http://clevelandfed.org/research/review/
Economic Review 2001 Q4

Monetary Policy and Asset Prices with Imperfect Credit Markets

by Charles T. Carlstrom and Timothy S. Fuerst

Charles T. Carlstrom is an economic advisor at the Federal Reserve Bank of Cleveland. Timothy S. Fuerst is the Owens-Illinois Professor in the Department of Economics at Bowling Green State University and a research associate at the Federal Reserve Bank of Cleveland.

Introduction

In a world with perfect capital markets (the world of the Modigliani–Miller theorem), a firm's financial position—that is, its debt versus its equity level—is irrelevant to its decisions on production and investment. The reason is that perfect capital markets let information flow freely. If an entrepreneur has a good idea for a new product, she will be able to produce it regardless of her personal financial position because outside investors, well informed and readily perceiving an attractive profit opportunity, will provide whatever financing is needed.

The supposition that an entrepreneur's financial position is irrelevant has important implications for monetary policy. A worthy production activity will be funded whatever the entrepreneur's finances may be. Therefore, monetary policy need not respond to asset prices.[1] The Modigliani–Miller theorem, however, is not necessarily meant to be a description of reality. On the contrary, a voluminous empirical literature supplies evidence that a firm's financial position *does* affect its ability to operate. But does this departure from the Modigliani–Miller theorem provide a rationale for basing monetary policy partly on equity prices? As it stands, the theorem provides an important benchmark and enforces careful thinking about financial markets' workings and the imperfections that would create a world where a firm's financial position (hence equity prices) affects its ability to engage in production.

Many possible imperfections could generate such a world. This article focuses on failures of information. Suppose that only the entrepreneur knows every detail of the proposed project, while outside investors financing the project have no way of knowing exactly what the entrepreneur would do with their funds. Suppose further that outside investors have limited ability to punish an entrepreneur who runs off with their money or squanders it on a misguided production activity. In this scenario, external investors are likely to provide financing only if they know they will be able to

1 A response might be warranted if equity prices help forecast macro variables of interest such as output and inflation.

recoup their investment if the project turns sour. One way to ensure this is to restrict the amount of funds they provide to the size of the entrepreneur's financial position. That is, external financing will be no greater than the collateral that investors can seize after the fact.

We have just summarized a story in which a firm's financial position, which we will henceforth call "collateral" or "net worth," has a powerful effect on a its ability to produce. Increases in its equity price will increase this collateral—and with it a firm's ability to produce. Clearly, this is no Modigliani–Miller world, but what role does monetary policy have in it? Can policy help the economy respond to the fundamental shocks that buffet it? Should policy respond to asset prices in such a world?

This article uses a theoretical model to address these questions. The model is highly stylized to keep the analysis tractable, but its essential point will survive more complicated modeling environments.[2] A key conclusion is that there is a role for activist monetary policy. Imperfect information imposes a collateral constraint on this economy, and monetary policy can be useful in alleviating this constraint by responding to productivity shocks or exogenous changes in equity prices.

I. The Model

The theoretical model consists of households and entrepreneurs. We will discuss the decision problems of each in turn.

Households

Households are infinitely lived, discounting the future at rate β. Their period-by-period utility function is given by

$$(1) \quad U(c_t, L_t) \equiv c_t - \frac{L_t^{1+\frac{1}{\tau}}}{1+\frac{1}{\tau}},$$

where c_t denotes consumption and L_t denotes work effort. We choose this form for convenience. Each period, the household decides how much to work at a real wage of w_t. The resulting labor supply relationship is given by

$$(2) \quad L_t = \left(\frac{w_t}{R_t}\right)^{\tau}.$$

Notice that labor supply responds positively to the real wage with elasticity τ. R_t denotes the gross nominal interest rate. Labor supply is negatively related to the nominal rate because we assume that households must use cash to facilitate their consumption purchases (a "cash-in-advance constraint").[3] Because the opportunity cost of holding cash is given by the gross nominal rate, higher nominal rates make it more difficult to turn labor income into consumption, thus discouraging labor supply. To put it another way, the gross nominal interest rate acts like a wage tax where $\frac{1}{R_t} = (1 - t_w)$. The celebrated "Friedman rule"—that the net nominal interest rate should be zero (or R=1)—is based directly on the observation that a zero interest rate eliminates this implicit wage tax.[4]

A household must also make a decision about consumption versus saving. Households can save only by acquiring shares to a real asset that pays out (real) dividends of D_t consumption goods at the end of time t. It is helpful to think of this as an apple tree that produces D_t apples in time t. The tree trades at share price q_t at the beginning of the period (before the time-t dividend is paid). Under our assumption on household preferences, the equilibrium real share price is given by dividends' present discounted value (the assumption of linear utility implies that the discount rate on dividends is the constant β)

$$(3) \quad \bar{q}_t = E_t \sum_{j=0}^{\infty} \beta^j D_{t+j}.$$

2 For example, empirical evidence suggests that collateral constraints have a stronger effect on small firms than on large ones (see Gertler and Gilchrist [1999]). We abstract from this heterogeneity and posit a single representative firm. Future efforts to quantify collateral effects should model heterogeneity more explicitly.

3 See the appendix for a precise statement of the household's problem and the resulting first-order conditions.

4 In our model, the first-best policy will be the Friedman rule. Our policy section includes analysis of a second-best problem where, for some unspecified reason, the monetary authority desires to keep the long-run average interest rate above zero, R>1.

If the share price were below this level ($q_t < \bar{q}_t$), then household demand for shares would be infinite; if the share price were above this level ($q_t > \bar{q}_t$), then household demand for shares would be negative infinity, that is, a desire to sell short. Thus, households will hold a finite and positive level of tree shares only if $\bar{q}_t$ is the equilibrium price. The dividend process is given by

$$D_{t+1} = (1-\rho_D)\, D_{ss} + \rho_D\, D_t + \varepsilon^D_{t+1}.$$

The symbol E_t denotes the rational forecast of future dividends; recall also that β is the rate of household time preference, which is also the real interest rate in this environment. Notice that the asset price depends only on the exogenous dividend process and that the share price is increasing in the current and future dividend levels. The exogenous discount process is an AR1, which means that next period's dividend is a weighted average of today's dividend (D_t) and the long-run average of dividends (D_{ss}) plus a random i.i.d. shock (ε^D_{t+1}).

Entrepreneurs

Entrepreneurs too are infinitely lived and have linear preferences over consumption. They are distinct from households in that they use a constant-returns-to-scale production technology in which labor produces consumption goods

(4) $\quad y_t = A_t H_t,$

where A_t is the current level of productivity, and H_t denotes the number of workers employed at real wage w_t. Like dividends productivity, A_t is an exogenous AR1 random process given by

$$A_{t+1} = (1-\rho_A)\, A_{ss} + \rho_A\, A_t + \varepsilon^A_{t+1}.$$

The entrepreneur is constrained by a borrowing limit. In particular, she must be able to cover her entire wage bill with collateral accumulated in advance. We will denote this collateral as n_t (net worth). The loan constraint is thus

(5) $\quad w_t H_t \leq n_t.$

Notice that all variables are in real terms.

Why is the firm so constrained? Many possible information stories would motivate such a constraint. We will assume the classic hold-up problem: Suppose that hired workers first supply their labor input but that output is subsequently produced if and only if the entrepreneur contributes her unique human capital to the process. This production sequence implies that the entrepreneur could force workers to accept lower wages ex post; otherwise, nothing would be produced. Workers, anticipating this hold-up possibility, will take steps to prevent it. This is harder than it sounds. For example, an equity-type arrangement in which worker and entrepreneur agree ex ante to split the production ex post will not work. After the worker has supplied his labor, the entrepreneur can refuse to provide her unique human capital unless the worker's share is made arbitrarily small. In that case, the worker's only choices are to accept this small share or to take nothing. The worker could seize the entrepreneur's existing assets, but then we are back to our collateral constraint. In fact, as Hart and Moore (1994) and Kiyotaki and Moore (1997) demonstrate, these hold-up problems can only be avoided completely if the entire wage bill is covered by existing collateral that workers could seize in case of default.[5]

We can easily enrich this story by assuming the existence of financial institutions that intermediate between workers and entrepreneurs. For example, suppose that such intermediaries provide within-period financing to entrepreneurs, who use it to pay workers. An intermediary, however, is concerned about the hold-up problem, so it limits its lending to the firm's net worth. This returns us to the collateral constraint described in equation (5).[6]

We assume in what follows that the loan constraint is binding, so that labor demand is given by

(6) $\quad H_t = \left(\dfrac{n_t}{w_t}\right).$

Notice that labor demand varies inversely (with a unit elasticity) to the real wage but is positively affected by the level of net worth. Firms that have more collateral can employ

5 This implicitly assumes a one-period problem so that an entrepreneur who withholds her labor cannot be punished by being deprived of future income.

6 Kiyotaki and Moore (1997) use a similar constraint. See Hart and Moore (1994) for more discussion of the hold-up problem.

more workers because hold-up problems are less severe. The binding collateral constraint implies that $A_t > w_t$, that is, the firm would like to hire more workers but is collateral-constrained.

An entrepreneur's only source of net worth is previously acquired ownership of apple trees. If we let e_{t-1} denote the number of tree shares acquired at the beginning of time t–1, then net worth at time t is given by

$$(7) \quad n_t = e_{t-1} q_t \,,$$

so that the loan constraint is given by

$$(8) \quad w_t H_t \leq e_{t-1} q_t \,.$$

As noted above, the assumption of a binding loan constraint implies that the firm's marginal profits per worker employed are $(A_t - w_t)$. These profits motivate the entrepreneur to acquire more net worth. We will need to limit this accumulation tendency so that collateral remains relevant. The entrepreneur's budget constraint is given by

$$(9) \quad c_t^e + e_t q_t = e_{t-1} q_t + e_t D_t + H_t (A_t - w_t).$$

The right side of the budget constraint equation is the entrepreneur's income in period t, which consists of her revenue from the sale of existing trees $(e_{t-1} q_t)$, dividends from new tree purchases $(e_t D_t)$, and profits $(H_t [A_t - w_t])$. The left side represents her potential purchases in period t. With her revenue, she purchases either consumption (c_t^e) or new tree shares $(e_t q_t)$. Using the binding loan constraint, we can rewrite this as

$$(10) \quad c_t^e + e_t (q_t - D_t) = e_{t-1} q_t \frac{A_t}{w_t} \,,$$

Because of the profit opportunities from net worth $(A_t > w_t)$, the entrepreneur would like to accumulate trees until the constraint no longer binds (trees are more valuable to collateral-constrained entrepreneurs than they are to households). To prevent this, we will assume that entrepreneurs must consume a fraction of their net income each period

$$(11) \quad c_t^e = (1 - \gamma) e_{t-1} q_t \frac{A_t}{w_t} \,,$$

so that entrepreneurial tree holdings evolve as

$$(12) \quad e_t (q_t - D_t) = \gamma e_{t-1} q_t \frac{A_t}{w_t} .$$

Below we will choose $\gamma < 1$ to offset the high return to internal funds, thus keeping the entrepreneur's collateral constrained in equilibrium. This forced-consumption-savings decision implies that households will price trees so that in equilibrium $q_t = \bar{q}_t$.

Equilibrium

In this theoretical model, there are two active markets, the market for apple trees and the labor market (the money market and bond market are discussed in the appendix). We normalize the supply of tree shares to unity so that the asset market clears with $e_t + s_t = 1$. The equilibrium tree price is given by (3). As for the labor market, equating labor supply with labor demand $(L_t = H_t)$ and solving for the real wage yields

$$(13) \quad w_t = n_t^{\frac{1}{1+\tau}} R_t^{\frac{\tau}{\tau+1}} .$$

The equilibrium real wage is increasing in net worth because higher net worth increases labor demand. The wage is also increasing in the nominal interest rate because a higher nominal rate decreases labor supply. Equilibrium employment is given by

$$(14) \quad L_t = \left(\frac{n_t}{R_t} \right)^{\frac{\tau}{1+\tau}} .$$

For the reasons already noted, employment responds positively to net worth and negatively to the nominal rate.

Log-Linearizing the Model

Because the model is relatively simple, it is convenient to express the equilibrium in terms of log deviations. In what follows, the ~ represents a percent deviation from the steady state.

$$(15) \quad \tilde{L}_t = \frac{\tau}{1+\tau} (\tilde{n}_t - \tilde{R}_t)$$

$$(16) \quad \tilde{n}_t = \tilde{q}_t + \tilde{e}_{t-1}$$

$$(17) \quad E_t \tilde{n}_{t+1} = \frac{\tau}{1+\tau} (\tilde{n}_t - \tilde{R}_t) + \tilde{A}_t ,$$

where (17) comes from (12) and the asset price (3). Using (16) to eliminate n_t, we can rewrite (15) and (17) in terms of e_t as

$$(18)\quad \tilde{L}_t = \frac{\tau}{1+\tau}(\tilde{q}_t + \tilde{e}_{t-1} - \tilde{R}_t)$$

$$(19)\quad \tilde{e}_t = \frac{\tau}{1+\tau}(\tilde{e}_{t-1} - \tilde{R}_t) + \tilde{A}_t + \left(\frac{\tau}{1+\tau} - \rho_D\right)\tilde{q}_t .$$

To calculate (19), we have also used the ability to express the share price (3) as

$$(20)\quad \tilde{q}_t = \tilde{D}_t \left(\frac{1-\beta}{1-\beta\rho_D}\right),$$

where ρ_D is the autocorrelation in the dividend process. To sum up, the model consists of equations (18)–(20). There is one predetermined variable, e_{t-1}, and there are three exogenous shocks: A_t, D_t, and R_t.

II. The Experiments

Before turning to the question of monetary policy, it is useful to sharpen one's economic intuition about the model by considering several experiments.

First Experiment: A Shock to Productivity (A_t)

Suppose that we hold all other variables constant and consider only shocks to productivity. Then we have

$$(21)\quad \tilde{L}_t = \frac{\tau}{1+\tau}\tilde{e}_{t-1}$$

$$(22)\quad \tilde{e}_t = \frac{\tau}{1+\tau}\tilde{e}_{t-1} + \tilde{A}_t .$$

By combining, we obtain

$$(23)\quad \tilde{L}_{t+1} = \frac{\tau}{1+\tau}(\tilde{L}_t + \tilde{A}_t).$$

Notice that contemporaneous employment does not respond to shocks to productivity, A_t (see [21]). This is a manifestation of the collateral constraint. When productivity is high, the firm would like to expand employment but it cannot because it must finance current activity with current collateral. Thus, the collateral constraint limits the firm's ability to respond to shocks.

There is, however, a delayed response. A positive shock to A_t has no effect on current employment, but it increases e_t and, through it, tomorrow's net worth (see [22]). Hence, employment responds with a lag to productivity shocks.

This lagged response generates persistence to a temporary shock. That is, even if the shock to A_t lasts only one period, the effect on employment, L_t, and thus on output, lasts much longer and only dies out at the rate given by $\tau/(1+\tau)$. If the shock to productivity is serially correlated, this effect remains, so that the collateral constraint prolongs the effect of the productivity shock.

Second Experiment: A Shock to Dividends

Proceeding as before, we have:

$$(24)\quad \tilde{L}_t = \frac{\tau}{1+\tau}\tilde{e}_{t-1} + \left(\frac{\tau}{1+\tau}\right)\left(\frac{1-\beta}{1-\beta\rho_D}\right)\tilde{D}_t$$

$$(25)\quad \tilde{e}_t = \frac{\tau}{1+\tau}\tilde{e}_{t-1} + \left(\frac{\tau}{1+\tau} - \rho\right)\left(\frac{1-\beta}{1-\beta\rho_D}\right)\tilde{D}_t .$$

By combining, we obtain

$$\tilde{L}_t = \frac{\tau}{1+\tau}(\tilde{L}_{t-1} + \tilde{\varepsilon}_t^D).$$

Recall that ε_t^D is the innovation in the dividend process. The most remarkable observation is that employment responds positively to dividend shocks, even though these shocks have no effect on either worker productivity or labor supply. Instead, dividends affect employment solely through the collateral constraint. Because trees are used as collateral, and a dividend shock drives up their price, the collateral constraint is relaxed and the firm can expand employment. Once again, these effects are highly persistent.

Third Experiment: A Monetary Policy Shock

We will assume that monetary policy is given by directives for the gross nominal interest rate, R_t. The implied path for the money supply can be backed out of the money demand relationship (see the appendix).

Proceeding as before, we have

$$(26)\quad \tilde{L}_t = \frac{\tau}{1+\tau}(\tilde{e}_{t-1} - \tilde{R}_t)$$

$$(27)\quad \tilde{e}_t = \frac{\tau}{1+\tau}(\tilde{e}_{t-1} - \tilde{R}_t).$$

By combining, we obtain

$$(28)\quad \tilde{L}_t = \frac{\tau}{1+\tau}(\tilde{L}_{t-1} - \tilde{R}_t).$$

There are two differences between the interest rate shock and the productivity shock. First, the interest rate shock has an immediate effect on employment because it alters labor supply contemporaneously. Second, its effect is negative because the higher interest rate lowers the households' desire to work. As in the previous cases, the shock has a persistent effect through the collateral constraint.

III. Monetary Policy

Optimal Monetary Policy

What is the nominal interest rate's optimal response to productivity and dividend shocks? To answer such a question, we need a welfare criterion. The most natural choice in the present context is the sum of household and entrepreneurial utility, which is given by

$$(29)\quad V_t \equiv c_t + c_t^e - \frac{L_t^{1+\frac{1}{\tau}}}{1+\frac{1}{\tau}} = A_t L_t + D_t - \frac{L_t^{1+\frac{1}{\tau}}}{1+\frac{1}{\tau}},$$

where the equality follows from the fact that total time-t consumption must equal the total supply of time-t consumption goods, which comes from the goods produced using the entrepreneur's production technology, and dividends produced by the apple tree. The only choice variable in V_t is employment. Maximizing V_t with respect to L_t yields the optimality condition

$$(30)\quad L_t = A_t^{\tau}.$$

We will call this solution the "first-best" outcome because the welfare criterion can go no higher. The first-best has two natural features. First, employment responds positively to productivity shocks. When productivity is high, it is efficient for employment to respond positively. Second, the first-best employment does not respond to dividend or share prices. The welfare criterion V_t is increasing in D_t, but these shocks have no effect on labor productivity; thus, it is efficient for employment not to respond to these shocks.

Is the first-best achievable? If there were no collateral constraint, we would have $w_t = A_t$, and the first-best could be achieved by setting $R_t = 1$, that is, by setting the net nominal rate to zero. This is the celebrated Friedman rule. It is optimal in this model because the cash-in-advance constraint on consumption distorts the labor margin.

But in a world with agency costs, the first-best is impossible because employment is given by (14), which, as noted above, is rendered too low ($A_t > w_t$) by the collateral constraint. Furthermore, according to (14), employment fluctuates with net worth and not with the level of productivity. Compared to the first-best outcome, these employment responses are dreadful. Contemporaneous employment does not respond to productivity, even though it is efficient to do so; employment, however, does respond to share prices which, in an efficient world, should not affect it. In short, the collateral constraint causes the economy to under-respond to productivity shocks and to over-respond to dividend shocks.

The advantage of the Friedman rule is that it minimizes the distortion on labor from the cash-in-advance-constraint.[7] The disadvantage is that a pegged zero nominal interest rate precludes the monetary authority's responding to shocks to make employment respond efficiently. It turns out that the benefit of a lower nominal interest rate always wins out in this

7 Recall that because cash must be held to facilitate transactions, higher nominal rates discourage labor supply in (2).

environment—the first-best policy is simply to set the nominal interest rate to zero (that is, $R=1$) and leave it there. But what happens if the monetary authority does not set the long-run interest rate to zero but keeps it positive for some unspecified reason?[8] Can monetary policy improve on this economy's ability to respond to shocks in this world? Yes. To illustrate, let us consider a second-best exercise.

Optimal Policy in Log Deviations

We take the steady state of the economy as given and use monetary policy so that the economy responds to shocks efficiently. Optimal employment (in log deviations) is given by

$$(35) \quad \tilde{L}_t = \tau \tilde{A}_t .$$

To find the optimal (second-best) interest rate policy, we can impose equation (35) in the system (18)–(19), and back out the implied interest rate. This exercise yields

$$(36) \quad \tilde{R}_t = \tilde{q}_t + \tilde{e}_{t-1} - (1+\tau)\tilde{A}_t$$

$$(37) \quad \tilde{e}_t = (1+\tau)\tilde{A}_t - \rho_D \tilde{q}_t .$$

By combining, we obtain

$$\tilde{R}_t = \varepsilon_t^D - (1+\tau)\left[\varepsilon_t^A + (\rho_A - 1)\tilde{A}_{t-1}\right].$$

What are the properties of this (second-best) optimal monetary policy?[9] When there is a positive shock to productivity A_t, the central bank should lower the nominal interest rate so that employment can expand efficiently. A constant-interest-rate policy does not allow this because of the collateral constraint, but a procyclical interest rate policy overcomes the collateral constraint and allows the economy to respond appropriately.

Suppose that productivity shocks are autocorrelated with coefficient ρ_A. A positive technology shock of 1 percent calls for an immediate interest rate decline of $(1+\tau)$ percent, but then an increase to $(1+\tau)(1-\rho_A)$. The increase is needed to prevent over-expansion of employment, because net worth rises with the initial interest rate decline.

In contrast, if there is a shock to share prices that drives up net worth, n_t, the central bank should increase the interest rate enough to keep employment constant. It is inefficient for employment to respond to these dividend shocks, and the central bank can ensure no response by raising the nominal rate in response. Notice, however, that even if a shock to share prices (dividends) is autocorrelated ($\rho_D > 0$), the optimal interest rate response is iid.

IV. Conclusion

This article addresses the question of how monetary policy should be conducted in a world where asset prices affect real activity directly because of binding collateral constraints, that is, a world in which the Modigliani–Miller theorem does not hold. How should monetary policy be conducted in such a world? Should it respond to asset prices? How should it respond to productivity movements? In this environment, there is a welfare-improving role for a monetary policy that responds actively to asset price and productivity shocks. This activist interest rate policy allows the economy to respond to shocks in a Pareto efficient manner. By assumption, monetary policy cannot eliminate the long-run impact of the information constraint, but it can improve welfare by smoothing the fluctuations in this constraint.

Our results are stark because all firms in the economy are subject to this hold-up problem. One can imagine an environment in which small firms are the ones most subject to agency costs. This will change the quantitative—but not the qualitative—predictions of the model.

This article uses a monetary model with flexible nominal prices. In contrast, Bernanke and Gertler (1999) analyze a similar question in a model with sticky prices. They conclude that as long as monetary policy responds aggressively to inflation, there is no rationale

8 For example, a positive nominal interest rate may be set to give the government inflation-tax revenues.

9 Optimal monetary policy refers to how the central bank should change the interest rate in response to technology shocks and share prices. Money growth is endogenous and, as discussed in the appendix, can be backed out of the money demand relationship, that is, the cash-in-advance constraint.

for a direct response to asset prices. They reach this conclusion because, in their model, asset price shocks directly increase aggregate demand and thus the price level. Hence, a policy that responds aggressively to inflation is automatically responding to asset prices. The model described in this article creates no direct link between inflation and asset prices, so the central bank must respond directly to the latter. It suggests that, to the extent that asset prices do not immediately lead to price inflation, there may be a role for a monetary policy response to asset price movements.

Appendix

The household's maximization problem is given by

$$\text{Max} \quad E\sum_{t=0}^{\infty}\beta^{t}\left\{c_t-\frac{L_t^{1+\frac{1}{\tau}}}{1+\frac{1}{\tau}}\right\}$$

$$\text{s.t.} \quad \frac{M_{t-1}+X_t}{P_t}+s_{t-1}q_t+s_tD_t$$

$$+\frac{R_{t-1}B_{t-1}-B_t}{P_t}-s_tq_t-c_t\geq 0$$

$$\frac{M_{t-1}+X_t}{P_t}+s_{t-1}q_t+s_tD_t+w_tL_t$$

$$+\frac{R_{t-1}B_{t-1}-B_t}{P_t}-s_tq_t-c_t-\frac{M_t}{P_t}\geq 0,$$

where B_t denotes bond holdings (in zero net supply), and households are assumed to receive lump-sum monetary injections, $X_t=\frac{M_t^s}{M_{t-1}^s}-1$, at the beginning of the period (M_t^s denotes the per capita money supply at time t). Notice that the bond and tree markets open either simultaneous to or before the consumption market. The first constraint is the cash-in-advance constraint: The cash remaining after leaving the bond and tree markets is the cash that can be used to purchase consumption. The second is the intertemporal budget constraint.

After minor simplification, household optimization is defined by the binding cash constraint and the following Euler equations:

(A1) $1=\beta R_tE_t(P_t/P_{t+1})$

(A2) $L\frac{1}{\tau}=w_t\beta E_t(\frac{P_t}{P_{t+1}})$

$$s_t=\infty \text{ if } q_t<\bar{q}_t$$

$$s_t \text{ indeterminate if } q_t=\bar{q}_t$$

$$s_t=0 \text{ if } q_t>\bar{q}_t, \text{ where}$$

$$\bar{q}_t=D_t+E_t\beta\bar{q}_{t+1}.$$

Substituting (A1) into (A2), we have

$$L_t=\left(\frac{w_t}{R_t}\right)^{\tau},$$

which is equation (2) in the text. Along with the equilibrium conditions given in the text, we also have $B_t=0$ and $M_t^s=M_t$. Since we are following an interest rate policy, the implied inflation behavior is given by (A1). The supporting money growth process can then be backed out of the binding cash-in-advance constraint.

References

Bernanke, Ben, and Mark Gertler. "Agency Costs, Net Worth, and Business Fluctuations," *American Economic Review*, vol. 79, no. 1 (1989), pp. 14–31.

Bernanke, Ben, and Mark Gertler. "Monetary Policy and Asset Price Volatility," Federal Reserve Bank of Kansas City *Economic Review*, vol. 84 (1999), pp. 17–52.

Bernanke, Ben, Mark Gertler, and Simon Gilchrist. "The Financial Accelerator in a Quantitative Business Cycle Framework," in John Taylor and Michael Woodford, eds., *Handbook of Macroeconomics*. Volume 1C. New York: Elsevier Science, 2000, pp. 1341–93.

Carlstrom, Charles T., and Timothy S. Fuerst. "Agency Costs, Net Worth, and Business Fluctuations: A Computable General Equilibrium Analysis," Federal Reserve Bank of Cleveland, Working Paper no. 9602, 1996.

Carlstrom, Charles T., and Timothy S. Fuerst. "Agency Costs, Net Worth, and Business Fluctuations: A Computable General Equilibrium Analysis," *American Economic Review*, vol. 87, no. 5 (1997), pp. 893–910.

Carlstrom, Charles T., and Timothy S. Fuerst. "Agency Costs and Business Cycles," *Economic Theory*, vol. 12, no. 3 (1998), pp. 583–97.

Carlstrom, Charles T., and Timothy S. Fuerst. "Monetary Shocks, Agency Costs and Business Cycles," *Carnegie-Rochester Series on Public Policy,* vol. 54 (2001), pp. 1–27.

Cooley, Thomas F., and Kwanghee Nam. "Asymmetric Information, Financial Intermediation, and Business Cycles," *Economic Theory,* vol. 12, no. 3 (1998), pp. 599–620.

Cooley, Thomas F., and Vincenzo Quadrini. "Monetary Policy and the Financial Decisions of Firms," New York University, unpublished manuscript, 1997.

Fisher, Jonas D.M. "Credit Market Imperfections and the Heterogeneous Response of Firms to Monetary Shocks," *Journal of Money, Credit, and Banking*, vol. 31, no. 2 (1999), pp. 187–211.

Fuerst, Timothy S. "Monetary and Financial Interactions in the Business Cycle," *Journal of Money, Credit, and Banking*, vol. 27, no. 4 (1995), pp. 1321–38.

Gertler, Mark, and Simon Gilchrist. "Monetary Policy, Business Cycles, and the Behavior of Small Manufacturing Firms," *Quarterly Journal of Economics*, vol. 109, no. 2 (1994), pp. 309–40.

Hart, Oliver, and John Moore. "A Theory of Debt Based on the Inalienability of Human Capital," *Quarterly Journal of Economics*, vol. 109, no. 4 (1994), pp. 841–79.

Kiyotaki, Nobuhiro, and John Moore. "Credit Cycles," *Journal of Political Economy*, vol. 105, no. 2 (1997), pp. 211–48.