ible policy expected to reduce inflation. In countries with high-inflation experiences, increases in short rates were not associated with decreases in forward rates.

A key maintained hypothesis in the view that movements in interest rates reveal information about inflation expectations is that the Fisher hypothesis, the hypothesis that nominal interest rates will incorporate a premium for expected inflation, holds. Suppose that the real rate is stationary around an average value of $\bar{r}$. Then, since $i_t = r_t + \pi^e_{t+1} = r_t + \pi_{t+1} + e_{t+1}$, where e_{t+1} is the inflation forecast error (which is stationary under rational expectations), the ex post real rate $i_t - \pi_{t+1}$ is stationary. Thus, if the nominal interest rate and the inflation rate are nonstationary, they must be cointegrated under the Fisher hypothesis. This is the sense in which long-term movements in inflation should be reflected in the nominal interest rate. Mishkin (1992) adopted this cointegrating interpretation of the Fisher relationship to test for the presence of a long-term relationship between inflation and nominal interest rates in the United States. If over a particular time period neither i nor π is integrated of order 1 but instead are both stationary, there is no real meaning to the statement that permanent shifts in the level of inflation should cause similar movements in nominal rates because such permanent shifts have not occurred. If either i or π is $I(1)$, they should both be $I(1)$, and they should be cointegrated. Mishkin found the evidence to be consistent with the Fisher relationship.

10.4 Macrofinance

A recent literature has developed that identifies the latent factors employed in finance models of the term structure to macroeconomic variables such as inflation, real economic activity, and monetary policy. The term structure is represented using affine no-arbitrage models, as in Dai and Singleton (2000). The unobserved latent variables that determine bond prices in these models are linked to macroeconomic variables, either through nonstructural statistical models such as a VAR (e.g., Ang and Piazzesi 2003) or by using a new Keynesian model to represent macroeconomic and monetary policy outcomes (e.g., Rudebusch and Wu 2007; 2008). Diebold, Piazzesi, and Rudebusch (2005) provided an overview of this research area and discussed some of the issues that arise in linking finance models and macroeconomic models.

Suppose there are two latent (unobserved) factors that determine bond prices.[17] Following Rudebusch and Wu (2007), denote these factors by L_t and S_t and assume they follow a VAR process given by

$$F_t \equiv \begin{bmatrix} L_t \\ S_t \end{bmatrix} = \rho \begin{bmatrix} L_{t-1} \\ S_{t-1} \end{bmatrix} + \Sigma e_t = \rho F_{t-1} + \Sigma e_t, \tag{10.30}$$

17. Rudebusch and Wu (2008) found that two-factor models are rich enough to fit the data adequately.

where e_t is independently and identically distributed as a normal mean zero unit variance process, where Σ is a 2×2 nonsingular matrix. Assume further that one can write the short-term interest rate i_t as a function of the two factors. Specifically,

$$i_t = \delta_0 + \delta_1 F_t. \tag{10.31}$$

Finally, assume the prices of risk associated with each factor are linear functions of the two factors, so that if $\Lambda_{i,t}$ is the price of risk associated with conditional volatility of factor i,

$$\Lambda_t = \begin{bmatrix} \Lambda_{L,t} \\ \Lambda_{S,t} \end{bmatrix} = \lambda_0 + \lambda_1 F_t. \tag{10.32}$$

If i_t is the return on a one-period bond, than the structure given by (10.30)–(10.32), together with the assumption that no-arbitrage opportunities exist, allows one to price longer-term bonds. In particular, if $b_{j,t}$ is the log price of a j-period nominal bond, one can show that

$$b_{j,t} = \bar{A}_j + \bar{B}_j F_t,$$

where

$$\bar{A}_1 = -\delta_0; \quad \bar{B}_1 = -\delta_1,$$

and for $j = 2, \dots, J$,

$$\bar{A}_{j+1} - \bar{A}_j = \bar{B}_j(-\Sigma\lambda_0) + \frac{1}{2}\bar{B}_j\Sigma\Sigma'\bar{B}_j + \bar{A}_1$$

$$\bar{B}_{j+1} = \bar{B}_j(\rho - \Sigma\lambda_1) + \bar{B}_1.$$

Empirical research aimed at estimating this type of no-arbitrage model generally finds that one factor affects yields at all maturities and so is called the level factor, whereas the other factor affects short and long rates differently and so is called the slope factor.

The macrofinance literature has attempted to identify the level and slope factors with macroeconomic factors. For example, in new Keynesian models, the short-term interest rate is often represented in terms of a Taylor rule of the form

$$i_t = r^* + \pi_t^T + a_\pi(\pi_t - \pi_t^T) + a_x x_t,$$

where π_t^T is the central bank's inflation target and x_t is the output gap. In this case, changes in the inflation target should affect nominal interest rates at all maturities by altering inflation expectations. Thus, it would seem to be a prime candidate for the level factor. The slope factor might then be capturing the central bank's policy actions intended to stabilize the economy in the short run. Thus, one could model the factors explicitly in terms of the policy behavior of the central bank.[18]

Of course, this approach requires that the behavior of inflation, the inflation target, and the output gap also be modeled. As noted, Ang and Piazzesi (2003) represented the behavior of the macroeconomic variables using a VAR representation. They grouped variables into a set related to inflation and a set related to real activity. By then using the principal component from each group, they obtained the two factors that determine the term structure. Macroeconomic factors are found to explain movements of short- and medium-term interest rates but little of the long-term interest rate. Rudebusch and Wu (2008) employed a simplified new Keynesian model to model the behavior of macroeconomic variables, and Rudebusch and Wu (2007) argued that shifts in the pricing of risk associated with the Fed's inflation target can account for shifts in the behavior of the term structure in the United States.

In new Keynesian models and other structural macroeconomic models, the consumption Euler equation linking the marginal utility of current consumption to the discounted real return and future marginal utilities plays a key role in linking real economic activity and real interest rates. However, the interest rate appearing in this equation is normally identified with the real policy rate controlled by the central bank. As Canzoneri, Cumby, and Diba (2007) showed, monetary tightening (a rise in the policy rate) is typically associated with a decline in future consumption growth, yet standard specifications of the Euler condition would imply that a decline in expected consumption growth should be associated with a fall in the real interest rate.[19]

10.5 Financial Frictions in Credit Markets

Money has traditionally played a special role in macroeconomics and monetary theory because of the relationship between the nominal stock of money and the aggregate price level. The importance of money for understanding the determination of the general level of prices and average inflation rates, however, does not necessarily

18. McCallum (1994b) (see section 10.3.2) can be viewed as an early attempt to link the term structure to the behavior of monetary policy. Ballmeyer, Hollifield, and Zin (2007) provided an explicit analysis of the role of the policy rule in a no-arbitrage model of the term structure.

19. With standard log preferences, the linearized Euler equation (see chapter 8) is

$$c_t = \mathrm{E}_t c_{t+1} - \left(\frac{1}{\sigma}\right) r_t,$$

so expected consumption growth $\mathrm{E}_t c_{t+1} - c_t = (\frac{1}{\sigma}) r_t$ and the real interest rate are positively related. Canzoneri, Cumby, and Diba (2007) showed how this relationship is affected by habit persistence (a common component of new Keynesian models), but they argued that habit persistence does not fully reconcil the Euler equation with the empirical effects of a monetary policy contraction.

imply that the stock of money is the key variable that links the real and financial sectors or the most appropriate indicator of the short-run influence of financial factors on the economy. Many economists have argued that monetary policy has direct effects on aggregate spending that do not operate through traditional interest rate or exchange rate channels, and a large literature has focused on credit markets as playing a critical role in the transmission of monetary policy actions to the real economy.

The *credit view* stresses the distinct role played by financial assets and liabilities. Rather than aggregate all nonmoney financial assets into a single category called *bonds*, the credit view argues that macroeconomic models need to distinguish between different nonmonetary assets, either along the dimension of bank versus nonbank sources of funds or, more generally, internal versus external financing. The credit view also highlights heterogeneity among borrowers, stressing that some borrowers may be more vulnerable to changes in credit conditions than others. Finally, investment may be sensitive to variables such as net worth or cash flow if agency costs associated with imperfect information or costly monitoring create a wedge between the cost of internal and external funds. A rise in interest rates may have a much stronger contractionary impact on the economy if balance sheets are already weak, introducing the possibility that nonlinearities in the impact of monetary policy may be important.

The credit channel also operates when shifts in monetary policy alter either the efficiency of financial markets in matching borrowers and lenders or the extent to which borrowers face rationing in credit markets so that aggregate spending is influenced by liquidity constraints. There are several definitions of nonprice credit rationing. Jaffee and Russell (1976) defined credit rationing as existing when at the quoted interest rate the lender supplies a smaller loan than the borrower demands. Jaffee and Stiglitz (1990), however, pointed out that this practice represents standard price rationing; larger loans will normally be accompanied by a higher default rate and therefore carry a higher interest rate. Instead, Jaffee and Stiglitz characterized "pure credit rationing" as occurring when, among a group of agents (firms or individuals) who appear to be identical, some receive loans and others do not. Stiglitz and Weiss (1981) defined equilibrium credit rationing as being present whenever "either (a) among loan applicants who appear to be identical some receive a loan and others do not, and the rejected applicants would not receive a loan even if they offered to pay a higher interest rate; or (b) there are identifiable groups of individuals in the population who, with a given supply of credit, are unable to obtain loans at any interest rate, even though with a larger supply of credit, they would" (394–395). The critical aspect of this definition is that at the market equilibrium interest rate there is an unsatisfied demand for loans that cannot be eliminated through higher interest rates. Rejected loan applicants cannot succeed in getting a loan by offering to pay a higher interest rate.

It is important to recognize that credit rationing is sufficient but not necessary for a credit channel to exist. A theme of Gertler (1988), Bernanke and Gertler (1989), and Bernanke (1993) was that agency costs in credit markets will vary countercyclically; a monetary tightening that raises interest rates and generates a real economic slowdown will cause firm balance sheets to deteriorate, raising agency costs and lowering the efficiency of credit allocation. Changes in credit conditions are not reflected solely in interest rate levels. Thus, the general issue is to understand how credit market imperfections affect the macroeconomic equilibrium and the channels through which monetary policy actions are transmitted to the real economy.

The main focus here is on credit markets for firms undertaking investment projects. This approach is chosen primarily for convenience; the theoretical models may also be applied to the consumer loan market, and there is evidence that a significant fraction of households behave as if they faced liquidity constraints that link consumption spending more closely to current income than would be predicted by forward-looking models of consumption.[20]

The role of credit effects in the transmission of monetary policy arises as a result of imperfect information between parties in credit relationships. The information that each party to a credit transaction brings to the exchange will have important implications for the nature of credit contracts, the ability of credit markets to match borrowers and lenders efficiently, and the role played by the rate of interest in allocating credit among borrowers. The nature of credit markets can lead to distinct roles for different types of lenders (e.g., bank versus nonbank) and different types of borrowers (e.g., small firms versus large firms).

Critical to the presence of a distinct credit channel is the presence of imperfections in financial markets. The first task, then, is to review theories of credit market imperfections based on adverse selection, moral hazard, monitoring costs and agency costs; this is done in sections 10.5.1–10.5.4. These theories help to explain many of the distinctive features of financial markets, from collateral to debt contracts to the possibility of credit rationing. This material provides the microfoundations for the macroeconomic analysis of credit channels in section 10.5.5. Section 10.6 reviews the empirical evidence on the role played by credit channels in the transmission of monetary policy actions.

10.5.1 Adverse Selection

Jaffee and Russell (1976) analyzed a credit market model in which there are two types of borrowers, “honest” ones who always repay and “dishonest” ones who

20. Empirical evidence on consumption and liquidity constraints can be found in Campbell and Mankiw (1989; 1991), who provided estimates of the fraction of liquidity-constrained households for a number of OECD countries.

repay only if it is in their interest to do so. Ex ante the two types appear identical to lenders. Default is assumed to impose a cost on the defaulter, and dishonest borrowers default whenever the loan repayment amount exceeds the cost of default. By assuming a distribution of default costs across the population of borrowers, Jaffee and Russell showed that the fraction of borrowers who default is increasing in the loan amount.[21] In a pooling equilibrium, lenders offer the same loan contract (interest rate and amount) to all borrowers because they are unable to distinguish between the two types.[22] If lenders operate with constant returns to scale, if there is free entry, and if funds are available to lenders at an exogenously given opportunity cost, then the equilibrium loan rate must satisfy a zero profit condition for lenders. Since the expected return on a loan is less than or equal to the interest rate charged, the actual interest rate on loans must equal or exceed the opportunity cost of funds to the lenders.[23]

The effects of borrower heterogeneity and imperfect information on credit market equilibria can be illustrated following Stiglitz and Weiss (1981). The lender's expected return on a loan is a function of the interest rate charged and the probability that the loan will be repaid, but individual borrowers differ in their probabilities of repayment. Suppose borrowers come in two types. Type G repays with probability q_g; type B repays with probability $q_b < q_g$. If lenders can observe the borrower's type, each type will be charged a different interest rate to reflect the differing repayment probabilities. If the supply of credit is perfectly elastic at the opportunity cost of r, and lenders are risk-neutral and able to lend to a large number of borrowers so that the law of large numbers holds, then all type G borrowers can borrow at an interest rate of r/q_g, whereas type B borrowers borrow at $r/q_b > r/q_g$. At these interest rates, the lender's expected return from lending to either type of borrower is equal to the lender's opportunity cost of r. No credit rationing occurs; riskier borrowers are simply charged higher interest rates.

Now suppose the lender cannot observe the borrower's type. It may be the case that changes in the terms of a loan (interest rate, collateral, amount) affect the mix of borrower types the lender attracts. If increases in the loan interest rate shift the mix of borrowers, raising the fraction of type B borrowers, the expected return to the lender might actually decline with higher loan rates because of adverse selection. In this case, further increases in the loan rate would lower the lender's expected prof-

21. See Smith (1983) for a general equilibrium version of Jaffee and Russell's model using an overlapping-generations framework.

22. This ignores the possibility of separating equilibrium in which the lender offers two contracts and the borrowers (truthfully) signal their type by the contract they choose.

23. If the probability of default was zero, the constant-returns-to-scale assumption with free entry would ensure that lenders charge an interest rate on loans equal to the opportunity cost of funds. If default rates are positive, then the expected return on a loan is less than the actual interest rate charged, and the loan interest rate must be greater than the opportunity cost of funds.

its, even if an excess demand for loans remains. The intuition is similar to that of Akerlof's market for lemons (Akerlof 1970). Assume that a fraction g of all borrowers are of type G. Suppose the lender charges an interest rate of r_l such that $gq_g r_l + (1-g)q_b r_l = r$, or $r_l = r/[gq_g + (1-g)q_b]$. At this loan rate, the lender earns the required return of r if borrowers are drawn randomly from the population. But at this rate, the pool of borrowers is no longer the same as in the population at large. Since $r/q_g < r_l < r/q_b$, the lender is more likely to attract type B borrowers, and the lender's expected return would be less than r.

Loans are, however, characterized by more than just their interest rate. For example, suppose a loan is characterized by its interest rate r_l, the loan amount L, and the collateral the lender requires C. The probability that the loan will be repaid depends on the (risky) return yielded by the borrower's project. If the project return is R, then the lender is repaid if

$$L(1 + r_l) < R + C.$$

If $L(1 + r_l) > R + C$, the borrower defaults and the lender receives $R + C$.

Suppose the return R is $R' + x$ with probability $\frac{1}{2}$ and $R' - x$ with probability $\frac{1}{2}$. The expected return is R', and the variance is x^2. An increase in x represents a mean preserving spread in the return disturbance and corresponds to an increase in the project's risk. Assume that $R' - x < (1 + r_l)L - C$ so that the borrower must default when the bad outcome occurs. If the project pays off $R' + x$, the borrower receives $R' + x - (1 + r_l)L$; if the bad outcome occurs, the borrower receives $-C$, that is, any collateral is lost. The expected profit to the borrower is

$$\mathrm{E}\pi^B = \frac{1}{2}[R' + x - (1 + r_l)L] - \frac{1}{2}C.$$

Define

$$x^*(r_l, L, C) \equiv (1 + r_l)L + C - R'. \tag{10.33}$$

Expected profits for the borrower are positive for all $x > x^*$. This critical cutoff value of x is increasing in r_l. Recall that increases in x imply an increase in the project's risk, as measured by the variance of returns. An increase in the loan rate r_l increases x^*, and this implies that some borrowers with less risky projects will find it unprofitable to borrow if the loan rate rises, while borrowers with riskier projects will still find it worthwhile to borrow. Because the borrower can lose no more than his collateral in the bad state, expected profits are a convex function of the project's return and therefore increase with an increase in risk (for a constant mean return).

While the expected return to the firm is increasing in risk, as measured by x, the lender's return is decreasing in x. To see this point, note that the lender's expected profit is

$$\mathrm{E}\pi^L = \frac{1}{2}[(1+r_l)L] + \frac{1}{2}[C + R' - x] - (1+r)L,$$

where r is the opportunity cost of funds to the lender. The lender's expected profit decreases with x. Because the lender receives a fixed amount in the good state, the lender's expected return is a concave function of the project's return and therefore decreases with an increase in risk.

Now suppose there are two groups of borrowers, those with $x = x_g$ and those with $x = x_b$, with $x_g < x_b$. Type x_g borrowers have lower-risk projects. From (10.33), if the loan rate r_l is low enough such that $x_b > x_g \geq x^*(r_l, L, C)$, then both types will find it profitable to borrow. If each type is equally likely, the lender's expected return is

$$\begin{aligned}\mathrm{E}\pi^L &= \frac{1}{4}[(1+r_l)L + C + R' - x_g] + \frac{1}{4}[(1+r_l)L + C + R' - x_b] - (1+r)L \\ &= \frac{1}{2}[(1+r_l)L + C + R'] - \frac{1}{4}(x_g + x_b) - (1+r)L, \qquad x^*(r_l, L, C) \leq x_g,\end{aligned}$$

which is increasing in r_l. But as soon as r_l increases to the point where $x^*(r_l, L, C) = x_g$, any further increase causes all x_g types to stop borrowing. Only x_b types will still find it profitable to borrow, and the lender's expected profit falls to

$$\mathrm{E}\pi^L = \frac{1}{2}[(1+r_l)L + C + R'] - \frac{1}{2}x_b - (1+r)L, \qquad x_g \leq x^*(r_l, L, C) \leq x_b.$$

As a result, the lender's expected profit as a function of the loan rate is increasing for $x^*(r_l, L, C) \leq x_g$ and then falls discretely at $1 + r_l = [x_g - C + R']/L$ as all low-risk types exit the market. This is illustrated in figure 10.2, where r^* denotes the loan rate that tips the composition of the pool of borrowers. For loan rates between r_1 and r^*, both types borrow and the lender's expected profit is positive. Expected profits are again positive for loan rates above r_2, but in this region only x_b types borrow.

The existence of a local maximum in the lender's profit function at r^* introduces the possibility that credit rationing will occur in equilibrium. Suppose at r^* there remains an excess demand for loans. Type x_g would not be willing to borrow at a rate above r^*, but type x_b would. If the lender responds to the excess demand by raising the loan rate, expected profits fall. Equilibrium may involve a loan rate of r^*, with some potential borrowers being rationed.[24] Thus, adverse selection provides one rationale for a lender's profit function that is not monotonic in the loan rate. Equi-

24. As figure 10.2 suggests, if the demand for loans is strong enough, the lender may be able to raise the loan rate sufficiently so that expected profits do rise.

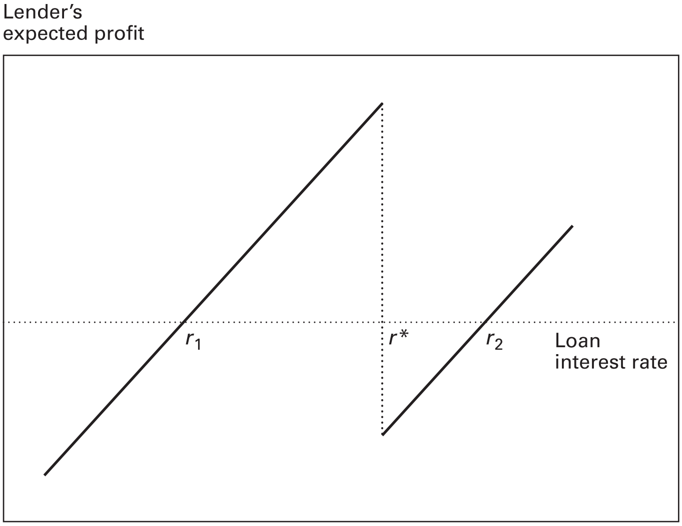

Figure 10.2
Expected loan profit with adverse selection.

librium credit rationing may exist because lenders find it unprofitable to raise the interest rate on loans even in the face of an excess demand for loans.

10.5.2 Moral Hazard

Moral hazard can arise in credit markets when the borrower's behavior is influenced by the terms of the loan contract. In the model of the previous section, the borrower decided whether to borrow, but the project's return was exogenous. Borrowers differed in terms of the underlying riskiness of their projects, and adverse selection occurred as loan rate changes affected the pool of borrowers. Suppose instead that each borrower can choose between several projects of differing risk. If the lender cannot monitor this choice, a moral hazard problem arises. The lender's expected return may not be monotonic in the interest rate charged on the loans. Higher loan rates lead the borrower to invest in riskier projects, lowering the expected return to the lender.

To illustrate this situation, again following Stiglitz and Weiss (1981), suppose the borrower can invest either in project A, which pays off R^a in the good state and 0 in the bad state, or in project B, which pays off $R^b > R^a$ in the good state and 0 in the bad state. Suppose the probability of success for project A is p^a and p^b for project B, with $p^a > p^b$. Project B is the riskier project. Further, assume the expected payoff from A is higher: $p^a R^a > p^b R^b$. By investing in A, the borrower's expected return is

$$\mathrm{E}\pi^A = p^a[R^a - (1 + r_l)L] - (1 - p^a)C,$$

where the borrower loses collateral C if the project fails. The expected return from project B is

$$\mathrm{E}\pi^B = p^b[R^b - (1 + r_l)L] - (1 - p^b)C.$$

The expected returns on the two projects depend on the interest rate on the loan r_l. It is straightforward to show that

$$\mathrm{E}\pi^A > \mathrm{E}\pi^B$$

if and only if

$$\frac{p^a R^a - p^b R^b}{p^a - p^b} > (1 + r_l)L - C.$$

The left side of this condition is independent of the loan rate, but the right side is increasing in r_l. Define r_l^* as the loan rate at which the expected returns to the borrower from the two projects are equal. This occurs when

$$(1 + r_l^*)L - C = \frac{p^a R^a - p^b R^b}{p^a - p^b}.$$

For loan rates less than r_l^*, the borrower will prefer to invest in project A; for loan rates above r_l^*, the riskier project B is preferred. The expected payment to the lender, therefore, will be $p^a(1 + r_l)L + (1 - p^a)C$ if $r_l < r_l^*$, and $p^b(1 + r_l)L + (1 - p^b)C$ for $r_l > r_l^*$. Since

$$p^a(1 + r_l^*)L + (1 - p^a)C > p^b(1 + r_l^*)L + (1 - p^b)C, \tag{10.34}$$

the lender's profits fall as the loan rate rises above r^*; the lender's profits are not monotonic in the loan rate.[25] Just as in the example of the previous section, this leads to the possibility that credit rationing may characterize the loan market's equilibrium.

10.5.3 Monitoring Costs

The previous analysis illustrated how debt contracts in the presence of adverse selection or moral hazard could lead to credit rationing as an equilibrium phenomenon.

25. To see this, note that using the definition of r_l^* implies that the left side of (10.34) is equal to $p^a[(1 + r_l^*)L - C] = p^a((p^a R^a - p^b R^b)/(p^a - p^b))$, and the right side is equal to $p^b[(1 + r_l^*)L - C] = p^b((p^a R^a - p^b R^b)/(p^a - p^b))$. The direction of the inequality follows because $p^a > p^b$.

One limitation of the discussion, however, was the treatment of the nature of the loan contract—repayment equal to a fixed interest rate times the loan amount in some states of nature, zero or a predetermined collateral amount in others—as exogenous. Williamson (1986; 1987a; 1987b) illustrated how debt contracts and credit rationing can arise, even in the absence of adverse selection or moral hazard problems, if lenders must incur costs to monitor borrowers.[26] The intuition behind his result is straightforward. Suppose the lender can observe the borrower's project outcome only at some positive cost. Any repayment schedule that ties the borrower's payment to the project outcome would require that the monitoring cost be incurred; otherwise, the borrower always has an incentive to underreport the success of the project. Expected monitoring costs can be reduced if the borrower is monitored only in some states of nature. If the borrower reports a low project outcome and defaults on the loan, the lender incurs the monitoring cost to verify the truth of the report. If the borrower reports a good project outcome and repays the loan, the lender does not need to incur the monitoring cost.

Following Williamson (1987a), assume there are two types of agents, borrowers and lenders. Lenders are risk-neutral and have access to funds at an opportunity cost of r. Each lender takes r as given and offers contracts to borrowers that yield, to the lender, an expected return of r. Assume there are two periods. In period 1, lenders offer contracts to borrowers who have access to a risky investment project that yields a payoff in period 2 of $x \in [0, \bar{x}]$. The return x is a random variable, drawn from a distribution known to both borrowers and lenders. The actual realization is observed costlessly by the borrower; the lender can observe it by first paying a cost of c. This assumption captures the idea that borrowers are likely to have better information about their own projects than do lenders. Lenders can obtain this information by monitoring the project, but such monitoring is costly.

In period 2, after observing x, the borrower reports the project outcome to the lender. Let this report be x^s. While x^s must be in $[0, \bar{x}]$, it need not equal the true x, since the borrower will have an incentive to misreport if doing so is in the borrower's own interest. By choice of normalization, projects require an initial resource investment of 1 unit. Although borrowers have access to an investment project, assume they have no resources of their own, so to invest they must obtain resources from lenders.

Suppose that monitoring occurs whenever $x^s \in S \subset [0, \bar{x}]$. Otherwise, the lender does not monitor. Denote by $R(x)$ the payment from the borrower to the lender if $x^s \in S$ and monitoring takes place. Because the lender monitors and therefore observes x, the repayment can be made a function of the actual x. The return to the lender net of monitoring costs is $R(x) - c$. If the reported value $x^s \notin S$, then no

26. Townsend (1979) provided the first analysis of optimal contracts when it is costly to verify the state.

monitoring occurs and the borrower pays $K(x^s)$ to the lender. This payment can only depend on the signal, not the true realization of x, since the lender cannot verify the latter. In this case, the return to the lender is simply $K(x^s)$. Whatever the actual value of $x^s \notin S$, the borrower will report the value that results in the smallest payment to the lender; hence, if monitoring does not occur, the payment to the lender must be equal to a constant, $\bar{K}$.[27] Since all loans are for 1 unit, $\bar{K} - 1$ is the interest rate on the loan when $x^s \notin S$.

If the reported signal is in S, then monitoring occurs so that the lender can learn the true value of x. The borrower will report x^s in S only if it is in her best interest, that is, reporting $x^s \in S$ must be incentive-compatible. For this to be the case, the net return to the borrower when $x^s \in S$, equal to $x - R(x)$, must exceed the return from reporting a signal not in S, $x - \bar{K}$. That is, incentive compatibility requires that

$$x - R(x) > x - \bar{K} \quad \text{or } \bar{K} > R(x) \quad \text{for all } x^s \in S.$$

The borrower will report a signal that leads to monitoring only if $R(x) < \bar{K}$ and will report a signal not in S (so that no monitoring occurs) if $R(x) \geq \bar{K}$.

The optimal contract is a payment schedule $R(x)$ and a value $\bar{K}$ that maximizes the borrower's expected return, subject to the constraint that the lender's expected return be at least equal to the opportunity cost r. Letting $\Pr[x < y]$ denote the probability that x is less than y, the expected return to the borrower can be written as the expected return conditional on monitoring occurring, times the probability that $R(x) < \bar{K}$, plus the expected return conditional on no monitoring occurring, times the probability that $R(x) \geq \bar{K}$:

$$\mathrm{E}[R^b] \equiv \mathrm{E}[x - R(x) | R(x) < \bar{K}] \Pr[R(x) < \bar{K}] + \mathrm{E}[x - \bar{K} | R(x) \geq \bar{K}] \Pr[R(x) \geq \bar{K}]. \tag{10.35}$$

The optimal loan contract maximizes this expected return subject to the constraint that the lender's expected return be at least r:

$$\mathrm{E}[R(x) - c | R(x) < \bar{K}] \Pr[R(x) < \bar{K}] + \bar{K} \Pr[R(x) \geq \bar{K}] \geq r. \tag{10.36}$$

The solution to this problem, and therefore the optimal loan contract, has $R(x) = x$. In other words, if the borrower reports a signal that leads the lender to monitor, then the lender takes the entire actual project return. This result corresponds to a loan default in which the lender takes over the project, incurs the monitoring cost c (which in this case can be thought of as a liquidation cost), and ends up with $x - c$. If the project earns a sufficient return, that is, $R(x) = x \geq \bar{K}$, then the

27. That is, suppose x_1 and x_2 are project return realizations such that the borrower would report x_1^s and $x_2^s \notin S$. If reporting x_1^s results in a larger payment to the lender, the borrower would always report x_2^s.

borrower pays the lender the fixed amount $\bar{K}$. Since $\bar{K}$ is independent of the realization of x, no monitoring is necessary. The presence of monitoring costs and imperfect information leads to the endogenous determination of the optimal loan contract.

The proof that $R(x) = x$ whenever monitoring takes place is straightforward. In equilibrium, the constraint given by (10.36) will be satisfied with equality. Otherwise, the payment to the lender could be reduced in some states, which would increase the expected return to the borrower. Hence,

$$\mathrm{E}[R(x) - c|R(x) < \bar{K}] \Pr[R(x) < \bar{K}] + \bar{K} \Pr[R(x) \geq \bar{K}] = r.$$

Any contract that called for $R(x) < x$ for some realizations of x could be replaced by another contract that increases repayment slightly when monitoring occurs but lowers $\bar{K}$ to decrease the range of x for which monitoring actually takes place. This can be done such that the lender's expected profit is unchanged.[28] Using the constraint for the lender's expected return, the expected return to the borrower can be written as

$$\begin{aligned}
\mathrm{E}[R^b] &= \mathrm{E}[x - R(x)|R(x) < \bar{K}] \Pr[R(x) < \bar{K}] + \{\mathrm{E}[x|R(x) \geq \bar{K}] - \bar{K}\} \Pr[R(x) \geq \bar{K}] \\
&= \mathrm{E}[x - R(x)|R(x) < \bar{K}] \Pr[R(x) < \bar{K}] + \mathrm{E}[x|R(x) \geq \bar{K}] \Pr[R(x) \geq \bar{K}] \\
&\quad - \{r - \mathrm{E}[R(x) - c|R(x) < \bar{K}] \Pr[R(x) < \bar{K}]\} \\
&= \mathrm{E}[x - c|R(x) < \bar{K}] \Pr[R(x) < \bar{K}] + \mathrm{E}[x|R(x) \geq \bar{K}] \Pr[R(x) \geq \bar{K}] - r \\
&= \mathrm{E}[x] - c \Pr[R(x) < \bar{K}] - r, \qquad (10.37)
\end{aligned}$$

where $\Pr[R(x) < \bar{K}]$ is the probability that monitoring occurs. Equation (10.37) shows that the expected return to the borrower is decreasing in $\bar{K}$. Any contract that lowers $\bar{K}$ and reduces the probability of monitoring while leaving the lender with an expected return of r will be strictly preferred by the borrower. Such a contract can be constructed if $R(x) < x$.[29]

To make the example more specific, suppose x is uniformly distributed on $[0, \bar{x}]$. The expected return to the lender is equal to

$$\int_0^{\bar{K}} (x - c)\frac{1}{\bar{x}}dx + \int_{\bar{K}}^{\bar{x}} \bar{K}\frac{1}{\bar{x}}dx.$$

28. $R(x) > x$ is ruled out by the assumption that the borrower has no other resources. If $R(x) < x$ for some x for which monitoring occurs, then the new contract, which increases $R(x)$ in those states, increases $R(x) - c$ when monitoring does occur. For a given $\bar{K}$, this increases $\mathrm{E}[R(x) - c|R(x) < \bar{K}]$, making the lender's expected profit greater than r. Since $\bar{K}$ is then lowered, monitoring occurs in fewer states, thereby reducing the lender's expected profit so that it again equals r.

29. One implication of (10.37) is that the borrower bears the cost of monitoring; the expected return to the borrower is equal to the total expected project return net of the opportunity cost of funds (r) and expected monitoring costs ($c \Pr[R(x) < \bar{K}]$).

The first term is the expected return to the lender if the borrower defaults, an outcome that occurs whenever $x < \bar{K}$; the probability of this outcome is $\bar{K}/\bar{x}$. The second term is the fixed payment received by the lender whenever $x \geq \bar{K}$, an outcome that occurs with probability $[\bar{x} - \bar{K}]/\bar{x}$. Evaluating the expected return and equating it to r yields the following condition to determine $\bar{K}$:

$$\left[\frac{1}{2}\left(\frac{\bar{K}^2}{\bar{x}}\right) - c\left(\frac{\bar{K}}{\bar{x}}\right)\right] + \bar{K}\left[1 - \left(\frac{\bar{K}}{\bar{x}}\right)\right] = r.$$

If $(\bar{x} - c)^2 > 2\bar{x}r$, this quadratic has two real solutions, one less than $\bar{x} - c$ and one greater than $\bar{x} - c$.[30] However, the effect of $\bar{K}$ on the lender's expected return is

$$\frac{\bar{K}}{\bar{x}} - \frac{c}{\bar{x}} + \left(1 - \frac{2\bar{K}}{\bar{x}}\right) = 1 - \frac{c + \bar{K}}{\bar{x}},$$

which becomes negative for $\bar{K} > \bar{x} - c$. This means that when the loan repayment amount is large, further increases in the contracted repayment would actually lower the lender's expected return; loan contracts with less monitoring (a lower $\bar{K}$) would be preferred by both borrower and lender; $\bar{K} > \bar{x} - c$ cannot be an equilibrium.

When the lender's expected profits are no longer monotonic in the loan interest rate but can actually decrease at higher interest rates, the possibility exists of an equilibrium in which some borrowers face credit rationing. In a nonrationing equilibrium, all borrowers receive loans.[31] The expected rate of return r is determined by the condition that loan demand equal loan supply, and the gross interest rate on loans, $\bar{K}$, is less than $\bar{x} - c$. In a credit rationing equilibrium, $\bar{K} = \bar{x} - c$, and not all potential borrowers receive loans. Even though there are unsatisfied potential borrowers, the interest rate on loans will not rise because the lenders' expected profits are decreasing in the loan rate when $\bar{K} > \bar{x} - c$. Even though all potential borrowers were assumed to be identical ex ante, some receive loans while others do not. The ones that do not get loans would be willing to borrow at an interest rate above the market rate, yet no lenders are willing to lend.

Williamson's model illustrates that neither adverse selection nor moral hazard is necessary for rationing to characterize credit markets. The presence of monitoring costs can account for both the general form of loan contracts in which monitoring

30. These are given by

$$\bar{x} - c \pm \sqrt{(\bar{x} - c)^2 - 2\bar{x}r}.$$

31. A complete specification of the model requires assumptions on the number of (potential) borrowers and lenders that ensures an upward-sloping supply curve of funds. See Williamson (1987a) for details on one such specfication.

occurs only when the borrower defaults—in which case the lender takes over the entire project's return—and for rationing to arise in some equilibria.

10.5.4 Agency Costs

Adverse selection, moral hazard, and monitoring costs all arise as important factors in any relationship in which a principal delegates decision-making authority to an agent. In credit markets, the lender delegates to a borrower control over resources. The inability to monitor the borrower's actions or to share the borrower's information gives rise to agency costs. Bernanke and Gertler (1989) and Gertler (1988) emphasized the role of agency costs that make external funding sources more expensive for firms than internal sources. As a consequence, a firm's balance sheet plays a role in affecting the cost of finance. In recessions, internal sources of funds decline, forcing firms to turn to external sources. But the deterioration of the firm's balance sheet worsens the agency problems and increases the cost of external funds, thereby further contracting investment spending and contributing to the recession. Thus, credit conditions can play a role in amplifying the impact of other shocks to the economy and affecting their propagation throughout the economy and through time.

In the model of Bernanke and Gertler (1989), firms are assumed to be able to observe the outcome of their own investment projects costlessly; others must incur a monitoring cost to observe project outcomes. Firms and lenders are assumed to be risk-neutral. Firms are indexed by efficiency type ω, distributed uniformly on $[0, 1]$. More efficient types (ones with low ω) need to invest fewer inputs in a given project. Projects themselves require inputs of $x(\omega)$, yielding gross payoff κ_1 with probability π_1, and $\kappa_2 > \kappa_1$ with probability $\pi_2 = 1 - \pi_1$. The function $x(.)$ is increasing in ω. The expected project return, $\pi_1\kappa_1 + \pi_2\kappa_2$, will be denoted κ. The realized outcome of a particular project can be observed costlessly by the firm undertaking the project and at cost c by others. Firms are assumed to have internal sources of financing equal to S; S is assumed to be less than $x(0)$, so that even the most efficient firm must borrow to undertake a project. Finally, let r denote the opportunity cost of funds to lenders; firms that do not undertake a project also receive this rate on their funds.[32]

If lenders could observe project outcomes costlessly, equilibrium would involve lenders' financing all projects whose expected payoff exceeds their opportunity cost of rx. Thus, all firms whose ω is less than a critical value ω^* defined by

$$\kappa - rx(\omega^*) = 0$$

would receive loans. Firms with $\omega < \omega^*$ borrow $B \equiv x(\omega) - S$.

32. Bernanke and Gertler developed a general equilibrium model; here a partial equilibrium version is described to focus on the role played by credit market imperfections in investment decisions.

With imperfect information, the firm clearly has an incentive to always announce that the bad outcome, κ_1, occurred. It will never pay for the lender to incur the monitoring cost if the firm announces κ_2. Let p be the probability that the firm is audited (i.e., the lender pays the monitoring cost to observe the true outcome) when the firm announces κ_1. Let P_1^a be the payment to the firm when κ_1 is announced and auditing takes place, P_1 the payment when κ_1 is announced and no auditing occurs, and P_2 the payment if κ_2 is announced. The optimal lending contract must maximize the expected payoff to the firm, subject to several constraints. First, the lender's expected return must be at least as great as her opportunity cost rB. Second, the firm must have no incentive to report the bad state when in fact the good state occurred. Third, even in the bad state, limited liability requires that P_1^a and P_1 be non-negative. The optimal contract is characterized by the values of $\{p, P_1^a, P_1, P_2\}$ that solve

$$\max \pi_1[pP_1^a + (1-p)P_1] + \pi_2 P_2$$

subject to

$$\pi_1[\kappa_1 - p(P_1^a + c) - (1-p)P_1] + \pi_2[\kappa_2 - P_2] \geq rB \tag{10.38}$$

$$P_2 \geq (1-p)(\kappa_2 - \kappa_1 + P_1) \tag{10.39}$$

$$P_1^a \geq 0 \tag{10.40}$$

$$P_1 \geq 0 \tag{10.41}$$

and $0 \leq p \leq 1$.

Only the constraint given by (10.39) may require comment. The left side is the firm's income in the good state. The right side gives the firm's income if the good state occurs but the firm reports the bad state. After reporting the bad state, the firm is audited with probability p. So with probability $1-p$ the firm is not audited, turns over $\kappa_1 - P_1$ to the lender. But the firm now gets to keep the amount $\kappa_2 - \kappa_1$ because, by assumption, the good state had actually occurred. If (10.39) is satisfied, the firm has no incentive to conceal the truth in announcing the project outcome.

Assuming an interior solution, the first-order necessary conditions for this problem are

$$\pi_1[(P_1^a - P_1) + \mu_1(P_1 - P_1^a - c)] + \mu_2(\kappa_2 - \kappa_1 + P_1) = 0 \tag{10.42}$$

$$\pi_1 p(1-\mu_1) + \mu_3 = 0 \tag{10.43}$$

$$\pi_1(1-p)(1-\mu_1) - \mu_2(1-p) + \mu_4 = 0 \tag{10.44}$$

$$\pi_2(1-\mu_1) + \mu_2 = 0, \tag{10.45}$$

where the μ_i are the (non-negative) Lagrangian multipliers associated with the constraints (10.38)–(10.41).

Since $\mu_3 \geq 0$, (10.43) implies that $\mu_1 \geq 1$. This means the constraint on the lender's return (10.38) holds with equality. With $\pi_1[\kappa_1 - p(P_1^a + c) - (1-p)P_1] + \pi_2[\kappa_2 - P_2] - r(x - S) = 0$, this can be added to the objective function, yielding an equivalent problem that the optimal contract solves, given by $\max[\pi_1(\kappa_1 - pc) + \pi_2\kappa_2]$, subject to (10.39) and the non-negative constraints on P_1^a and P_1. However, $\pi_1(\kappa_1 - pc) + \pi_2\kappa_2 = \kappa - \pi_1 pc$, and with κ an exogenous parameter, this new problem is equivalent to minimizing expected auditing costs $\pi_1 pc$.

If the return to the lender, rB, is less than the project return even in the bad state κ_1, then no auditing is ever necessary and $p = 0$. Agency costs are therefore zero whenever $\kappa_1 \geq rB$. Recall that the amount borrowed, B, was equal to $x(\omega) - S$, where S represented the firm's internal funds invested in the project, so the no-agency-cost condition can be written

$$S \geq x(\omega) - \frac{\kappa_1}{r} \equiv S^*(\omega).$$

Any type ω with internal funds greater than or equal to $S^*(\omega)$ can always repay the lender, so no auditing on the project is required. When $S < S^*(\omega)$, a situation Bernanke and Gertler labeled as one of *incomplete collateralization*, constraints (10.38)–(10.41) all hold with equality. Since auditing is costly, the optimal auditing probability is just high enough to ensure that the firm truthfully reports the good state when it occurs. From the incentive constraint (10.39), $P_2 = (1-p)(\kappa_2 - \kappa_1)$ since $P_1 = P_1^a = 0$ (the firm keeps nothing in the bad state). Substituting this into the lender's required return condition (10.38),

$$p = \frac{r[x(\omega) - S] - \kappa_1}{\pi_2(\kappa_2 - \kappa_1) - \pi_1 c}.$$

The auditing probability is decreasing in the return in the good state (κ_2) and the firm's own contribution S. If the firm invests little in the project and borrows more, then the firm receives less of the project's return in the good state, increasing its incentive to falsely claim that the bad state occurred. To remove this incentive, the probability of auditing must rise.

Bernanke and Gertler characterized the expected costs of project auditing, $\pi_1 pc$, as the *agency costs due to asymmetric information*. As they showed, some firms with intermediate values of ω (i.e., neither the most nor the least efficient) will find that the investment project is not worth undertaking if they have only low levels of internal funds to invest. The probability of auditing that lenders would require makes agency costs too high to justify the investment. If the firm had a higher level of internal funds, it would undertake the project. Even though the opportunity costs of funds r and the project inputs x and returns (κ_1 and κ_2) have not changed, variations in S can alter the number of projects undertaken. This illustrates how investment levels may depend on the firm's internal sources of financing. Agency costs drive a wedge between the costs of internal and external funds, so investment decisions will depend on variables such as cash flow that would not play a role if information were perfect. Since a recession will worsen firms' balance sheets, reducing the availability of internal funds, the resulting rise in agency costs and the reduction in investment may serve to amplify the initial cause of a recession.

10.5.5 Macroeconomic Implications

The presence of credit market imperfections can play a role in determining how the economy responds to economic disturbances and how these disturbances are propagated throughout the economy and over time. Various partial equilibrium models have provided insights into how imperfect information and costly state verification affect the nature of credit market equilibria. The next step is to embed these partial equilibrium models of the credit market within a general equilibrium macroeconomic model so that the qualitative and quantitative importance of credit channels can be assessed. As Bernanke, Gertler, and Gilchrist (1996) discussed, there are difficulties in taking this step. For one, distributional issues are critical. Private sector borrowing and lending do not occur in a representative-agent world, so agents must differ in ways that give rise to borrowers and lenders. And both the source of credit and the characteristics of the borrower matter, so not all borrowers and not all lenders are alike. Changes in the distribution of wealth or the distribution of cash flow can affect the ability of agents to obtain credit. Incorporating heterogeneity among agents in a tractable general equilibrium model can lead to new complexities when the nature of debt and financial contracts in the model economy should be derived from the characteristics of the basic technology and informational assumptions of the model environment.

General Equilibrium Models

Two early examples of general equilibrium models designed to highlight the role of credit factors are due to Williamson (1987b) and Bernanke and Gertler (1989). In these models, credit markets play an important role in determining how the economy responds to a real productivity shock. Williamson embedded his model of financial intermediation with costly monitoring (see section 10.5.3) in a dynamic general equilibrium model. In response to shocks to the riskiness of investment, credit rationing increases, loans from intermediaries fall, and investment declines. The decline in investment reduces future output and contributes to the propagation of the initial shock. Bernanke and Gertler (1989) incorporated the model of costly state verification reviewed in section 10.5.4 into a general equilibrium framework in which shocks to productivity drive the business cycle dynamics. A positive productivity shock increases the income of the owners of the production technology; this rise in their net worth lowers agency costs associated with external financing of investment projects, allowing for increased investment. This serves to propagate the shock through time.

Kiyotaki and Moore (1997) developed a model that illustrates the role of net worth and credit constraints on equilibrium output. In their model economy, there are two types of agents. One group, called *farmers*, can combine their own labor with land to produce output. They can borrow to purchase additional land but face credit constraints in so doing. These constraints arise because a farmer's labor input is assumed to be critical to production—once a farmer starts producing, no one else can replace him—and the farmer is assumed to be unable to precommit to work. Thus, if any creditor attempts to extract too much from a farmer, the farmer can simply walk away from the land, leaving the creditor with only the value of the land; all current production is lost. The inability to precommit to work plays a role similar to the assumption of cost state verification; in this case, the creditor is unable to monitor the farmer to ensure that he continues to work. As a result, the farmer's ability to borrow will be limited by the collateral value of his land.

Letting k_t denote the quantity of land cultivated by farmers, output by farmers is produced according to a linear technology:

$$y_{t+1}^f = (a + c)k_t,$$

where ck_t is nonmarketable output ("bruised fruit" in the farmer analogy) that can be consumed by the farmer.

The creditors in Kiyotaki and Moore's model are called *gatherers*. They too can use land to produce output, employing a technology characterized by decreasing returns to scale. The output of gatherers is

$$y_{t+1}^g = G(\bar{k} - k_t); \qquad G' \geq 0;\ G'' \leq 0,$$

where $\bar{k}$ is the total fixed stock of land, so $\bar{k} - k_t$ is the land cultivated by gatherers.

Utility of both farmers and gatherers is assumed to be linear in consumption, although gatherers are assumed to discount the future more. Because of the linear utility, and the assumption that labor generates no disutility, the socially efficient allocation of the fixed stock of land between the two types of agents would ensure that the marginal product of land is equalized between the two production technologies, or

$$G'(\bar{k} - k^*) = a + c, \tag{10.46}$$

where k^* is the efficient amount of land allocated to farmers.

Consider the market equilibrium. Taking the gatherers first, given that they are not credit-constrained and have linear utility, the real rate of interest will simply equal the inverse of their subjective rate of time preference: $R = 1/\beta$.[33] Again exploiting the unconstrained nature of the gatherers' decision, the value of a unit of land, q_t, must satisfy

$$q_t = \beta[G'(\bar{k} - k_t) + q_{t+1}].$$

The present value of a unit of land is just equal to the discounted marginal return G' plus its resale value at time $t+1$. Since $\beta = R^{-1}$, this condition can be rewritten as

$$\frac{1}{R}G'(\bar{k} - k_t) = q_t - \frac{q_{t+1}}{R} \equiv u_t. \tag{10.47}$$

The variable u_t will play an important role in the farmers' decision problem. To interpret it, q_{t+1}/R is the present value of land in period $t+1$. This represents the collateralized value of a unit of land; a creditor who lends q_{t+1}/R or less against a piece of land is sure of being repaid. The price of a unit of land at time t is q_t, so u_t is the difference between the cost of the land and the amount that can be borrowed against the land. It thus represents the downpayment a farmer will need to make in order to purchase more land.

Kiyotaki and Moore constructed the basic parameters of their model to ensure that farmers will wish to consume only their nonmarketable output (ck_{t-1}). Farmers then use the proceeds of their marketable output plus new loans minus repayment of old loans (including interest) to purchase more land. However, the maximum a farmer can borrow will be the collateralized value of the land, equal to $q_{t+1}k_t/R$. Hence, if b_t is the farmer's debt,

$$b_t \leq \frac{q_{t+1}k_t}{R}. \tag{10.48}$$

This can be shown to be a binding constraint in equilibrium, and the change in the farmer's land holdings will be

$$q_t(k_t - k_{t-1}) = ak_{t-1} + \frac{q_{t+1}k_t}{R} - Rb_{t-1},$$

where b_{t-1} is debt incurred in the previous period. Rearranging,

33. The standard Euler condition for optimal consumption requires that $u_c(t) = \beta R u_c(t+1)$, where $u_c(s)$ is the marginal utility of consumption at date s. With linear utility, $u_c(t) = u_c(t+1) = h$ for some constant h. Hence, $h = \beta R h$ or $R = 1/\beta$.

$$k_t = \frac{(a + q_t)k_{t-1} - Rb_{t-1}}{u_t}. \tag{10.49}$$

The numerator of this expression represents the farmer's net worth—current output plus land holdings minus existing debt. With u_t equal to the required down payment per unit of land, the farmer invests his entire net worth in purchasing new land.

To verify that the borrowing constraint is binding, it is necessary to show that the farmer always finds it optimal to use all marketable output to purchase additional land (after repaying outstanding loans). Suppose instead that the farmer consumes a unit of output over and above ck_{t-1}. This yields marginal utility u_c (a constant by the assumption of linear utility), but by reducing the farmer's land in period t by $1/u_t$, this additional consumption costs

$$u_c\left[\beta_f \frac{c}{u_t} + \beta_f^2\left(\frac{a}{u_t}\left(\frac{c}{u_{t+1}} + \beta_f\left(\frac{a}{u_{t+1}}\left(\frac{c}{u_{t+2}} + \cdots\right)\cdots\right)\cdots\right)\cdots\right)\right]$$

since the $1/u_t$ units of land purchased at time t would have yielded additional consumption c/u_t plus marketable output a/u_t that could have been used to purchase more land that would have yielded c/u_{t+1} in consumption, and so on. Each of these future consumption additions must be discounted back to time t using the farmer's discount rate β_f. It will be demonstrated subsequently that the steady-state value of u will be a. Making this substitution, the farmer will always prefer to use marketable output to purchase land if

$$1 < \left[\beta_f \frac{c}{a} + \beta_f^2\left(\frac{a}{a}\left(\frac{c}{a} + \beta_f\left(\frac{a}{a}\left(\frac{c}{a} + \cdots\right)\cdots\right)\cdots\right)\cdots\right)\right] = \frac{\beta_f}{1 - \beta_f}\frac{c}{a},$$

or

$$\frac{a + c}{a} > \frac{1}{\beta_f} > R. \tag{10.50}$$

Kiyotaki and Moore assumed that c is large enough to ensure that this condition holds. This means farmers would always like to postpone consumption and will borrow as much as possible to purchase land. Hence, the borrowing constraint will bind.

Equation (10.49) can be written as $u_t k_t = (a + q_t)k_{t-1} - Rb_{t-1}$. But $Rb_{t-1} = q_t k_{t-1}$ from (10.48), so $u_t k_t = ak_{t-1}$. Now using (10.47) to eliminate u_t, the capital stock held by farmers satisfies the following difference equation:

$$\frac{1}{R} G'(\bar{k} - k_t)k_t = ak_{t-1}. \tag{10.51}$$

Assuming standard restrictions on the gatherers' production function, (10.51) defines a convergent path for the land held by farmers.[34] The steady-state value of k is then given as the solution k^{ss} to

$$\frac{1}{R}G'(\bar{k} - k^{ss}) = a. \tag{10.52}$$

Multiplying through by R, $G'(\bar{k} - k^{ss}) = Ra$. From (10.47) this implies

$$u^{ss} = a.$$

Equation (10.52) can be compared with (10.46), which gives the condition for an efficient allocation of land between farmers and gatherers. The efficient allocation of land to farmers, k^*, was such that $G'(\bar{k} - k^*) = a + c > Ra = G'(\bar{k} - k^{ss})$, where the inequality sign is implied by (10.50). Since the marginal product of gatherers' output is positive but declines with the amount of land held by gatherers, it follows that $k^{ss} < k^*$. The market equilibrium is characterized by too little land in the hands of farmers. As a consequence, aggregate output is too low.

Using the definition of u, the steady-state price of land is equal to $q^{ss} = Ra/(R-1)$, and steady-state debt is equal to $b^{ss} = q^{ss}k^{ss}/R = ak^{ss}/(R-1)$. The farmer's debt repayments each period are then equal to $Rb^{ss} = [R/(R-1)]ak^{ss} > ak^{ss}$.

Kiyotaki and Moore extended this basic model to allow for reproducible capital and were able to study the dynamics of the more general model. The simple version, though, allows the key channels through which credit affects the economy's equilibrium to be highlighted. First, output is inefficiently low because of borrowing restrictions; even though farmers have access to a technology that at the steady state is more productive than that of gatherers, they cannot obtain the credit necessary to purchase additional land. Second, the ability of farmers to obtain credit is limited by their net worth. Equation (10.49) shows how the borrowing constraint makes land holdings at time t dependent on net worth (marketable output plus the value of existing land holdings minus debt). Third, land purchases by farmers will depend on asset prices. A fall in the value of land that is expected to persist (so q_t and q_{t+1} both fall) reduces the farmers' net worth and demand for land. This follows from (10.49), which can be written as $k_t = (q_t k_{t-1}/u_t) + (ak_{t-1} - Rb_{t-1})/u_t$. A proportional fall in q_t and q_{t+1} leaves the first term, $q_t k_{t-1}/u_t$, unchanged. The second term increases in absolute value, but at the steady state, $Rb > ak$, so this term is negative. Thus, farmers' net worth declines with a fall in land prices.

These mechanisms capture the financial accelerator effects, as can be seen by considering the effects of an unexpected but transitory productivity shock. Suppose the

34. As long as $G'(\bar{k} - k)$ is monotonically increasing in k, $G'(\bar{k}) < a$, and $G'(0) > a$, there will be a single stable equilibirum.

output of both farmers and gatherers increases unexpectedly at time t. If the economy was initially at the steady state, then if Δ is the productivity increase for farmers, (10.49) implies

$$u(k_t)k_t = (a + \Delta a + q_t - q^{ss})k^{ss}, \tag{10.53}$$

since $q^{ss}k^{ss} = Rb^{ss}$ from the borrowing constraint, and the required downpayment u is written as a function of k.[35] Two factors are at work in determining the impact of the productivity shock on the farmers' demand for land. First, because marketable output rises by Δak^{ss}, this directly increases farmers' demand for land. Second, the term $(q_t - q^{ss})k^{ss}$ represents a capital gain on existing holdings of land. Both factors act to increase farmers' net worth and their demand for land.

One way to highlight the dynamics is to examine a linear approximation to (10.53) around the steady state. Letting e denote the elasticity of the user cost of land $u(k)$ with respect to k, the left side of (10.53) can be approximated by

$$ak^{ss}[1 + (1 + e)\hat{k}],$$

using the fact that $u(k^{ss}) = a$ and letting $\hat{x}$ denote the percentage deviation of a variable x around the steady state.[36] The right side is approximated by

$$(a + \Delta a + q^{ss}\hat{q}_t)k^{ss}.$$

Equating these two and using the steady-state result that $q^{ss} = Ra/(R - 1)$ yields

$$(1 + e)\hat{k} = \Delta + \frac{R}{R - 1}\hat{q}_t. \tag{10.54}$$

The capital gain effect on farmers' land purchases is, as Kiyotaki and Moore emphasized, scaled up by $R/(R - 1) > 1$ because farmers are able to leverage their net worth. This factor can be quite large; if $R = 1.05$, the coefficient on $\hat{q}_t$ is 21.

The asset price effects of the temporary productivity shock reinforce the original disturbance. These effects also generate a channel for persistence. When more land is purchased in period t, the initial rise in aggregate output persists.[37]

Agency Costs and General Equilibrium

Carlstrom and Fuerst (1997) embedded a model of agency costs based on Bernanke and Gertler (1989) in a general equilibrium framework that can be used to investigate

35. Recall that $u_t = G'(\bar{k} - k_t)/R$, from (10.47).

36. The elasticity e is equal to $[u'(k^{ss})k^{ss}]/u(k^{ss}) = u'(k^{ss})k^{ss}/a$, where u' denotes the derivative of u with respect to k. Since u is increasing in $\bar{k} - k$, $u' < 0$.

37. Recall that at the margin, farmers are more productive than gatherers; a shift of land from gatherers to farmers raises total output.

the model's qualitative and quantitative implications. In particular, they studied the way agency costs arising from costly state verification affect the impact that shocks to net worth have on the economy.[38]

In their model, entrepreneurs borrow external funds in an intraperiod loan market to invest in a project that is subject to idiosyncratic productivity shocks. Suppose entrepreneur j has a net worth of n_j and borrows $i_j - n_j$. The project return is $\omega_j i_j$, where ω_j is the idiosyncratic productivity shock. Entrepreneurs have private information about this shock, whereas lenders can observe it only by incurring a cost. If the interest rate on the loan to entrepreneur j is r_j^k, then the borrower defaults if

$$\omega_j < \frac{(1+r_j^k)(i_j - n_j)}{i_j} \equiv \bar{\omega}_j.$$

If the realization of ω_j is less than $\bar{\omega}_j$, the entrepreneur's resources, $\omega_j i_j$, are less than the amount needed to repay the loan, $(1+r_j^k)(i_j - n_j)$. If default occurs, the lender monitors the project at a cost μi_j.

Carlstrom and Fuerst derived the optimal loan contract between entrepreneurs and lenders and showed that it is characterized by i_j and $\bar{\omega}_j$. Given these two parameters, the loan interest rate is

$$1 + r_j^k = \frac{\bar{\omega}_j i_j}{i_j - n_j}.$$

Suppose the distribution function of ω_j is $\Phi(\omega_j)$. The probability of default is $\Phi(\bar{\omega}_j)$. Let q denote the end-of-period price of capital. If the entrepreneur does not default, she receives $q\omega_j i_j - (1+r_j^k)(i_j - n_j)$. If the borrower defaults, she receives nothing. If $f(\bar{\omega})$ is defined as the fraction of expected net capital output received by the entrepreneur, then

$$\begin{aligned} q i_j f(\bar{\omega}_j) &\equiv q\left\{\int_{\bar{\omega}}^{\infty} \omega i_j \Phi(d\omega) - [1-\Phi(\bar{\omega}_j)](1+r_j^k)(i_j - n_j)\right\} \\ &= q i_j\left\{\int_{\bar{\omega}}^{\infty} \omega \Phi(d\omega) - [1-\Phi(\bar{\omega}_j)]\bar{\omega}_j\right\}. \end{aligned} \tag{10.55}$$

The expected income of the lender is

$$q\left\{\int_0^{\bar{\omega}} \omega i_j \Phi(d\omega) - \mu i_j \Phi(\bar{\omega}_j) + [1-\Phi(\bar{\omega}_j)](1+r_j^k)(i_j - n_j)\right\}.$$

38. See also Kocherlakota (2000).

If $g(\varpi_j)$ is defined as the fraction of expected net capital output received by the lender, then

$$qi_j g(\varpi_j) \equiv qi_j \left\{ \int_0^{\varpi} \omega \Phi(d\omega) - \mu \Phi(\varpi_j) + [1 - \Phi(\varpi_j)]\varpi_j \right\}. \tag{10.56}$$

By adding together (10.55) and (10.56), one finds that

$$f(\varpi_j) + g(\varpi_j) = 1 - \mu \Phi(\varpi_j) < 1. \tag{10.57}$$

Hence, the total expected income to the entrepreneur and the lender is less than the total expected project return (the fractions sum to less than 1) because of the expected monitoring costs.

The optimal lending contract maximizes $qif(\varpi)$ subject to

$$qig(\varpi) \geq i - n \tag{10.58}$$

and

$$qif(\varpi) \geq n,$$

where, for convenience, the j notation has been dropped. The first constraint reflects the assumption that these are intraperiod loans, so the lender just needs to be indifferent between lending and retaining funds. The second constraint must hold if the entrepreneur is to participate; it ensures that the expected payout to the entrepreneur is greater than the net worth the entrepreneur invests in the project. Carlstrom and Fuerst showed that this second constraint always holds, so it will be ignored in the following. Using (10.57), the optimal loan contract solves

$$\max_{i,\varpi} \{ qif(\varpi) + \lambda [qi(1 - \mu\Phi - f(\varpi)) - i + n] \}.$$

The first-order conditions for i and ϖ are

$$qf(\varpi) + \lambda [q(1 - \mu\Phi - f(\varpi)) - 1] = 0 \tag{10.59}$$

and

$$qif'(\varpi) - \lambda qi(\mu\phi + f'(\varpi)) = 0,$$

where $\phi = \Phi'$ is the density function for ω. Solving this second equation for λ,

$$\lambda \left[1 + \frac{\mu\phi(\varpi)}{f'(\varpi)} \right] = 1. \tag{10.60}$$

Now multiplying both sides of (10.59) by $[1 + \mu\phi(\varpi)/f'(\varpi)]$ and using (10.60) yields, after some rearrangement,

$$q\left[1 - \mu\Phi + \mu\phi(\bar{\omega})\frac{f(\bar{\omega})}{f'(\bar{\omega})}\right] = 1. \tag{10.61}$$

Finally, from the constraint (10.58),

$$qig(\bar{\omega}) = i - n. \tag{10.62}$$

Equation (10.61) determines $\bar{\omega}$ as a function of the price of capital q, the distribution of the shocks, and the cost of monitoring. All three of these factors are the same for all entrepreneurs, so all borrowers face the same $\bar{\omega}$, justifying the dropping of the j subscript. Writing $\bar{\omega} = \bar{\omega}(q)$, investment i can be expressed using (10.62) as a function of q and n:

$$i(q, n) = \left[\frac{1}{1 - qg(\bar{\omega}(q))}\right]n. \tag{10.63}$$

Expected capital output is

$$I^s(q, n) = i(q, n)[1 - \mu\Phi(\bar{\omega})]. \tag{10.64}$$

The optimal contract has been derived while taking the price of capital, q, as given. In a general equilibrium analysis, this price must also be determined. To complete the model specification, assume that firms produce output using a standard neoclassical production function employing labor and capital:

$$Y_t = \theta_t F(K_t, H_t),$$

where θ_t is an aggregate productivity shock. Factor markets are competitive. Households supply labor and rent capital to firms. If households wish to accumulate more capital, they can purchase investment goods at the price q_t from a mutual fund that lends to entrepreneurs. These entrepreneurs then create capital goods using the project technology just described and end the period by making their consumption decision.[39] This last choice then determines the net worth entrepreneurs carry into the following period.

If net worth is constant, Carlstrom and Fuerst showed, their general equilibrium model can be mapped into a standard real business cycle model with capital adjust-

39. Carlstrom and Fuerst assumed that entrepreneurs discount the future more heavily than households and that their utility is linear. The Euler condition for entrepreneurs is

$$q_t = \beta\gamma \mathrm{E}_t[q_{t+1}(1 - \delta) + F_K(t+1)]\left[\frac{q_{t+1}f(\bar{\omega}_{t+1})}{1 - q_{t+1}g(\bar{\omega}_{t+1})}\right], \qquad 0 < \gamma < 1,$$

where the first term on the right side is the return to capital and the second term is the additional return on internal funds.

ment costs. They argued that agency costs therefore provide a means of endogenizing adjustment costs. Because net worth is not constant in their model, however, variations in entrepreneur net worth can serve to propagate shocks over time. For example, a positive productivity shock increases the demand for capital, and this pushes up the price of capital. By increasing entrepreneurs' net worth, the rise in the price of capital increases the production of capital (see (10.64)). By boosting the return on internal funds, the rise in the price of capital also induces entrepreneurs to reduce their own consumption to build up additional net worth. The endogenous response of net worth causes investment to display a hump-shaped response to an aggregate productivity shock. This type of response is more consistent with empirical evidence than is the response predicted by a standard real-business-cycle model in which the maximum impact of a productivity shock on investment occurs in the initial period.

Agency Costs and Sticky Prices

In chapter 6, it was emphasized that nominal rigidities play an important role in transmitting monetary policy disturbances to the real economy. Bernanke, Gertler, and Gilchrist (1999) combined nominal rigidities with an agency cost model to explore the interactions between credit market factors and price stickiness. They developed a tractable framework by employing a model with three types of agents: households, entrepreneurs, and retailers. Entrepreneurs borrow to purchase capital. Costly state verification in the Bernanke, Gertler, and Gilchrist model implies that investment will depend positively on entrepreneurs' net worth, just as it did in the Carlstrom and Fuerst (1997) model (see (10.63)). Entrepreneurs use capital and labor to produce wholesale goods. These wholesale goods are sold in a competitive goods market to retailers. Retailers use wholesale goods to produce differentiated consumer goods that are sold to households. Wholesale prices are flexible, but retail prices are sticky. This model exhibits a financial accelerator (Bernanke, Gertler, and Gilchrist 1996); movements in asset prices affect net worth and amplify the impact of an initial shock to the economy.

Sticky price adjustment in the retail sector is modeled following Calvo (see chapter 6) so that in each period there is a fixed probability that the individual retail firm can adjust its price. When a firm does adjust, it sets its price optimally. As a result, the rate of inflation of retail prices is a function of expected future inflation and given by real marginal cost in the retail sector. Since retail firms simply purchase wholesale goods at the competitive wholesale price P_t^w and resell these goods to households, real marginal cost for retailers is just the ratio of wholesale to retail prices.

Bernanke, Gertler, and Gilchrist (1999) calibrated a log-linearized version of their model to study the role the financial accelerator plays in propagating the impact of a monetary policy shock. They found that it increases the real impact of a policy shock. A positive nominal interest rate shock reduces the demand for capital, and this lowers the price of capital. The decline in the value of capital lowers entrepreneurs' net worth. As a consequence, the finance premium demanded by lenders rises, and this further reduces investment demand. Thus, a multiplier effect operates to amplify the initial impact of the interest rate rise. The contraction in the wholesale sector lowers wholesale prices relative to sticky retail prices. The retail price markup increases, reducing retail price inflation.

The financial crisis of 2007–2009 has led to a rapidly growing literature that incorporates financial frictions, often based on the Bernanke, Gertler, and Gilchrist (1999) approach, in models with nominal rigidities designed to address monetary policy issues. For example, in a model without capital, Demirel (2007) assumed firms must borrow to finance inputs into the production process. Christiano, Motto, and Rostagno (2007) embedded the Bernanke-Gertler-Gilchrist model of agency costs in a DSGE model with sticky wages and prices, which they then fit to U.S. and euro area data. De Fiore and Tristani (2008) developed a model with sticky prices and costly state verification that leads to agency costs because firms must borrow to finance their wage payments. Cúrdia and Woodford (2008) allowed for interest rates paid by borrowers and received by savers to differ. They found that the optimal Taylor rule calls for responding to credit spreads. Monacelli (2008) added financial frictions by incorporating the presence of collateral constraints on borrowing by the household sector. In the context of open-economy models, Gertler, Gilchrist, and Natalucci (2007) embedded the financial accelerator into a model of a small open economy to study the role of exchange rate regimes. They found that financial frictions play a significant role in accounting for output declines in the face of an exogenous rise in the country's risk premium.

10.6 Does Credit Matter?

Given the global recession triggered by the financial crisis beginning in the United States in 2007, the question of whether credit matters seems to be easily answered with a resounding yes. However, the role of credit and its importance for understanding macroeconomic fluctuations has historically been a source of controversy. If credit channels are important for the monetary transmission process, then evolution in financial markets due to changes in regulations or financial innovations will change the manner in which monetary policy affects the real economy. This also implies that the level of real interest rates may not provide a sufficient indicator of the stance of monetary policy. And credit shocks may have played an independent role in creating economic fluctuations. In this section, the empirical evidence on the credit channel is reviewed. The coverage is selective; a number of surveys discuss (and extend) the empirical work in the area (Gertler 1988; Gertler and Gilchrist 1993; Ramey 1993; Kashyap and Stein 1994; Hubbard 1995; Bernanke, Gertler, and Gilchrist 1996).

In an influential article, Bernanke (1983) provided evidence consistent with an important role for nonmonetary financial factors in accounting for the severity of the Great Depression in the United States. After controlling for unexpected money growth, he found that proxies for the financial crises of the early 1930s contributed significantly to explaining the growth rate of industrial production in his regression analysis.[40] If pure monetary causes were responsible for the decline in output during the Depression, the other measures of financial disruptions should not add explanatory power to the regression.

As Bernanke noted, his evidence is ''not inconsistent'' with the proposition that the financial crisis in the United States represented a distinct nonmonetary channel through which real output was affected during the Depression. The evidence is not conclusive, however; an alternative hypothesis is simply that the Depression itself was the result of nonmonetary factors (or at least factors not captured by unanticipated money growth) and that these factors caused output to decline, businesses to fail, and banks to close. By controlling only for unanticipated money growth, Bernanke's measures of financial crisis may only have been picking up the effects of the underlying nonmonetary causes of the Depression. Still, Bernanke's results offered support for the notion that the massive bank failures of the 1930s in the United States were not simply a sideshow but were at least partially responsible for the output declines.

Attempts to isolate a special role for credit in more normal business cycle periods have been plagued by what are essentially similar identification problems. Are movements in credit aggregates a reflection of shifts in demand resulting from effects operating through the traditional money channel, or do they reflect supply factors that constitute a distinct credit channel? Most macroeconomic variables behave similarly under either a money view or a credit view, so distinguishing between the two views based on time series evidence is difficult. For example, under the traditional money channel view, a contractionary shift in monetary policy raises interest rates and reduces investment spending. The decline in investment is associated with a decline in credit demand, so quantity measures of both bank and nonbank financing should fall. The competing theories are not sufficiently powerful to permit sharp predictions about the timing of interest rate, money, credit, and output movements that would allow the alternative views to be tested. As a consequence, much of the empirical work has focused on compositional effects, seeking to determine whether there are differential impacts of interest rate and credit movements that might distinguish between the alternative views.

40. Bernanke employed the real change in the deposits at failing banks and the real change in the liabilities of failing businesses as measures of the financial crises.

10.6.1 The Bank Lending Channel

Discussions of the credit channel often distinguish between a *bank lending channel* and a broader financial accelerator mechanism.[41] The bank lending channel emphasizes the special nature of bank credit and the role of banks in the economy's financial structure. In the bank lending view, banks play a particularly critical role in the transmission of monetary policy actions to the real economy. Policy actions that affect the reserve positions of banks will generate adjustments in interest rates and in the components of the banking sector's balance sheet. Traditional models of the monetary transmission mechanism focus on the impact of these interest rate changes on money demand and on consumption and investment decisions by households and firms. The ultimate effects on bank deposits and the supply of money are reflected in adjustments to the liability side of the banking sector's balance sheet.

The effects on banking sector reserves and interest rates also influence the supply of bank credit, the asset side of the balance sheet. If banks cannot offset a decline in reserves by adjusting securities holdings or raising funds through issuing nonreservable liabilities (such as CDs in the United States), bank lending must contract. If banking lending is *special* in the sense that bank borrowers do not have close substitutes for obtaining funds, variation in the availability of bank lending may have an independent impact on aggregate spending. Key, then, to the bank lending channel is the lack of close substitutes for deposit liabilities on the liability side of the banking sector's balance sheet and the lack of close substitutes for bank credit on the part of borrowers.

Imperfect information plays an important role in credit markets, and bank credit may be special, that is, have no close substitutes, because of information advantages banks have in providing both transactions services and credit to businesses. Small firms in particular may have difficulty obtaining funding from nonbank sources, so a contraction in bank lending will force these firms to contract their activities.

Banks play an important role in discussions of the monetary transmission mechanism, but the traditional approach stresses the role of bank liabilities as part of the money supply. Part of the reason for the continued focus on the liabilities side is the lack of convincing empirical evidence that bank lending plays a distinct role in the transmission process through which monetary policy affects the real economy. As C. Romer and Romer (1990b) summarized this literature, "A large body of recent theoretical work argues that the Federal Reserve's leverage over the economy may stem as much from the distinctive properties of the loans that banks make as from the unique characteristics of the transaction deposits that they receive. . . . Examining

41. A variety of excellent surveys and overviews of the credit channel is available. These include Gertler (1988); Bernanke (1993); Gertler and Gilchrist (1993); Ramey (1993); Kashyap and Stein (1994); Bernanke and Gertler (1995); Cecchetti (1995); Hubbard (1995); and Bernanke, Gertler, and Gilchrist (1999).

the behavior of financial variables and real output in a series of episodes of restrictive monetary policy, we are unable to find any support for this view'' (196–197).

One of the first attempts to test for a distinct bank lending channel was that of S. King (1986). He found that monetary aggregates were better predictors of future output than were bank loans. More recently, Romer and Romer (1990b) and Ramey (1993) reached similar conclusions. Unfortunately, existing theories are usually not rich enough to provide sharp predictions about timing patterns that are critical for drawing conclusions from evidence on the predictive content of macroeconomic variables. This is particularly true when behavior depends on forward-looking expectations. Anticipations of future output movements can lead to portfolio and financing readjustments that will affect the lead-lag relationship between credit measures and output. Because a decline in output may be associated with inventory buildups, the demand for short-term credit can initially rise, and the existence of loan commitments will limit the ability of banks to alter their loan portfolios quickly. These factors make money credit and output timing patterns difficult to interpret.

In part, Romer and Romer's negative assessment reflects the difficult identification problem mentioned earlier. A policy-induced contraction of bank reserves will lead to a fall in both bank liabilities (deposits) and bank assets (loans and securities). With both sides of the banking sector's balance sheet shrinking, it is clearly difficult to know whether to attribute a subsequent decline in output to the money channel, the credit channel, or both.[42] Kashyap, Stein, and Wilcox (1993) addressed this problem by examining the composition of credit between bank and nonbank sources. Under the money view, a contractionary policy raises interest rates, lowering aggregate demand and the total demand for credit. Consequently, all measures of outstanding credit should decline. Under the bank lending view, the contractionary policy has a distinct effect in reducing the supply of bank credit. With bank credit less available, borrowers will attempt to substitute other sources of credit, and the relative demand for nonbank credit should rise. Thus, the composition of credit should change if the bank lending view is valid, with bank credit falling more in response to contractionary monetary policy than other forms of credit.

Kashyap, Stein, and Wilcox did find evidence for the bank lending channel when they examined aggregate U.S. data on bank versus nonbank sources of finance, the latter measured by the stock of outstanding commercial paper. Using the Romer and Romer (1990a) dates to identify contractionary shifts in monetary policy,[43] Kashyap,

42. The identification problems are not quite so severe in attempting to estimate the role of credit supply versus credit demand shocks on the economy. A contractionary bank credit supply shock would generally lower loan quantity and raise loan interest rates; a contraction in loan quantity caused by a demand shock would lower loan interest rates.

43. C. Romer and Romer (1990a) based their dating of monetary policy shifts on a reading of FOMC documents. See chapter 1.

Stein, and Wilcox found that the financing mix shifts away from bank loans following a monetary contraction. However, this occurs primarily because of a rise in commercial paper issuance, not a contraction in bank lending. Den Haan, Summer, and Yamashiro (2007) find that commercial lending at banks actually increases following a contractionary monetary policy shock.

Evidence based on aggregate credit measures can be problematic, however, if borrowers are heterogeneous in their sensitivity to the business cycle and in the types of credit they use. For example, the sales of small firms fluctuate more over the business cycle than those of large firms, and small firms are more reliant on bank credit than large firms that have greater access to the commercial paper market. Contractionary monetary policy that causes both small and large firms to reduce their demand for credit will cause aggregate bank lending to fall relative to nonbank financing as small firms contract more than large firms. This could account for the behavior of the debt mix even in the absence of any bank lending channel. Oliner and Rudebusch (1995; 1996b) argued that this is exactly what happens. Using disaggregate data on large and small firms, they showed that in response to a monetary contraction, there is no significant effect on the mix of bank/nonbank credit used by either small or large firms. Instead, the movement in the aggregate debt mix arises because of a general shift of short-term debt away from small firms and toward large firms. They concluded that the evidence does not support the bank lending channel as an important part of the transmission process of monetary policy. Similar conclusions were reached by Gertler and Gilchrist (1994) in an analysis also based on disaggregated data.

While the bank lending channel as part of the monetary policy transmission process may not be operative, it might still be the case that shifts in bank loan supply are a cause of economic fluctuations. In the United States, the 1989–1992 period generated a renewed interest in credit channels and monetary policy.[44] An unusually large decline in bank lending and stories, particularly from New England, of firms facing difficulty borrowing led many to seek evidence that credit markets played an independent role in contributing to the 1990–1991 recession. One difficulty in attempting to isolate the impact of credit supply disturbances is the need to separate movements caused by a shift in credit supply from movements due to changes in credit demand.

Walsh and Wilcox (1995) estimated a monthly VAR in which bank loan supply shocks are identified with innovations in the prime lending rate. They showed that their estimated loan supply innovations are related to changes in bank capital ratios,

44. See, for example, Bernanke and Lown (1992); the papers collected in Federal Reserve Bank of New York (1994); and Peek and Rosengren (1995).

changes in required reserves, and the imposition of credit controls. This provides some evidence that the innovations are actually picking up factors that affect the supply of bank loans. While prime rate shocks are estimated to lower loan quantity and output, they were not found to play a major causal role in U.S. business cycles, although their role was somewhat atypically large during the 1990–1991 recession.

10.6.2 The Broad Credit Channel

The broad credit channel is not restricted to the bank lending channel. Credit market imperfections may characterize all credit markets, influencing the nature of financial contracts, raising the possibility of equilibria with rationing, and creating a wedge between the costs of internal and external financing. This wedge arises because of agency costs associated with information asymmetries and the inability of lenders to monitor borrowers costlessly. As a result, cash flow and net worth become important in affecting the cost and availability of finance and the level of investment spending. A recession that weakens a firm's sources of internal finance can generate a *financial accelerator* effect; the firm is forced to rely more on higher-cost external funds just at the time the decline in internal finance drives up the relative cost of external funds. Contractionary monetary policy that produces an economic slowdown will reduce firm cash flow and profits. If this policy increases the external finance premium, there will be further contractionary effects on spending. In this way, the credit channel can serve to propagate and amplify an initial monetary contraction.

Financial accelerator effects can arise from the adjustment of asset prices to contractionary monetary policy. Borrowers may be limited in the amount they can borrow by the value of their assets that can serve as collateral. A rise in interest rates that lowers asset prices reduces the market value of borrowers' collateral. This reduction in value may then force some firms to reduce investment spending as their ability to borrow declines. The evidence in support of a broad credit channel was surveyed by Bernanke, Gertler, and Gilchrist (1996), who concluded, "We now have fairly strong evidence—at least for the case of firms—that downturns differentially affect both the access to credit and the real economic activity of high-agency-cost borrowers" (14).

Hubbard (1995) and Bernanke, Gertler, and Gilchrist (1996) listed three empirical implications of the broad credit channel. First, external finance is more expensive for borrowers than internal finance. This should apply particularly to uncollateralized external finance. Second, because the cost differential between internal and external finance arises from agency costs, the gap should depend inversely on the borrower's net worth. A fall in net worth raises the cost of external finance. Third, adverse shocks to net worth should reduce borrowers' access to finance, thereby reducing their investment, employment, and production levels.

If, as emphasized under the broad credit channel, agency costs increase during recessions and in response to contractionary monetary policy, then the share of credit going to low-agency-cost borrowers should rise. Bernanke, Gertler, and Gilchrist characterized this as the *flight to quality*. Aggregate data are likely to be of limited usefulness in testing such a hypothesis because most data on credit stocks and flows are not constructed based on the characteristics of the borrowers. Because small firms presumably are subject to higher agency costs than large firms, much of the evidence for a broad credit channel has been sought by looking for differences in the behavior of large and small firms in the face of monetary contractions.

Gertler and Gilchrist (1994) documented that small firms do behave differently than large firms over the business cycle, being much more sensitive to cyclical fluctuations. Kashyap, Lamont, and Stein (1994) found that inventory investment by firms without access to public bond markets appears to be affected by liquidity constraints.[45] Oliner and Rudebusch (1996a) assessed the role of financial factors by examining the behavior of small and large firms in response to changes in monetary policy. Interest rate increases in response to a monetary contraction lower asset values and the value of collateral, increasing the cost of external funds relative to internal funds. Since agency problems are likely to be more severe for small firms than for large firms, the linkage between internal sources of funds and investment spending should be particularly strong for small firms after a monetary contraction. Oliner and Rudebusch did find that the impact of cash flow on investment increases for small firms, but not for large firms, when monetary policy tightens.

10.7 Summary

This chapter has examined a number of issues related to financial markets and monetary policy, including the question of price level determinacy with interest rate pegs, the role of the term structure of interest rates, and imperfect information in credit markets. The economics of imperfect information provides numerous insights into the structure of credit markets. Credit market imperfections commonly lead to situations in which the lender's expected profits are not monotonic in the interest rate charged on a loan; expected profits initially rise with the loan rate but can then reach a maximum before declining. Thus, equilibrium may be characterized by credit rationing: excess demand fails to induce lenders to raise the loan rate because doing so lowers their expected profits. Perhaps more important, balance sheets matter. Variations in borrowers' net worth affect their ability to gain credit. A recession

45. They focused on the 1981–1982 recession in the United States, a recession typically attributed to tight monetary policy.

that lowers cash flows or a decline in asset prices that lowers net worth will reduce credit availability and increase the wedge between the costs of external and internal finance. The resulting impact on aggregate demand can generate a financial accelerator effect.

In general, skepticism surrounds the existence and importance of the credit channel, or at least it did before the financial crisis of 2007–2009. Certainly the previous evidence on the empirical importance of a distinct bank lending channel for monetary policy was mixed. Although periods of monetary contraction are followed by a fall in bank credit relative to open market credit, this may reflect simple composition effects and not a bank lending channel. The access to managed liabilities also suggests that variations in banking sector reserves caused by changes in monetary policy will affect bank lending mainly through traditional interest rate channels. The evidence for a broad credit channel or for financial accelerator effects is more favorable. Recessions are associated with a flight to quality. Small firms, a group likely to face large agency costs in obtaining external financing, are affected more severely during recessions. Net worth and cash flow do seem to affect investment, inventory, and production decisions.

10.8 Problems

1. For the model of (10.1)–(10.4) and the policy rule (10.9), find the rational-expectations equilibrium expression for the price level as a function of m_{t-1} and the model shocks. Verify that i_t fluctuates randomly around the target i^T, $\mu \to \infty$, and the variance of the nominal rate around the targeted value i^T will shrink to zero, but the price level can remain determinate. (Hint: The model can be solved using the method of undetermined coefficients. See Sheffrin 1983; McCallum 1989; or Attfield, Demery, and Duck 1991.)

2. Redo problem (10.1) using the policy rule (10.10) instead of (10.9).

3. Suppose (10.1) is replaced by a Taylor sticky price adjustment model of the type studied in chapter 6. Is the price level still indeterminate under the policy rule (10.5)? What if prices adjust according to the Calvo sticky price model?

4. Suppose the money supply process in (10.20) is replaced with

$$m_t = \gamma m_{t-1} + \sigma q_{t-1} + \phi_t$$

so that the policymaker is assumed to respond with a lag to the real rate shock, with the parameter σ viewed as a policy choice. Thus, policy involves a choice of γ and σ, with the parameter σ capturing the systematic response of policy to real interest rate shocks. Show how the effect of q_t on the one- and two-period nominal interest rates