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Growth Expectation

Ippei Fujiwara

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Abstract

For a long time, changes in expectations about the future have been thought to be significant sources of economic fluctuations, as argued by Pigou (1926). Although creating such an expectation-driven cycle (the Pigou cycle) in equilibrium business cycle models was considered to be a difficult challenge, as pointed out by Barro and King (1984), recently, several researchers have succeeded in producing the Pigou cycle by balancing the tension between the wealth effect and the substitution effect stemming from the higher expected future productivity. Seminal research by Christiano, Ilut, Motto and Rostagno (2007) explains the "stock market boom-bust cycles," characterized by increases in consumption, labor inputs, investment and the stock prices relating to high expected future technology levels, by introducing investment growth adjustment costs, habit formation in consumption, sticky prices and an inflation-targeting central bank. We, however, show that such a cycle is difficult to generate based on "growth expectation," which reflect expectations of higher productivity growth rates. Thus, Barro and King's (1984) prediction still applies.

Keywords: Expectations; Equilibrium Business Cycle; Technological Progress
JEL classification: C52, D58, E32

*Director and Senior Economist, Institute for Monetary and Economic Studies, Bank of Japan (E-mail: ippei.fujiwara@boj.or.jp)

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1 Introduction

For a long time, changes in expectations about the future have been thought to be significant sources of economic fluctuations. For example, Pigou (1926) states that "while recognizing that the varying expectations of business men may themselves be in part a psychological reflex of good and bad harvests – while not, indeed, for the present inquiring how these varying expectations themselves come about – we conclude definitely that they, and not anything else, constitute the immediate cause and direct causes or antecedents of industrial fluctuations." It has, however, been considered a difficult challenge to create such an expectation–driven cycle, namely the "Pigou cycle"[1] in equilibrium business cycle models. Barro and King (1984) point out that "With a simple one–capital–good technology, no combination of income effects and shifts to the perceived profitability of investment will yield positive comovements of output, employment, investment and consumption." Only recently have several researchers succeeded in generating the Pigou cycle by balancing the tension between the wealth effect and the substitution effect stemming from higher expected future productivity. The pioneering work of Beaudry and Portier (2004) was the first to generate the Pigou cycle in an equilibrium business cycle model. By introducing the multi–sectoral adjustment costs, the complementarity between consumption and investment is intensified so that consumption, labor and investment exhibit comovements reflecting forecast errors. Jaimovich and Rebelo (2006) reduce the wealth effect from the news shock by employing Greenwood, Hercowitz and Huffman (1988)–type preferences.[2] They also increase the substitution effect by introducing investment growth adjustment costs,[3] which were first introduced by Christiano, Eichenbaum and Evans (2005). They do so in order to generate expectation–driven business cycle. Denhaan and Kaltenbrunner (2007) use the labor search and matching framework to show that matching frictions offset reduced labor supply reflecting the wealth effect. Because high expected productivity induces firms to post more vacancies, both consumption and investment increase in response to positive news about future productivity. Kobayashi, Nakajima and Inaba (2007) demonstrate that the Pigou cycle can emerge in a model that incorporates collateral constraints. Good news raises the current price of land, which relaxes the collateral constraint and reduces the inefficiency in the labor market. If this effect is sufficiently strong, equilibrium labor supply increases, as do output, investment and consumption. Beaudry, Collard and Portier (2006) focus on the extensive margin of

[1] We follow the terminology used by Beaudry and Portier (2004).
[2] They further assume time–non–separable preferences.
[3] For the foundations of investment growth adjustment costs, see Lucca (2007).

efficiency, namely technological progress in the form of the number of newly introduced goods. Anticipation of the arrival of new goods does not have any wealth effect but does induce investment, which is needed for the production of such new goods. This creates what authors term "Gold Rush Fever."

Christiano, Ilut, Motto and Rostagno (2007, henceforth CIMR) is of particular interest. First, their work is based on the *de facto* standard macroeconomic model used by policy making institutions such as central banks. Currently, many central banks construct their core macroeconomic models by following the influential work of Christiano et al. (2005).[4] These models have sufficiently rich dynamics to explain the trend apparent in data by incorporating investment growth adjustment costs, habit formation in consumption, sticky prices and wages, and an inflation–targeting central bank. We know the empirically plausible range of parameter values for this type of model. Second, the CIMR can explain not only comovements in consumption, employment and investment, but also "stock market boom–bust cycles," characterized by increases in stock prices relating to high expected levels of future technology. This is a useful contribution because it implies that strict inflation targeting, which is the benchmark principle in the implementation of modern monetary policy, risks generating bubbles.

The research cited has deepened our understanding of the effects of expectations about future events on current variables. The associated models, however, incorporate rather unrealistic expectations about the future. That is, they make assumptions about expectations of the future technology level, not the growth rate.[5] In the above studies, if a positive technology shock is anticipated for the subsequent year, then the technology growth rate is expected to decrease from that year onwards. The anticipation of a negative growth rate following a positive level technology shock seems unrealistic.[6] For example, professional forecasters usually predict a higher growth rate, rather than a higher level following news about future technological progress.[7] Therefore, in this paper, we also examine the effect of people temporarily anticipate the higher technology growth rate by using the model employed by CIMR; for this model, empirically reasonable ranges of parameter values are

[4]See, for example, Adolfson, Laseen, Linde and Villani (2007), Erceg, Guerrieri and Gust (2006), Smets and Wouters (2003) and Laxton and Pesenti (2003).

[5]The assumption about technological process made by Denhaan and Kaltenbrunner (2007) can be considered a combined assumption about the growth rate and the level of technology.

[6]With a positive deterministic trend technology growth, the growth rate will not become negative.

[7]This is connected to the argument in time–series analyses about whether the time trend is stochastic or deterministic with stationary shocks around it causing variables to fluctuate.

readily available.[8] Indeed, in their seminal research, Beaudry and Portier (2006), who use a structural VAR with long–run restrictions to identify a news shock as one that affects the stock price but has no permanent effects on labor productivity, assume an expectation shock relating to a higher future growth rate of technology. It is shown that such an expectation–driven cycle is difficult to generate under the assumption of "growth expectation," under which there is an expectation of a higher productivity growth rate. Thus, the Barro and King (1984) conjecture still applies.

This paper is structured as follows. In Section 2, we briefly describe the model and state the assumption made about technological process. Then, in Section 3, we present simulation results for growth expectation. We summarize our findings in Section 4.

2 The Model

Because our model is similar to that of CIMR, we relegate the detailed derivations of the model, detrending and log–linearization to the appendix. In this section, we focus on explaining the shock process and how expectation shocks are simulated.[9]

The model incorporates continuum of households and firms each within the unit mass, a central bank and a fiscal authority. The monopolistically competitive equilibrium in this paper is determined as follows. Households determine optimally the demand for goods, the supply of capital and the supply of labor in a monopolistically competitive labor market by choosing the desired wage subject to a Rotemberg (1982)–type adjustment cost.[10] Firms choose the amount of goods to supply by setting the desired price in a monopolistically competitive market subject to the Rotemberg–type adjustment cost. Firms also optimally choose labor demand and the capital stock. The central bank sets nominal interest rates by following the Taylor

[8] In addition to the time-series arguments, recently, it has become more common to assume a shock to the growth rate rather than to the level. For example, in order to explain the realistic size of the premium, Bansal and Yaron (2004) introduce the concept of "Long Run Risk." Aguiar and Gopinath (2007) show that business cycles in the emerging economies are better explained by trend shocks than by level shocks. Furthermore, the IS shock in the standard dynamic new Keynesian model, which is usefully summarized by Walsh (2003) and Woodford (2003) can be considered a growth rate shock to technology.

[9] The Matlab code for the simulations used in this paper are available upon request. Fujiwara and Kang (2006) provides a tool for using Dynare for expectation shocks.

[10] We use the Rotemberg–type cost instead of a Calvo (1983)–type staggered price settings because of its analytical tractability, and also because, when using Calvo pricing, one must assume indexation with possible trend growth. For the latter, see CIMR and Schmitt-Grohé and Uribe (2006).

(1993)–type rule. The fiscal authority from households the lump–sum tax, which funds the subsidies that enable households to avoid undersupplies of labor and goods.

2.1 Shock Process

The notable feature of the model used in this paper is the assumption about technological progress. Simulations are conducted based on the standard technology level shock as well as the technology growth rate shock, represented by the stochastic trend. For the latter, we assume that the trend technology follows the process described below:

$$Z_t = \mu \exp(u_t) Z_{t-1}, \tag{1}$$

where Z is the trend technology, u is the technology growth shock, and μ is the average growth rate of technology. The technology growth rate shock is further assumed to follow an AR (1) process:

$$u_t = \rho_u u_{t-1} + \chi_{u,t-p} + \varepsilon_{u,t},$$

where χ denotes an expectation shock, which, at period t, is anticipated to occur at period p. Because we do not assume any population growth in this paper, such variables as output, consumption and capital are denominated by this trend technology. Hence, the model produces a stationary rational expectation equilibrium, details of which are shown in the appendix. The standard technology level shock z appears in the production function for firm j as follows:

$$Y_{j,t} = [Z_t \exp(z_t) h_{j,t}]^{1-\alpha} K_{j,t}^{\alpha},$$

where Y is the output, h is hours worked, K is the capital stock, and α is the labor share. This technology level shock is also assumed to follow an AR (1) process:

$$z_t = \rho_z z_{t-1} + \chi_{z,t-p} + \varepsilon_{z,t}. \tag{2}$$

2.2 Expectation Shock

To show how to incorporate an expectation shock, we first explain the general solution of the rational expectation model. A rational expectation model can be represented as follows:[11]

$$\overline{\alpha_0}\mathrm{E}_t\widehat{z}_{t+1} + \overline{\alpha_1}\widehat{z}_t + \overline{\alpha_2}\widehat{z}_{t-1} + \overline{\beta}_0\mathrm{E}_t s_{t+1} + \overline{\beta}_1 s_t = 0, \tag{3}$$

[11] For the most part, we follow Christiano (2002).

and

$$s_t = \overline{P} s_{t-1} + \varepsilon_t. \tag{4}$$

where variables with overlines are matrices of coefficients, $\widehat{z}$ is the vector of endogenous variables and s is the vector of shocks. The solution that we want to obtain is

$$\widehat{z}_t = \overline{A}\widehat{z}_{t-1} + \overline{B} s_t. \tag{5}$$

By substituting, equations (4) and (5) into (3), we obtain

$$\overline{\alpha_0}\,\overline{A}^2 + \overline{\alpha_1}\,\overline{A} + \overline{\alpha_2} = 0, \tag{6}$$

and, if there exist only trivial solutions,

$$\left(\overline{\beta_0} + \overline{\alpha_0}\,\overline{B}\right)\overline{P} + \left(\overline{\beta_1} + \overline{\alpha_1}\,\overline{B} + \overline{\alpha_0}\,\overline{AB}\right) = 0. \tag{7}$$

Matrix $\overline{A}$ and $\overline{B}$ in the solutions to equations (4) and (5) are computed by solving the equations (6) and (7). Whether we can obtain a unique $\overline{A}$ depends on the standard Blanchard and Kahn (1980) condition.

Simulations of expectation shocks can be conducted by making adjustments to $\overline{\beta_0}$ and $\overline{\beta_1}$, in which case, we can obtain a new $\overline{B}$ matrix. For simplicity, we consider the case in which there is only a standard technology level shock z in equation (2). As a simple example, suppose that we receive news that "productivity is raised in period 2" (that is, currently, p=2), but that, come period 2, this news turns out to be false.[12] The above equation is represented in canonical form as follows:

$$\begin{pmatrix} z_t \\ \chi_{z,t} \\ \chi_{z,t-1} \end{pmatrix} = \begin{pmatrix} \rho_z & 0 & 1 \\ 0 & 0 & 0 \\ 0 & 1 & 0 \end{pmatrix} \begin{pmatrix} z_{t-1} \\ \chi_{z,t-1} \\ 0 \end{pmatrix} + \begin{pmatrix} \varepsilon_{z,t} \\ \chi_{z,t} \\ 0 \end{pmatrix}. \tag{8}$$

Adding a news shock $\chi_{z,0}$ at period 0 yields

$$\begin{pmatrix} z_0 \\ \chi_{z,0} \\ \chi_{z,-1} \end{pmatrix} = \begin{pmatrix} \rho_z & 0 & 1 \\ 0 & 0 & 0 \\ 0 & 1 & 0 \end{pmatrix} \begin{pmatrix} z_{-1} \\ \chi_{z,-1} \\ \chi_{z,-2} \end{pmatrix} + \begin{pmatrix} 0 \\ \chi_{z,0} \\ 0 \end{pmatrix}.$$

Although $\chi_{z,0}$ does not affect z_0 or $\mathrm{E}_0 z_1$, the shock to technology at period 2 that is expected in period 0 becomes

$$\mathrm{E}_0 \begin{pmatrix} z_2 \\ \chi_{z,2} \\ \chi_{z,1} \end{pmatrix} = \begin{pmatrix} \rho^2 & 1 & \rho \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} z_0 \\ \chi_{z,0} \\ \chi_{z,-1} \end{pmatrix}.$$

[12] In the simulations below, we also report results for the case in which the initial guess comes true.

Hence, we have

$$\mathrm{E}_0 z_2 = \chi_{z,0},$$

since

$$z_0 = \chi_{z,-1} = 0.$$

Therefore, the shock to technology at period 2 that is expected in period 0 becomes $\chi_{z,0}$. If such expectations materialize, then the simulation is conducted by using the appropriate s vector and $\overline{\beta_0^*}$, $\overline{\beta_1^*}$ and $\overline{B^*}$ as defined below. When period 2 comes, however, such a positive shock does not occur. This is because $\chi_{z,0}$ is offset by χ_2 because $\chi_2 = -\varepsilon_0$. These notations are represented by

$$\begin{pmatrix} z_2 \\ \chi_{z,2} \\ \chi_{z,1} \end{pmatrix} = \begin{pmatrix} \rho_z & 0 & 1 \\ 0 & 0 & 0 \\ 0 & 1 & 0 \end{pmatrix} \begin{pmatrix} z_1 \\ \chi_{z,1} \\ \chi_{z,0} \end{pmatrix} + \begin{pmatrix} \varepsilon_{z,2} \\ 0 \\ 0 \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix}.$$

Thus, although we can generate shocks as at period 0 and 1 such that a technology shock is expected at period 2, it turns out that there is a bubble expectation in period 2.

The canonical form of the shock process continues to be represented by equation (4). We must, however, construct a new shock vector s^* that incorporates an expectation shock term $\chi_{z,t}$ as follows:

$$s_t^* = \begin{pmatrix} z_t \\ \chi_{z,t} \\ \chi_{z,t-1} \end{pmatrix}.$$

We obtain a new $\overline{\beta_0^*}$ and $\overline{\beta_1^*}$ from the original $\overline{\beta_0}$ and $\overline{\beta_1}$ by adding zero vectors to the columns corresponding to $\chi_{z,t}$ in S. We can write the new $\overline{P^*}$ as

$$\overline{\beta_0^*} = \begin{pmatrix} & 0 & 0 \\ \beta_0 & 0 & 0 \\ & 0 & 0 \end{pmatrix},$$

$$\overline{\beta_1^*} = \begin{pmatrix} & 0 & 0 \\ \beta_1 & 0 & 0 \\ & 0 & 0 \end{pmatrix},$$

and

$$\overline{P^*} = \begin{pmatrix} \rho_z & 0 & 1 \\ 0 & 0 & 0 \\ 0 & 1 & 0 \end{pmatrix}.$$

Then, we compute a new $\overline{B^*}$ matrix from equation (7) by using Christiano (2002). Thus, impulse responses under an expectation shock are produced by using equations (4) and (5).

3 Simulation Results

First, we examine the case in which there is no nominal rigidity, as is the case with the real model. Then, we examine the case in which there are price and wage rigidities; this case generates a stock market boom–bust cycle.

3.1 Real Model

As explained in the introduction, in the standard real business cycle model, comovements in consumption, investment and labor hours cannot be generated by a news shock to future technology. This is because expectations about future new technologies increases the real rate of return and generate wealth effects. Therefore, if the wealth effect outweights the effect of the increased real rate of return, consumption and leisure increase. However, as labor hours decrease, output declines. At the same time, investment is reduced because consumption increases and output decreases. If effect on the expected real rate of return dominates—that is, if the substitution effect outweights the wealth effect—investment and labor hours increase. Because productivity has not yet increased, output growth is smaller than that in investment. Therefore, consumption falls. Thus, in each case, we cannot have positive comovements in consumption, investment and labor supply.

CIMR can generate positive comovements in consumption, investment and hours worked from a news shock about future productivity improvements by incorporating the investment intertemporal adjustment costs and habit formation in consumption. These are realistic assumptions that are commonly used in dynamic general equilibrium modeling of policy experiments by central banks. Intuitively, CIMR first try to generate increased labor supply by introducing investment growth adjustment costs through an increased substitution effect, and then they appropriately allocate the additional output that derives from the increased labor supply between consumption and investment.

3.1.1 Level Shock

We first reproduce CIMR's investigation. The shock process anticipated by economic agents is illustrated Figure 1. A positive one percent technology level shock is expected to occur at period 4. Because this level shock is assumed to follow an AR (1) process, the expected growth rate has a spike at period 4 but it is expected to be negative thereafter as the level shock decays.

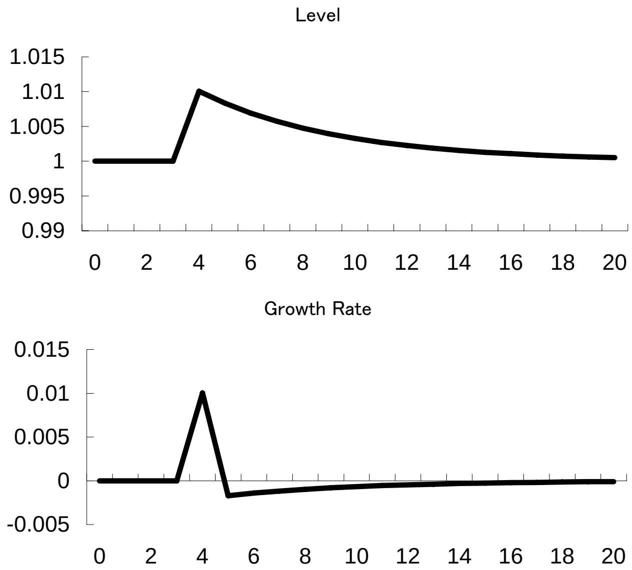

Figure 1: Level Shock Process

The impulse responses for the shock described above are illustrated in Figure 2. As CIMR found, hours worked, consumption and investment increase for an expected positive technology level shock.

3.1.2 Growth Shock

It is assumed that agents anticipate a growth rate shock process, as illustrated in Figure 3. In this case, although it is assumed that growth will eventually cease, it is anticipated that technology will not return to its previous level. Hence, the wealth effect is more prevalent in this shock scenario than before.

Figure 4 shows the impulse responses for such a growth rate shock. Because this figure shows the responses of the detrended variables, variables such as consumption and investment should be multiplied by the trend technology when the anticipate shock occurs. Yet, because we are interested in the case in which the anticipated shock fails to materialize, we can ignore the trending problem as there is no change in the trend growth rate. Analyzing the case in which the shock actually occurs enables our understanding of the rational expectations formed by agents when they receive the signal. As expected from the strong wealth effect implied by the shock process illustrated in Figure 3, consumption and leisure increase.[13] Consequently, labor

[13]Consumption and leisure increase even under very high parameter for habit forma-

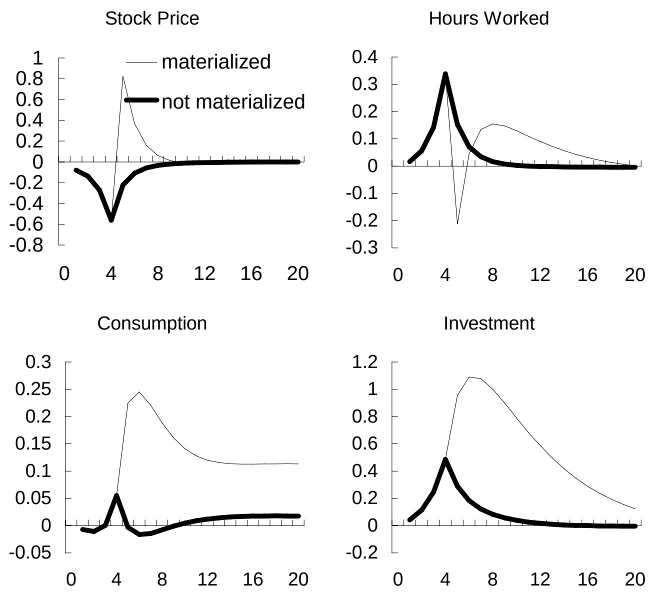

Figure 2: Level Shock: Real Model

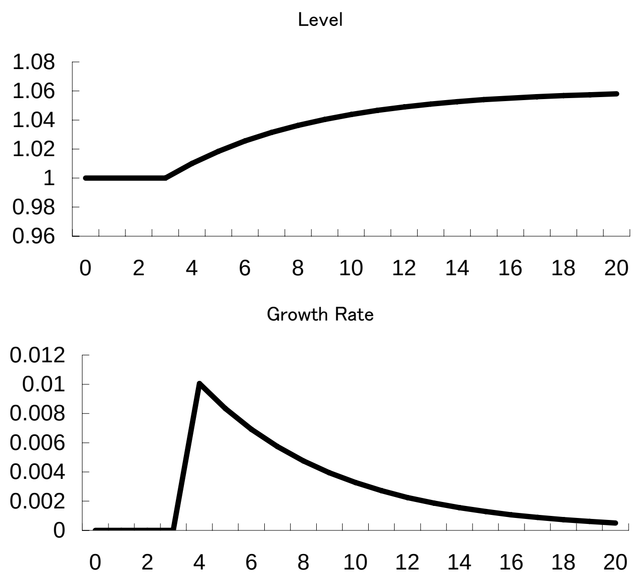

Figure 3: Growth Shock Process

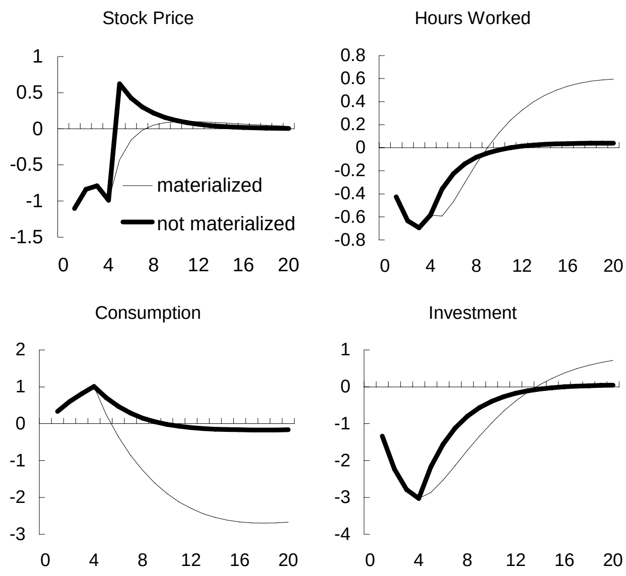

Figure 4: Growth Shock: Real Model

input and investment are reduced. To generate increased substitution effects, which operate through increased rates of return, we examine the case in which there are extremely high investment adjustment costs (larger than those in the baseline case by a factor 1,000).

Impulse responses in this model are shown in Figure 5. Even with such extremely high adjustment costs, we cannot produce an increase in investment. To reduce the strength of the wealth effect, rather than use the persistent growth rate shock assumed in previous exercises, we further examine the case in which there is a one–off anticipated permanent increase in the level of technology, as shown in Figure 6, when there are extremely high investment adjustment costs (larger than those in the baseline case by a factor of 1,000). Impulse responses for this case are illustrated in Figure 7. The decreased wealth effect and the increased substitution effect from higher adjustment costs generate comovements in hours worked, consumption and investment. The most significant finding of the exercises so far is, however, that comovements only occur for parameter values that are unrealistic given the estimated obtained from the so–called canonical dynamic general equilibrium models based on Christiano et al. (2005).

tion. Further increase in the parameter for habit formation does not change the results qualitatively.

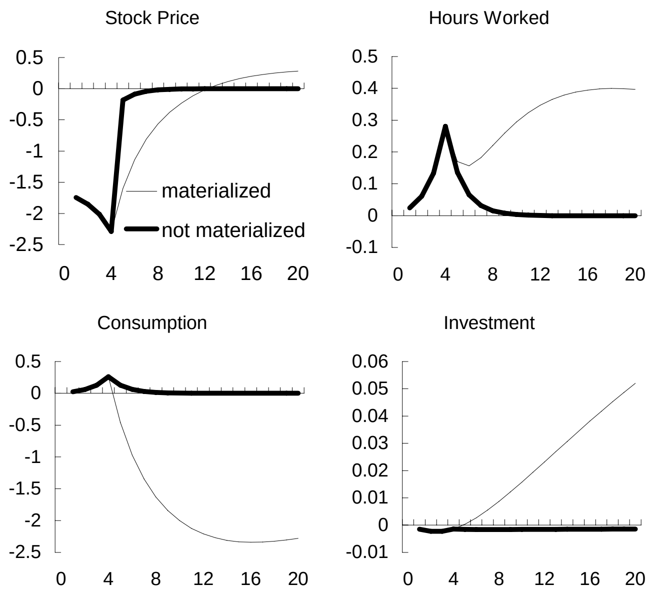

Figure 5: Growth Shock: Real Model with Very High S"

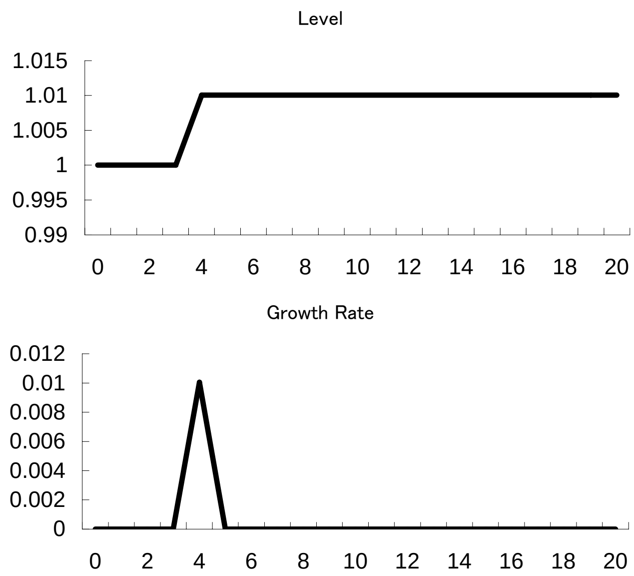

Figure 6: Growth Shock Process (no persistence)

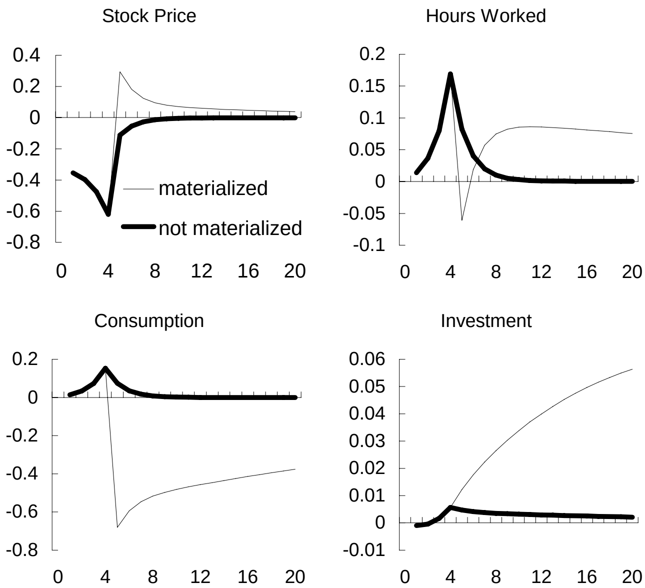

Figure 7: Growth Shock: Real Model with Very High S" and $\rho_u = 0$

3.2 Extended Model with Nominal Rigidities

Although we generated positive comovements in consumption, investment and working hours for a positive news shock to new technology, the theoretical stock price decreases. This seems counter–intuitive, but it can be explained examining the following capital demand and capital supply equations:

$$P_{K',t} = \sum_{i=1}^{\infty} \mathrm{E}_t \prod_{j=1}^{i} \frac{\pi_{t+j}}{R^n_{t+j-1}} (1-\delta)^{i-1} \alpha \phi_t \left[Z_t \exp(z_t) \right]^{1-\alpha} h_t^{1-\alpha} K_t^{\alpha-1}, \tag{9}$$

$$P_{K',t} = \frac{1}{1 - S\left(\frac{I_t}{I_{t-1}}\right) - S'\left(\frac{I_t}{I_{t-1}}\right)\frac{I_t}{I_{t-1}}} - \frac{\mathrm{E}_t \pi_{t+1}}{R^n_t} \frac{P_{K',t+1} S'\left(\frac{I_{t+1}}{I_t}\right)\frac{I^2_{t+1}}{I^2_t}}{1 - S\left(\frac{I_t}{I_{t-1}}\right) - S'\left(\frac{I_{t+1}}{I_t}\right)\frac{I_t}{I_{t-1}}}. \tag{10}$$

Equation (9) is interpreted as the capital demand function, according to which households equate the theoretical price of capital to the present discounted value of future dividends. Equation (10) is the capital supply function. Capital producers choose the price of capital, represented by the left–hand side, based on the marginal cost of producing a unit of capital, which is

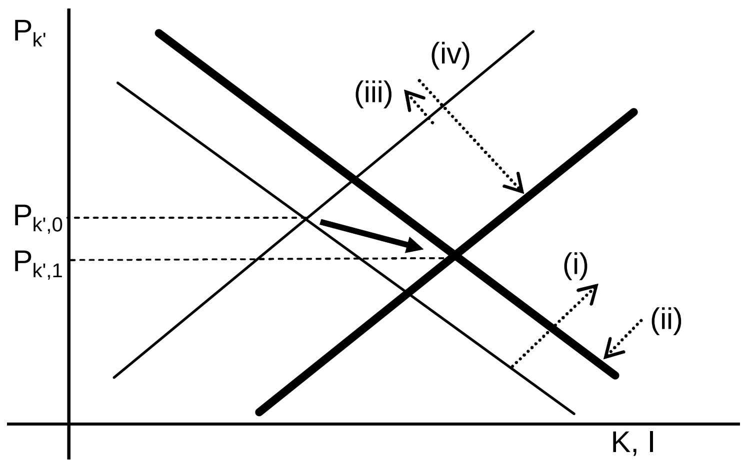

Figure 8: Capital Equilibrium

represented by the right–hand side.[14] Figure 8, which illustrates the relationship between equations (9) and (10), clarifies the dynamic transition of the theoretical capital price from period 0 to period 1. Economy is at $P_{K',0}$ initially. Following the receipt of a positive news shock about future technology, the capital demand curve shifts upwards because of the expected increase in dividends; see panel (i). This upward shift of the demand curve is, however, mitigated by an increase in real interest rates, which are determined by the intertemporal ratio of the marginal utility from consumption, as shown by panel (ii). Concerning supply–side developments, increase in investment caused by the positive news shock raises marginal cost contemporaneously, as in panel (iii); this effect is represented by the first term on the right–hand side of equation (10). An increase in current investment, however, reduces the adjustment costs incurred because of higher investment growth in the future. This is represented by the second term in equation (10). Therefore, as shown in panel (iv), even though investment in period 1 increases, the capital supply curve shifts downwards. In the aggregate, given these demand and supply conditions, the theoretical stock price falls from $P_{K',0}$ to $P_{K',1}$ following a positive expectation shock to productivity. To explain a stock price bubble in this setting, CIMR incorporate both sticky prices and wages.[15] CIMR also

[14] To be precise, the role of capital producers is played by households in this model. Having capital producers who are separate from households would, however, make no difference to the analysis.

[15] In particular, the sticky wage mechanism, introduced by Erceg, Henderson and Levin (2000), has direct effects on the Pigou cycle. Barro and King (1984) state that "We should stress the result that consumption and leisure end up moving in the same direction. We

adopt the Taylor (1993)–type instrument rule.[16] A positive news shock to future productivity implies that future marginal costs will be lower. If price setting is mainly forward looking (that is, incorporates little indexation and imposes few barriers to the acquisition of new information), then the current inflation rate is lower. Hence, according to the Taylor–type instrument rule, under which there are aggressive reactions to inflation developments, nominal as well as real interest rates are lowered. This shifts the capital demand curve in Figure 8 outwards. As a result, according to CIMR, a stock price boom can occur after an expectation shock hits the economy.

3.2.1 Level Shock

For the model with nominal rigidities, Figure 9 below shows the responses for the technology level shock, as did Figure 1 for the baseline model. As stated above, the introduction of nominal rigidities and an inflation–targeting central bank leads lower nominal interest rates, reflecting better future technology, through a lower inflation rate, to contribute to increasing the stock price. Furthermore, reduced interest rates and the wage changes, which reflect an increase in the future marginal product of labor through the sticky wage mechanism, make comovements in hours worked, consumption and investment more evident. The sticky wage mechanism alters the trade–off between consumption and leisure. Because the response of current inflation to expected events is crucial in generating the stock market boom–bust cycle, when prices as well as wages are not indexed, the boom–bust cycle is more evident.

The response of the stock price is minimal. The size of the response seems to be magnified by having more persistent expectations of future technology growth. Next, we show that this simply generates outcomes that are less realistic.

always get this result if (i) utility is separable over time, (ii) consumption and leisure are superior goods, and (iii) the current schedule for labor's marginal product does not shift. Changes in prospective conditions end up affecting household's total current real expenditure on consumption and leisure. Given time–separable utility, this change amounts solely to an income effect, which moves consumption and leisure in the same direction if both goods are superior. Thus, the two goods can move in opposite directions only if there is a shift in the (schedule for the) current relative price, which is the real wage rate. But we rule this out by assuming no shift in the schedule for labor's current marginal product." The sticky wage mechanism can alter the real wage rate to reflect future technological improvements.

[16] As shown in the appendix, CIMR assumes a forward–looking Taylor–type rule. This also helps to generate stock market boom–bust cycles.

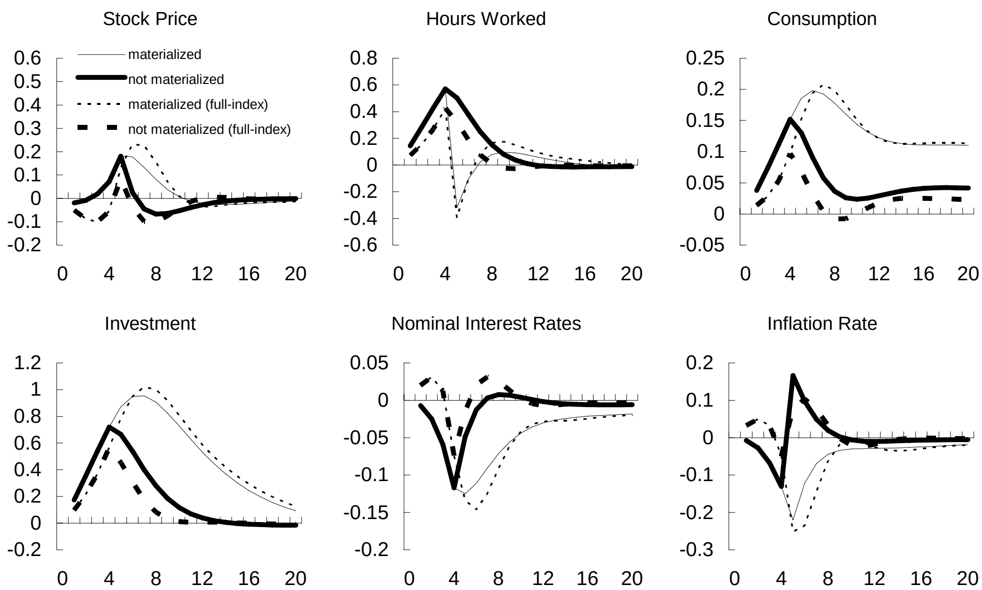

Figure 9: Level Shock: New Keynesian Model

3.2.2 Growth Shock

Similarly to Figure 3, Figure 10 illustrates impulse responses for the expected growth rate shock. Similarly to the case of the real model, in this model, we cannot produce comovements in stock prices, hours worked, consumption and investment. This is because of the strong wealth effect in this economy. Unlike in the case with of real model illustrated in Figure 4, however, in this model, hours worked increases. This is consistent with the finding of Barro and King (1984) that “Thus, the two goods can move in opposite directions only if there is a shift in the (schedule for the) current relative price, which is the real wage rate.” Because of the sticky wage mechanism, the real wage rate changes to reflect the increase in the future marginal product of labor. This raises current real wages and makes leisure more expensive. The divergence of labor and investment is exacerbated by monetary tightening, which reflects the increase in the inflation rate following the receipt of positive news about the future productivity growth rate. We revisit this issue in the next exercise.

Similarly, to Figure 6, Figure 11 shows the responses following a permanent increase in the technology level shock, when investment intertemporal adjustment costs are extremely high (100 larger than those in the baseline model). Because of the high investment growth adjustment costs and the reduced wealth effect, comovements in hours worked, consumption and investment are possible. Detrended consumption declines substantially follow-

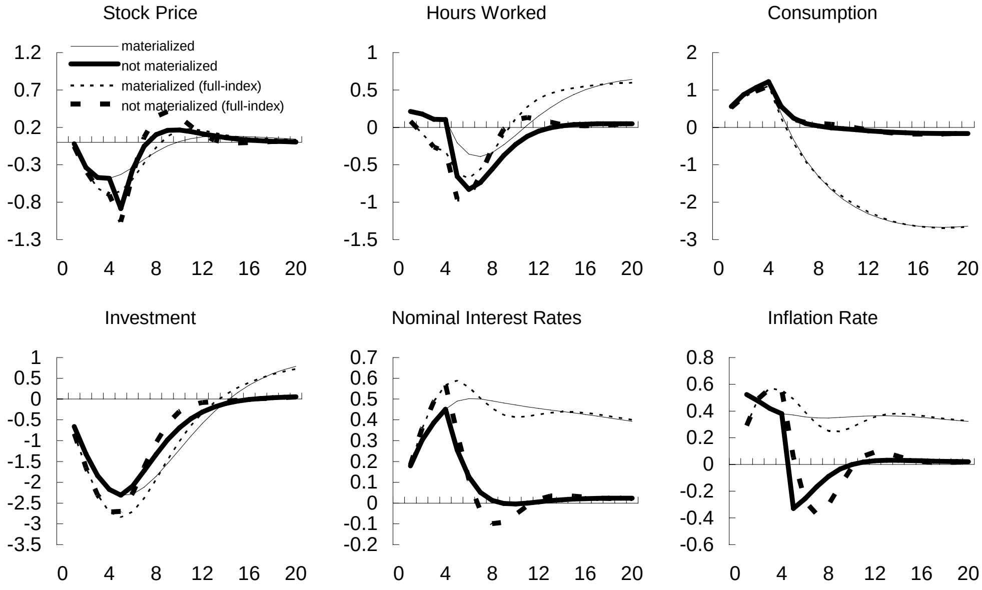

Figure 10: Growth Shock: New Keynesian Model

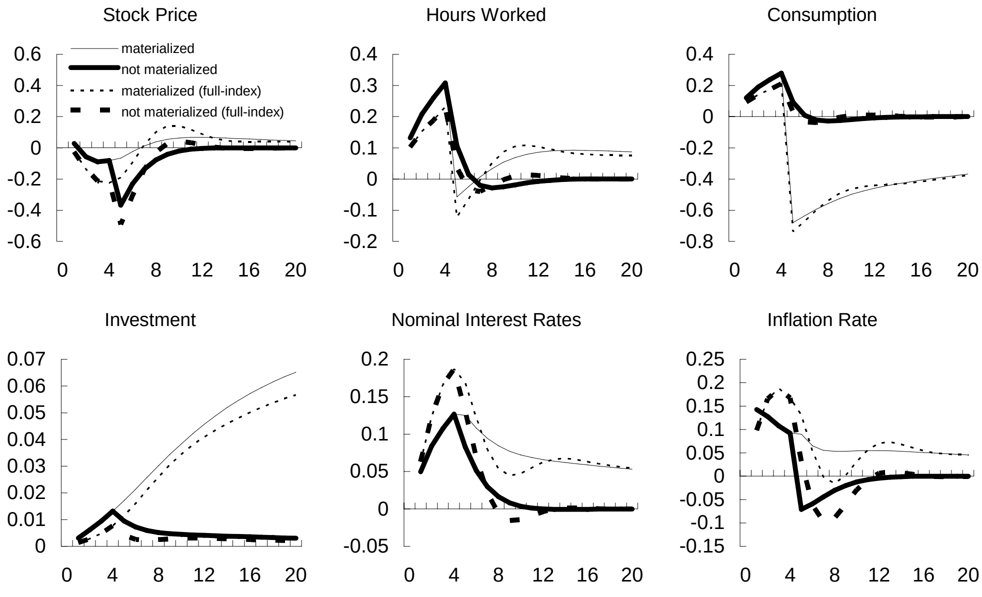

Figure 11: Growth Shock: New Keynesian Model with very high S" and $\rho_u = 0$

ing the confirmation that the news is true because investment must increase substantially.

Nevertheless, even if investment growth adjustment costs increase and the wealth effect is reduced, there will be no stock market boom in this case. As explained above, this is because inflation rates are higher under growth expectation than when a technology level shock is expected. This is explained below. It is clear from thin lines in Figures 10 and 11, that investment must eventually increase following the permanent positive change in productivity. When investment growth adjustment costs are high, agents try to increase investment as soon as they receive the signal. Yet, because agents know that they will be rich in the future, they would like to consume more and have more leisure through the wealth effect. To mitigate these two motives, that is, by increasing both consumption and investment, agents need to work more hours although they prefer leisure to work. These developments raise the current marginal cost and therefore inflation rates. Thus, both nominal interest rates and eventually real interest rates are raised by the central bank following its Taylor–type instrument rule.[17] By contrast, CIMR predict deflation, low interest rates and an asset price boom, which is more consistent with the data during an asset price boom.[18]

4 Conclusion

In this paper, we showed that it is difficult to produce the Pigou cycle, which is characterized by comovements in hours worked, consumption and investment, in equilibrium business cycle models that incorporate growth expectation. We found that empirically implausible values for some parameters are required to generate the Pigou cycle under growth expectation. Furthermore, we found that generating a stock market boom–bust cycle, which is a Pigou cycle augmented by a positive reaction of the stock price, is even more difficult. Even if one uses empirically implausible parameters, it is vir-

[17] This is similar to the predictions of the canonical new Keynesian model. The output gap, measured as the deviation from the output at the flexible price equilibrium, increases according to the Euler equation when there is a shock to the technology growth rate but decreases when there is a shock is to the level of technology.

[18] If we alter the forecast horizon of the news shock, the very short–living expectation–driven business cycle can materialize with small persistence in the growth rate shock. This is because by shortening the forecast horizon, the substitution effect to increase the current capital to prepare for the future increase in the technology becomes stronger, that is, the news shock becomes closer to the contemporaneous shock. Yet, inflation rates becomes higher initially, that is not very much consistent with the data. For the analysis on the forecast horizon of the news shocks, see Fujiwara, Hirose and Shintani (2008).

tually impossible to get the stock price to react positively to news of higher future productivity growth. Labor inputs must be increased in the face of a substantial wealth effect to meet the demand for investment subject to the adjustment costs. This results in higher inflation and, thereby, through the operations of the inflation–targeting central bank, higher real interest rates. The key mechanism used by CIMR to generate a stock market boom–bust cycle is an outward shift of the capital demand curve following a fall in real interest rates. Under growth expectation, because of strong wealth effects, it seems inconceivable that, in the standard model, one could have both deflation and output growth without an expansion of the production frontier. Therefore, we conclude that Barro and King's (1984) predictions continues to apply.

In future research, we aim to solve the problem of generating the Pigou cycle from growth expectation by considering the filtering problem in the context of the permanent components of news shocks, as examined by Edge, Laubach and Williams (2007), and in the context of limited information about news shocks, as analyzed by Sims (2003) and Reis (2006).

Appendix: Model Derivation

The model consists of four agents, firms, consumers, the central bank and the fiscal authority.

Firms are assumed to face a cost minimization problem subject to a Rotemberg–type adjustment cost. The real marginal cost ϕ is derived from the cost minimization problem when each firm j minimizes its total cost subject to the production technology by choosing labor inputs h and the capital K, as follows:

$$\min_{h_{j,t},K_{j,t}} \frac{W_t}{P_t} h_{j,t} + r_t^K K_{j,t},$$

subject to

$$Y_{j,t} = \left[Z_t \exp\left(z_t\right) h_{j,t}\right]^{1-\alpha} K_{j,t}^{\alpha},$$

where W is the nominal wage, P is the price level and r^K is the cost of capital. Each firm sets its prices in order to maximize the real dividend D subject to the Rotemberg–type adjustment cost:

$$D_{j,t} = \left(1+\tau\right) \frac{P_{j,t,}}{P_t} Y_{j,t} - \phi_t Y_{j,t} - \frac{\zeta_p}{2}\left(\frac{P_{j,t}}{P_{j,t-1}} - 1\right)^2 Y_t,$$

and the downward sloping demand curve stemming from the monopolistic competition:

$$Y_{j,t} = \left(\frac{P_{j,t,}}{P_t}\right)^{-\theta_p} Y_t,$$

where ζ_p is the parameter for the Rotemberg–type adjustment cost, θ_p is the elasticity of substitution among differentiated goods, and τ is the production subsidy rate. As is clear from the equation that defines the real dividend, the steady state inflation rate is assumed to be zero.

Each household i supplies labor in a monopolistically competitive labor market and maximizes utility U:

$$U_{i,t} = \log\left(C_{i,t} - bC_{i,t-1}\right) - \psi_L \frac{h_{i,t}^{1+\sigma_L}}{1+\sigma_L},$$

where b is the parameter for habit formation, ψ_L determines the size of labor dis–utility and σ_L is the Frish elasticity of the labor substitution, subject to the budget constraint:[19]

$$\frac{B_{i,t+1}}{P_t} = R^n_{t+1}\frac{B_{i,t}}{P_t} + (1+\tau_W)\frac{W_{i,t}}{P_t}h_{i,t}\left\{1 - \frac{\zeta_w}{2}\left[\frac{W_{i,t}}{\mu\exp(u_t)\,W_{i,t-1}} - 1\right]^2\right\}$$
$$+ r^K_t K_{i,t} + D_{i,t} - C_{i,t} - I_{,it} - T_{i,t},$$

the capital formation equation, in which the depreciation rate is δ:

$$K_{i,t+1} = (1-\delta)K_{i,t} + \left[1 - S\left(\frac{I_{i,t}}{I_{i,t-1}}\right)\right] I_{i,t},$$

where the investment adjustment cost takes the form:

$$S\left(\frac{I_t}{I_{t-1}}\right) = S''\left\{\frac{\left(\frac{I_t}{I_{t-1}}\right)^2}{2} - \left(\frac{I_t}{I_{t-1}}\right)\mu\exp(u_t) + \frac{[\mu\exp(u_t)]^2}{2}\right\},$$

and the downward sloping labor demand stemming from the monopolistically competitive labor market:

$$h_{j,t} = \left(\frac{W_{j,t,}}{W_t}\right)^{-\theta_h} h_t,$$

where B is the nominal debt,[20], R^n is the nominal interest rate, I is investment, T is a lump–sum tax, τ_W is the labor subsidy rate, and ζ_w is the parameter for the Rotemberg–type adjustment cost.

The central bank sets short–term nominal interest rates by following a Taylor–type rule as follows:

$$R^n_{t+1} = \rho R^n_{t-1} + (1-\rho)\left[R + \eta\left(\frac{\mathrm{E}_t P_{t+1}}{P_t} - 1\right) + \eta_y\left(\frac{Y_t}{Y^+_t} - 1\right)\right],$$

where ρ controls the history dependency of monetary policy, η is the coefficient on inflation, η_y is that on the output gap and Y^+ is aggregate output on a non–stochastic steady–state growth path.[21] The forward–looking monetary policy rule on future inflation contributes to producing the Pigou cycle

[19] We detrend variables by using equation (1). Therefore, both wage and investment adjustment costs are affected by the trend growth shock. The results do not change even we exclude the effects from the growth rate shock on adjustment costs.

[20] Aggregate debt, namely B, is set to be zero.

[21] Therefore, in this paper, the output gap is not the theoretical output gap measured as the deviation from output at the flexible price equilibrium.

because nominal interest rates fall as the marginal cost is reduced because of expected higher productivity.

The fiscal authority simply collects the lump–sum tax from households and subsidizes monopolistically competitive firms and workers as follows:

$$\tau Y + \tau_W \frac{W}{P} h = \int_0^1 T_i di = T.$$

A Level Equations

From the first–order conditions and the resource constraint, we obtain a model in 12 level equations under the symmetric equilibrium,[22] in which the inflation rates is

$$\pi_t = \frac{P_t}{P_{t-1}},$$

and the theoretical value of the stock price $P_{K'}$ is the ratio of the Lagrange multiplier for capital formation to that on the budget constraint:

$$P_{K',t} = \frac{\mu_t}{\lambda_t}.$$

[22] Both firms and households are assumed to be within the unit mass.

$$
\begin{array}{ll}
\text{(L1)} & [Z_t \exp(z_t) h_t]^{1-\alpha} K_t^{\alpha} = C_t + I_t + \frac{\theta_W}{\theta_W - 1} \frac{W_t}{P_t} h_t \frac{\zeta_w}{2} \left[\frac{W_t}{\mu \exp(u_t) W_{t-1}} - 1 \right]^2 \\
 & + \frac{\zeta_p}{2} (\pi_t - 1)^2 [Z_t \exp(z_t) h_t]^{1-\alpha} K_t^{\alpha}, \\
\text{(L2)} & K_{t+1} = (1-\delta) K_t + \left[1 - S\left(\frac{I_t}{I_{t-1}} \right) \right] I_t, \\
\text{(L3)} & \frac{1}{C_t - bC_{t-1}} - \lambda_t - b \mathrm{E}_t \beta \frac{1}{C_{t+1} - bC_t} = 0, \\
\text{(L4)} & \frac{W_t}{P_t} = (1-\alpha) \phi_t [Z_t \exp(z_t)]^{1-\alpha} h_t^{-\alpha} K_t^{\alpha}, \\
\text{(L5)} & \varphi_t - 1 + \frac{\zeta_w}{2} \left(\frac{W_t}{\mu \exp(u_t) W_{t-1}} - 1 \right)^2 \\
 & - \frac{\zeta_w}{\theta_h - 1} \left(\frac{W_t}{\mu \exp(u_t) W_{t-1}} - 1 \right) \frac{W_t}{\mu \exp(u_t) W_{t-1}} \\
 & + \beta \frac{\zeta_w}{\theta_h - 1} \left(\frac{W_{t+1}}{\mu \exp(u_{t+1}) W_t} - 1 \right) \left(\frac{W_{t+1}}{\mu \exp(u_{t+1}) W_t} \right)^2 \frac{\lambda_{t+1}}{\lambda_t} \frac{P_t}{P_{t+1}} \frac{h_{t+1}}{h_t} = 0, \\
\text{(L6)} & \varphi_t = \frac{\psi_L h_t^{\sigma_L}}{\lambda_t \frac{W_t}{P_t}}, \\
\text{(L7)} & r_t^K = \alpha \phi_t [Z_t \exp(z_t)]^{1-\alpha} h_t^{1-\alpha} K_t^{\alpha-1}, \\
\text{(L8)} & P_{K',t} = \beta \frac{\lambda_{t+1}}{\lambda_t} \mathrm{E}_t \left[r_{t+1}^K + P_{K',t+1}(1-\delta) \right], \\
\text{(L9)} & -1 + P_{K',t} \left[1 - S\left(\frac{I_t}{I_{t-1}} \right) \right] - P_{K',t} S'' \left[\frac{I_t}{I_{t-1}} - \mu \exp(u_t) \right] \frac{I_t}{I_{t-1}} \\
 & + \beta \mathrm{E}_t P_{K',t+1} \frac{\lambda_{t+1}}{\lambda_t} S'' \left[\frac{I_{t+1}}{I_t} - \mu \exp(u_t) \right] \frac{I_{t+1}^2}{I_t^2} = 0, \\
\text{(L10)} & (1-\theta_p) + \theta_p \phi_t - \zeta \left(\frac{P_t}{P_{t-1}} - 1 \right) \frac{P_t}{P_{t-1}} \\
 & + \mathrm{E}_t \beta \frac{\lambda_{t+1}}{\lambda_t} \zeta_p \left(\frac{P_{t+1}}{P_t} - 1 \right) \frac{P_{t+1}}{P_t} \frac{[Z_{t+1} \exp(z_{t+1}) h_{t+1}]^{1-\alpha} K_{t+1}^{\alpha}}{[Z_t \exp(z_t) h_t]^{1-\alpha} K_t^{\alpha}} = 0, \\
\text{(L11)} & R_t^n = \rho R_{t-1}^n + (1-\rho) \left\{ R + \eta \mathrm{E}_t \pi_{t+1} + \eta_y \left\{ \frac{[Z_t \exp(z_t) h_t]^{1-\alpha} K_t^{\alpha}}{(Z_t h)^{1-\alpha} K^{\alpha}} - 1 \right\} \right\}, \\
\text{(L12)} & -\frac{\lambda_t}{P_t R_t^n} + \mathrm{E}_t \beta \frac{\lambda_{t+1}}{P_{t+1}} = 0.
\end{array}
$$

B Detrended Equations

To obtain the equilibrium conditions in terms of nongrowing variables only, we detrend variables by using equation (1) as follows:

$$c_t = \frac{C_t}{Z_t},\ i_t = \frac{I_t}{Z_t},\ k_t = \frac{K_t}{Z_{t-1}},\ \widetilde{\lambda}_t = Z_t \lambda_t,\ w_t = \frac{W_t}{P_t Z_t},\ \pi_t = \frac{P_t}{P_{t-1}},\ \text{and } \pi_t^W = \frac{w_t}{w_{t-1}},$$

$$\begin{aligned}
&\text{(DL1)} && [\exp(z_t) h_t]^{1-\alpha} \left[\frac{k_t}{\mu \exp(u_t)}\right]^{\alpha} = c_t + i_t + \tfrac{\theta_W}{\theta_W - 1} w_t h_t \tfrac{\zeta_w}{2} \left(\tfrac{w_t}{w_{t-1}} \pi_t - 1\right)^2 \\
& && + \tfrac{\zeta_p}{2} (\pi_t - 1)^2 [\exp(z_t) h_t]^{1-\alpha} \left[\frac{k_t}{\mu \exp(u_t)}\right]^{\alpha} \\
&\text{(DL2)} && k_{t+1} = \tfrac{(1-\delta) k_t}{\mu \exp(u_t)} + \left\{1 - [\mu \exp(u_t)]^2 S'' \left[\frac{\left(\frac{i_t}{i_{t-1}}\right)^2}{2} - \tfrac{i_t}{i_{t-1}} + \tfrac{1}{2}\right]\right\} i_t, \\
&\text{(DL3)} && \frac{1}{c_t - \frac{b c_{t-1}}{\mu \exp(u_t)}} - \widetilde{\lambda}_t - b \mathrm{E}_t \beta \frac{1}{c_{t+1} \mu \exp(u_{t+1}) - b c_t} = 0, \\
&\text{(DL4)} && w_t = (1-\alpha) \phi_t [\exp(z_t)]^{1-\alpha} h_t^{-\alpha} \left[\frac{k_t}{\mu \exp(u_t)}\right]^{\alpha}, \\
&\text{(DL5)} && (1-\theta_h) + \theta_h \varphi_t - (1-\theta_h) \tfrac{\zeta_w}{2} \left(\pi_t^W \pi_t - 1\right)^2 \\
& && -\zeta_w \left(\pi_t^W \pi_t - 1\right) \pi_t^W \pi_t \\
& && +\beta \zeta_w \left(\pi_{t+1}^W \pi_{t+1} - 1\right) \left(\pi_{t+1}^W \pi_{t+1}\right)^2 \tfrac{\lambda_{t+1}}{\lambda_t} \tfrac{1}{\pi_{t+1}} \tfrac{h_{t+1}}{h_t} = 0, \\
&\text{(DL6)} && \varphi_t = \frac{\psi_L h_t^{\sigma_L}}{\widetilde{\lambda}_t w_t}, \\
&\text{(DL7)} && r_t^K = \alpha \phi_t [\exp(z_t)]^{1-\alpha} h_t^{1-\alpha} \left[\frac{k_t}{\mu \exp(u_t)}\right]^{\alpha-1}, \\
&\text{(DL8)} && P_{K',t} = \beta \frac{\widetilde{\lambda}_{t+1}}{\mu \exp(u_{t+1}) \widetilde{\lambda}_t} \mathrm{E}_t \left[r_{t+1}^K + P_{K',t+1}(1-\delta)\right], \\
&\text{(DL9)} && -1 + P_{K',t} \left\{1 - [\mu \exp(u_t)]^2 S'' \left[\frac{\left(\frac{i_t}{i_{t-1}}\right)^2}{2} - \tfrac{i_t}{i_{t-1}} + \tfrac{1}{2}\right]\right\} \\
& && -P_{K',t} [\mu \exp(u_t)]^2 S'' \left(\tfrac{i_t}{i_{t-1}} - 1\right) \tfrac{i_t}{i_{t-1}} \\
& && +\beta \mathrm{E}_t P_{K',t+1} \tfrac{\lambda_{t+1}}{\lambda_t} S'' \left(\tfrac{i_{t+1}}{i_t} - 1\right) \left(\tfrac{i_{t+1}}{i_t}\right)^2 [\mu \exp(u_{t+1})]^2 = 0, \\
&\text{(DL10)} && (1-\theta_p) + \theta_p \phi_t - \zeta (\pi_t - 1) \pi_t \\
& && +\mathrm{E}_t \beta \tfrac{\widetilde{\lambda}_{t+1}}{\widetilde{\lambda}_t} \zeta_p (\pi_{t+1} - 1) \pi_{t+1} \tfrac{\exp(u_{t+1})}{\exp(u_t)} \left[\tfrac{\exp(z_{t+1}) h_{t+1}}{\exp(z_t) h_t}\right]^{1-\alpha} \left(\tfrac{k_{t+1}}{k_t}\right)^{\alpha} = 0, \\
&\text{(DL11)} && R_t^n = \rho R_{t-1}^n + (1-\rho) \left\{R + \eta \mathrm{E}_t \pi_{t+1} + \eta_y \left[\tfrac{\exp(z_t) h_t^{1-\alpha} k_t^{\alpha}}{h^{1-\alpha} k^{\alpha}} - 1\right]\right\}, \\
&\text{(DL12)} && \frac{\mathrm{E}_t \pi_{t+1}}{R_t^n} = \mathrm{E}_t \beta \frac{\widetilde{\lambda}_{t+1}}{\widetilde{\lambda}_t \mu \exp(u_{t+1})}, \\
&\text{(DL13)} && \pi_t^W = \frac{w_t}{w_{t-1}}.
\end{aligned}$$

C Steady States

By eliminating the time subscript, we can obtain the non-stochastic steady states of 13 variables.

(SS1) $\pi = 1,$

(SS2) $\pi^W = 1,$

(SS3) $\phi = 1,$

(SS4) $\varphi = 1,$

(SS5) $\tilde{P}_{K'} = 1,$

(SS6) $R = \frac{\mu}{\beta},$

(SS7) $r^K = \frac{\mu}{\beta} - 1 + \delta,$

(SS8) $$w = (1-\alpha)\left(\frac{\frac{\mu}{\beta}-1+\delta}{\alpha}\right)^{\frac{\alpha}{\alpha-1}},$$

(SS9) $$h = \left\{\frac{\left(\frac{\frac{\mu}{\beta}-1+\delta}{\alpha}\right)(1-\alpha)(\mu-b\beta)}{\left[\left(\frac{\frac{\mu}{\beta}-1+\delta}{\alpha}\right)-\mu+(1-\delta)\right]\psi_L(\mu-b)}\right\}^{\frac{1}{\sigma_L+1}},$$

(SS10) $$k = \left(\frac{\frac{\mu}{\beta}-1+\delta}{\alpha}\right)^{\frac{1}{\alpha-1}}\frac{1}{\mu}\left\{\frac{\left(\frac{\frac{\mu}{\beta}-1+\delta}{\alpha}\right)(1-\alpha)(\mu-b\beta)}{\left[\left(\frac{\frac{\mu}{\beta}-1+\delta}{\alpha}\right)-\mu+(1-\delta)\right]\psi_L(\mu-b)}\right\}^{\frac{1}{\sigma_L+1}},$$

(SS11) $$i = [\mu-(1-\delta)]\left\{\frac{\left(\frac{\frac{\mu}{\beta}-1+\delta}{\alpha}\right)(1-\alpha)(\mu-b\beta)}{\left[\left(\frac{\frac{\mu}{\beta}-1+\delta}{\alpha}\right)-\mu+(1-\delta)\right]\psi_L(\mu-b)}\right\}^{\frac{1}{\sigma_L+1}}\left(\frac{\frac{\mu}{\beta}-1+\delta}{\alpha}\right)^{\frac{1}{\alpha-1}},$$

(SS12) $$\widetilde{\lambda} = (1-\alpha)\left(\frac{\frac{\mu}{\beta}-1+\delta}{\alpha}\right)^{\frac{\alpha}{1-\alpha}}\psi_L\left\{\frac{(1-\alpha)\left(\frac{\frac{\mu}{\beta}-1+\delta}{\alpha}\right)(\mu-b\beta)}{\left[\left(\frac{\frac{\mu}{\beta}-1+\delta}{\alpha}\right)-\mu+(1-\delta)\right]\psi_L(\mu-b)}\right\}^{\frac{\sigma_L}{\sigma_L+1}},$$

(SS13) $$c = \left(\frac{\frac{\mu}{\beta}-1+\delta}{\alpha}\right)^{\frac{1}{\alpha-1}}\left[\left(\frac{\frac{\mu}{\beta}-1+\delta}{\alpha}\right)-\mu+(1-\delta)\right]\left\{\frac{\left(\frac{\frac{\mu}{\beta}-1+\delta}{\alpha}\right)(1-\alpha)(\mu-b\beta)}{\left[\left(\frac{\frac{\mu}{\beta}-1+\delta}{\alpha}\right)-\mu+(1-\delta)\right]\psi_L(\mu-b)}\right\}^{\frac{1}{\sigma_L+1}}.$$

D Linearized Equations

The linearized system of equations is as follows, where:

$$\hat{x}_t = \frac{dx_t}{x},$$

$$
\begin{array}{ll}
\text{(l1)} & h^{1-\alpha}\left(\frac{k}{\mu}\right)^{\alpha}\left[(1-\alpha)\, z_t + (1-\alpha)\,\widehat{h}_t + \alpha\widehat{k}_t - \alpha u_t\right] - c\widehat{c}_t - i\widehat{i}_t = 0, \\
\text{(l2)} & -\widehat{k}_{t+1} + \frac{(1-\delta)}{\mu}\left(\widehat{k}_t - u_t\right) + \frac{i}{k}\widehat{i}_t = 0, \\
\text{(l3)} & \left(c - \frac{bc}{\mu}\right)^{-2}\left[-c\widehat{c}_t + \frac{bc}{\mu}\widehat{c}_{t-1} - \frac{bc}{\mu}u_t\right] - \widetilde{\lambda}\widehat{\widetilde{\lambda}}_t \\
 & +b\beta\,(\mu - b)^{-2}\, c^{-1}\,(\mu \mathrm{E}_t\widehat{c}_{t+1} - b\widehat{c}_t + \mu \mathrm{E}_t u_{t+1}) = 0, \\
\text{(l4)} & -\widehat{w}_t + \widehat{\phi}_t + (1-\alpha)\, z_t - \alpha\widehat{h}_t + \alpha\widehat{k}_t - \alpha u_t = 0, \\
\text{(l5)} & -\widehat{\pi}_t - \widehat{\pi}_t^W + \beta \mathrm{E}_t\widehat{\pi}_{t+1} + \beta \mathrm{E}_t\widehat{\pi}_{t+1}^W + \frac{\theta_h - 1}{\zeta_w}\widehat{\varphi}_t = 0, \\
\text{(l6)} & -\widehat{\varphi}_t + \sigma_L\widehat{h}_t - \widehat{\widetilde{\lambda}}_t - \widehat{w}_t = 0, \\
\text{(l7)} & -\widehat{r}_t^K + \widehat{\phi}_t + (1-\alpha)\,\widehat{z}_t + (1-\alpha)\,\widehat{h}_t + (\alpha - 1)\,\widehat{k}_t + (1-\alpha)\, u_t = 0, \\
\text{(l8)} & -\widehat{P}_{K',t} + \mathrm{E}_t\widehat{\widetilde{\lambda}}_{t+1} - \mathrm{E}_t u_{t+1} - \widehat{\widetilde{\lambda}}_t + \frac{\beta r^K}{\mu}\mathrm{E}_t\widehat{r}_{t+1}^K + \frac{\beta(1-\delta)}{\mu}\mathrm{E}_t\widehat{P}_{K',t+1} = 0, \\
\text{(l9)} & \widehat{P}_{K',t} - (1+\beta)\, S''\mu^2\widehat{i}_t + \mu^2 S''\widehat{i}_{t-1} + \beta S''\mu^2 \mathrm{E}_t\widehat{i}_{t+1} = 0, \\
\text{(l10)} & -\widehat{\pi}_t + \beta \mathrm{E}_t\widehat{\pi}_{t+1} + \frac{\theta_p}{\zeta_p}\widehat{\phi}_t = 0, \\
\text{(l11)} & -R^n\widehat{R}_t^n + \rho R^n\widehat{R}_{t-1}^n + (1-\rho)\,\eta \mathrm{E}_t\widehat{\pi}_{t+1} + (1-\rho)\,(1-\alpha)\,\eta_y z_t \\
 & +(1-\rho)\,(1-\alpha)\,\eta_y\widehat{h}_t + (1-\rho)\,\alpha\eta_y\widehat{k}_t = 0, \\
\text{(l12)} & \mathrm{E}_t\widehat{\pi}_{t+1} - \widehat{R}_t^n - \mathrm{E}_t\widehat{\widetilde{\lambda}}_{t+1} + \widehat{\widetilde{\lambda}}_t + \mathrm{E}_t\widehat{u}_{t+1} = 0, \\
\text{(l13)} & -\widehat{\pi}_t^W + \widehat{w}_t - \widehat{w}_{t-1} = 0.
\end{array}
$$

E Parameters

Calibrated parameters are shown in Table 1. Because the model is solved at quarterly intervals, the parameters are in quarterly terms.

Table 1
Parameter values

Parameter	Value	Description and Definitions
θ_p	6	$\theta_p/(\theta_p-1)$ is the markup in the goods market
θ_w	21	$\theta_w/(\theta_w-1)$ is the markup in the labor market
ζ_p	27.454	The Rotemberg adjustment cost in goods
ζ_w	199.0819	The Rotemberg adjustment cost in labor
α	0.4	Labor share
b	0.63	Habit formation parameter
β	$1.01358^{-.25}$	Subjective discount factor
μ	1	The average growth rate
ψ_L	109.82	The level of labor dis–utility
S"	2.48	The level of investment adjustment costs
ρ	0.81	Coefficient on the lagged interest rate
η	1.95	Coefficient on the inflation rate
η_y	0.18	Coefficient on the output gap
ρ_u	0.83	AR (1) parameter on the growth shock
ρ_z	0.83	AR (1) parameter on the level shock
p	4	A shock is expected to occur at p

The parameters are calibrated to the same values used by CIMR, except for ζ_p, ζ_w, μ and S". Because we use the Rotemberg–type adjustment while Calvo (1983)–type staggered price setting is assumed by CIMR, we set ζ_p and ζ_w so that the coefficients on the output gap and the real wage gap are equal in these two settings.[23] For example, according to Calvo pricing, the linearized new Keynesian Phillips curve, which is the counterpart to (110), is

$$-\widehat{\pi}_t+\beta \mathrm{E}_t\widehat{\pi}_{t+1}+\frac{\left(1-\xi_p\right)\left(1-\beta\xi_p\right)}{\xi_p}\widehat{\phi}_t=0.$$

Because ξ_p is assumed to be 0.63 by CIMR, we set ζ_p to 27.454. Similarly, we set ζ_w to 199.0819.

[23] Roberts (1995) shows that the linearized versions of the new Keynesian Phillips curve based on these two assumptions are equivalent.

Concerning μ, although it is straightforward to incorporate trend growth in the model, we assume an average trend growth rate of zero so that we can examine the effect of anticipated shocks without having to worry about scaling. However, this does not affect the results.

For investment growth adjustment costs, we assume a slightly different functional form from that used by CIMR. Given that the aim of this paper is to determine whether the expectation–driven business cycle can be generated from empirically plausible parameters, we instead use the standard functional form for investment adjustment costs adopted by Christiano et al. (2005) and Smets and Wouters (2003). Therefore, S" is set to the estimated value reported in Christiano et al. (2005).

Furthermore, instead of following CIMR in assuming the partial indexation of prices and wages, we obtain results based on both full–indexation and no indexation. In the full–indexation case, the Rotemberg–type adjustment cost is written as

$$\frac{\zeta_p}{2}\left(\frac{P_{j,t}}{P_{j,t-1}}/\frac{P_{t-1}}{P_{t-2}}-1\right)^2 Y_t.$$

A similar functional form is used for wage adjustment costs.

When the real model is simulated, we choose large values for θ_p , θ_w and η and choose values for ζ_p and ζ_w that are close to zero. Furthermore, we alter the monetary policy rule from one based on the one–period ahead inflation rate to one based on the current inflation rate.

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