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Technological change and monetary policy in a sticky-price model

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ABSTRACT

We developed a sticky-price model that introduces the factors of (a) the non-separability of consumption and labor in the utility function and (b) a technological change induced by the investment of profits, to analyze the determinacy of equilibrium. We found that while engaging in inflation targeting increases the probability of determinacy, engaging in share-price targeting decreases the probability of determinacy in a standard sticky-price model; engaging in both inflation targeting and share-price targeting can increase the probability of determinacy in our model.

1. Introduction

Many studies have examined the determinacy of equilibrium within the so-called New Keynesian (NK) model, in which prices and nominal wages are assumed to be sticky (Bernanke and Woodford, 1997; Clarida et al., 2000; Carlstrom and Fuerst, 2001; Bullard and Mitra, 2002; Kurozumi, 2006). The standard NK model introduces a monetary policy rule, such as the Taylor rule, which posits that the inflation rate is an explanatory variable and the interest rate is the control variable in an equation that describes a policy action. One basic property of the NK model is that for the equilibrium path to be determinate, it should satisfy the "Taylor principle",[1] which states that the central bank governing an economy must raise the interest rate by more than one unit for every one unit increase in the inflation rate; that is, denoting the elasticity of the interest rate with respect to the inflation rate by τ, the Taylor principle can be written as $\tau > 1$, which is a necessary condition for equilibrium determinacy in the standard NK model.

Carlstrom and Fuerst (2007) demonstrate that in an economy with sticky prices, adding share prices to the Taylor rule as an explanatory variable – that is, engaging in share-price targeting – increases the probability of indeterminacy.[2] In a sticky-price model, an increase in the inflation rate decreases firm profit and a decrease in firm profit decreases share prices. Thus, if the central bank targets both inflation rate and share prices, it should aim to not only raise the interest rate in response to an increase in the inflation rate but also lower the interest rate in response to a decrease in share prices. Consequently, the central bank will not raise the interest rate to a level sufficiently high to satisfy the Taylor principle, leading to equilibrium indeterminacy.

Contrary to Carlstrom and Fuerst's (2007) finding, this study demonstrates that adding the variable of share prices to the Taylor rule as an explanatory variable may not increase the probability of indeterminacy if the following two factors are also introduced into the model:

- Non-separability of consumption and labor in the utility function
- Technological change induced by the investment of profits

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[1] For details of the monetary policy analysis using the NK model, see Woodford (2003) and Galí (2008).

[2] Carlstrom and Fuerst (2007) examined equilibrium determinacy not only in a model with sticky prices but also in a model with sticky wages. This study focuses on the model with sticky prices.

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First, we assume that consumption and labor are additively non-separable in the utility function, an assumption that has an analytical rather than an economic meaning. Carlstrom and Fuerst (2007) represent the utility function as follows:

$$u\left(C_t, L_t, \frac{M_{t+1}}{P_t}\right) = \frac{C_t^{1-\sigma} - 1}{1-\sigma} - \frac{L_t^{1+\gamma}}{1+\gamma} + V\left(\frac{M_{t+1}}{P_t}\right), \tag{1}$$

where $\sigma > 0$, $\gamma > 0$, C_t denotes consumption, L_t denotes labor, and $\frac{M_{t+1}}{P_t}$ denotes the real cash balances. As Carlstrom and Fuerst do not introduce technological change (i.e., productivity growth) into the model, there is no analytical problem within it that is related to the existence of equilibrium even if C_t and L_t are additively separable, as shown in Eq. (1).

However, if a technological change is introduced, as in our model, there cannot be a steady-growth equilibrium if (a) C_t does not take the logarithmic form ($\sigma = 1$) or (b) C_t and L_t are not additively non-separable.[3] In this study, we adopt the utility function that is characterized by the non-separability of C_t and L_t because it is more general in the sense that it allows σ to take values other than 1.

Second, we assume that technological change is induced by the investment of profits in accordance with the endogenous growth theory developed by Uzawa (1965) and Lucas (1988), which posits that technological change occurs when a proportion of resources is invested in education or human capital. In this study, we posit that firms' investment of a proportion of profits in technology education induces technological change,[4] and under this assumption, reconsider the effect of engaging in share-price targeting on equilibrium determinacy.

In our model, an increase in the inflation rate may increase share prices through a change in the rate of technological change if σ is larger than 1. In such a case, the interest rate may increase to a much greater degree if the central bank considers share prices as well as the inflation rate as an explanatory variable than if it considers the inflation rate as the sole explanatory variable. Thus, our model implies that engaging in share-price targeting may increase the ease of satisfying the Taylor principle.

This paper is organized as follows. Section 2 describes the development of a sticky-price model that incorporates a Taylor-type monetary policy rule. Section 3 linearizes the model before Section 4 derives a necessary and sufficient condition for equilibrium determinacy. After Section 5 analyzes several numerical examples, Section 6 draws conclusions regarding the results of the analysis.

2. Model

The proposed model assumes the existence of an economy characterized by many homogeneous households and many firms that produce differentiated goods.

2.1. Households

Households live infinitely and obtain utility from consumption C_t and the real cash balances M_{t+1}/P_t and disutility from labor L_t at every period.[5] We assume that the utility function of a household is represented by

$$u\left(C_t, L_t, \frac{M_{t+1}}{P_t}\right) = \frac{\left(C_t e^{-\frac{L_t^{1+\chi}}{1+\chi}}\right)^{1-\sigma} - 1}{1-\sigma} + \frac{(M_{t+1}/P_t)^{1-\mu} - 1}{1-\mu}, \tag{2}$$

where $\sigma > 0$, $\chi > 0$, and $\mu > 0$.

As shown in Eq. (2), C_t and L_t are additively non-separable, a primary feature of our model. Although this equation appears complex, we can regard it as the general form of Eq. (1) because it contains Eq. (1) as a special case. Assuming $\sigma = 1$ in Eq. (2), it follows that $u(C_t, L_t, \frac{M_{t+1}}{P_t}) = \ln C_t - \frac{L_t^{1+\chi}}{1+\chi} + \frac{(M_{t+1}/P_t)^{1-\mu}-1}{1-\mu}$. In this function, C_t and L_t are additively separable, as in Eq. (1). Thus, Carlstrom and Fuerst's (2007) model can be considered a special case ($\sigma = 1$) of our model. The parameter σ denotes the elasticity of the marginal utility of consumption, the reciprocal of the elasticity of the substitution of intertemporal consumption, and the coefficient of relative risk aversion.

[3] See King et al. (1988) for details.

[4] Christiano et al. (2003) also proposed an NK model that introduces the element of productivity growth. However, unlike our model, their model assumes that productivity increases exogenously.

[5] We adopt the assumption of the so-called "cash-when-I'm-done" (CWID) timing, which posits that the cash balances held by a household at the end of period t (beginning of period $t + 1$) enter the utility function in period t. An alternative assumption is the "cash-in-advance" (CIA) timing, which posits that the cash balances held by a household that purchases goods from the market in period t enter the utility function in period t. According to Carlstrom and Fuerst (2007), the timing, whether CWID or CIA, makes no "qualitative" difference in the outcome when one analyzes the effect of a current-looking policy, defined as a policy that controls a current control variable in response to the current explanatory variables, as we do in this study. Thus, under either timing assumption, the primary outcome — the effect of engaging in share-price targeting on equilibrium determinacy — is the same. For ease of calculation, we adopt the assumption of CWID timing.