment opportunity in either a high productive project or a low productive one to derive a non-linear relation between financial development and the emergence of bubbles. We provide with a theoretical model of credit cycles which focuses on intergenerational transactions in an overlapping generations (OLG) model as an alternative source of instability at an intermediate level of financial development.

A model of credit cycles has been developed by Kiyotaki and Moore (1997) in an infinitely-lived agent model. This type of credit market imperfection has been examined by many studies. For example, Iakoviello (2005) has incorporated nominal debt contracts and collateral constraints tied to housing values. Sakuragawa and Sakuragawa (2009) have extended their model to an endogenous growth model. Kasa (1998) has developed a small open economy OLG model in which agents face a constant probability of dying. Kunieda and Shibata (2005) have modified Kasa's analysis by deriving a closed-form solution of the current account dynamics. Unlike previous studies, we focus on intergenerational transactions in an OLG model since intergenerational trades reflect financial development in terms of social security. In a two-period OLG model, one cannot analyze an intertemporal trade across different generations overlap only for one period. The three-period setting enables us to examine intergenerational transactions without ignoring the life-cycle aspect.

As a three-period OLG model, Bhattacharya and Russell (2003) have examined the properties of two-period monetary cycles in a pure exchange economy. De la Croix and Michel (2002) have constructed a three-period Diamond's (1965) model in which each generation supplies labor to firms in the first and the second periods. This paper incorporates credit market imperfection into de la Croix and Michel (2002) to generate cycles of the growth factor of the discounted wage or briefly the wage growth factor.

We show that two-period cycles emerge because there coexist two types of generations, i.e. the young who will receive wages as well as return of capital when middle-aged, while the middle-aged who will only receive return of capital when old. When the young accumulate less capital than the middle-aged, the young face collateral constraints, and the output in the next period declines. Then, the decrease in wages and the increase in return of capital lead to the decline in the wage growth factor. On the other hand, when the young accumulate capital enough to borrow capital, the increase in wages and the decreases in return of capital lead to the increase in the wage growth factor. In other words, 'low capital and moderate growth' and 'moderate capital and low growth' may generate two-period cycles of the wage growth factor. We also show that whether financial development stabilizes the economy or not depends on the degree of credit market imperfection.

This paper is constructed as follows. Section 2 presents the model. Section 3 characterizes the dynamics of capital accumulation. Conclusions appear in Section 4.

2. The Model

The model incorporates credit market imperfection into de la Croix and Michel (2002) and studies the effects of the degree of credit market imperfection on dynamics of capital accumulation.

Time is discrete and goes from zero to infinity. Every period, N_t consumers are born and each lives for three periods. Let $n \in (-1, +\infty)$ denote the population growth rate: $N_{t+1} = (1+n)N_t$. All agents have perfect foresight. We call each age cohort 'young', 'middle-aged' and 'old'.

There are three goods: labor, capital, and a consumption good. We assume that the middle-aged consumers run firms by employing the young consumers. A young consumer supplies one unit of labor, while a middle-aged consumer supplies $h \gtreqless 1$ units of labor inelastically. Old consumers supply neither labor nor capital. Thus, the total amount of labor is $N_t + hN_{t-1} = (1+h+n)N_{t-1}$ in period t.

The young and the middle-aged supply labor to firms at the beginning of period t, and receive the real wage w_t during the period. They allocate this income between current consumption and savings, convert the savings into capital, and then supply the capital to firms at the end of the period. The young become middle-aged and run firms next period.

Firms owned by the middle-aged produce consumption goods at the beginning of period $t+1$. They pay wages w_{t+1} to the young and the middle-aged, and repay the return to the middle-aged and the old during the period. Let R_{t+1} denote the gross rate of return in period $t+1$. The old consume all repayments they receive at the end of the period.

Let $K_{y,t}$ and $K_{m,t}$ be the capital accumulated by the young and the middle-aged at the end of the period, respectively. Capital is homogeneous and the aggregate capital is denoted by K_t. Let $\kappa_t, \kappa_{y,t}, \kappa_{m,t}$ be the aggregate capital, the capital accumulated by the young and the middle-aged in period t per capita of labor force, respectively, i.e. $\kappa_t = K_t/(N_{t+1} + hN_t)$, $\kappa_{y,t} = K_{y,t}/(N_{t+1} + hN_t)$, and $\kappa_{m,t} = K_{m,t}/(N_{t+1} + hN_t)$.

A consumption good is produced from capital and labor via Cobb-Douglas production function with productivity γ: $\gamma K_{t-1}^{\alpha} N_t^{1-\alpha}$ in period t. The consumption good is either consumed or invested to build future capital. There are no adjustment costs and that capital depreciates completely after one period. Let c_t, d_{t+1}, and e_{t+2} be consumptions per capita of generation t when young, middle-aged and old, respectively. A household derives utility from consumption goods: $U = \ln c_t + \beta \ln d_{t+1} + \beta^2 \ln e_{t+2}$.

In the model, only the middle-aged who accumulated capital when young are able to run firms. Then, the threat of not producing and not repaying the debt by the middle-aged is ex post credible, which may cause suspension of intergenerational loan to the young ex ante. Since capital of the young functions as collateral for a loan, the middle-aged lend capital to the young by setting the capital of the young as collateral to be retrieved in case of default.

Let $\psi \in [0, +\infty)$ be defined as a 'collateral rate' which is the ratio of loan available for the young to the capital of the young. It represents a degree of credit market imperfection. In Aghion et al. (2004), the parameter corresponding to the collateral rate, called a 'credit multiplier', reflects the level of financial development in the domestic economy. If the credit multiplier is 0, the credit market collapses and investors can only invest their own wealth. As the multiplier increases, the level of financial development increases. In our model, the collateral rate ψ reflects the level of financial development in terms of social security. As ψ increases, the young can borrow more capital from the middle-aged, which means that intergenerational transactions are facilitated. Hence, if ψ is 0, intergenerational transactions are suspended and the young cannot borrow capital, while if ψ is infinity, the credit market is perfect and the young can borrow as much capital as they want.

If the capital of the young exceeds the intergenerational loan, they fully repay the return in the next period; otherwise they deliver collateral to the old. To avoid default, the middle-aged lend capital up to the expected amount of capital of the young. Hence, a collateral constraint in period t is given as $\kappa_{m,t} \leq \psi \kappa_{y,t}$ under rational expectation. The budget constraints of generation t are given as follows.

$$w_t = c_t + (1+h+n)\kappa_{y,t}, \quad \kappa_t = \kappa_{y,t} + \kappa_{m,t}, \quad \kappa_{m,t} \le \psi\kappa_{y,t}, \tag{1}$$

$$(1+h+n)\gamma\kappa_t^{\alpha} = (1+n)(1+h+n)\kappa_{m,t+1} + (1+n)w_{t+1} + R_{t+1}(1+h+n)\kappa_{m,t} + d_{t+1}, \tag{2}$$

$$R_{t+2}(1+n)(1+h+n)\kappa_{m,t+1} = e_{t+2}, \tag{3}$$

where $\gamma(1+h+n)\kappa_t^{\alpha}$ is the output per capita of generation t.

The life-time budget constraint is obtained by consolidating equations (1), (2), and (3).

$$c_t + \frac{d_{t+1}}{R_{t+1}} + \frac{e_{t+2}}{R_{t+1}R_{t+2}} = \Omega_t,$$
$$\Omega_t \equiv w_t + \frac{(\gamma\kappa_t^{\alpha} - w_{t+1})(1+h+n)}{R_{t+1}} - (1+h+n)\min\{\kappa_{y,t}+\kappa_{m,t}, (1+\psi)\kappa_{y,t}\} + \frac{hw_{t+1}}{R_{t+1}}. \tag{4}$$

Since the capital of the young always exceeds the loan, they repay the return. The life-time income of generation t depends on the relative size of his collateralized capital to intergenerational loan, i.e. $\kappa_t = \min\{\kappa_{y,t} + \kappa_{m,t}, (1+\psi)\kappa_{y,t}\}$, where $(1+\psi)\kappa_{y,t}$ implies that the capital accumulated by the young plays a dual role of collateral for loans and factors of production as in Kiyotaki and Moore (1997).

Each household choose $\kappa_{y,t}$ and $\kappa_{m,t+1}$ to maximize his utility U. We confine our attention to interior solutions. Substituting equations (1), (2) and (3) into the utility function U, and utilizing equation (4), the optimal consumptions are given by equation (5).

$$c_t = \frac{\Omega_t}{1+\beta+\beta^2}, \quad d_{t+1} = \frac{\beta\Omega_t}{1+\beta+\beta^2}R_{t+1}, \quad e_{t+2} = \frac{\beta^2\Omega_t}{1+\beta+\beta^2}R_{t+1}R_{t+2}. \tag{5}$$

Firms maximize profits given real wages and real interest rates. Then, equilibrium wages, interest rates, and the resource constraint are given by equations (6), (7), and (8).

$$w_t = \gamma(1-\alpha)\kappa_{t-1}^{\alpha}, \tag{6}$$

$$R_t = \gamma\alpha\kappa_{t-1}^{\alpha-1}, \tag{7}$$

$$(N_t + hN_{t-1})\gamma\kappa_{t-1}^{\alpha} = N_tc_t + N_{t-1}d_t + N_{t-2}e_t + K_{y,t} + K_{m,t}. \tag{8}$$

Equilibrium is given the initial capital $K_{y,-1} > 0$ and $K_{m,-1} > 0$, a sequence of prices $\{R_t, w_t\}$ and nonnegative variables $\{N_t, K_t, K_{m,t}, K_{y,t}, \kappa_t, \kappa_{y,t}, \kappa_{m,t}\}$ such that

(i) (c_t, d_{t+1}, e_{t+2}) solve household's maximization problem and are given by equation (5).

(ii) $\{R_t, w_t\}$ satisfy equations (7) and (6), respectively.

(iii) the goods market clearing condition is given by equation (8).

(iv) the capital market clearing condition is given as follows:

$$K_t = K_{y,t} + K_{m,t} = (N_{t+1} + hN_t)\kappa_{y,t} + (N_{t+1} + hN_t)\kappa_{m,t} = (N_{t+1} + hN_t)\kappa_t.$$

Substituting equilibrium interest rates and wages into the life-time income Ω_t and using budget constraints, capital stocks of the young and the middle-aged are given as follows:

$$\kappa_{y,t} = \frac{\beta(1+\beta)\gamma(1-\alpha)\kappa_{t-1}^{\alpha} - h(1-\alpha)\kappa_t/\alpha}{(1+\beta+\beta^2)(1+h+n)},$$
$$\kappa_{m,t} = \frac{\beta^2\{\gamma(1-\alpha)\kappa_{t-2}^{\alpha} + h(1-\alpha)\kappa_{t-1}/\alpha\}\gamma\alpha\kappa_{t-1}^{\alpha-1}}{(1+\beta+\beta^2)(1+n)(1+h+n)}.$$

Hence, the dynamics of capital is given by equation (9).

$$\kappa_t = \frac{\alpha\beta}{\alpha(1+\beta+\beta^2)(1+h+n) + h(1-\alpha)}[(1+\beta)\gamma(1-\alpha)\kappa_{t-1}^{\alpha} + \frac{\beta\{\gamma(1-\alpha)\kappa_{t-2}^{\alpha} + h(1-\alpha)\kappa_{t-1}/\alpha\}\gamma\alpha\kappa_{t-1}^{\alpha-1}}{1+n}]. \quad (9)$$

Let x_t denote the ratio of the discounted wage of generation $t+1$ to the wage of generation t, indicating the growth factor of the discounted wage or briefly the wage growth factor:

$$x_t \equiv \frac{w_{t+1}/R_{t+1}}{w_t} = \frac{\kappa_t}{\alpha\gamma\kappa_{t-1}^{\alpha}}.$$

Dividing both sides of equation (9) by $\alpha\gamma\kappa_{t-1}^{\alpha}$, we obtain the dynamics of the wage growth factor:

$$x_t = a + b\frac{1}{x_{t-1}} \equiv f(x_{t-1}), \text{ where} \quad (10)$$
$$a \equiv \frac{\beta(1-\alpha)\{1+n+\beta(1+h+n)\}}{(1+n)\{\alpha(1+\beta+\beta^2)(1+h+n) + h(1-\alpha)\}},$$
$$b \equiv \frac{\beta^2(1-\alpha)}{(1+n)\{\alpha(1+\beta+\beta^2)(1+h+n) + h(1-\alpha)\}}.$$

Since $f'(x) < 0$, the dynamics are oscillatory and converge to the steady state x_1^* given as follows:

$$x_1^* = \frac{a + \sqrt{a^2+4b}}{2}.$$

Since $|f'(x_1^*)| = b/x^{*2} = b/(ax_1^* + b)$ and $x_1^* > 0$ imply $|f'(x_1^*)| < 1$, x_1^* is locally stable. The dynamics of κ_t follows $\kappa_t = \alpha\gamma x_1^* \kappa_{t-1}^{\alpha} \equiv \bar{f}(\kappa_{t-1})$ and monotonically converges to its steady state κ_1^*:

$$\kappa_1^* = \{\frac{\alpha\gamma(a + \sqrt{a^2 + 4b})}{2}\}^{\frac{1}{1-\alpha}},$$

which is also locally stable since $|\bar{f}'(\kappa_1^*)| = \alpha < 1$.

3. Dynamics of Capital Accumulation

Depending on the level of capital stock, there exist many equilibrium paths. Among them, we focus on the following cases.

Case 1: a stationary equilibrium in which $\kappa_{m,t} < \psi\kappa_{y,t}$ holds for all t.

Case 2: a stationary equilibrium in which $\kappa_{m,t} = \psi\kappa_{y,t}$ holds for all t.

Case 3: stationary periodic equilibria that display two-period cycles in which $\kappa_{m,t} < \psi\kappa_{y,t}$ holds for some periods i and $\kappa_{m,t} = \psi\kappa_{y,t}$ holds for some periods j.

In Case 1, the dynamics of x_t converges to x_1^* since collateral constraints are not binding.

In Case 2, all generations face collateral constraints. The dynamics of capital is given by equation (11).

$$\kappa_t = \kappa_{y,t} + \kappa_{m,t} = (1+\psi)\kappa_{y,t} = \frac{(1+\psi)\beta(1+\beta)\gamma(1-\alpha)\kappa_{t-1}^{\alpha} - h(1-\alpha)\kappa_t/\alpha}{(1+\beta+\beta^2)(1+h+n)}. \quad (11)$$

Dividing both sides of equation (11) by $\alpha\gamma\kappa_{t-1}^{\alpha}$, and utilizing the definition of the wage growth factor x_t, we obtain the dynamics of the wage growth factor:

$$x_t = (1+\psi)a_2, \text{ where } a_2 \equiv \frac{(1+\psi)\beta(1+\beta)(1-\alpha)}{\alpha(1+\beta+\beta^2)(1+h+n) + h(1-\alpha)}. \quad (12)$$

The dynamics converge to the steady state x_2^* given as follows:

$$x_2^* = (1+\psi)a_2,$$

which is locally stable.

Figure 1 depicts the dynamics of x_t in the case of $\psi = 1$. The dynamics of κ_t follows $\kappa_t = (1+\psi)\alpha\gamma a_2 \kappa_{t-1}^{\alpha} \equiv \bar{f}(\kappa_{t-1})$ and monotonically converges to its steady state κ_2^*:

$$\kappa_2^* = \{(1+\psi)\alpha\gamma a_2\}^{\frac{1}{1-\alpha}},$$

which is also locally stable since $|\bar{f}'(\kappa_2^*)| = \alpha < 1$.

The existence condition of Case 1 is as follows:

$$x_2^* > x_1^* \Leftrightarrow \frac{[(1+\psi)(1+\beta)\{\psi(1+n)(1+\beta) - \beta h\} - h](1-\alpha)}{(1+\beta+\beta^2)(1+h+n)} > \alpha. \quad (13)$$

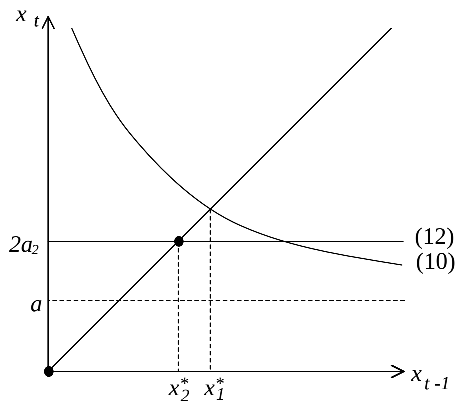

Figure 1 The dynamics of the wage growth factor

Case 1 exists under a standard set of parameters $\alpha = 0.3$, $\beta = 0.45$ [*1], $n = 0$, $h = 1$, and $\psi = 1$. Case 2 exists in an economy with a high α. As the labor income share $1 - \alpha$ decreases, the young cannot accumulate capital enough, and Case 2 is likely to emerge. Since the left side of equation (13) is decreasing in h, an economy with higher productivity of the middle-aged is also likely to face collateral constraints. It implies that each generation has no incentive to accumulate capital when the middle-aged can earn sufficient wage.

In Case 3, $\kappa_{m,t} < \psi\kappa_{y,t}$ holds for some periods i, while $\kappa_{m,t} = \psi\kappa_{y,t}$ holds for some periods j. The dynamics of the wage growth factor for periods i and periods j are given by equation (10) and equation (12), respectively. Thus, a dynamics from period $i-1$ to period i is given by equation (14).

$$x_i = a + \frac{b}{x_{i-1}}. \tag{14}$$

On the other hand, dynamics from period $j-1$ to period j is given by $x_j = (1+\psi)a_2$. When $i-1 = j$ or $j-1 = i$, a regime switch occurs. Hence, cycles of period 2 between $x_i = a + b/\{(1+\psi)a_2\}$ and $x_j = (1+\psi)a_2$ emerges.

An economic interpretation of the cycles is as follows. When the young and the middle-aged anticipate the decrease in wages and the increase in return of capital, the young accumulate less capital than the middle-aged because the young will earn wages as well as return of capital and pay the return of capital to the middle-aged, while the middle-aged

[*1] The parameter β is set to equal to $0.99^{80} \approx 0.45$ given that a quarterly psychological discount factor of 0.99 for 20 years.

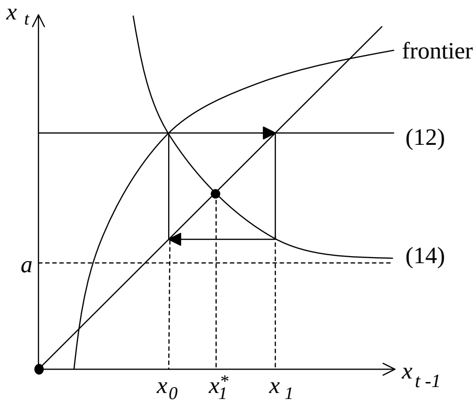

Figure 2 Two-period cycles of the wage growth factor

receive the return of capital in the next period. This leads to the decrease in output, the decrease in wages and the increase in return of capital in the next period, resulting in the decline in the wage growth factor. On the other hand, when the young and the middle-aged anticipate the increase in wages and the decrease in return of capital, the young accumulate capital enough to borrow capital. This leads to the increase in output, the increase in wages and the decrease in return of capital in the next period, resulting in the increase in the wage growth factor. These two patterns, i.e. 'low capital and moderate growth' and 'moderate capital and low growth' may generate two-period cycles of the wage growth factor.

Since $\psi\kappa_{y,t} > \kappa_{m,t}$ holds in an unconstrained economy, the wage growth factor should satisfy the following condition.

$$\frac{\beta(1+\beta)}{h} - \frac{\beta^2}{\psi h(1+n)}(\frac{1}{x_{t-1}} + h) > x_t. \tag{15}$$

A regime switch from an unconstrained economy to a constrained one occurs if the equation (15) holds with equality.

Figure 2 depicts two-period cycles of the wage growth factor in Case 3. In the figure, the downward sloping and the horizontal line indicate the dynamics of the wage growth factor under an unconstrained economy and a constrained economy, respectively, and the upward sloping indicates the frontier which separates the two regimes. This frontier meets at a point where loci of the wage growth factor in an unconstrained and constrained economy. An economy located in the region above this frontier curve faces collateral constraints. An increase in ψ shifts up the frontier so that the economy is more likely to

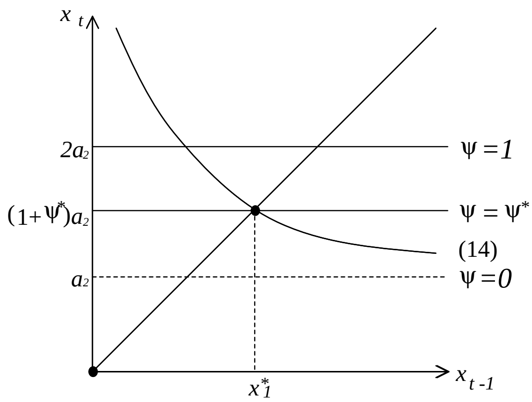

Figure 3 The dynamics of wage growth factor corresponding to different collateral rates

be unconstrained.

Figure 3 depicts some graphs of collateral constraints corresponding to different collateral rates ψ. It shows that a various dynamics of capital emerges depending on the level of the collateral rate ψ. Let ψ^* denote the collateral rate which satisfies $(1+\psi)a_2 = x_1^*$, i.e.

$$\psi^* \equiv \frac{a - 2a_2 + \sqrt{a^2 + 4b}}{2a_2} > 0.$$

Note that the frontier corresponding to ψ^* intersects the other two loci of the wage growth factor at ψ^*. If $\psi^* < \psi$, two-period cycles of the wage growth factor may emerge. The range of cycles is decreasing in ψ, and disappears at ψ^*. If $0 \leq \psi < \psi^*$, all generations face collateral constraints as in Case 2.

An increase in ψ corresponds to the process of financial development as in Aghion et al. (2004). It follows that financial development enhances economic growth if $0 < \psi < \psi^*$, while the development enables an underdeveloped economy to escape from poverty trap, but may cause endogenous fluctuations if $\psi^* \leq \psi$. Hence, financial development may not be desirable in terms of economic stability. At the same time, if financial development proceeds, the country at an intermediate level can reach the developed stage.

4. Conclusions

This paper has examined intergenerational transactions under credit market imperfection to show that credit cycles emerge in moderately developed economies in an OLG model. We have showed that two patterns of 'low capital and moderate growth' and 'moderate capital and low growth' arising from the coexistence of two types of generations, i.e. the young who will earn wages as well as rate of return while the middle-aged who will receive rate of return, generate two-period cycles of the wage growth factor. We have also showed that the effects of financial development on economic stability depends on the degree of credit market perfection.

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