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COLLATERAL CONSTRAINT AND NEWS-DRIVEN CYCLES

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We develop business-cycle models with financial constraints, the driving force of which is news about the future (i.e., changes in expectations). We assume that an asset with fixed supply ("land") is used as collateral, and firms need to hold collateral to finance their input costs. The latter feature introduces an interaction between the inefficiencies in the financial market and in the factor market. Good news raises the price of land today, which relaxes the collateral constraint. It, in turn, reduces the inefficiency in the labor market. If this force is sufficiently strong, the equilibrium labor supply increases. So do output, investment, and consumption. Our models also generate procyclical movement in Tobin's Q. We also show that when the news turns out to be wrong, the economy may fall into a recession.

Keywords: News-Driven Cycles, Collateral Constraints, Tobin's Q, Bankruptcies

1. INTRODUCTION

In this paper we develop models of business cycles driven by "news shocks" (i.e., changes in expectations) through financial frictions. The current financial crisis from 2007 through today might be a good example that shows the relevance of such a model. It originated with the collapse of the boom in the U.S. real estate market. On one hand, it is likely that such a large fluctuation in real estate prices reflects, to a large extent, changes in expectations about returns in the future. On the other hand, it would be difficult to understand the large impact on the real

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economy of the real-estate collapse, without considering some form of financial-market frictions. This is our major motivation for building a expectation-driven business-cycle model with financial constraints.

Recently there has been growing interest in examining the role of such news shocks as a driving force of business cycles. The literature includes, among others, Beaudry and Portier (2004, 2007), Christiano and Fujiwara (2006), Christiano et al. (2007), Den Haan and Kaltenbrunner (2009), Jaimovich and Rebelo (2009), and Lorenzoni (2009). As is well known, in the standard real business cycle model, news shocks move consumption and labor in opposite directions due to the wealth effect. For instance, if an increase in the expected level of future productivity raises the present discounted value of income, the consumer increases both consumption and leisure today, and hence reduces labor supply. It follows that output and investment decline as well.

For news shocks to generate business cycles (i.e, comovement between consumption, investment, labor, and output), the papers listed above modify preferences and/or technology from the standard model. For instance, Beaudry and Portier (2004, 2007) introduce a certain type of complementarity between production technologies in a two-sector model; Christiano et al. (2007) introduce habit persistence in consumers' preferences and a specific form of adjustment costs in investment; Jaimovich and Rebelo (2009) assume preferences without income effect on labor supply, the same adjustment cost as Christiano et al. and variable capital utilization.

In this paper, we propose a different mechanism to generate news-driven cycles. Our story is based on collateral constraint, and fluctuations in asset prices play a key role in generating news-driven cycles. We consider an economy with a productive asset with fixed supply ("land"). Producers must pay the costs for inputs, such as labor, in advance of production, and they need external funds to finance them. The amount that they can borrow is limited by the value of the collateral (land and/or capital). Its important consequence is that the collateral constraint makes the allocation of labor inefficient by introducing a wedge between the marginal product of labor and the marginal rate of substitution between leisure and consumption. Furthermore, the wedge becomes greater as the collateral constraint binds more tightly. Thus, the labor market inefficiency and the financial market inefficiency are closely linked.

We consider two models of collateral constraint. For the sake of exposition, we start with a very simple model of collateral constraint, which has a representative household. In this model, news of a productivity increase in the future generates a boom today, as follows. The news raises the price of land today, which relaxes the collateral constraint. Because the input finance is collateral-constrained, the relaxation of the collateral constraint reduces the inefficiency in the labor market (the gap between the wage rate and the marginal product of labor becomes lower). It shifts the labor demand curve outward. If this force is sufficiently strong, it overcomes the wealth effect on the labor supply schedule, and the equilibrium labor supply increases. So do output and investment. Consumption increases because of the wealth effect of the good news. Augmented by adjustment cost of investment, the model also generates procyclical movement in Tobin's Q.

We then consider a version of Carlstrom and Fuerst's (1998) model, which has two types of agents: households (lender) and entrepreneurs (borrowers). Having two types of agents brings about a new feature. In the representative-household model, when the news actually turns out to be false, the economy essentially jumps back to the initial steady state, although there is some transitional dynamics. In particular, false information does not cause a recession: the level of output does not became lower than the steady state level. In our second model, with two types of agents, however, if the information turns out to be wrong, the economy falls into a recession. This is because, when the good news arrives, the price of the collateral asset increases, and hence entrepreneurs need a smaller share of land to achieve the desired value of collateral. Hence, in response to the good news about the future, entrepreneurs sell their land. When the news turns out to be wrong, the land price essentially goes back to its steady state level. However, because the share of land held by entrepreneurs is smaller than the steady state level, the value of their collateral is smaller than the steady state level. It follows that the financial constraint becomes tighter, which increases the labor market inefficiency, and reduces labor, output, and consumption.

In addition to the papers cited above, our paper is also closely related to a recent paper by Jermann and Quadrini (2007). In their model, good news about future productivity stimulates current economic activity because of financial constraint, just as in our model. However, the mechanism is very different. Their economy consists of heterogeneous firms with decreasing returns, whose sizes are constrained by a borrowing constraint. The good news about future productivity relaxes the borrowing constraint, and thereby makes the size distribution of firms in the economy more efficient. This is how such news may generate a boom in their economy. However, given that the firm-size distribution changes only gradually over time, their model is more suitable than our model to account for medium to long-run fluctuations. In this sense, their model and ours should be viewed as complementary rather than substitutes.

The organization of the paper is as follows. In the next section, we describe our first model. The collateral constraint is formalized in the manner of Kiyotaki and Moore (1997). In Section 3, we describe the second model, in which the collateral constraint is formalized in the manner of Carlstrom and Fuerst (1998). Section 4 provides concluding remarks.

2. MODEL 1: LACK OF COMMITMENT

In this section we describe our first model of collateral constraint. The collateral constraint arises because borrowers cannot credibly commit to repay their debt. For simplicity, the first model is set up so that we can use a representative household framework. Thanks to this, the dynamics of the model can be easily and clearly understood. We shall see that what is crucial in our model is the interaction between financial market inefficiency and labor market inefficiency. We shall also see that, with adjustment costs of investment, our model naturally generates procyclical movement in Tobin's Q.

2.1. Basic Model

Our model economy is a closed economy that consists of continua of identical households and banks, whose measures are both normalized to one. A representative household consists of a worker–manager pair. At the beginning of each period, the worker and the manager split, and act separately until the end of the period. The worker supplies labor n_t to a firm owned by another household at the wage rate w_t. The manager hires labor $\tilde{n}_t$ and purchases intermediate input m_t from other households to produce output y_t, using the following production technology:

$$y_t = A_t^{(1-\eta)(1-\alpha)} m_t^{\eta} a_t^{(1-\eta)\nu} k_t^{(1-\eta)\alpha} \tilde{n}_t^{(1-\eta)(1-\alpha-\nu)}, \tag{1}$$

where k_t is capital and a_t is land, both of which the manager owns at the beginning of period t. Parameter A_t represents the level of productivity. The productivity growth rate, $\zeta_t \equiv \ln A_t - \ln A_{t-1}$, evolves stochastically following an AR(1) process:

$$\zeta_t = (1-\rho)\overline{\zeta} + \rho\zeta_{t-1} + \epsilon_t, \tag{2}$$

where $\rho > 0$, and ϵ_t is an i.i.d. noise with mean zero.

We assume that a bank can issue banknotes that can be circulated in the economy as payment instruments. The manager needs to borrow banknotes because we assume that he must pay for the inputs in advance of production. Let b_t be the amount that the manager borrows. Then, given b_t, the manager's choice of $\tilde{n}_t$ and m_t is constrained by

$$w_t\tilde{n}_t + m_t \leq b_t. \tag{3}$$

Borrowing and lending are intraperiod; if R_t is the gross rate of bank loans, the manager is supposed to repay $R_t b_t$ after production. (As discussed below, because borrowing and lending are intraperiod, $R_t = 1$ in equilibrium.) As in Kiyotaki and Moore (1997), however, the manager cannot fully commit himself to repay the debt. He can abscond without repayment at the end of period t, and the bank cannot keep track of the absconder's identity from the next period on. Instead, an imperfect commitment technology is available for the manager and the bank: The manager can put up part of the capital and land that he owns as collateral, and the bank can seize the collateral when the borrower absconds. Therefore, the value of the collateral gives the upper limit of the bank loan,

$$b_t \leq \phi k_t + \psi q_t a_t, \tag{4}$$

where ϕ and ψ ($0 \leq \phi, \psi \leq 1$) are the ratios of respective assets that can be put up as collateral, and q_t is the price of land in period t. The bank's problem is to maximize the return on the loan, $(R_t - 1)b_t$. Because the bank faces no risk of default if the intraperiod loan b_t satisfies (4), competition among banks implies that the return on the loan should be zero ($R_t - 1 = 0$) in equilibrium. Therefore, in equilibrium, the banks become indifferent to the amount of b_t, and work as passive liquidity suppliers to the households. So we can neglect the banks' decision-making, because it has no effect on the equilibrium dynamics of this economy. Conditions (3) and (4) together imply the following collateral constraint on the manager's purchase:

$$w_t\tilde{n}_t + m_t \leq \phi k_t + \psi q_t a_t. \tag{5}$$

At the end of period t, after production, the household sells y_t, repays $R_t b_t$, and determines consumption, c_t, investment, i_t, and land, a_{t+1}, subject to the flow budget constraint

$$c_t + i_t + q_t a_{t+1} + R_t b_t = q_t a_t + w_t n_t + b_t + \pi_t,$$

where π_t is the profit from the firm owned by this household: $\pi_t = y_t - m_t - w_t\tilde{n}_t$, and $R_t = 1$ in the equilibrium. The reduced form of the budget constraint is

$$c_t + i_t + q_t a_{t+1} = q_t a_t + w_t n_t + y_t - m_t - w_t\tilde{n}_t. \tag{6}$$

A representative household maximizes its lifetime utility, U, defined over sequences of consumption and leisure, $1 - n_t$. To ensure the existence of a balanced growth path, we assume the following class of utility functions:

$$U = E_0 \sum_{t=0}^{\infty} \beta^t \frac{1}{1-\sigma}[c_t(1-n_t)^{\gamma}]^{1-\sigma}, \tag{7}$$

where E_0 denotes the expectation conditional on the information available at time 0. The law of motion for capital accumulation is

$$k_{t+1} = i_t + (1-\delta)k_t, \tag{8}$$

where δ is the rate of capital depreciation.

The dynamics of this economy are determined as the solution to the representative household's problem, in which the household maximizes (7) subject to (1), (2), (5), (6), and (8). The market clearing conditions are

$$y_t = c_t + i_t + m_t, \tag{9}$$

$$n_t = \tilde{n}_t, \tag{10}$$

$$a_t = 1. \tag{11}$$

Note that the final output is also used as the intermediate input in this model, as is usually assumed in the literature [see, for example, Rotemberg and Woodford (1995), Comin and Gertler (2006), and Chari et al. (2007)].

The role of the collateral constraint. Our model departs from the standard real business cycle model in a minimal way. The only difference is the collateral constraint on input finance.[1] For instance, if ϕ and ψ in (5) were so large that the collateral constraint does not bind at all, our model would reduce simply to the standard model. How does our collateral constraint affect the economy? The key is the interaction between inefficiencies in the labor market and in the financial market.

To see this, let λ_t and μ_t be the Lagrange multipliers associated with (6) and (5), respectively, and form the Lagrangian as (for the sake of exposition ignore the other constraints for now)

$$\sum_{t=0}^{\infty} \beta^t \Bigg\{ \frac{1}{1-\sigma}[c_t(1-n_t)^{\gamma}]^{1-\sigma} + \mu_t[\phi k_t + \psi q_t a_t - w_t \tilde{n}_t - m_t] \\ + \lambda_t[q_t a_t + w_t n_t + y_t - m_t - w_t \tilde{n}_t - c_t - i_t - q_t a_{t+1}] \Bigg\}.$$

The labor supply decision implies that the marginal rate of substitution equals the wage rate

$$\gamma \frac{c_t}{1-n_t} = w_t,$$

which is standard. The labor demand decision, however, is different from the standard model and it does not imply that the marginal product of labor equals the wage rate. Using the equilibrium condition $n_t = \tilde{n}_t$, the labor demand condition is expressed as

$$(1-\eta)(1-\alpha-\nu)\frac{y_t}{n_t} = (1+x_t)w_t, \tag{12}$$

where $x_t \equiv \mu_t/\lambda_t$ measures how tightly the collateral constraint (5) binds. Because the left-hand side of (12) is the marginal product of labor, x_t is the wedge between the marginal product of labor and the wage rate. We have $x_t > 0$ if the collateral constraint binds, and x_t can be viewed as a measure of the financial market inefficiency. At the same time, it is the wedge between the marginal product of labor and the wage rate, and hence it is a measure of the labor market inefficiency.

Notice that the effect of a reduction in x_t on the labor demand function is similar to the effect of a positive productivity shock. As long as a higher price of a collateral asset today relaxes the collateral constraint, it affects the labor demand curve in the same way as a positive productivity shock today, by reducing the inefficiency in the labor market. It is then clear how our collateral constraint helps generate news-driven cycles. Suppose that a piece of news arrives that there is a positive productivity shock in the future. This news raises the land price today, and tends to relax the collateral constraint.[2] Other things being equal, this reduces the labor/financial market inefficiency, x_t, and shifts the labor demand curve outward.

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If this force is strong enough to overcome the wealth effect on the labor supply curve, the equilibrium labor supply rises, and so do consumption, investment, and output.

Our result implies that the collateral constraint on input payment may be a powerful tool for reproducing business cycles, in contrast to the formulation by Kiyotaki and Moore (1997). In their model, consumption smoothing and capital accumulation are distorted, because the agents cannot issue optimal amounts of intertemporal debt, because debt issuance is constrained by collateral. These intertemporal distortions in consumption and capital accumulation are said to have quantitatively insignificant effects in business fluctuations [see Cordoba and Ripoll (2004)]. Our result show, however, that when working capital expenditure (or input payment) is constrained, the collateral constraint may have a significant effect on business fluctuations.

The role of intermediate inputs. The requirement of intermediate inputs, m_t, in the production technology (1) is not necessary to generate news-driven cycles in our model. The collateral constraint (5) is enough for that purpose. However, it reinforces the effect of the collateral constraint and does increase the set of parameter values that are consistent with news-driven cycles.

To see this, note that the first-order condition for m_t is

$$\eta \frac{y_t}{m_t} = \frac{\lambda_t + \mu_t}{\lambda_t} = 1 + x_t. \tag{13}$$

As the demand for labor, the demand for the intermediate good, m_t, is also distorted when the collateral constraint (5) binds (i.e., when $x_t > 0$). Equation (13) shows that in response to a fall in the financial market inefficiency, x_t, the intermediate input, m_t, increases more than proportionally to the increase in gross output, y_t. This is an additional force shifting the labor demand curve (12) outward, and hence reinforces the mechanism described above. Indeed, using (13) to eliminate m_t, the marginal product of labor can be expressed as

$$(1-\eta)(1-\alpha-\nu)\frac{y_t}{n_t} = (1-\eta)(1-\alpha-\nu)\left(\frac{\eta}{1+x_t}\right)^{\frac{\eta}{1-\eta}} A_t^{1-\alpha} a_t^{\nu} k_t^{\alpha} n_t^{-\alpha-\nu}.$$

As long as $\eta > 0$ and $x_t > 0$, a fall in the financial market inefficiency, x_t, expands the marginal product of labor.

The above mechanism can also be seen by looking at the total factor productivity (TFP) in the production of value added, $y_t - m_t$. By eliminating m_t from (1), the gross output production function can be written as

$$y_t = \left(\frac{\eta}{1+x_t}\right)^{\frac{\eta}{1-\eta}} A_t^{1-\alpha} a_t^{\nu} k_t^{\alpha} n_t^{1-\alpha-\nu}.$$

It follows that the production function for value added is

$$y_t - m_t = \left(1 - \frac{\eta}{1+x_t}\right)\left(\frac{\eta}{1+x_t}\right)^{\frac{\eta}{1-\eta}} A_t^{1-\alpha} a_t^{\nu} k_t^{\alpha} n_t^{1-\alpha-\nu}. \qquad \textbf{(14)}$$

Thus, TFP for the production of value added, $\tilde{A}(A_t, x_t)$, is defined as

$$\tilde{A}(A_t, x_t) \equiv \left(1 - \frac{\eta}{1+x_t}\right)\left(\frac{\eta}{1+x_t}\right)^{\frac{\eta}{1-\eta}} A_t^{1-\alpha}, \qquad \textbf{(15)}$$

where $\partial \tilde{A}/\partial x < 0$ if $\eta, x_t > 0$. Thus, a fall in the financial market inefficiency increases TFP in the production of value added.[3]

Numerical experiments. Our numerical experiments follow Christiano et al. (2007). For $t \leq 0$, the economy is at the deterministic steady state, where the representative agent believes that there shall be no productivity shock at all in the future: $\epsilon_t = 0$ for all t. In period $t = 1$, the agent receives news that there will be a positive productivity shock at $t = T$: $\epsilon_T = \bar{\epsilon} > 0$. The agent is totally confident about the news, so that, for $t = 1, \ldots, T-1$, he or she believes that $\epsilon_T = \bar{\epsilon}$ with probability one. At $t = T$, however, the news may or may not turn out to be true, and both cases are considered. There is no productivity shock except possibly at $t = T$: $\epsilon_t = 0$ for $t \neq T$.

The unit of time is a quarter, and we set $T = 5$ so that the news received in period 1 says that the productivity shock occurs in a year later. The parameter values are set as follows: $\beta = 0.99$; $\gamma = 0.5$; $\sigma = 0.5$; $\delta = 0.025$; $\eta = 0.5$; $\alpha = 0.3$; $\nu = 0.03$; $\phi = 0$; $\psi = 0.1$; $\bar{\zeta} = 0$; $\rho = 0.95$; $\bar{\epsilon} = 0.0025$. Most of these values seem standard. As a benchmark, we consider the case where only land is used as collateral ($\phi = 0$), but including capital in the collateral ($\phi > 0$) does not change the main result. We focus on the former case because banking practices in the United States show that nearly half of the commercial and industrial loans made by U.S. banks are secured by collateral [Federal Reserve Survey of Terms of Business Lending (2010)]. Especially for commercial loans, the typical asset used as collateral is real estate [Survey of Consumer Finances, Board of Governors of the Federal Reserve System (2004)]. The value of ψ is chosen so that the collateral constraint binds tightly enough to generate the news-driven cycle.[4] With this value, the steady-state value of $x_t = \mu_t/\lambda_t$ is 0.085.

For our story of news-driven cycles to work, the elasticity of intertemporal substitution (EIS), σ^{-1}, must be greater than one. This is because, if the EIS is less than one, a higher rate of productivity growth tends to increase the real interest rate so much that the value of land relative to output declines. Thus, in order for a future productivity shock to relax the collateral constraint, we need the EIS to be greater than one. In our simulation, we set the EIS equal to two ($\sigma = 0.5$). Here, we would like to stress that what matters in our model is a high EIS rather than a low risk aversion coefficient (there is nothing stochastic in our simulation), although

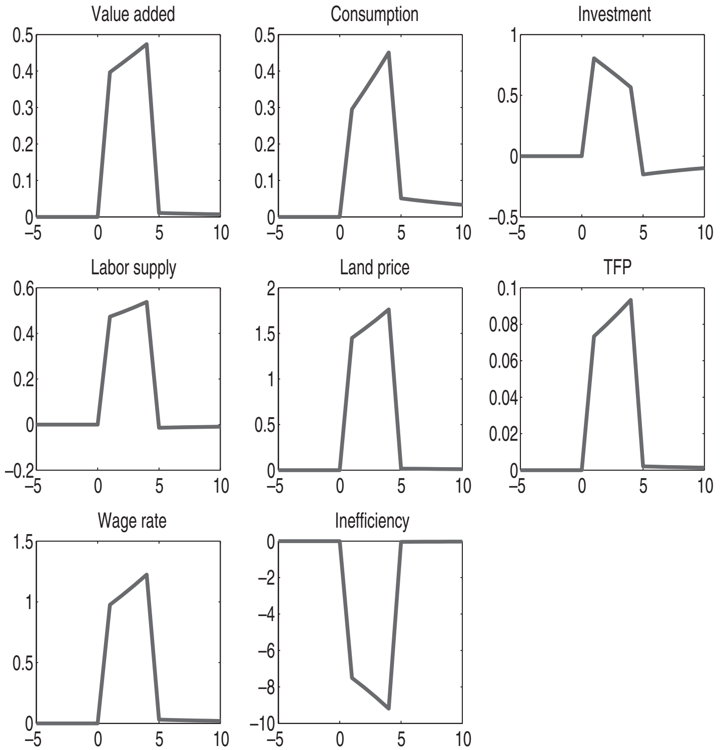

FIGURE 1. Model 1: The case where the news turns out to be false. (Percentage deviations from the steady state. The same applies hereafter.)

our utility function does not distinguish them. The empirical evidence seems to be mixed regarding the size of the EIS. But the empirical studies supporting the conclusion that the EIS is greater than one include, among others, Mulligan (2002), Gruber (2006), and Vissing-Jorgensen and Attanasio (2003). In addition, Bansal and Yaron (2004), for instance, show that assuming an EIS greater than one helps to explain the equity premium puzzle in their long-run risk model.

The model is first detrended by A_t, and then solved numerically by log-linearization using the method of Uhlig (1999). Figures 1 and 2 plot the dynamic responses of the economy to the news shock. They correspond to the case where the news turns out to be wrong, and the case where it turns out to be correct, respectively.[5] Both figures show that the positive news shock raises output, consumption, investment, and labor for $t = 1, \ldots, 4$. This comovement of the main macro variables can be understood by looking at the behavior of the Lagrange multipliers, λ_t and μ_t. When the news of a future increase in productivity arrives in period 1, the value of land held by the representative agent rises, and also her expected future wage rates go up. As a result, her marginal utility of wealth, λ_1,

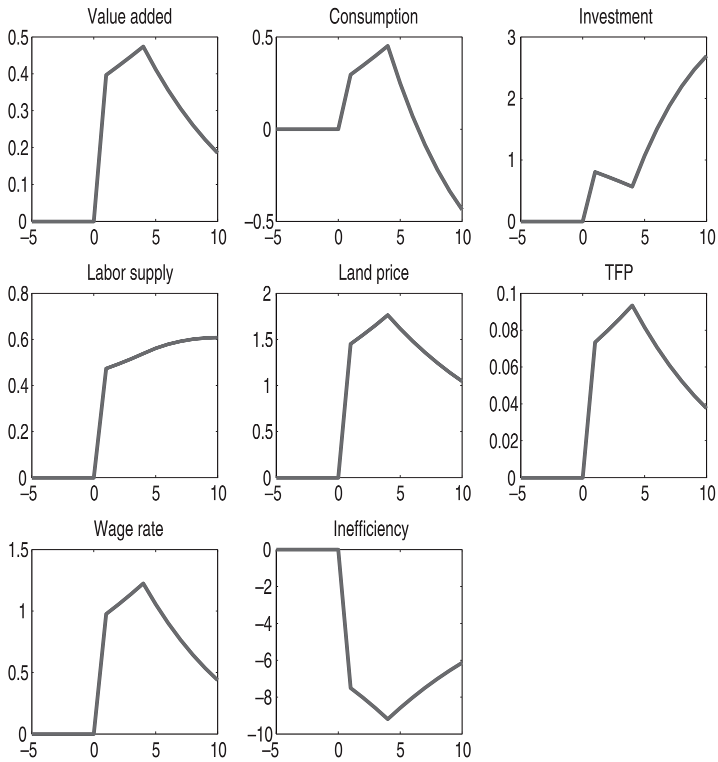

FIGURE 2. Model 1: The case where the news turns out to be correct.

falls, and consumption increases. Other things being equal, this tends to reduce labor supply. Thanks to the collateral constraint, however, in our model, the higher land price relaxes the collateral constraint, and hence lowers μ_1 and $x_1 = \mu_1/\lambda_1$. As discussed above, a lower x_1 reduces the inefficiency in the factor markets, which increases both the wage rate, w_1, and the TFP. With this effect sufficiently strong, labor supply increases, and so do output and investment.

It may be interesting to look at how the yield curve spread responds to a news shock in our model. Let r_t^T denote the T-period real interest rate from date t to $t + T$, which is defined implicitly by

$$\left(\frac{1}{1 + r_t^T}\right)^T = E_t\left[\frac{\beta^T U_c(t+T)}{U_c(t)}\right],$$

where

$$U_c(t) = \frac{\partial}{\partial c}\frac{1}{1-\sigma}[c_t(1-n_t)^\gamma]^{1-\sigma}.$$

The news of an increase in productivity causes an increase in consumption and a decrease in leisure, which lead to a rise in the interest rate. As agents attempt

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to smooth their consumption and leisure, the short-term rate rises more than the long-term rate. Hence the yield curve responds negatively to positive news. The empirical evidence [Stock and Watson (1999, Table 2, Series 51: Yield curve spread (long-short))] shows that the yield curve indeed responds negatively to a positive output shock. Therefore, the prediction of our model concerning the yield curve seems to be consistent with the empirical data.[6]

Figure 1 shows that if the news turns out to be false in period 5, the economy goes back to the initial steady state almost immediately. In particular, the level of output does not fall below the steady-state level. We follow Jaimovich and Rebelo (2009) and define a *recession* as an event in which the level of output falls below the steady-state level. In this sense, false information does not create a recession in this version of our model. We shall see in Section 3 that in our second model, which is based on costly state verification, the economy falls into a recession when the news turns out to be false.

2.2. Adjustment Costs and Tobin's Q

In previous work, such as Jaimovich and Rebelo (2009) and Christiano et al. (2007), a specific form of adjustment cost of investment is necessary to generate news-driven cycles. Following the terminology of Christiano et al. (2007), the *level* specification of adjustment cost is

$$k_{t+1} = (1-\delta)k_t + i_t - H\left(\frac{i_t}{k_t}\right)k_t, \tag{16}$$

where

$$H(x) = \frac{\sigma_H}{2\delta}(x-\overline{x})^2.$$

Here $\overline{x}$ is the steady state level of i_t/k_t. The *flow* specification of adjustment cost is

$$k_{t+1} = (1-\delta)k_t + i_t - G\left(\frac{i_t}{i_{t-1}}\right)i_t, \tag{17}$$

where

$$G(x) = \frac{\sigma_G}{2}(x-\overline{x})^2.$$

Here $\overline{x}$ is the steady state level of i_t/i_{t-1}.

The models of Jaimovich and Rebelo (2009) and Christiano et al. (2007) generate news-driven cycles with the flow specification (17), but not with the level specification (16) of adjustment cost. Furthermore, as discussed in detail by Christiano et al. (2007), their model does not yield procyclical movement in Tobin's Q, which may not be consistent with the observation that stock prices fluctuate procyclically.[7] The model of Jaimovich and Rebelo (2009) has the same problem. In this section, we show that our model can generate news-driven cycles with both specifications of adjustment cost, and that Tobin's Q fluctuates procyclically in response to the news shock.

For the sake of simplicity, we continue to focus on the case where $\phi = 0$ in the collateral constraint (5).[8] Let $\lambda_{c,t}$, μ_t, and $\lambda_{k,t}$ be the Lagrange multipliers associated with the flow budget constraint (6), the collateral constraint (5), and the law of motion of capital (16) or (17), respectively. Then Tobin's Q is defined as the (shadow) price of installed capital, $p_{k',t}$:

$$p_{k',t} = \frac{\lambda_{k,t}}{\lambda_{c,t}}.$$

Let us start with the level specification (16). The first-order condition for i_t implies the familiar relationship between the level of investment and Tobin's Q

$$\frac{i_t}{k_t} = \delta + \frac{\delta}{\sigma_H}\frac{p_{k',t} - 1}{p_{k',t}}.$$

Thus, the investment–capital ratio is higher than the steady state value δ if and only if Tobin's Q is greater than unity. Letting $\hat{i}_t \equiv \ln(i_t/A_t)$, $\hat{k}_t \equiv \ln(k_t/A_{t-1})$, and $\hat{p}_{k',t} \equiv \ln p_{k',t}$, its log-linear approximation is written as

$$\hat{i}_t = \frac{1}{\sigma_H}\hat{p}_{k',t} + \hat{k}_t - \zeta_t,$$

where $\zeta_t = \ln A_t - \ln A_{t-1}$. Hence, with this specification, procyclical investment implies procyclical Tobin's Q.

As a benchmark, we set $\sigma_H = 1$; that is, the elasticity of investment with respect to Tobin's Q is unity, which is consistent with the empirical evidence. The other parameter values are the same as those used for Figure 1. Figure 3 shows the impulse responses to the same news shock as in Figure 1, where the news turns out to be false. The news shock increases Tobin's Q, as well as other macroeconomic variables. It is worth noting that introducing the adjustment cost of investment enlarges the set of parameter values that are consistent with news-driven cycles. For instance, the EIS, σ^{-1}, can be made very close to unity. Figure 4 plots the result when $\sigma = 0.9$. The effects of the news shock are smaller than for the benchmark case of $\sigma = 0.5$, but we still obtain comovements of the variables of interest.

With the flow specification (17), the relationship between the level of investment and Tobin's Q becomes less clear. The first-order condition for i_t is written as

$$p_{k',t}\left[1 - G\left(\frac{i_t}{i_{t-1}}\right) - G'\left(\frac{i_t}{i_{t-1}}\right)\frac{i_t}{i_{t-1}}\right] + \beta p_{k',t+1}G'\left(\frac{i_{t+1}}{i_t}\right)\left(\frac{i_{t+1}}{i_t}\right)^2 = 1.$$

We set $\sigma_G = 15.1$ following Christiano et al. (2007). The other parameter values are the same as before. Figure 5 plots the impulse responses to the news shock. Again, the model is successful in generating comovements, including Tobin's Q.

Our success in reproducing procyclical Tobin's Q may be explained as follows: Loosening of the collateral constraint increases labor and intermediate inputs,

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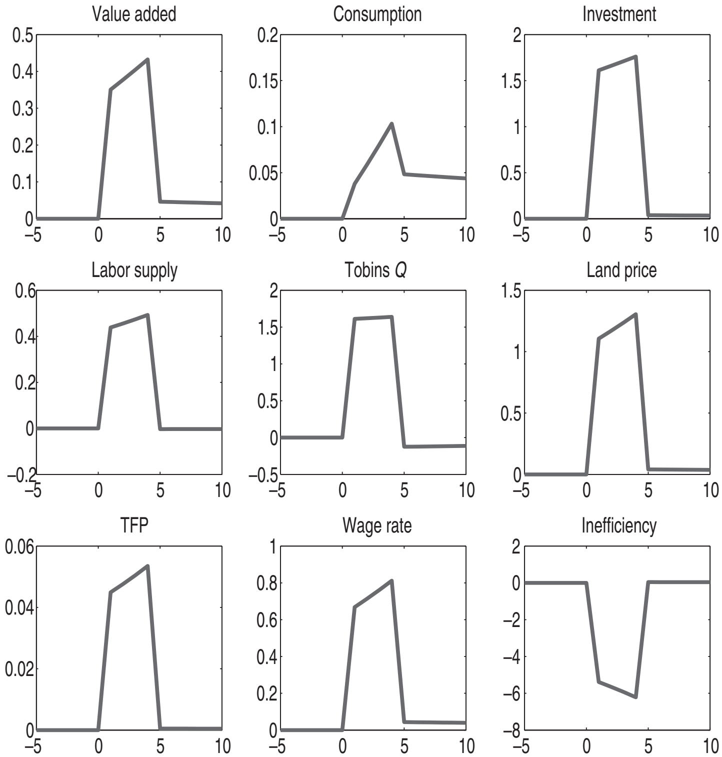

FIGURE 3. Model 1 with the level specification of adjustment cost: The case where the news turns out to be false.

leading to an increase in the marginal product of capital. Therefore, capital becomes more valuable, implying a higher Tobin's Q. On the other hand, in Christiano et al.'s (2007) model and in Jaimovich and Rebelo's (2009) model, when the good news arrives, agents anticipate that they need to pay large adjustment costs during transition to the new steady state; thus, agents increase investment today to reduce the adjustment cost that they must pay in the future; and the increase in investment makes capital more abundant and cheaper today. Christiano et al. needs to introduce sticky prices and a Taylor-type monetary policy rule to generate procyclicality in the price of capital. We do not need such a complication in the model to explain capital prices. Policy implications are quite different: On one hand, Christiano et al. conclude that the news-driven cycle, if it exists at all, should be caused by mechanical conduct of monetary policy and therefore the central bank is to be blamed; on the other hand, our model implies that the news-driven cycle may be an inevitable feature of the economy in which agents are subject to collateral constraints.

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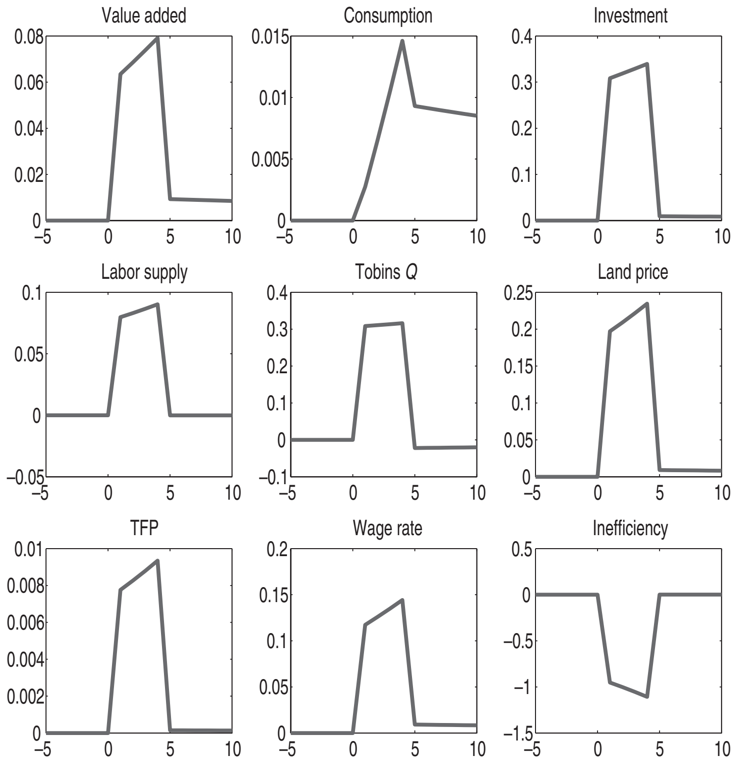

FIGURE 4. Model 1 with the level specification of adjustment cost and $\sigma = 0.9$: The case where the news turns out to be false.

3. MODEL 2: COSTLY STATE VERIFICATION

In this section we consider a version of the costly-state-verification model due to Carlstrom and Fuerst (1997, 1998). Specifically, we augment Carlstrom and Fuerst's (1998) model with land, and assume that only land can be used as collateral in the debt contract. The key difference from the first model is that the second model has two types of agents: households (lenders) and entrepreneurs (borrowers). We first show that this two-agent model can also reproduce news-driven cycles, and that with the level specification of the adjustment cost, it can reproduce procyclicality of Tobin's Q. The basic mechanism that generates this result is the same as in the first model. Furthermore, in our second model, when the news of a future increase in productivity turns out to be wrong, the economy falls into a recession (the level of output falls below the steady state level). This feature is absent in our first model, as well as in the models of Christiano et al. (2007) and Jaimovich and Rebelo (2009).[9]

The economy consists of a representative household and a continuum of entrepreneurs with unit mass. The household consumes, supplies labor, accumulates

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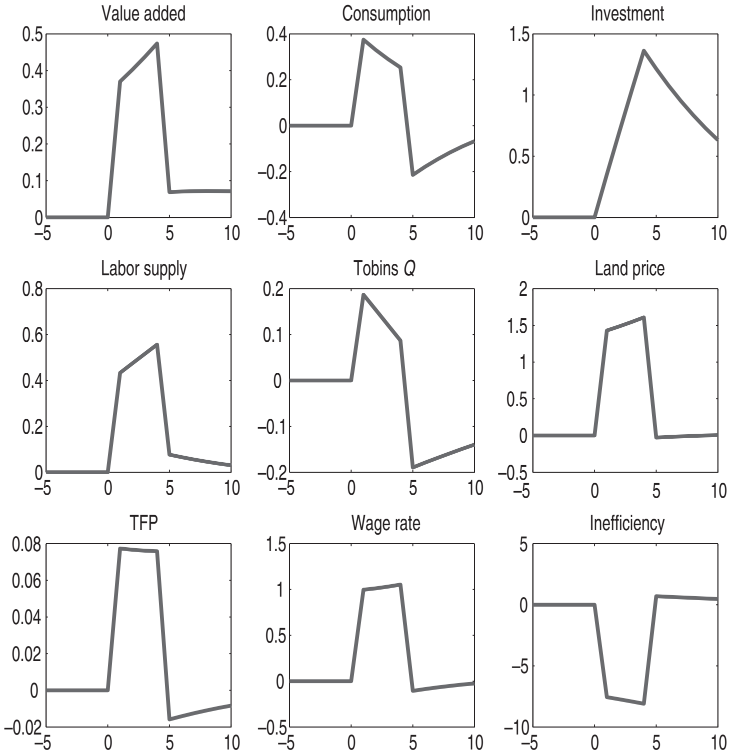

FIGURE 5. Model 1 with the flow specification of adjustment cost: The case where the news turns out to be false.

capital, holds land, and lends to entrepreneurs. An entrepreneur produces output under idiosyncratic risk, holds land, and borrows from the household.

3.1. Household

The household maximizes (7) subject to the flow budget constraint

$$c_t + i_t + q_t a_t = w_t n_t + r_{k,t} k_t + (q_t + r_{a,t}) a_t + (R_t - 1) b_t \tag{18}$$

and the law of motion for capital accumulation, either (16) or (17), where $r_{k,t}$ and $r_{a,t}$ are the rental rates of capital and land, respectively, and $(R_t - 1)b_t$ is the return on intraperiod loans, b_t, to entrepreneurs. Although entrepreneurs are subject to idiosyncratic risk, the loans to them are intermediated through a mutual fund so that the household faces no risk. Because the loans are made within period, $R_t = 1$ must hold in equilibrium. Thus, the household becomes indifferent to b_t in the equilibrium.

Let $\lambda_{c,t}$ and $\lambda_{k,t}$ be the Lagrange multipliers associated with the flow budget constraint (18) and the law of motion of capital accumulation (16) or (17), respectively. Then Tobin's Q, $p_{k',t}$, is defined as

$$p_{k',t} \equiv \frac{\lambda_{k,t}}{\lambda_{c,t}}.$$

3.2. Entrepreneurs

Entrepreneurs are indexed by $i \in [0, 1]$. We assume that only land can be used as collateral in the debt contract. As a result, entrepreneurs do not hold physical capital. Entrepreneur i holds land, $a'_t(i)$, at the beginning of period t, produces output, $y_t(i)$, and then determines consumption, $c'_t(i)$, and land holdings, $a'_{t+1}(i)$. Entrepreneurs faces an idiosyncratic productivity shock in producing output. Specifically, entrepreneur i produces $y_t(i)$, employing intermediate input, $m_t(i)$, land services, $\tilde{a}_t(i)$, capital services, $k_t(i)$, and labor input, $n_t(i)$, under an idiosyncratic shock, $\omega_t(i)$, using the following production technology:

$$y_t(i) = \omega_t(i) F[A_t, m_t(i), \tilde{a}_t(i), k_t(i), n_t(i)], \tag{19}$$

where

$$F(A, m, a, k, n) = A^{(1-\eta)(1-\alpha)} m^{\eta} a^{(1-\eta)\nu} k^{(1-\eta)\alpha} n^{(1-\eta)(1-\alpha-\nu)}.$$

The idiosyncratic shock $\omega_t(i)$ is private information; it is i.i.d. across agents and across time; its probability distribution and density function are denoted by $\Phi(\omega)$ and $\phi(\omega)$, respectively; its mean is unity, and its standard deviation is denoted by σ_ω. Note that $\tilde{a}_t(i) \neq a'_t(i)$, in general. If $\tilde{a}_t(i) > a'_t(i)$, entrepreneur i rents $\tilde{a}_t(i) - a'_t(i)$ from another entrepreneur or the household; and if $\tilde{a}_t(i) < a'_t(i)$, he rents $a'_t(i) - \tilde{a}_t(i)$ to another entrepreneur.

The quantities of inputs, $m_t(i)$, $\tilde{a}_t(i)$, $k_t(i)$, $n_t(i)$, are determined prior to the realization of $\omega_t(i)$. Therefore, the input costs, $s_t(i) \equiv m_t(i) + w_t n_t(i) + r_{k,t} k_t(i) + r_{a,t} \tilde{a}_t(i)$, must be paid in advance. Cost minimization and the Cobb–Douglas technology lead to the following first-order conditions:

$$w_t n_t(i) = (1-\eta)(1-\alpha-\nu) s_t(i),$$

$$r_{k,t} k_t(i) = (1-\eta)\alpha s_t(i),$$

$$r_{a,t} \tilde{a}_t(i) = (1-\eta)\nu s_t(i),$$

$$m_t(i) = \eta s_t(i).$$

Let $e_t(i)$ be the net worth of entrepreneur i. Because the only asset that entrepreneur i holds at the beginning of period t is $a'_t(i)$, her net worth is given by

$$e_t(i) = (q_t + r_{a,t}) a'_t(i).$$

Because $s_t(i)$ must be paid in advance, entrepreneur i needs to borrow $s_t(i) - e_t(i)$ from the household. Let p_t be the markup rate; that is, a project of size $s_t(i)$ yields gross return $p_t s_t(i)\omega_t(i)$. Let $\mu p_t s_t(i)$ be the cost of monitoring a project of size $s_t(i)$. As discussed by Carlstrom and Fuerst (1997, 1998), given $\{p_t, e_t(i)\}$, the optimal debt contract is described by $\{s_t(i), \overline{\omega}_t\}$. Here, the borrower with net worth $e_t(i)$ conducts a project of size $s_t(i)$, and pays back to the lender $p_t s_t(i)\overline{\omega}_t$ as long as $\omega_t(i) \geq \overline{\omega}_t$. If $\omega_t(i) < \overline{\omega}_t$, then the borrower defaults, and pays back only $p_t s_t(i)\omega_t(i) < p_t s_t(i)\overline{\omega}_t$. Thus $\Phi(\overline{\omega}_t)$ equals the fraction of entrepreneurs who default. As shown in the Appendix, the optimal debt contract $\{s_t(i), \overline{\omega}_t\}$ is determined as

$$s_t(i) = \frac{e_t(i)}{1 - p_t g(\overline{\omega}_t)},$$

$$\frac{1}{p_t} = 1 - \Phi(\overline{\omega}_t)\mu + \phi(\overline{\omega}_t)\mu \frac{f(\overline{\omega}_t)}{f'(\overline{\omega}_t)},$$

where $f(\omega)$ and $g(\omega)$ are the functions defined in the Appendix.

Given $\{p_t, \overline{\omega}_t\}$, entrepreneur i chooses $\{c'_t(i)\}$ and $\{a'_{t+1}(i)\}$ to maximize his utility,

$$E_0 \sum_{t=0}^{\infty} (\beta')^t c'_t(i),$$

subject to the flow budget constraint

$$c'_t(i) + q_t a'_{t+1}(i) = p_t s_t(i) \max\{\omega_t(i) - \overline{\omega}_t, 0\},$$

where $s_t(i) = (q_t + r_{a,t})a'_t(i)/[1 - p_t g(\overline{\omega}_t)]$. We assume that $\beta' < \beta$ to ensure that entrepreneurs are borrowing-constrained in equilibrium.[10]

Because of the linearity in the entrepreneurs' utility and the debt contract, the entrepreneurial sector is easily aggregated by integration over i. Let z_t denotes the aggregate variable of $z_t(i)$ for $z_t(i) = s_t(i), c'_t(i), a'_t(i)$, etc. The aggregate variables solve

$$\max E_0 \sum_{t=0}^{\infty} (\beta')^t c'_t, \qquad \textbf{(20)}$$

subject to

$$c'_t + q_t a'_{t+1} = p_t s_t f(\overline{\omega}_t), \qquad \textbf{(21)}$$

where

$$s_t = \frac{(q_t + r_{a,t})a'_t}{1 - p_t g(\overline{\omega}_t)}, \qquad \textbf{(22)}$$

$$\frac{1}{p_t} = 1 - \Phi(\overline{\omega}_t)\mu + \phi(\overline{\omega}_t)\mu \frac{f(\overline{\omega}_t)}{f'(\overline{\omega}_t)}. \qquad \textbf{(23)}$$

The total output produced is

$$y_t = A_t^{(1-\eta)(1-\alpha)} m_t^{\eta} \tilde{a}_t^{(1-\eta)\nu} k_t^{(1-\eta)\alpha} n_t^{(1-\eta)(1-\alpha-\nu)}. \tag{24}$$

Because the price of output is unity (numeraire), p_t is the mark-up rate:

$$y_t = p_t s_t. \tag{25}$$

The market clearing conditions are

$$c_t + c_t' + i_t + m_t = [1 - \Phi(\overline{\omega}_t)\mu] y_t, \tag{26}$$

$$\tilde{a}_t = 1. \tag{27}$$

The factor market equilibrium conditions are given by

$$w_t n_t = (1-\eta)(1-\alpha-\nu) s_t, \tag{28}$$

$$r_{k,t} k_t = (1-\eta)\alpha s_t, \tag{29}$$

$$r_{a,t} \tilde{a}_t = (1-\eta)\nu s_t, \tag{30}$$

$$m_t = \eta s_t. \tag{31}$$

3.3. Equilibrium

The equilibrium dynamics of this economy are determined by the solution to the household's problem, i.e., maximization of (7) subject to (18) and either (16) or (17); the aggregate entrepreneurs' problem, (20)–(23); and the conditions (24)–(31).[11]

3.4. Financial-Market Inefficiency and Factor-Market Inefficiency

As in the first model, a crucial feature of this model is the interaction between the inefficiencies in the financial market and in the factor market. The inefficiency in the factor market is measured by the markup rate, p_t, which is the wedge between the marginal products and the input prices. For instance, it follows from (25) and (28) that the marginal product of labor equals p_t times the wage rate,

$$(1-\eta)(1-\alpha-\nu)\frac{y_t}{n_t} = p_t w_t;$$

and similar conditions hold for the other inputs.

The financial-market inefficiency may be measured by $\overline{\omega}_t$, which is the threshold value for default. Equation (23) implies that $p_t = p(\overline{\omega}_t)$ is an increasing function of $\overline{\omega}_t$; that is, an increase in the financial market inefficiency will raise the factor market inefficiency. In addition, the definition of $g(\overline{\omega}_t)$ in the Appendix implies that $p(\overline{\omega}_t)g(\overline{\omega}_t)$ is an increasing function of $\overline{\omega}_t$. It follows from (22) that, other things being equal, a higher land price, q_t, lowers the financial market inefficiency, $\overline{\omega}_t$.

Therefore, this model has the same mechanism as the first one: a higher land price q_t tends to reduce the financial market inefficiency $\overline{\omega}_t$, which, in turn, decreases the factor-market inefficiency p_t. This is the basic mechanism that generates news-driven cycles.

Similarly, as in the first model, the requirement of intermediate inputs, m_t, implies that the (observed) TFP depends negatively on the inefficiency of the financial market. The value added in this economy is given by $[1-\Phi(\overline{\omega}_t)\mu]y_t - m_t$. Then, define the TFP in this economy, $\tilde{A}(A_t, p_t, \overline{\omega}_t)$, as

$$[1 - \Phi(\overline{\omega}_t)\mu]y_t - m_t = \tilde{A}(A_t, p_t, \overline{\omega}_t)\tilde{a}_t^{\nu} k_t^{\alpha} n_t^{1-\alpha-\nu}. \tag{32}$$

Equations (24), (25), (31), and (32) imply that

$$\tilde{A}(A_t, p_t, \overline{\omega}_t) \equiv \left[1 - \Phi(\overline{\omega}_t)\mu - \frac{\eta}{p_t}\right]\left(\frac{\eta}{p_t}\right)^{\frac{\eta}{1-\eta}} A_t^{1-\alpha}. \tag{33}$$

Because of the monitoring cost, the financial market inefficiency $\overline{\omega}_t$ directly affects the TFP through the term $\Phi(\overline{\omega}_t)\mu$. But the negative dependence of $\tilde{A}_t$ on p_t is based on the same mechanism as we have seen in (15). Hence, the TFP is, again, a decreasing function of the financial-market inefficiency, $\overline{\omega}_t$. As a result, other things being equal, a higher land price, q_t, tends to increase the TFP. Although $\eta > 0$ is not necessary to generate news-driven cycles, it reinforces the mechanism that drives news-driven cycles.

3.5. Numerical Experiments

We conduct the same experiments as in Section 2: At $t = 1$, the agents receive a signal that $\epsilon_T = \overline{\epsilon} > 0$, which turns out to be true or false at $t = T$. The parameter values are set as follows: $\beta = 0.99$; $\beta' = \beta \times 0.973$; $\sigma = 0.5$; $\gamma = 0.5$; $\eta = 0.5$; $\nu = 0.03$; $\alpha = 0.3$; $\delta = 0.025$; $\sigma_H = 1$; $\sigma_G = 15.1$; $\sigma_\omega = 0.37$; $\mu = 0.15$; $\rho = 0.95$; $\overline{\epsilon} = 0.0025$; and $T = 5$. Here, the values for β', σ_ω, and μ are taken from Carlstrom and Fuerst (1998). The rest are the same as in Section 2.2.

Here we report the case where the news turns out to be wrong at $t = T$. The results for the level specification model (16) and for the flow specification model (17) are shown in Figures 6 and 7, respectively. Just as in the representative-agent model of Section 2.2, the news of a future productivity increase brings about a boom in periods $t = 1, \ldots, T-1$. Aggregate consumption, value added, investment, and labor all rise during these periods.[12] The measured TFP also rises for $t = 1, \ldots, T-1$. The mechanism by which the news shock produces the boom is the same as in the previous model. Tobin's Q rises with the level specification of adjustment cost, whereas it does not rise with the flow specification.

In this model, it may be interesting to look at how the risk premium responds to a news shock.[13] Let p_t^r denote the risk premium, which is defined implicitly by

$$p_t\overline{\omega}_t s_t = \left(1 + p_t^r\right)(s_t - e_t).$$

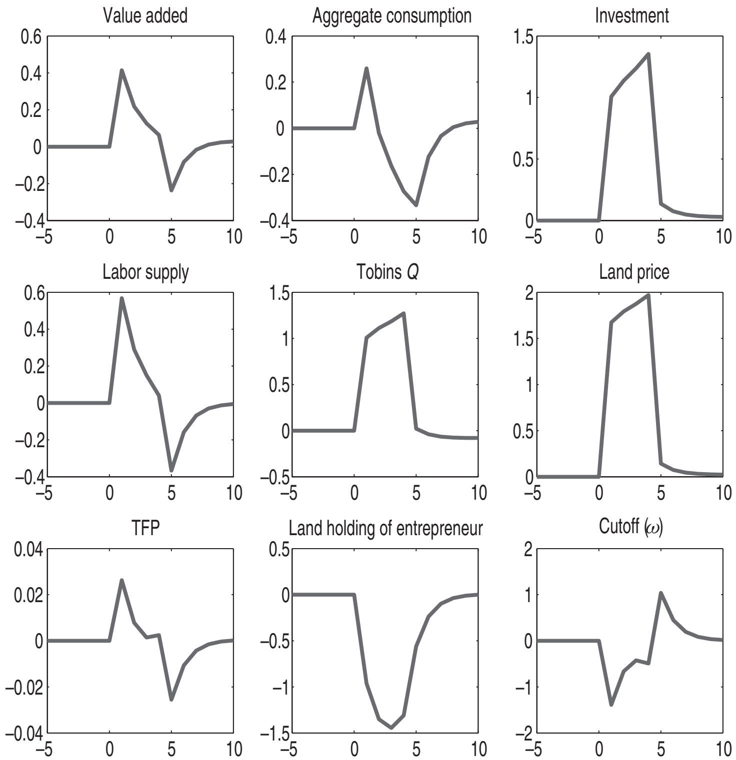

FIGURE 6. Model 2 with the level specification of adjustment cost: The case where the news turns out to be false.

It follows that

$$p_t^r = \frac{\overline{\omega}_t}{g(\overline{\omega}_t)} - 1.$$

Because $\hat{p}_t^r = \{1 - g'(\overline{\omega})\overline{\omega}/g(\overline{\omega})\}\hat{\omega}_t$, where the variables with the circumflex are the percentage deviations from the steady-state values, and $\{1 - g'(\overline{\omega})\overline{\omega}/g(\overline{\omega})\} > 0$ under the parameter values we use, it follows that the risk premium moves countercyclically in response to the news shock. Such a movement of the risk premium appears to be consistent with the evidence. For instance, Stock and Watson (1999, Table 2, series 52: Commercial paper/Treasury Bill spread) show that a higher risk premium today predicts a lower level of output in the future.

What is notable in the second model is what happens when the news turns out to be wrong in period $t = T$. In the previous model with a representative household, when the news turns out to be wrong in period $t = T$, the economy essentially jumps back to the initial steady state, although there is some transitional dynamics (see Figures 1, 3, and 5). In particular, after the news turns out to be wrong, the

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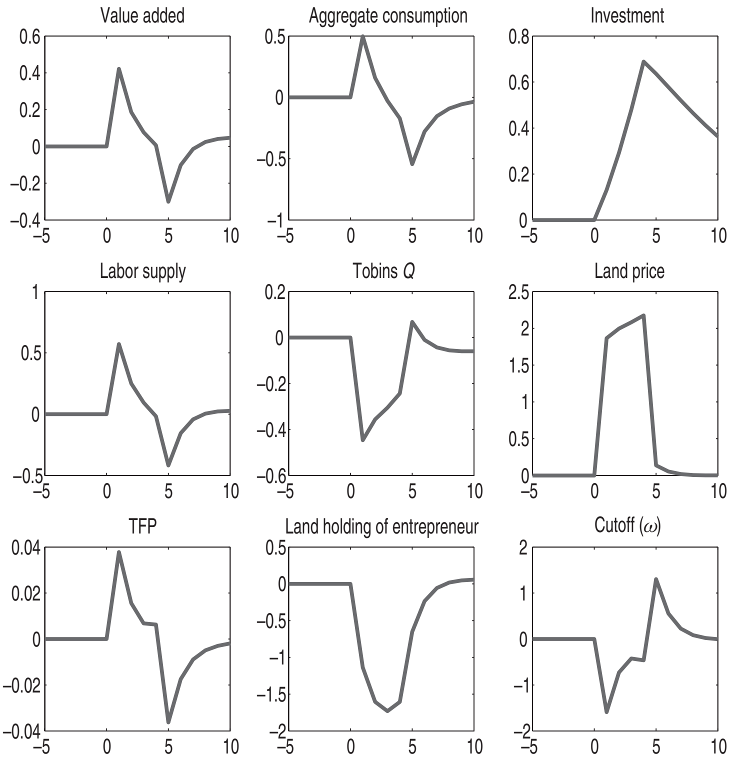

FIGURE 7. Model 2 with the flow specification of adjustment cost: The case where the news turns out to be false.

economic activity does not fall below the steady state level. This implies that the wrong news does not cause the economy to fall into a recession by Jaimovich and Rebelo's (2009) definition. That is not true in our second model. In period $t = T$, when the news turns out to be false, value added, consumption, and labor supply became lower than their steady state levels.

What causes this remarkable difference is the fact that there are two types of agents in the second model: borrowers and lenders. Look at the dynamics of the share of land held by entrepreneurs, $\{a'_{t+1}\}$ (note that in the figures, the plotted value of a' at t is a'_{t+1}, rather than a'_t). When the good news hits the economy in period $t = 1$, entrepreneurs sell their land to households so that a'_2 is lower than the steady state level, $\overline{a}'$, which is reflected in the sharp decline in a' occurring at $t = 1$ in Figures 6 and 7. Entrepreneurs sell their land in period 1, because, given the increase in the land price caused by the good news, entrepreneurs need less land to achieve their desired level of net worth (or collateral). So the share of land held by entrepreneurs becomes lower than the steady state level as long as the price of land is higher than its steady state level. It follows that, when the news turns out to be wrong in period T, the share of land held by entrepreneurs at the beginning of period T is lower than the steady state value: $a'_T < \overline{a}'$. The entrepreneurs' borrowing constraint (22) and the markup equation (25) imply that, at $t = T$, gross output equals

$$y_T = \frac{p(\overline{\omega}_T)}{1 - p(\overline{\omega}_T)g(\overline{\omega}_T)}(q_T + r_{a,T})a'_T.$$

Here, $p(\overline{\omega})/(1 - p(\overline{\omega})g(\overline{\omega}))$ is increasing in $\overline{\omega}$. Because at this point our agents realize that the productivity increase is not happening, the land price goes back to the steady state value: $q_T \approx \bar{q}$. Then, the fact that entrepreneurs hold a share of land which is less than the steady state level, $a'_T < \overline{a}'$, implies that the financial market inefficiency gets higher, $\overline{\omega}_T > \overline{\omega}$, which, in turn, raises the factor market inefficiency, p_T. (Recall that (23) implies that $p_T = p(\overline{\omega}_T)$ is an increasing function of $\overline{\omega}_T$.) As a result, the economy falls into a recession in period $t = T$, as the figures show. Note also that the countercyclicality in $\overline{\omega}_t$ in the figures can be interpreted as the countercyclicality in bankruptcies, which seems realistic but is not reproduced in the original models of Carlstrom and Fuerst (1997, 1998).

4. CONCLUSION

We proposed two models of business cycles, which are driven by changes in expectations or news about the future through financial constraints. The global financial crisis in 2008 has shown dramatically that the financial frictions, interacting with the collapse of asset bubbles, can cause a large impact on real activities. The asset-price collapse might have been caused by a change in the expectations about the future. Our aim in this paper is to shed some light on the interaction between expectational changes and financial frictions that appears to be a key to understand the current financial crisis. We have seen that such news-driven cycles can be reproduced by models with collateral constraint.

Our main assumptions are that an asset with fixed supply ("land") is used as collateral, and that firms are collateral-constrained to finance the input costs. The first assumption is to ensure that the price of a collateralized asset fluctuates enough in response to news about future productivity growth. The second assumption is to introduce an interaction between the financial market inefficiency and the factor market inefficiency. A positive news about the future productivity growth raises the asset price today and relaxes the collateral constraint. Because the input finance is collateral-constrained, the relaxation of the collateral constraint reduces the inefficiency in the factor market. This interaction can generate the news-driven cycles. Augmented by the adjustment cost of investment, the models can generate procyclical movement on Tobin's Q. Furthermore, in our second model, the economy can fall into a recession when good news turns out to be false.

In comparison with the existing models of the news-driven cycles, our collateral constraint models are simpler and exhibit more realistic performance. Collateral constraint on input finance by a fixed-supply asset may be a good ingredient for developing a comprehensive theory of the business cycles from a point of the "News" view [Beaudry and Portier (2005)].

NOTES

1. Our model is close in spirit to Mendoza (2010). He assumes that payment for inputs is collateral-constrained, whereas capital is used as collateral.
2. For this to be the case, the elasticity of intertemporal substitution, $1/\sigma$, must be sufficiently high.
3. It is pointed out by Chari et al. (2007) that frictions in financing intermediate inputs are observed as changes in the TFP in a standard growth model. The same mechanism works in our model.
4. Note that our model reduces to the standard real business cycle model if ψ is so large that the collateral constraint does not bind. This is why setting ψ at a low enough value is necessary to produce the news-driven cycle. For instance, if we set $\psi \geq 0.15$ in our benchmark model, the consumption and the investment move to the opposite directions in response to the news shock.
5. The plotted values are detrended ones. This is why variables such as value added and consumption decline for $t \geq 5$ in Figure 2, that is, in the case where the productivity shock does hit the economy in period five as the news has suggested.
6. We thank an anonymous referee for suggesting that we analyze the yield curve.
7. To make Tobin's Q procyclical, they augment their model with sticky prices and wages, and a certain form of monetary policy rule.
8. If $\phi \neq 0$, the collateral constraint must be modified as $w_t \tilde{n}_t + m_t \leq \phi p_{k',t} k_t + \psi q_t a_t$.
9. Note that the original model of Carlstrom and Fuerst (1998) does not generate news-driven cycles. The success of our model in this respect is due to the introduction of an asset in fixed supply (land) in the debt contract.
10. Strictly speaking, we need to avoid the possibility that the net worth of each entrepreneur becomes zero. For that purpose, Carlstrom and Fuerst (1997) assume that entrepreneurs supply labor. Here, however, for simplicity, we follow Carlstrom and Fuerst (1998) and consider the limiting case where entrepreneurs' labor income is approximately zero. Explicit consideration of entrepreneurs' labor does not change our result.
11. The total amount of loans from the household to entrepreneurs is given by $b_t = s_t - (q_t + r_{a,t}) a'_t$, though it is irrelevant to the dynamics.
12. The aggregate consumption is the sum of the household's consumption and the entrepreneurs' consumption. As can be inferred from the dynamics of $\lambda_{c,t}$, the household's consumption slightly declines for $t = 1, \ldots, T-1$. The aggregate consumption rises because the entrepreneurs' consumption increases by amounts that are more than offsetting the declines in the household's consumption.
13. We thank an anonymous referee for suggesting that we consider this.

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APPENDIX

Following Carlstrom and Fuerst (1998), we derive the optimal contract for intraperiod debt for an entrepreneur who faces an idiosyncratic risk.

We consider an entrepreneur with his or her own fund x. If he or she undertakes a project of size s, it generates stochastic return $p\omega s$ units of output, where p is a constant that represents the market rate of markup, and ω is a unit-mean i.i.d. random variable. The probability distribution of ω is $\Phi(\omega)$ and the probability density is $\phi(\omega)$. The entrepreneur must borrow $s-x$ from the household, whereas ω is private information for the entrepreneur. The lender must pay μps to monitor the outcome of the project, where μ is a constant.

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As Carlstrom and Fuerst (1998) argue briefly, it is well known that in this costly-state-verification setting, the optimal financial contract is a risky debt. Given (p, x), the optimal contract is characterized by $(s, \overline{\omega})$, where s is the size of the project, i.e., the size of the borrowing is $s - x$; and the amount that the borrower repays is

$$ps \times \min\{\omega, \overline{\omega}\}. \tag{A.1}$$

$\overline{\omega}$ can be viewed as the threshold value for default: The lender will monitor the project outcome if and only if the entrepreneur reports that ω is less than $\overline{\omega}$; and in such a case the lender will confiscate all the returns from the project, $ps\omega$.

Define $f(\overline{\omega})$ and $g(\overline{\omega})$ as the expected shares of output for the entrepreneur and the lender, respectively:

$$f(\overline{\omega}) \equiv \int_0^\infty (\omega - \min\{\omega, \overline{\omega}\})\, \Phi(d\omega), \tag{A.2}$$

$$g(\overline{\omega}) \equiv \int_0^\infty \min\{\omega, \overline{\omega}\}\Phi(d\omega) - \Phi(\overline{\omega})\mu. \tag{A.3}$$

We assume that lending is fully diversified across projects, so that the lender only cares about the expected rate of return, and that borrowing and lending are intraperiod, so that the equilibrium rate of return is unity. Under these assumptions, the optimal contract $(s, \overline{\omega})$ is determined as the solution to the following problem, given (p, x):

$$\max_{s,\overline{\omega}} psf(\overline{\omega}) \;\; \text{s.t. } psg(\overline{\omega}) \geq (s - x). \tag{A.4}$$

The solution is (implicitly) given as

$$\frac{1}{p} = 1 - \Phi(\overline{\omega})\mu + \phi(\overline{\omega})\mu \frac{f(\overline{\omega})}{f'(\overline{\omega})}, \tag{A.5}$$

$$s = \frac{1}{1 - pg(\overline{\omega})} x. \tag{A.6}$$

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