

Understanding Expectation-Driven Fluctuations

— A Labor-Market Approach*

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Abstract

This paper presents a unified analysis of neoclassical models that can generate expectation-driven business cycles under anticipated future technology shocks (or news shocks). It shows that the ability or inability of various RBC models to generate positive comovement of aggregate variables hinges crucially on the structure of the labor market equilibrium. The analysis provides a simple and intuitive guide to understanding the existing literature and to searching for new models that can explain the data under news shocks.

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1 Introduction

Recently, there has been a revival of interest in the hypothesis that news about future technology shocks can generate business cycles, regardless of whether the news is later rectified or not (see, e.g., Beaudry and Portier 2004, 2006, 2007, Jaimovich and Rebelo 2009). This literature takes on a different approach to understanding expectations-driven business cycles from the traditional sunspot literature. The sunspot literature emphasizes self-fulfilling expectations as an equilibrium outcome within the rational expectations framework. Within this framework, random changes in expectations can serve as an independent source of business cycles aside from shocks to fundamentals. On the other hand, the "news shock" literature does not require the economy to have self-fulfilling expectations equilibria. It only requires an information structure under which future shocks are anticipated.

Forward looking agents have the incentive to react to news about future fundamental shocks even before the shocks are realized. The question is: Can such anticipative reactions generate dynamic movements that resemble the business cycle? Beaudry and Portier (2006) provided empirical evidence from the stock market that such anticipative reactions to future productivity changes could generate business cycles¹. Yet, it turns out that it is quite difficult for standard real business cycle (RBC) models to generate business cycle comovements under news shocks.

This difficulty was first acknowledged by Barro and King (1984), and confirmed later by many other researchers.² The objective of this paper is to provide a synthetic and unifying analysis on the conditions under which news about future technology shocks can generate business cycle comovement (among consumption, hours, investment, and output) within the standard framework of constant returns to scale production technologies. These conditions are characterized intuitively by using labor market diagrams.

The remainder of the paper is organized as follows. Section 2 discusses the intuition for news shocks to generate business cycle comovements using labor market diagrams. Sections 3-6 discuss specific models that correspond to the analysis in Section 2. Section 7 concludes

the paper.

2 Intuition

Three key points need to be emphasized in order to understand the issues and the challenges at hand. First, a future (unrealized) technology shock is the same as a future (unrealized) income shock. Under the permanent income theory, forward-looking consumers have incentives to respond to news about such shocks in the present. Since future shocks are not materialized in the present, any reactions to news from consumers are equivalent to autonomous changes in current consumption demand (without any changes in the current fundamentals). This suggests that news shocks act very much like autonomous consumption demand shocks. Hence, if a model is able to generate business cycles under autonomous consumption demand shocks, it would also be able to generate business cycles under news shocks. Therefore, the difficulty for standard RBC models to generate business cycles under news shocks is associated with the well-known difficulty of generating business cycles under consumption demand shocks. One of the particular challenges has been to generate procyclical labor productivity under constant returns to scale technologies.³ Currently, news-shock literature ignores this challenge and emphasizes only the explanation of positive comovements among consumption, labor, investment, and output. This paper follows the existing literature in this respect.

Second, given the aggregate resource constraint where consumption plus investment equals output, comovement between consumption and investment automatically implies comovement between consumption and output as well as comovement between investment and output. Since output is produced by labor, this also implies comovement with labor. However, the converse is not true. That is, comovement between consumption and output (or labor) does not necessarily imply comovement with investment because consumption can crowd out savings. This suggests that business cycle comovements are guaranteed if consumption and investment are assumed to be complements, as in the model of Beaudry and

Portier (2004, 2007). However, it may be desirable to construct models in which consumption and investment are not complements by assumption, but are instead derived from a deeper microfoundation. This leaves us with only one option— finding models that can generate comovement between consumption and labor.

Third, positive comovements among consumption, labor, and investment do not necessarily imply *positive* responses to good news about future technology changes. For example, it is possible to generate recessionary rather than expansionary responses to news about future technology progress, yet the variables move together in the same direction. Therefore, the requirement for generating positive responses to good news imposes an additional constraint on model builders.

With these three key points in mind, we now turn to the labor-market diagrammatic analysis. In a standard neoclassical model with a log-separable utility function, an autonomous rise in consumption leads to an increase in leisure and a decrease in labor supply. Unless firms increase labor demand significantly to induce a strong substitution effect on leisure, it is impossible to generate comovement between consumption and labor (or output) under news shocks. One possibility for resolving this problem is to abandon the log-separable utility function, as in Jaimovich and Rebelo (2009) have done. However, there are also other possibilities, which amount to increasing firms' labor demands and the real wages to induce a strong enough substitution effect on leisure.

[INSERT FIGURE 1]

Consider Figure 1. The $D-D$ curve represents the labor demand curve. In standard RBC models, the labor demand curve slopes down because of diminishing marginal product of labor. The $S-S$ curve represents the labor supply curve. For a given consumption level, high wages induce the household to supply more labor (assuming the substitution effect dominates). Hence, the labor supply curve slopes up. In such a case, an autonomous increase in consumption shifts the labor supply curve upward to $S'-S'$. Since the capital stock is predetermined, the labor demand curve will not shift. Therefore, as the figure shows, in

equilibrium an increase in consumption will always result in an opposite movement in labor along the labor demand curve. Output will also decrease accordingly. By the resource constraint, an increase in consumption together with a decrease in output will always lead to a decrease in investment. Hence, the standard RBC model cannot generate comovements under news shocks.

However, there are many possible ways to alter the equilibrium outcome in Figure 1. Figure 2 illustrates several possibilities in which an increase in consumption leads to an increase in labor in equilibrium. These possibilities are classified into two groups: one with normally sloped labor supply and demand curves, and the other with "abnormally" sloped labor supply and demand curves. It will be shown that all of these possible cases can find correspondence in RBC models with constant returns to scale production technologies.

[INSERT FIGURE 2]

In window (a), both labor supply and demand curves have normal slopes and an autonomous increase in consumption shifts the labor supply curve upward. However, there is also a simultaneous upward shift of the labor demand curve. As long as the shift in the labor demand curve is larger than the shift in the labor supply curve, labor (and real wage) will increase in equilibrium. In window (b), both labor supply and demand curves have normal slopes, but an increase in consumption shifts the labor supply curve downward. With the labor demand curve relatively fixed, this can lead to higher labor in equilibrium. In window (c), the labor demand curve has a normal slope but the labor supply curve slopes down and is steeper than the demand curve. In this case, increases in consumption that shift the supply curve upward will lead to increases in equilibrium labor and the real wage. In window (d), the labor supply curve has a normal slope, but the labor demand curve slopes up and is steeper than the supply curve. In this case, increases in consumption that shift the supply curve upward will lead to increases in equilibrium labor and the real wage.

It can be shown that certain types of standard RBC models imply a downward sloping wage-hours locus that represents a reduced-form labor supply curve, or an upward sloping

wage-hours locus that represents a reduced-form labor demand curve. In such cases, the diagrammatic analyses in windows (c) and (d) can be utilized for understanding comovements. With this in mind, it will be shown that each possible configuration presented in Figure 2 corresponds to some DSGE models with constant returns to scale technologies and a unique saddle path equilibrium. These models will be discussed in the order shown in Figure 2. Some of these models are taken from the existing literature while others are newly constructed in this paper. The main objective is to use the labor market diagram as a unifying framework for the analysis.

3 Models with Labor Demand Curve Shifting Upward

In a standard RBC model, the labor demand curve is determined by the familiar first-order condition,

$$w_t = (1 - \alpha)K_t^\alpha N_t^{-\alpha},$$

where w is the real wage, K is the predetermined capital stock and N is labor. Log-linearizing this first-order condition around a steady state gives

$$\hat{w}_t = \alpha \hat{K}_t - \alpha \hat{N}_t,$$

where the circumflex denotes log deviation from the steady state. The linearized labor demand curve is downward sloping. Since the capital stock is predetermined, the curve does not shift when the labor supply curve shifts in Figure 1.

There are many ways to make the labor demand curve shift in response to an autonomous change in consumption. One possibility is to introduce variable capacity utilization (e.g., Greenwood, Hercowitz and Huffman 1988, Yi 1998) so that the labor demand function becomes

$$\hat{w}_t = \alpha \hat{e}_t + \alpha \hat{K}_t - \alpha \hat{N}_t, \tag{1}$$

where e_t denotes the utilization rate of capital. If it is possible to construct a model in which the capacity utilization rate depends positively on consumption, then the model has the potential to generate comovement under news shocks (as shown in window (a) of Figure 2). It turns out that the model of Jaimovich and Rebelo (2009) belongs to this class of models where the capital utilization rate depends positively on consumption.

Another possibility is to introduce imperfect competition so that the labor demand function becomes

$$\hat{w}_t = \hat{\phi}_t + \alpha \hat{K}_t - \alpha \hat{N}_t, \quad (2)$$

where ϕ_t is the marginal cost. If it is possible to construct a model in which the marginal cost depends positively on consumption, then this model also has the potential to generate comovement under news shocks. It turns out that a version of the Calvo sticky price model is one such model. The two possibilities are discussed separately below.

3.1 The Model of Jaimovich and Rebelo (2009)

A simple version of Jaimovich and Rebelo's model (2009) can be described as a social planner's problem in which the planner solves

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \log \left[C_t - A_n \frac{N_t^{1+\gamma_n}}{1+\gamma_n} \right]$$

subject to

$$C_t + I_t = (e_t K_t)^\alpha N_t^{1-\alpha},$$

$$K_{t+1} = I_t [1 - \varphi(I_t/I_{t-1})] + [1 - \delta(e_t)] K_t.$$

where e_t is capacity utilization, $\delta(e_t)$ is the rate of capital depreciation endogenously determined by capacity utilization, and $I_t \varphi(I_t/I_{t-1})$ is an adjustment cost function in investment. To simplify notations, the technology shock term in the production function is ignored. This model has three distinctive features: a utility function that yields no income effect on con-

sumption, variable capacity utilization, and dynamic adjustment cost in investment. This utility function implies that an increase in consumption does not shift the labor supply curve. Such a feature alleviates the problem of negative comovement between consumption and labor supply. The dynamic adjustment cost implies a desire to smooth investment intertemporally. Given that there is an anticipated change in future technology, firms will anticipate future increases in investment. However, an increase in future investment creates a desire to increase the current investment due to adjustment costs. These features make the capacity utilization rate an increasing function of consumption and future investment. Hence, capacity utilization will increase in response to an autonomous increase in current consumption and shift the labor demand curve upward.

To view this analytically, it is useful to derive the reduced-form labor demand curve, which is⁴

$$\hat{w}_t = \frac{\alpha\mu(1+\beta)\frac{C_Y}{I_Y}\hat{C}_t + \beta\mu\alpha\hat{I}_{t+1}}{\theta - \alpha + \alpha\mu(1+\beta)/I_Y} + \left[\frac{(1-\alpha)\theta}{\theta - \alpha + \alpha\mu(1+\beta)/I_Y} - 1 \right] \hat{N}_t, \quad (3)$$

where $\mu = \varphi''(1)$, $\theta = \frac{\bar{u}\delta'}{\delta}$. The labor demand curve is downward sloping, and both consumption \hat{C}_t and future investment \hat{I}_{t+1} enter the intercept term. The labor supply curve of this model is given by

$$\hat{w}_t = \gamma_n \hat{N}_t. \quad (4)$$

Suppose agents anticipate a future technology shock. Consumption increases. This will shift the labor demand curve upward while the labor supply curve is unchanged. In equilibrium, both consumption and labor increase. Meanwhile, \hat{I}_{t+1} also increases, making the labor demand curve shift even more. Therefore, the model is able to generate positive comovements as well as positive responses.

Capacity utilization is crucial in this model. Without capacity utilization, the intercept term of the labor demand curve will disappear and the labor demand curve will no longer respond to news shocks. However, capacity utilization is not sufficient. The utility function

and investment adjustment costs are also important. For example, with a standard utility function, the labor supply curve will shift up when consumption increases. Thus, the labor demand curve has to shift up much more in order to generate an increase in labor. On the other hand, if there is no adjustment cost, capacity utilization will be a function of labor only and become independent of consumption.⁵ An increase in consumption will not shift the labor demand curve nor the labor supply curve. Consequently, labor and output will not change. This implies that investment will be crowded out by consumption if there are no adjustment costs of investment. To calibrate the model, set $\gamma_n = 0.4$, $\theta = \frac{\bar{u}\delta'}{\delta} = 1.15$ as in Jaimovich and Rebelo (2009), and set $\varphi''(1) = \mu = 1.5$, which is slightly higher than the one used in their model. The calibrated parameter values are summarized in Table 1.

[INSERT TABLE 1]

The impulse responses of the model to an anticipated TFP shock that will be realized four periods later are graphed in Figure 3. Notice that the model generates not only positive comovements but also positive responses for all variables⁶.

[INSERT FIGURE 3]

3.2 The Sticky Price Model

It is well known that sticky prices can generate endogenous markup and time-varying marginal cost. Since a future technology shock will increase future output, the future price level will decrease. This means in a standard Calvo-type sticky price model, firms have incentives to decrease prices today in anticipation of a future technology shock. This leads to a fall in the desired markup and an increase in the real marginal cost ϕ in equation (2), which shifts the labor demand curve upward. If the shift is large enough, consumption and labor will comove.

Consider a standard sticky price model where the final goods are produced using the technology $Y = \left[\int_0^1 Y(i)^{\frac{\sigma-1}{\sigma}} di \right]^{\frac{\sigma}{\sigma-1}}$, and the intermediate goods are produced by monopolists using the technology $Y(i) = K(i)^\alpha N(i)^{1-\alpha}$. An intermediate firm adjusts its price in each period with a probability of θ . Assume that money is introduced into the economy by a general cash-in-advance (CIA) constraint, $\lambda \hat{C} + (1 - \lambda) \hat{I} \leq \hat{M} - \hat{P}$, where $\lambda \in [0, 1]$, M is the aggregate money supply and P is the general price level.⁷

The log-linearized aggregate labor demand curve is

$$\hat{w}_t = \hat{\phi}_t + \alpha \hat{K}_t - \alpha \hat{N}_t, \quad (5)$$

where the marginal cost ϕ enters as an intercept term in the labor demand curve. The marginal cost is linked to the rate of inflation by the Phillips curve, $\hat{\pi}_t = \beta E_t \hat{\pi}_{t+1} + \kappa \hat{\phi}_t$, where $\kappa = \frac{(1-\theta)(1-\beta\theta)}{\theta} > 0$. The CIA constraint implies a relationship between inflation and changes in future consumption and investment spending. Substituting this constraint into the Phillips curve gives the relationship between the marginal cost and the aggregate demand, which leads to the following labor demand curve,

$$\begin{aligned} \hat{w}_t = & \left\{ \beta[(1 - \lambda) \hat{I}_{t+1} + \lambda \hat{C}_{t+1}] + (1 + \beta) \frac{(1 - \lambda) C_Y - \lambda I_Y}{I_Y} \hat{C}_t \right\} \frac{1}{\kappa} \\ & - \left[\alpha + \frac{(1 + \beta)(1 - \lambda)(1 - \alpha) \hat{N}_t}{\kappa I_Y} \right] \hat{N}_t. \end{aligned}$$

In this case, an increase in current consumption together with increases in future consumption and investment will shift the labor demand curve upward. The smaller the parameter λ , the larger the shift. Hence, the model can explain the comovement among consumption, labor, investment, and output (see Figure 4).⁸ A difference between this model and the model of Jaimovich and Rebelo (2009) is that the labor response becomes negative when the technology shock is realized in period 5. This suggests that unanticipated technology shocks generate negative labor responses in sticky price models, a prediction consistent with

the recent empirical findings (see Galí 1999, Basu, Fernald and Kimball 2006).

[INSERT FIGURE 4]

4 Models with Labor Supply Curve Shifting Downward

In a standard RBC model with separable preferences, $U = \frac{C^{1-\gamma}}{1-\gamma} - A_n \frac{N_t^{1+\gamma_n}}{1+\gamma_n}$, the labor supply function is determined by the equation,

$$\hat{w}_t = \hat{C}_t + \gamma_n N_t,$$

where $\gamma_n \geq 0$ is the inverse elasticity of labor supply. This supply curve is upward sloping with consumption as the curve shifter. Suppose it is possible to introduce a new shifting variable, X_t , into the labor supply function such that X_t moves in the opposite direction of current consumption, then the model has the potential to generate comovement under news shocks. It turns out that the habit formation model of Christiano, Motto, and Rostagno (2006) is one such model. When consumers are habit forming, future consumption enters the labor supply function as an additional shift variable aside from the current consumption. When there is an anticipated change in future income, the movement in future consumption may exceed the movement in current consumption. Thus, the labor supply curve can shift downward.

To see this, consider an economy in which a representative household solves

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{(C_t - \eta C_{t-1})^{1-\gamma}}{1-\gamma} - A_n \frac{N_t^{1+\gamma_n}}{1+\gamma_n} \right]$$

subject to

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

where $\varphi(\frac{I_t}{I_{t-1}})I_t$ is the adjustment cost in investment, such that $\varphi(1) = 0$, $\varphi'(1) = 0$ and $\varphi''(1) = \mu$. The log-linearized labor demand curve is the same as the one in the standard RBC model

$$\hat{w}_t = \alpha \hat{K}_t - \alpha \hat{N}_t; \tag{6}$$

while the labor supply curve changes to

$$\hat{w}_t = \gamma(1 + \tilde{\eta} + \beta\tilde{\eta})\hat{C}_t - \beta\gamma\tilde{\eta}E_t\hat{C}_{t+1} - \gamma\tilde{\eta}\hat{C}_{t-1} + \gamma_n\hat{N}_t, \tag{7}$$

where $\tilde{\eta} = \eta/[(1 - \beta\eta)(1 - \eta)]$. Due to habit formation, the real wage is negatively affected by future consumption. If a rise in consumption today is followed by a larger rise in consumption tomorrow, the labor supply curve will shift downward and lead to higher employment and output in equilibrium.

[INSERT FIGURE 5]

Habit formation alone without investment adjustment costs can generate positive comovement if γ is sufficiently small. For example, if the utility function is almost linear in consumption ($\gamma = 0.3, \eta = 0.8$), the model can generate positive comovements. For large γ , positive comovement requires both habit formation and investment adjustment costs. The investment adjustment cost is helpful for two reasons. First, the presence of investment adjustment cost implies that crowding out investment is less desirable when consumption rises. Compared with models without adjustment cost, the magnitude of the increase in current consumption is reduced. Second, given that when the future TFP shock realizes the total supply of goods will increase, the presence of adjustment cost means that a sharp increase in investment in the future is also less desirable. As a result, the magnitude of the

increase in future consumption is larger. These two effects together imply that it is easier for future consumption to increase more than current consumption. The impulse responses are shown in Figure 5.⁹ Similar to the sticky price model, this model is able to generate positive comovements before the future TFP shock is realized, and labor decreases temporarily after the shock is realized.

5 Models with Downward Sloping Labor Supply Curve

One way to make the reduced-form labor supply curve slope downward is to find a model in which a shift variable (X) of the labor supply curve is a negative function of the number of hours worked,

$$\hat{w}_t = \gamma \hat{C}_t + \hat{X}(N_t) + \gamma_n \hat{N}_t,$$

where $\frac{d \log X}{d \log N} < -\gamma_n$. In this case, the reduced-form labor supply curve becomes downward sloping,

$$\hat{w}_t = \gamma \hat{C}_t - \tilde{\eta} \hat{N}_t,$$

where $\tilde{\eta} = \frac{d \log X}{d \log N} - \gamma_n > 0$. It turns out that the model of Beaudry and Portier (2007) falls into this class of models.¹⁰ Their model can be described as a social planner's problem in which the planner solves:

$$\max E_0 \sum_{t=0}^{\infty} \beta^t [\log C_t - A_n N_t]$$

subject to

$$(C_t^\sigma + I_t^\sigma)^{\frac{1}{\sigma}} = A_t K_t^\alpha N_t^{1-\alpha},$$

$$K_{t+1} = I_t + (1 - \delta)K_t,$$

where $\sigma > 1$ is the measure of complementarity between consumption and investment. If σ is infinite, the optimal allocation consumption is always equal to the investment, and

the resource constraint becomes $C_t = I_t = A_t K_t^\alpha N_t^{1-\alpha}$. In this extreme case, a change in consumption leads to an equal change in investment. By the resource constraint, labor has to change in the same direction.

To examine the ability of this model to generate comovement for a realistic value of σ , it is useful to consider the labor market equilibrium condition. The labor demand curve is given by

$$\hat{w}_t = \alpha \hat{K}_t - \alpha \hat{N}_t, \quad (8)$$

while the reduced-form labor supply curve is given by

$$\hat{w}_t = \hat{C}_t + \frac{(1-\sigma)}{\sigma} \hat{N}_t. \quad (9)$$

Clearly, if σ is large enough ($\sigma > \frac{1}{1-\alpha}$), the slope of the reduced-form labor supply curve becomes negative and steeper than the labor demand curve as shown in window (c) of Figure 2. In such a case, an increase in consumption leads to an increase in labor in equilibrium. The implied change in output is $\Delta \hat{Y}_t = \frac{\sigma(1-\alpha)}{(\sigma-1)(1-\alpha)-\alpha} \Delta \hat{C}_t$. Hence, as long as $(\sigma-1)(1-\alpha) > \alpha$ and $\alpha < \frac{1}{2}$, we have $\Delta \hat{Y}_t > \Delta \hat{C}_t$. When the change in output is larger than the change in consumption, the resource constraint then implies an increase in investment. The impulse responses to a future TFP shock that will be realized four periods from now are graphed in Figure 6, where $\sigma = 1.65$ (as in Beaudry and Portier 2007) and the other parameters are the same as in Table 1.

[INSERT FIGURE 6]

Figure 6 shows that the model is able to generate comovements. However, this model implies a counter-factual recession rather than a boom when a positive future TFP shock is anticipated. The negative impulse responses to an anticipated future TFP shock imply that households have stronger incentives to increase leisure rather than consumption. This is

because a one percentage increase in consumption requires a similar increase in investment due to the complementarity between consumption and investment, which requires a very large increase in labor due to the diminished marginal product of labor. This may not yield as much utility in comparison to an increase in leisure. Hence, households would prefer choose to decrease consumption and investment.

However, allowing for investment adjustment cost in this model can resolve this problem. Assume $K_{t+1} = I_t[1 - \varphi(I_t/I_{t-1})] + (1 - \delta)K_t$, where $\varphi(1) = \varphi'(1) = 0$ and $\varphi''(1) = \mu > 0$. The labor market equilibrium condition is not affected by this change. Consequently, the model's ability to generate comovements is not affected. However, as discussed earlier, the presence of investment adjustment cost implies that current investment and future investment are complements. Since a positive future technology shock will increase future investment, reducing current investment would not be optimal if μ is large enough. In this case, consumption would also increase. The impulse responses for $\mu = 10$ and $\sigma = 5$ are graphed in Figure 7, which shows positive responses from all variables to a future TFP shock.

[INSERT FIGURE 7]

6 Models with Upward Sloping Labor Demand Curve

Analogous to the reduced-form downward sloping labor supply curve, if one can find a model in which the shift variable of the labor demand curve (X) is a positive function of the number of hours worked,

$$\hat{w}_t = \hat{X}(N_t) + \alpha \hat{K}_t - \alpha \hat{N}_t,$$

where $\frac{d \log X}{d \log N} = \omega > \alpha$, such that the reduced-form labor demand curve becomes upward sloping,

$$\hat{w}_t = \alpha \hat{K}_t + (\omega - \alpha) \hat{N}_t,$$

with $(\omega - \alpha) > 0$, then the model has the potential to generate positive comovements under news shocks.

In this section, a model with imperfect competition is constructed, in which the marginal cost $\phi_t(N)$ is a positive function of the number of hours worked with elasticity $\frac{d \log \phi}{d \log N} > \alpha^{11}$. Since the household problem is standard, the focus is on the production side in the following discussion.

The production consists of two sectors. In the final good sector, firms use capital K_t and a continuum of intermediate goods to produce final goods. Motivated by the deep-habit model of Ravn, Schmitt-Grohe, and Uribe (2006), the technologies for the final good sector are given by

$$Y_t = AK_t^\alpha Z_t^{1-\alpha},$$

where

$$Z_t - b = \left[\int_0^1 (y_t(i) - b)^{\frac{\sigma-1}{\sigma}} di \right]^{\frac{\sigma}{\sigma-1}}.$$

If Z_t enters the utility function directly, this specification is then a variation of the deep-habit model. If $b = 0$, this specification is the Dixit-Stiglitz monopolistic competition model with constant price elasticity. The presence of $b > 0$ gives rise to counter-cyclical markup in a way similar to the deep-habit model of Ravn, Schmitt-Grohe, and Uribe (2006). In a symmetric equilibrium, $y_t(i) = y_t(j)$, which means that this production technology exhibits constant return to scale; hence, the final good producer earns zero profit. For notational convenience, it is useful to define a price index $P_{Z,t} = \left[\int_0^1 p_t^{1-\sigma}(i) di \right]^{1-\sigma}$. The first order condition implies $P_{Z,t} = (1 - \alpha)Y_t/Z_t$. The demand for each intermediate $y_t(i)$ can be written as

$$y_t(i) = \left[\frac{p_t(i)}{P_{Z,t}} \right]^{-\sigma} (Z_t - b) + b.$$

The firm's problem is to choose a price $p_t(i)$ that solves

$$\max_{p_t(i)} [p_t(i) - w_t] \left\{ \left[\frac{p_t(i)}{P_{X,t}} \right]^{-\sigma} (Z_t - b) + b \right\}.$$

The optimal price is determined by the equation

$$\left\{ \frac{p_t^{-\sigma}(i)(Z_t - b)}{P_{Z,t}^{-\sigma}} + b \right\} = \sigma \frac{p_t(i) - w_t}{p_t(i)} \frac{p_t^{-\sigma}(i)(Z_t - b)}{P_{Z,t}^{-\sigma}}.$$

In a symmetric equilibrium, $p_t(i) = P_{Z,t}$ and $Z_t = N_t$. This implies the total production of final goods is $Y_t = A_t K_t^\alpha N_t^{1-\alpha}$ and the real wage is

$$w_t = (1 - \alpha) \left[1 - \frac{1}{\sigma} \frac{N_t}{N_t - b} \right] \frac{Y_t}{N_t}.$$

The marginal cost is determined by $\phi_t = 1 - \frac{1}{\sigma} \frac{N_t}{N_t - b}$, where N is the steady-state value of labor. By normalizing $b = \tilde{b}N$, we see that ϕ_t is an increasing function of N_t . The elasticity of the marginal cost to labor is obtained as follows

$$\hat{\phi}_t = \frac{\tilde{b}}{1 - \tilde{b}} \frac{1}{(1 - \tilde{b})\sigma - 1} \hat{N}_t = \omega \hat{N}_t.$$

Suppose attention is limited to the calibrated value of $(1 - \tilde{b})\sigma = 10$, which implies an average markup of 10% in the steady-state, then ω depends only on \tilde{b} . In such a case, note that if \tilde{b} approaches one, ω approaches infinity. Given this, the model is able to generate an upward sloping reduced-form labor demand curve with a slope that is steeper than that of the labor supply curve. Consequently, the model can explain the positive comovement among consumption, labor, investment, and output.

To see this, consider the reduced-form labor demand curve,

$$\hat{w}_t = \alpha \hat{K}_t + (\omega - \alpha) \hat{N}_t, \tag{10}$$

where $\omega > 0$. For large values of ω such that $\omega > \alpha$, an abnormal labor demand curve is obtained, as shown in window (d) of Figure 2. In such a case, a shift in the demand curve due to higher consumption can lead to higher labor in equilibrium.

Whether investment is able to comove with consumption or not depends on how much output can increase. By the labor market equilibrium condition, we obtain $\hat{N}_t = \frac{1}{\omega - \alpha - \gamma_n} \hat{C}_t$, and by the production function we have $\hat{Y}_t = \frac{1-\alpha}{\omega - \alpha - \gamma_n} \hat{C}_t$. The resource constraint implies $\hat{I}_t = \left(\hat{Y}_t - C_Y \hat{C}_t \right) / I_Y$, where C_Y is the steady-state consumption share and I_Y is the investment share. In order for both consumption and investment to increase, it must be true that $\frac{1-\alpha}{\omega - \alpha - \gamma_n} > C_Y$. This condition is easily satisfied in the model because any value of ω satisfying $\alpha + \gamma_n < \omega < \frac{1-\alpha}{C_Y} + \alpha + \gamma_n$ will meet this condition. Hence, the model is capable of generating expectation-driven business cycles for a large range of parameter values.

Although the model has an upward sloping labor demand curve if ω is large enough, it does not exhibit indeterminacy as the Benhabib and Farmer (1994) model does.¹² However, there is a parameter range, $\omega_l \leq \omega \leq \omega_h$, where the model tends to be explosive and has no solution. For the parameter values in Table 1, $\omega_l \simeq 0.39$ and $\omega_h \simeq 1$. Therefore, we can set $\omega = 1.1$ to ensure stationarity. The rest of the parameters are set as in Table 1, which are standard in the literature. The implied consumption output ratio in the steady state is $C_Y = 0.76$ and the output consumption elasticity in this case is $\frac{1-\alpha}{\omega - \alpha - \gamma_n} = 0.87 > C_Y$. The impulse responses to an anticipated future TFP shock are depicted in Figure 8. The picture shows that output, labor, consumption, and investment all increase and comove together in responding to a future TFP shock.

[INSERT FIGURE 8]

Summary. To facilitate the comparison of different models, the findings thus far are summarized in Table 2. The signs impulse responses of different models to a future TFP shock are shown. As Beaudry and Portier (2006) have found, output, consumption, labor and investment all increase in the data when response to an anticipated future increase in TFP. However, as the table shows, not all of the models that were considered above can

generate positive responses to positive future TFP shocks, even though all of them can generate positive comovements among these variables. Therefore, the responses to "news shocks" provide an additional litmus test for business cycle models.

[INSERT TABLE 2]

7 Conclusion

In this paper, the labor market diagram has been shown to be a useful tool for studying and constructing business cycle comovements in response to future TFP shocks. Our analysis provides an integrated approach for understanding the conditions under which comovements in different and seemingly unrelated models can be generated. Although this paper has focused on shocks to future TFP, the application of the simple labor market diagram is not limited to that. Responses to non-TFP shocks can also be analyzed using our framework. The labor market diagram also suggests a possible way to differentiate the models in Table 2. For example, in both window (a) and window (d) of Figure 2, the real wage increases under a future TFP shock, while it decreases in both window (b) and (c). Hence a formal evaluation of the real wage dynamics (for example, the model's ability to match the conditional impulse response from a VAR considering future TFP shocks) in these models would be one way to empirically test and differentiate these alternative models. Another future research topic of particular interest is the implication of future monetary policy changes. In an economy where monetary policy is endogenous, the ways that the economy responds to future fundamental shocks also depend on agents' beliefs about how the monetary policy would react to such shocks. In this case, the monetary policy can itself become a source of speculation.

Notes

¹The literature on identifying news shocks has been developing rapidly (see Barsky and Sims 2009, Beaudry and Lucker 2009, Beaudry and Portier 2005, Schmitt-Grohe and Uribe 2008).

²See Cochrane (1994), Danthine, Donaldson, and Johnsen (1998), Beaudry and Portier (2004, 2007), Christiano, Motto, and Rostagno (2006), Den Haan and Kaltenbrunner (2007), Jaimovich and Rebelo (2009), and Kobayashi, Nakajima, and Inaba (2007), among others.

³For literature on generating business cycles with procyclical labor productivity under consumption demand shocks, see Wen (2004).

⁴Some terms such as \hat{I}_{t-1} and \hat{K}_t are ignored since they are zero in the impact period in a log-linear model.

⁵In this case the reduced-form labor demand curve remains downward sloping. The possibility of upward sloping labor demand curves are discussed in Section 7.

⁶Jaimovich and Rebelo (2008) show the same mechanism in the model of Jaimovich and Rebelo (2009) can also explain international comovements.

⁷A similar setup can be found in the model of Wang and Wen (2006) which studies the persistence problem of the sticky price model.

⁸The impulse responses in Figure 4 are obtained under the extreme case of $\lambda = 0$. If $\lambda = 1$ as in the standard CIA model, sticky prices cannot explain comovements unless the utility function is almost to linear in consumption.

⁹The parameter values are set as follows: $\eta = 0.7$, $\mu = 7.6$, $\gamma = 1$ and $\gamma_n = 0$.

¹⁰Their model can also be analyzed by using normally sloped labor supply and demand

curves; however, the analysis becomes much simpler if the reduced-form is used.

¹¹The endogenous markup model in this section yields an upward-sloping labor demand curve in the reduced form regardless of the type of shocks. Hence the model has the ability to generate comovements in response to any future shocks. In the sticky price model in section 3.2, the direction of the markup (as a shifting term in the labor demand curve) depends on the type of future shocks. Hence the ability of sticky price model to generate comovements in response to future shocks would depend on the types of shocks.

¹²The labor diagram that Benhabib and Farmer used is not a sufficient condition for indeterminacy. For example, their model with investment adjustment costs still has an upward sloping labor demand curve, but it is determinate (see Wen 2001).

Table

Table 1. Calibrated Parameter Values

Model	Parameter Values
A. Jaimovich and Rebelo (2009)	
Preference	$\beta = 0.99, \gamma_n = 0.4$
Production	$\alpha = 1/3, \bar{\delta} = 0.025$
B. Sticky Prices (2006)	$\gamma = 1, \gamma_n = 0, \theta = 0.8$
C. Christiano et al. (2006)	$\gamma_n = 0, \eta = 0.7, \mu = 7.6$
D. Beaudry and Portier (2007)	
without adjustment cost	$\sigma = 1.65$
with adjustment cost	$\sigma = 5, \mu = 10$
E. Model with endogenous Markup	$\omega = 1.1$

Table 2. Impulse Responses of Different Models

Model	\hat{Y}_t	\hat{N}_t	\hat{C}_t	\hat{I}_t
A. Jaimovich and Rebelo (2009)	+	+	+	+
B. Sticky Price	+	+	+	\pm
C. Christiano et al. (2006)	+	+	+	+
D. Beaudry and Portier (2007)				
without adjustment cost	-	-	-	-
with adjustment cost	+	+	+	+
E. Model with Endogenous Markup	+	+	+	+

Note: The response of investment in the sticky price model depends on whether investment is subject to the CIA constraint aside from consumption.

Figure

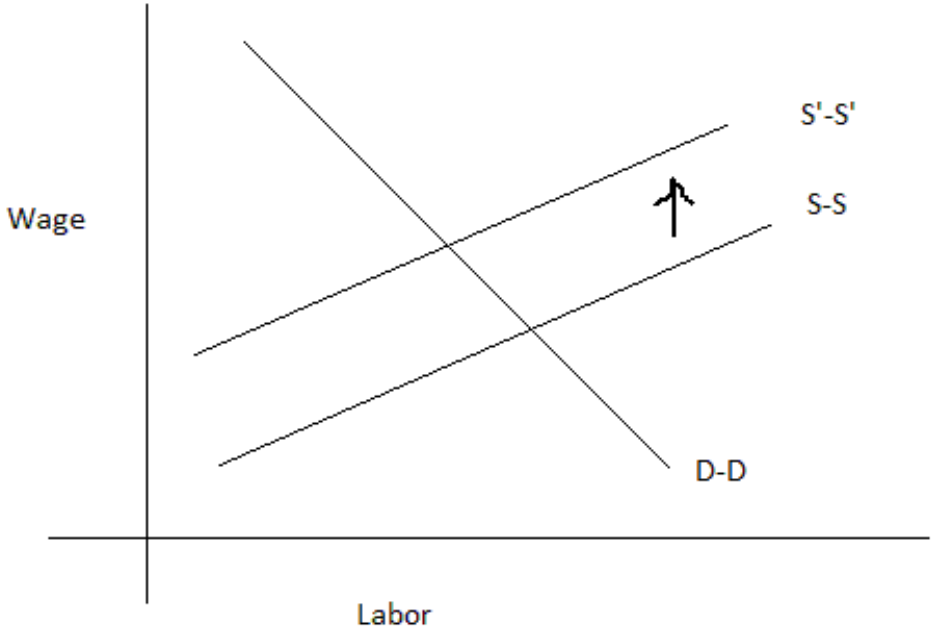


Fig. 1. The effect of an increase in consumption on the labor market

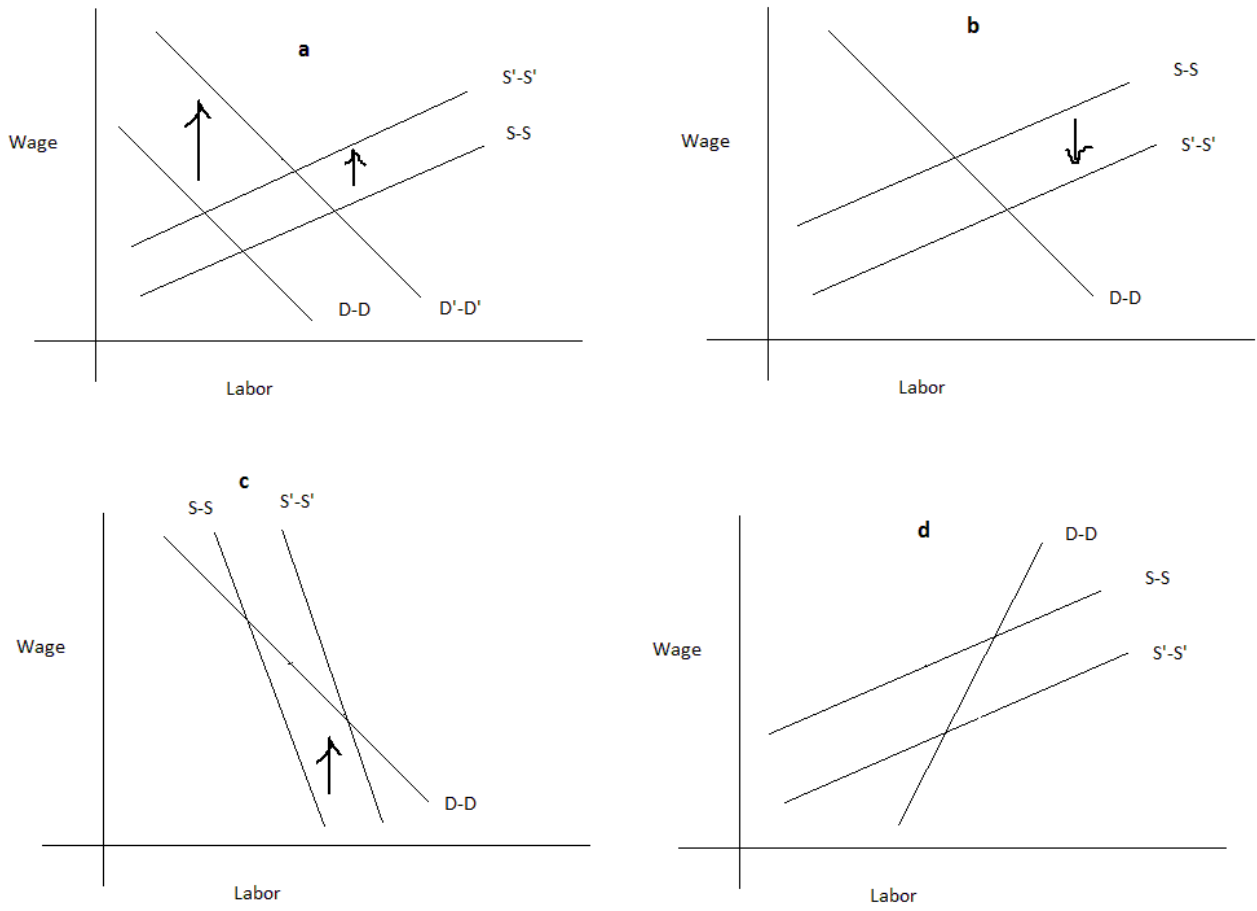


Fig. 2. Possible effects of an autonomous increase in consumption in different models.

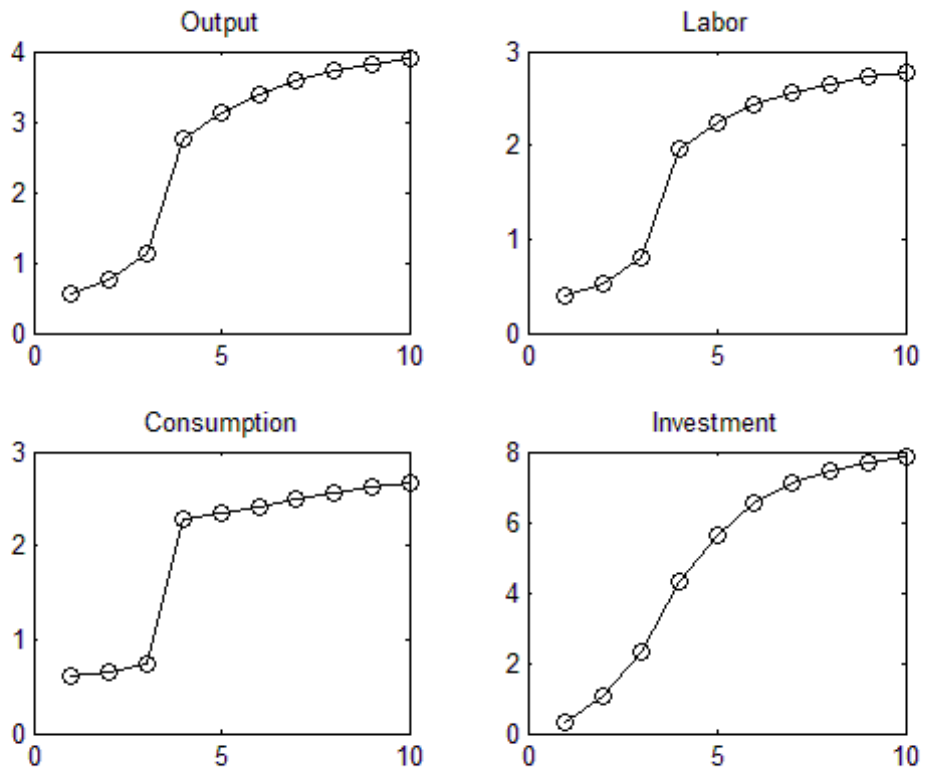


Fig. 3. Impulse response in the Jaimovich-Rebelo model.

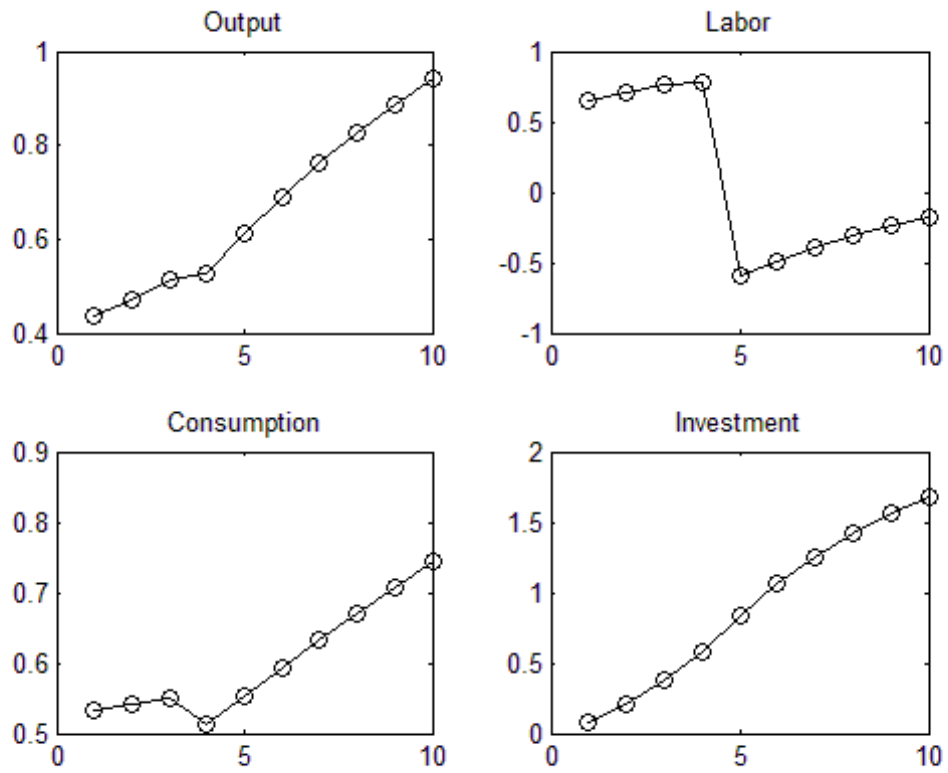


Fig. 4. Impulse responses in the sticky price model.

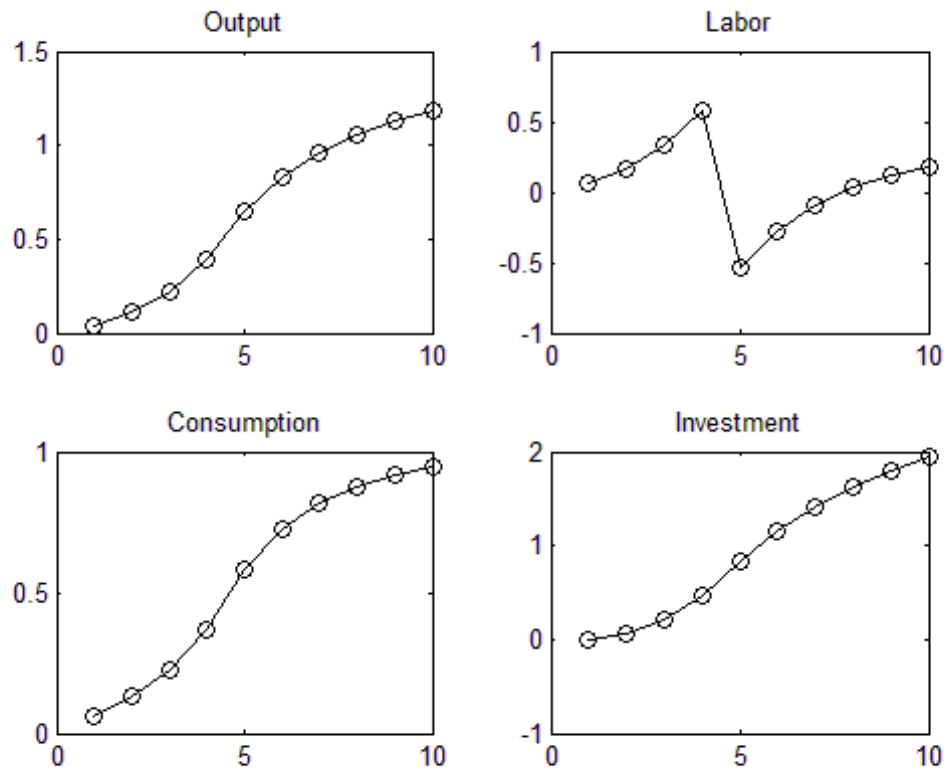


Fig. 5. Impulse responses in the Christiano et al. model.

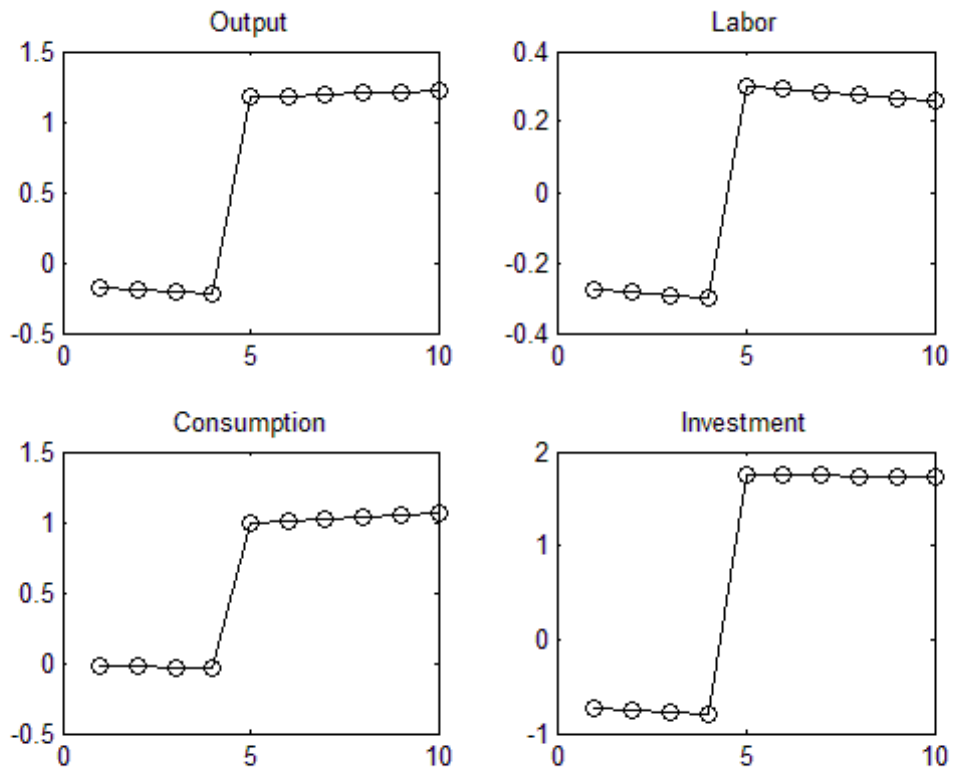


Fig. 6. Impulse responses in the Beaudry-Portier model without adjustment cost.

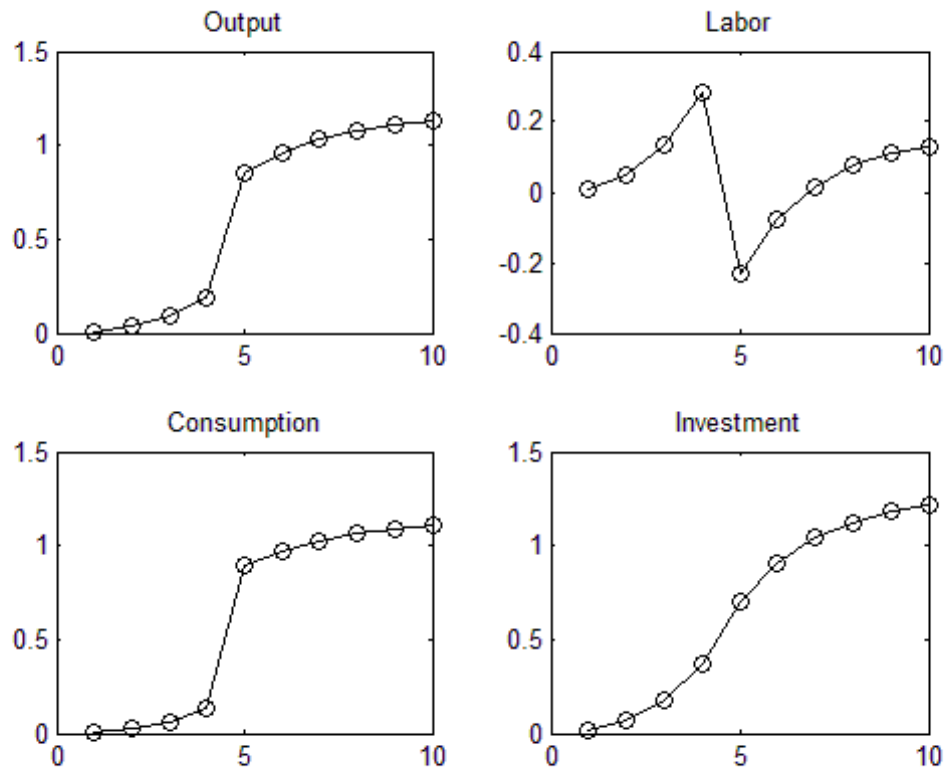


Fig. 7. Impulse responses in the Beaudry-Portier model with adjustment cost.

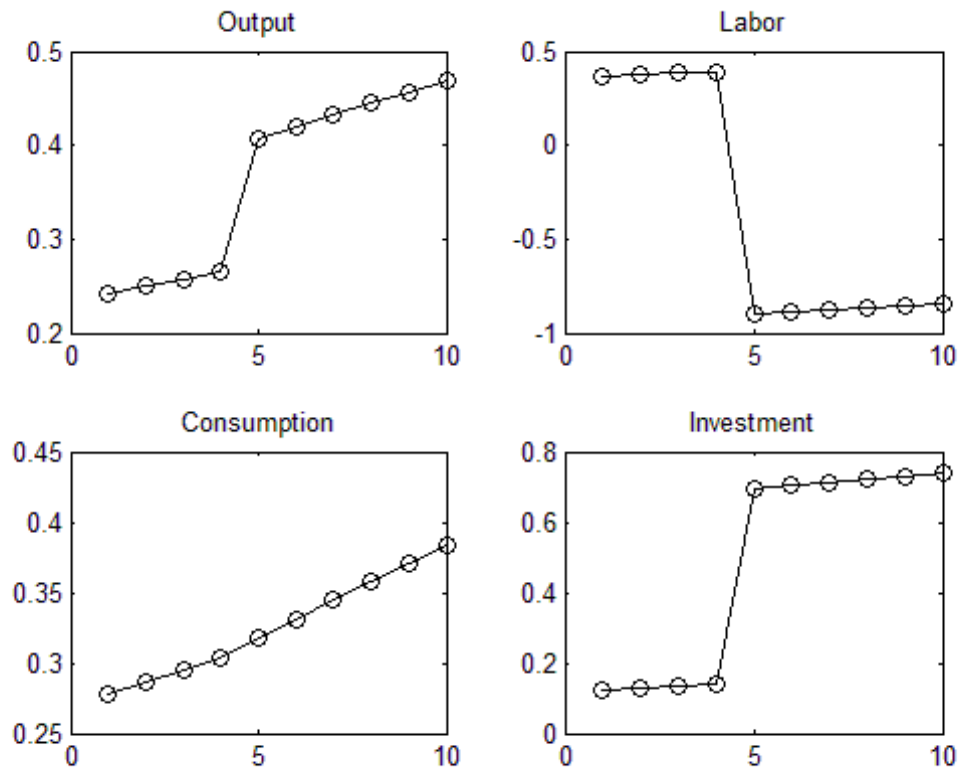


Fig. 8. Impulse responses in the endogenous markup model.

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