Two Perspectives on Growth and Taxes

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Robert Solow's (1956) neoclassical model reigns as the standard theory of economic growth. The Solow model begins with the assumption that capital accumulation is subject to diminishing marginal returns. It attributes sustained growth in national income per capita to technological progress that proceeds at a constant, exogenously given rate. Thus, it is an *exogenous growth model*.

Recently, economists have developed alternatives to the Solow model that build on Frank Knight's (1944) earlier theory of economic growth. These economists follow Knight by adopting an all-encompassing definition of capital that accounts for improvements in land, human capital, and scientific knowledge as well as for physical capital. Again along with Knight, they argue that under this broad definition, capital accumulation should be subject to constant, rather than diminishing, marginal returns. In their models, sustained growth occurs even in the absence of exogenous technological change. Hence, these are *endogenous growth models*.

This article presents versions of both the Solow model of exogenous growth and the Knightian model of endogenous growth. In doing so, it illustrates that the differences between these two models are more than purely technical ones; indeed, the differences are of great relevance to contemporary policy debate in the United States. Specifically, Section 1 shows that in the Solow model, a change in the rate of income taxation affects the level, but not the growth rate, of per-capita output. Section 2 demonstrates that in the Knightian model, in contrast, changes in tax rates do influence long-run growth.

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Since the two models have such very different policy implications, determining which more accurately describes growth in the U.S. economy remains an important task. Thus, Section 3 concludes the article with a review of the empirical work on income taxation and economic growth.

1. THE SOLOW MODEL WITH TAXES

In the Solow model, time periods are indexed by $t = 0, 1, 2, \ldots$. Like many other contemporary macroeconomic models, the Solow model considers the behavior of a single, infinitely lived representative agent. This representative agent's individual quantities translate into per-capita quantities when the results are applied to understand actual economies.

The representative agent produces output Y_t with capital K_t during each period t according to a production function of the form

$$Y_t = AK_t^{\alpha}. \tag{1}$$

Since $0 < \alpha < 1$, equation (1) indicates the presence of diminishing marginal returns to capital accumulation: successive incremental additions to the capital stock yield progressively smaller increases in total output. Figure 1 illustrates this property of equation (1). It shows that the marginal return on capital, equal to $R = \alpha AK_t^{\alpha-1}$, is a decreasing function of the capital stock K_t.

The representative agent saves amount S_t during period t in order to add to his capital stock in period $t+1$. The Solow model assumes that saving S_t is governed by

$$S_t = S(R - R^*), \tag{2}$$

where S is an increasing function of the marginal return on capital R. Thus, the representative agent saves more when the return on capital is higher. R^* represents the rate of return on capital that is so low that the agent no longer finds it worthwhile to save; when $R = R^*$, $S_t = S(0) = 0$.

Figure 1 traces out the dynamics generated by the interaction between the production function (1) and the saving function (2). With the initial capital stock given by K_0, the marginal rate of return R_0 exceeds R^*, so that saving is positive. The representative agent continues to save and accumulate capital until the marginal return has fallen to R^*. At this point, $K_t = K^*$, and saving stops.

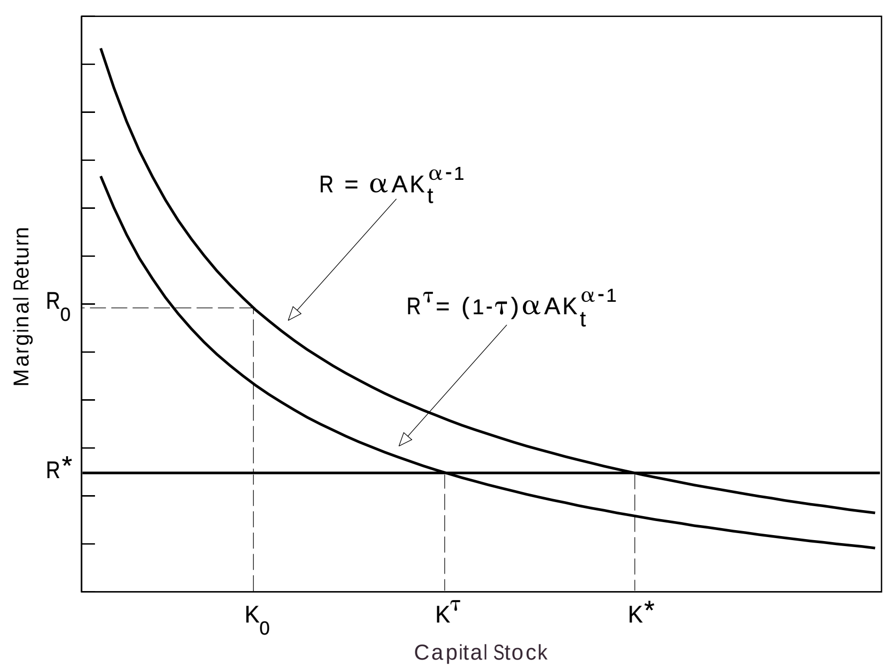
When the government imposes an income tax τ, the representative agent's after-tax income becomes $(1 - \tau)AK_t^{\alpha}$ and his after-tax marginal return on capital becomes $R^{\tau} = (1 - \tau)\alpha AK_t^{\alpha-1}$. Thus, the income tax τ induces the parallel downward shift in the marginal return schedule that is also shown in Figure 1. Since the representative agent cares only about his after-tax return, his saving now stops when R^{τ} reaches R^*. Starting from the initial capital stock K_0, capital accumulation continues only until $K_t = K^{\tau}$.

Thus, Figure 1 reveals how the income tax affects aggregate output in the Solow model. Since it lowers the effective marginal return on capital, the tax weakens the representative agent's incentives to save. Lower saving translates into a smaller capital stock. Consequently, the level of output ultimately attained with the tax, $A(K^{\tau})^{\alpha}$, is lower than the level of output $A(K^{*})^{\alpha}$ achieved without the tax.

Figure 1 also shows that with or without the tax, the Solow model implies that the marginal return on capital eventually falls to R^{*}, so that capital accumulation and growth ultimately cease. Historically, many economists have used this implication of the diminishing marginal returns assumption to argue that the growth of the U.S. economy, or indeed any capitalist economy, cannot be sustained. Alvin Hansen (1939), for example, interprets the Great Depression of the 1930s as a symptom of a low rate of return on capital and warns that the U.S. economy might stagnate permanently.

In light of the U.S. economy's recovery from the Depression and its continuing expansion since then, however, Solow augments the production function

Figure 1 Taxes in the Solow Model



(1) so that his model can account for sustained growth. Specifically, Solow assumes that the parameter A increases steadily over time at the rate μ. Output at time t is then described by

$$Y_t = A_t K_t^{\alpha}, \tag{3}$$

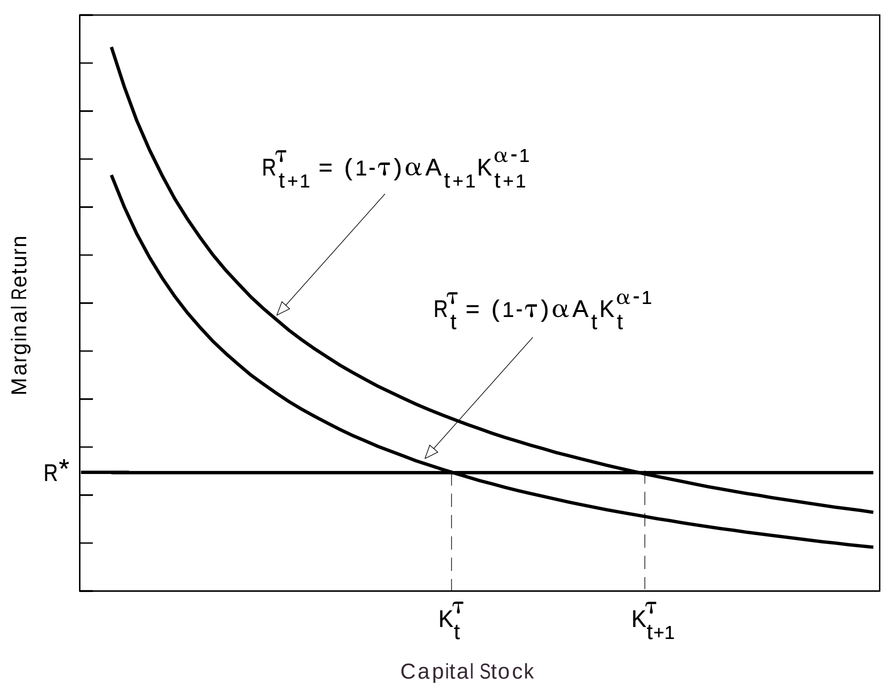
where

$$A_{t+1} = \mu A_t. \tag{4}$$

When A_t increases, the representative agent produces more output with the same capital stock. Thus, equations (3) and (4) capture the effects of constant technological progress.

Figure 2 illustrates the effect of an increase in the parameter A. The government continues to impose the tax τ. At the end of time t, the capital stock K_t^{τ} has reached the level consistent with the minimum rate of return R^*; without technological change, the economy would grow no further. When A increases from A_t at time t to A_{t+1} at time $t+1$, however, the marginal return schedule shifts upward from R_t^{τ} to R_{t+1}^{τ}. The marginal return rises above R^* and capital

Figure 2 Technological Change in the Solow Model



accumulation begins again. The capital stock increases to K^{τ}_{t+1}. Thus, by constantly offsetting the effects of diminishing marginal returns, the kind of continual technological progress described by equation (4) generates sustained growth in the Solow model.

A key assumption behind equation (4) is that μ is completely exogenous. This assumption makes the Solow model an exogenous growth model. Although the tax τ creates adverse effects on incentives that lead to a lower level of output, it has no influence on the process of technological change that determines the economy's long-run rate of growth. Thus, taxes have *level effects* but not *growth effects* in the Solow model.

The Solow model's key implication that tax policies have level effects but not growth effects can also be derived more rigorously with a mathematical treatment of the model. As above, the representative agent produces output according to the production function with exogenous technological change described by equations (3) and (4). The government levies the flat-rate income tax τ.

The government uses its tax revenue to provide the representative agent with a lump-sum transfer of G_t units of output at each date t. The distinction between the flat-rate tax and the lump-sum transfer must be emphasized. The flat-rate tax reduces the agent's effective return on capital and hence weakens his incentives to save. The agent receives the lump-sum transfer no matter how much he saves; the payment G_t has no effect on incentives.

At each date t, the representative agent's total income consists of his after-tax output $(1-\tau)Y_t$ and government transfer G_t. The agent divides this income between consumption C_t and investment I_t; he faces the budget constraint

$$(1-\tau)Y_t + G_t = C_t + I_t. \tag{5}$$

From consuming C_t during period t, the representative agent derives utility measured by $\ln(C_t)$, where ln denotes the natural logarithm. His lifetime utility is then

$$\sum_{t=0}^{\infty} \beta^t \ln(C_t), \tag{6}$$

where $0 < \beta < 1$ is a factor that discounts utility in future periods relative to utility in the current period. By investing I_t at time t, the agent adds to his capital stock at time $t+1$, so that

$$K_{t+1} = (1-\delta)K_t + I_t, \tag{7}$$

where δ is capital's depreciation rate.

The representative agent maximizes the utility function (6) subject to the constraints (3)–(5) and (7). Cass (1965) demonstrates that the solution to this maximization problem dictates that consumption and capital eventually grow at the same rate γ and the consumption-capital ratio converges to the constant ξ. Formally,

$$\lim_{t\to\infty} C_{t+1}/C_t = \lim_{t\to\infty} K_{t+1}/K_t = \gamma \tag{8}$$

and

$$\lim_{t\to\infty} C_t/K_t = \xi. \tag{9}$$

Like the representative agent, the government faces a budget constraint that requires that its receipts τY_t equal its expenditures G_t in every period t:

$$\tau Y_t = G_t. \tag{10}$$

Together, equations (3), (5), (7), and (10) imply that the economy's aggregate resource constraint is

$$A_t K_t^{\alpha} = Y_t = C_t + I_t = C_t + K_{t+1} - (1-\delta)K_t. \tag{11}$$

That is, output equals consumption plus investment.

In light of equations (8) and (9), equation (11) determines the long-run growth rate that is predicted by the Solow model. Dividing (11) by K_t and taking the limit of both sides yields

$$\lim_{t\to\infty} A_t/K_t^{1-\alpha} = \xi + \gamma - (1-\delta). \tag{12}$$

Since the right-hand side of equation (12) is constant, this condition implies that A_t and $K_t^{1-\alpha}$ must eventually grow at the same rate. Equation (4) indicates that the growth rate of A_t is μ; equation (8) implies that the long-run growth rate of $K_t^{1-\alpha}$ is $\gamma^{1-\alpha}$. Hence, it must be that $\mu = \gamma^{1-\alpha}$ or, equivalently, that

$$\gamma = \mu^{1/(1-\alpha)}. \tag{13}$$

Equations (3) and (4) then imply that the long-run growth rate of output is

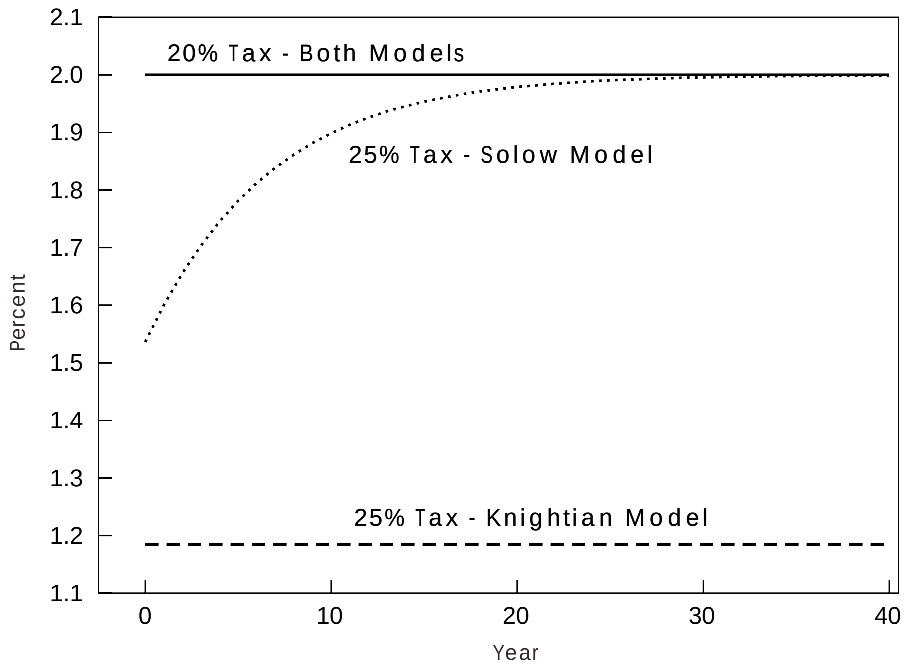
$$\lim_{t\to\infty} Y_{t+1}/Y_t = \lim_{t\to\infty}(A_{t+1}/A_t)(K_{t+1}/K_t)^{\alpha} = \mu\mu^{\alpha/(1-\alpha)} = \mu^{1/(1-\alpha)}. \tag{14}$$

Equation (14) reveals again the Solow model's key implication: the long-run growth rate is ultimately determined by the rate of technological progress μ. The tax rate τ appears nowhere in equation (14); changes in the tax rate have no effect on long-run growth.

A numerical example illustrates the effects of taxes on growth in more detail. With $\alpha = 0.333$, $\mu = 1.0133$, $\beta = 0.988$, and $\delta = 0.1$, King and Rebelo (1990) show that if each period in the Solow model represents one year, then the model economy's long-run annual growth rate is 2 percent, about the average growth rate of output per capita in the twentieth-century United States.

With these parameter values, Figure 3 plots the growth rates of two Solow economies. Both have constant tax rates, but $\tau = 0.20$ in the first and $\tau = 0.25$ in the second. The economies both start with the same capital stock, set so that

Figure 3 Growth in the Solow and Knightian Models



the economy with $\tau = 0.20$ always grows at its long-run rate of 2 percent. Thus, this numerical exercise isolates the effects of an increase in taxes from 20 to 25 percent.

The figure shows that the higher tax rate does slow the economy's growth in the short run. Initially, the growth rate is less than 1.54 percent under the 25 percent tax, compared to 2 percent under the 20 percent tax. Eventually, however, the growth rates of the two economies converge, exactly as required by equation (14). Thus, the results once again illustrate that changes in tax policy have level effects but not growth effects in the Solow model.

2. A KNIGHTIAN MODEL WITH TAXES

Maddison (1987, Table 1, p. 650) reports that the growth rate of the U.S. economy averaged 4.2 percent annually during 1870–1913, 2.8 percent annually during 1913–1950, 3.7 percent annually during 1950–1973, and 2.3 percent annually during 1973–1984. As the results of the previous section demonstrate, the Solow model attributes all changes in an economy's long-run growth rate to changes in its rate of exogenous technological progress. Thus, according to Solow's model, the variation in long-run growth documented by Maddison must be due to fluctuations over time in μ. Similarly, among the 92 countries for which complete data are recorded by Summers and Heston (1991, Table III, pp. 356–58), the average growth rate of real per-capita GDP from 1980 through 1988 ranged from 7.8 percent for China to -8.2 percent for Trinidad and Tobago; growth in the United States during this period averaged 2.3 percent. The Solow model also implies that this international variation in growth rates must be due to cross-country differences in μ.

Solow's model does not suggest how μ is ultimately determined, however. Thus, the model essentially leaves unexplained the enormous variation in long-run growth rates that is observed both within countries over time and across countries at any given point in time. This shortcoming of the Solow model has led economists to search for alternative models that do identify sources of variation in long-run growth. One new line of inquiry draws on a theory of economic growth, due to Frank Knight (1944), that predates the formulation of the Solow model.

Knight challenges the conventional view that it is useful to organize factors of production into the three categories of land, labor, and physical capital. According to this conventional view, land is permanently fixed in supply. Labor supply is slightly more variable, but is ultimately limited in the short run by the size of the working population. Only the stock of physical capital can be quickly and easily increased over time.

Knight points out that while land may be fixed in quantity, there is no limit to improvements that can be made in its quality. As a matter of fact, landowners continually develop and improve their property. The productive capacity of an economy's land thereby increases over time, much as the productive capacity of its physical capital stock continually expands as a result of new investment.

Similarly, argues Knight, the quantity of labor may be fixed in the short run, but the quality of the workforce is easily augmented. Just as an entrepreneur invests today to obtain a more productive capital stock tomorrow, a worker allocates time to education and training today so as to become more productive tomorrow. In other words, an economy accumulates human capital as well as physical capital.

In fact, Knight goes on to suggest that the process of technological change is itself just the fruit of another kind of investment. Entrepreneurs and workers search continually for new, more efficient methods of production. Their research and development efforts require resources in the present, but yield a return in the form of increased productivity in the future.

Thus Knight, like Solow, assigns an important role to technological progress in his theory of economic growth. But while Solow assumes that technological progress occurs at an exogenously given rate, Knight views the process as endogenous: the same incentives that induce agents to accumulate physical capital drive them to search for technological and scientific advances. In light of this distinction, Knight's is an endogenous growth model.

Knight replaces the traditional categories of land, labor, and physical capital with an all-encompassing definition of capital that accounts for improvements in the quality of land, the accumulation of human capital, and the endogenous process of technological change as well as for physical capital. Knight then argues that the various forms of capital he identifies are complements in production. There may be diminishing returns to accumulating one type of capital alone, but there is no tendency for their marginal product to fall as all types are increased together. Under Knight's broad definition of capital, therefore, production features constant, rather than diminishing, returns.

Recent papers by Jones and Manuelli (1990), Barro (1990), King and Rebelo (1990), and Rebelo (1991) incorporate Knight's ideas into contemporary models of economic growth. The simplest of these models differs from Solow's only in its specification of the production function. Here, the representative agent produces output with capital in each period t according to the linear production function

$$Y_t = AK_t. \tag{15}$$

The parameter A is once again constant in equation (15); there is no exogenous technological change. Instead, this model adopts Knight's idea that technological advances occur endogenously and should be accounted for in a comprehensive definition of the capital stock K_t. Equation (15) also drops the exponent α on capital, reflecting Knight's assumption of no diminishing returns.

The implications of Knight's theory can be derived by considering the properties of the production function (15) along with the saving function $S_t = S(R - R^*)$. Consider first the case where there are no taxes. Equation (15) then implies that the marginal return to capital is the constant A; because of the no-diminishing-returns assumption, this return does not depend on the size of the capital stock K_t. Since the return on capital $R = A$ never falls to the critical level R^*, capital accumulation continues forever.

Unlike the Solow model, therefore, this Knightian model accounts for sustained growth in output per capita even in the absence of exogenous technological change. Recalling that Knight's all-encompassing definition of capital accounts for endogenous technological progress, the return $R = A > R^*$ provides the representative agent with an incentive to add continually to the stock of technological knowledge. Economic growth continues as long as this incentive is preserved. The Knightian model therefore contradicts Hansen's (1939) view that an economy will stagnate without exogenous technological change.

The flat-rate income tax τ in the Knightian model shifts the marginal return schedule down from $R = A$ to $R^\tau = (1-\tau)A$. Sustained growth still occurs if it is the case that $R^\tau > A$. But since the tax permanently lowers the effective rate of return, it also permanently weakens the agent's incentive to accumulate all types of capital. Hence, unlike the Solow model, this Knightian model predicts that taxes affect the growth rate as well as the level of aggregate output. That is, tax policies have both level and growth effects.

The policy implications of the Solow and Knightian models can be traced back to the different ways in which these two models account for the process of technological change. The Solow model depicts technological change as a completely exogenous process; hence, tax rates do not influence long-run growth. The Knightian model, on the other hand, treats technological change as part of the endogenous process of capital accumulation. Just as higher tax rates weaken the representative agent's incentive to accumulate physical capital, they induce him to slow down his search for more efficient methods of production. Consequently, tax rates do help determine the rate of long-run growth.

In fact, the Knightian model predicts that any economic policy that changes incentives for the accumulation of broadly defined capital will also influence the rate of long-run growth. Since such policies differ widely over time and across countries, this model identifies potential sources of variation in long-run growth rates that the Solow model does not.

As suggested by the analysis above, the mathematical formulation of the Knightian model differs from that of the Solow model only in terms of the production function. Now the representative agent maximizes the utility function (6) subject to the budget constraint (5) and the capital accumulation equation (7) as well as the linear production function (15). King and Rebelo (1990) show that the solution to this maximization problem is such that consumption, capital, and output always grow at the constant rate ω:

$$C_{t+1}/C_t = K_{t+1}/K_t = Y_{t+1}/Y_t = \omega, \tag{16}$$

where

$$\omega = \beta[(1-\tau)A + (1-\delta)]. \tag{17}$$

Equation (17) indicates that the economy's growth rate depends negatively on the tax rate τ, so that taxes have growth effects as well as level effects in the Knightian model. Figure 3 illustrates these effects in more detail by repeating its numerical exercise for the Knightian model. As before, $\beta = 0.988$ and $\delta = 0.1$. With $A = 0.165$, output grows at the annual rate of 2 percent under a constant 20 percent tax rate (King and Rebelo 1990). The figure uses these parameter values to plot the growth rates of two Knightian economies, one with $\tau = 0.20$ and the other with $\tau = 0.25$. Thus, as before, the exercise illustrates the effects of a tax increase from 20 to 25 percent.

The figure shows that the growth rate decreases from 2 percent under the 20 percent tax rate to 1.19 percent under the 25 percent tax rate. Moreover, as equations (16) and (17) imply, there is no tendency for the growth rates of the two economies to converge; the growth rate falls permanently in response to higher taxes. Once again, therefore, the results demonstrate that tax policies have both level and growth effects in the Knightian model.

3. EMPIRICAL STUDIES OF TAXATION AND GROWTH

Although Figure 3 illustrates that the Solow and Knightian models have different implications for the effects of taxation on long-run growth, this difference may seem to be just a technical matter at first. After all, the tax increase in the Solow model does not permanently decrease growth as in the Knightian model, but it does result in slower growth for more than two decades. When expressed in terms of the level rather than the growth rate of output, however, the difference is enormous. In the Solow model, the increase in the tax rate from 20 to 25 percent decreases the level of output by 3.17 percent over 40 years. In the Knightian model, the same tax increase reduces the level of output by 27.5 percent over 40 years.

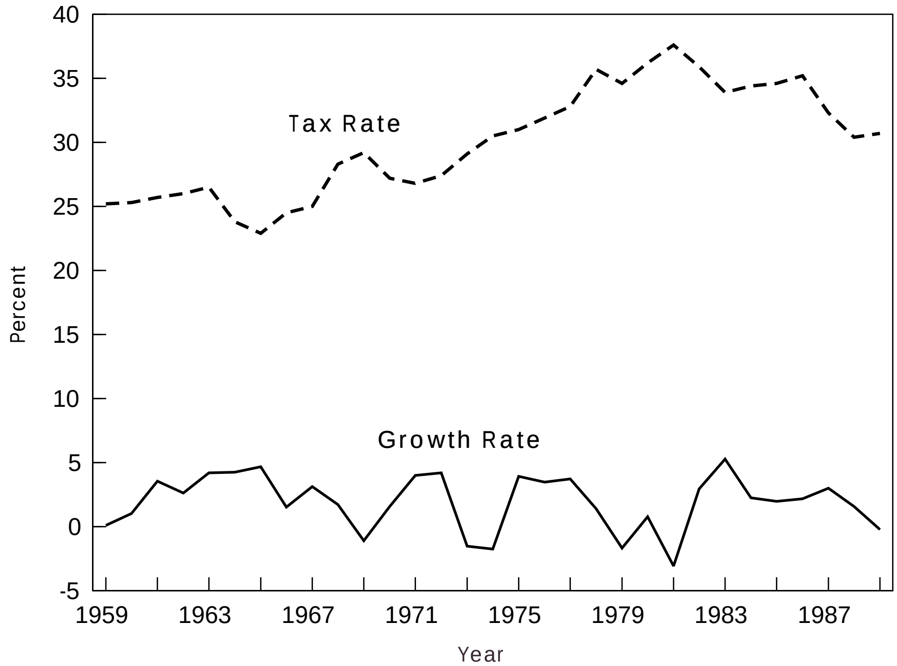
Policymakers in the United States have recently called for increases in marginal tax rates, which they argue will help to close the federal budget deficit without significant losses in output. Others disagree, claiming that higher taxes inevitably lead to slower growth. As the results of the previous sections show, competing economic theories lend support to both sides in this debate. On the one hand, the Solow model describes an environment in which tax rates do not affect long-run growth; on the other, the Knightian model confirms the view that higher taxes do hinder growth.

Thus, the next step in applying the theories to understand the U.S. economy is to determine empirically whether or not changes in tax rates actually translate into changes in long-run growth. If taxes do not influence long-run growth, then the Solow model and its policy implications should be taken seriously. If taxes do help determine long-run growth, however, then the Knightian model and its implications are to be preferred.

Figure 4 plots the growth rate of real per-capita GDP (taken from the *Economic Report of the President* 1993) along with Barro and Sahasakul's (1986) tax rate series (updated to run through 1989) for the United States. The graph suggests that there has been a negative relationship between growth and taxes over the postwar period. In fact, a simple regression of the growth rate on the tax rate yields a negative coefficient that is statistically significant at the 10 percent level. Cebula and Scott (1992) use quarterly series from 1957 through 1984 to regress growth in real per-capita GDP on various measures of fiscal policy, including the top personal income tax rate. They also find that changes in taxes have a negative and statistically significant effect on growth.

A problem with using these results to discriminate between the Solow and Knightian growth models arises because even in the Solow model, changes

Figure 4 Growth and Tax Rates in the U.S. Economy



in tax rates affect growth in the short run. As Figure 3 reveals, it is only in the long run that taxes influence growth in the Knightian model but not in the Solow model. Thus, the negative short-run correlation between taxes and growth that appears in Figure 4 is consistent with the implications of both models. Likewise, since Cebula and Scott do not distinguish between short-run and long-run changes in growth, their results cannot be interpreted as decisive evidence against the Solow model either.

Kocherlakota and Yi (1993) recognize the problem of distinguishing between short-run and long-run changes in growth and sidestep this problem by taking a slightly different approach to test the Solow model against the Knightian theory. They note that in addition to having distinct implications for the effects of taxes on the growth rate of output, the two models have different predictions for the effects of taxes on the level of output. Specifically, the Solow model predicts that temporary changes in tax rates have only temporary effects on the level of output. The Knightian model, in contrast, predicts that temporary changes in taxes permanently affect the level of output.

Kocherlakota and Yi assume that all changes in U.S. tax rates, 1917–1983, are temporary ones, and they use a statistical model that distinguishes between temporary and permanent changes in the level of real GNP. Their estimate indicates that temporary increases in tax rates have translated into permanent decreases in the level of output; this result supports the Knightian model. On the other hand, the estimate is not statistically significant, which suggests that the Solow model may be more realistic. Overall, Kocherlakota and Yi's results may simply indicate that even with 65 years of data and with the most powerful statistical techniques, it is very difficult to extract much information about the determinants of long-run growth from the U.S. time series.

Other researchers circumvent the problem of distinguishing between short-run and long-run changes in growth by using international cross-sectional data rather than time series data. With cross-sectional data, growth rates within each country can be averaged over extended periods of time in order to smooth out short-run fluctuations and thereby identify long-run trends. In addition, by drawing on the experiences of many different countries, cross-sectional data bring more information to bear on the question of whether tax rates affect long-run growth. On the other hand, compared to time series studies, those that use cross-sectional data must make the additional assumption that the same mechanisms through which taxes influence aggregate activity in the United States operate in the other countries as well, so that conclusions that apply internationally also hold for the United States.

Existing cross-sectional studies differ in that some use the average tax rate, the ratio of total tax receipts to national income, while others use the marginal tax rate, the additional taxes paid when income rises incrementally, to estimate the effects of taxes on growth. In both of the theoretical models presented above, the simple flat-rate tax is such that the average and marginal tax rates coincide. In reality, however, tax rates differ with the source and level of income, so that average and marginal tax rates diverge. Since economic decisions depend on the marginal tax rate, this measure is more appropriate for investigating the effects of taxes on growth. Data on marginal tax rates are often unavailable, however; average tax rates must then serve as a proxy.

Marsden (1983) takes data from 20 countries, 1970–1979. He organizes these countries into ten pairs; each pair consists of countries with similar levels of per-capita income but different average tax rates. In each pair, he finds that the country with the lower tax rate has a higher rate of real GDP growth. As a matter of fact, all of the ten low-tax countries have higher growth rates than any of the high-tax countries. This pattern also appears in Marsden's regression results, which show that average tax rates have a significantly negative effect on growth across countries.

In Reynolds' (1985) sample, industrial countries with high average tax rates, including Sweden, Belgium, and the Netherlands, grew at an average rate of 1.7 percent between 1976 and 1983. In contrast, those with low average tax rates, such as the United States, Portugal, and Japan, averaged 4.1 percent growth. About the effects of marginal tax rates, Reynolds notes:

> Supply-side tax theory would predict that economic performance in Ontario, Canada, with a top tax rate of 51 percent, would be superior to that of Quebec, with its 60 percent rate. It would predict that development in Puerto Rico, with a top tax rate of 68 percent, would fall behind that of any U.S. state. It would predict that Australia would outperform New Zealand, that Cyprus would outperform Greece, that the state of New Jersey would grow faster than New York, and so on. All of these predictions are correct. (P. 557)

Among developing countries, Reynolds finds that those with the highest marginal tax rates have economies that contracted by 1.4 percent annually, 1979–1983. Those with the lowest marginal tax rates, on the other hand, have economies that grew by 4.9 percent annually.

Skinner (1987) uses cross-sectional data from 31 sub-Saharan African countries, 1965–1982. His regression equation shows that the average tax rate has a negative and statistically significant effect on growth.

Average tax rates and growth turn out to be positively correlated in Rabushka's (1987) sample of 49 developing economies, 1960–1982. Rabushka interprets this finding as evidence that governments in more prosperous countries are able to levy more taxes than those in slower-growing nations, rather than as evidence that higher taxes lead to faster growth. Unlike average tax rates, he notes, marginal tax rates are negatively correlated with growth. The country with the lowest marginal tax rate, Hong Kong, has one of the highest growth rates in the sample, averaging 7 percent annually. A group of countries with the highest marginal tax rates, in contrast, grew at the average annual rate of only 1.9 percent.

Most recently, Martin and Fardmanesh (1990) and Engen and Skinner (1992) estimate cross-sectional regression equations and find that average tax rates are significantly and negatively related to growth in real income per capita. Martin and Fardmanesh's sample includes data from 76 countries, 1972–1981; Engen and Skinner's consists of data from 107 countries, 1970–1985.

Thus, many cross-sectional studies appear to support the hypothesis that tax rates influence long-run growth and thereby point to the Knightian model as the more accurate description of the U.S. economy. Only three of these studies, however, use more than ten years' worth of data. The others suffer from the same problem as Cebula and Scott's: by averaging data over a brief time interval, they may not adequately distinguish between short-run and long-run variation in growth. In addition, there are still other cross-country studies that lend support to the Solow model by indicating that changes in tax rates do not affect the long-run growth rate of output.

Using a sample of 63 countries, 1970–1979, Koester and Kormendi (1989) begin by noting that both average and marginal tax rates appear to be negatively associated with growth. They go on to point out, however, that the level of GDP is negatively related to growth, suggesting that smaller countries grow faster than more developed ones. They note, in addition, that average tax rates are positively correlated with the level of GDP; like Rabushka, they suggest that this correlation indicates that more affluent countries have governments that levy more taxes. Together, these last two correlations raise the possibility that earlier studies may have mistakenly concluded that changes in tax rates have long-run effects on growth, since the negative correlation between taxes and growth may simply reflect the fact that for independent reasons, both tax rates and growth rates are related to the level of income.

To allow for this possibility, Koester and Kormendi add the level of GDP to their growth regressions; by holding the level of income constant, they focus on the direct link between taxes and growth. While the coefficients on both average and marginal tax rates are still negative in the expanded regressions, neither is statistically significant. Garrison and Lee (1992) find that these results continue to hold when the data set is extended through 1984. Thus, these studies suggest that changes in tax rates do not have important growth effects.

Easterly and Rebelo (1993) calculate marginal tax rates for 32 countries in 1984. They regress the growth rate of per-capita consumption from 1980 through 1988 on the marginal tax rate as well as the level of per-capita GDP (following Koester and Kormendi) and measures of two other variables, educational attainment and political instability, that may explain cross-country differences in growth rates. Like Koester and Kormendi, Easterly and Rebelo obtain a negative but statistically insignificant coefficient on the marginal tax rate. Thus, their results also appear to support the Solow model.

Easterly and Rebelo note, however, that they cannot reject the hypothesis that all of their regressors are jointly insignificant. Like Kocherlakota and Yi's time series results, therefore, Easterly and Rebelo's cross-country results may simply indicate that there is insufficient information about the determinants of growth in their sample.

Thus, a review of the literature reveals that no strong conclusions can yet be reached as to which model, Solow's exogenous growth model or the Knightian endogenous growth model, is more appropriate for studying the effects of taxation on growth in the U.S. economy. A number of papers present evidence that tax rates do affect long-run growth, but others find no significant relationship.

The literature points to several problems that need to be overcome in future empirical work. Time series studies must effectively discriminate between short-run and long-run changes in growth, for it is only long-run changes that distinguish the competing models. Cross-sectional studies must distinguish between average and marginal tax rates, since marginal tax rates most directly affect economic decisions but are frequently difficult to measure. Cross-sectional studies must also address the possibility, first raised by Koester and Kormendi, that simple correlations may not reflect the direct effects of taxation on growth. Finally, Easterly and Rebelo's results suggest that efforts to collect tax and growth rate data from a wider sample of countries than has been previously considered might prove useful in sharpening the statistical results.

The massive federal budget deficit in the United States makes it likely that policymakers will continue to advocate significant tax increases in the years ahead. Since the Solow and Knightian models offer such different predictions for the effects of these tax increases on output, the empirical relationship between taxation and growth remains an important unsettled issue for future research.

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Firm Size, Finance, and Investment

John A. Weinberg

There is something in our national consciousness that looks fondly upon the small firm. This affection for small business is not entirely unwarranted. Small firms account for an important part of economic activity.[1] A vast majority of all businesses in the United States are small; over 90 percent have fewer than 20 employees. Small firms accounted for between 40 and 50 percent of GNP and over 60 percent of net job growth in the 1980s.[2] Such figures have drawn considerable attention in recent discussions of attempts to ease securities and bank regulation or to promote other policies concerning the financing of small firms.

This long-standing affection has at times generated significant public policy. Much of our antitrust policy was arguably generated more by a general mistrust of bigness and desire to protect small business than by a concern for the inefficiencies of monopoly pricing. Recently, much attention has been paid to the plight of the small firm in raising capital in the face of recently strengthened bank regulation. Indeed, it seems that a necessary part of the debate over any proposed public policy action, from health care to tax policy, is the question of how it will affect small firms.

A related working paper, "Learning, Firm Size and Investment," was presented at the University of Kentucky, and the author thanks the seminar participants, and Dan Black in particular, for their comments. This article has also benefited from discussions with Jeff Lacker and with Gordon Phillips on this and ongoing joint work. The views expressed herein are the author's and do not necessarily represent the views of the Federal Reserve Bank of Richmond or the Federal Reserve System.

[1] Small firms can be defined as those with fewer than 500 employees or those with revenues or assets below some standard. The Small Business Administration uses the employment definition, while the Securities and Exchange Commission uses a revenue standard ($15 million annually) for exemption from some registration requirements.

[2] These figures are drawn from the Small Business Administration (1992).

This article examines some aspects of the financial behavior of small firms as compared to larger firms. A particular focus is the question of whether there is a failure in financial markets that limits the activities of small firms. Both theoretical and empirical analyses of financial behavior have suggested that such a market failure might exist. The theoretical arguments center on problems of asymmetric information; when lenders are less well informed than borrowers about borrowers' conditions and activities, credit markets may not clear in the conventional fashion.[3] Such a failure of markets to function efficiently might suggest a role for government intervention to improve the allocation of financial capital.

Recent evidence on the investment behavior of large and small firms suggests the possibility that informational problems weigh more heavily on small firms. In particular, there is evidence that investment by smaller firms is more sensitive to factors that, in a world of perfect capital markets, are not expected to affect investment. The first section of this article surveys some of the evidence on differences in financial behavior across firm sizes, including the evidence on investment behavior.

The second section turns to theoretical interpretations of the evidence. The first of these interpretations is the theory of market failures due to asymmetric information, building on the idea that a firm's insiders will often know more than outsiders about the firm's prospects. This asymmetry can increase the cost of raising funds from outside investors. The asymmetric information perspective has led some to conclude that the market typically fails to provide sufficient financial capital.

While the likely effects of informational constraints may well vary with firm size, the interpretation of differences in behavior in terms of asymmetric information implicitly treats firm size as exogenous. The central point of this article is that an attempt to provide a theoretical explanation of differences in behavior across firm sizes should begin with a theory of firm size. The next subsection describes such a theory, drawing from the industrial organization literature; it is a life cycle theory in which firms, when they are young, learn about their productive capabilities. This learning drives the differences in behavior between large and small firms. It turns out that this theory, without informational market failures, is consistent with much of the evidence on firm size and financial behavior. Hence, movement toward a theory that jointly determines size and financial behavior weakens the case for a market failure interpretation of the evidence.

Section 3 discusses some implications for public policy toward the financing of small firms. Under the theory of market failure due to adverse selection,

[3] Greenwald and Stiglitz (1986) present a general theory of market failures in the presence of asymmetric information.

investment undertaken by small firms is inefficiently low compared to a world of perfect information. Some have argued that government intervention can move financial markets in the direction of greater efficiency by giving favorable treatment to small firms. Under the alternative theory, there is no market failure and no role for government intervention.

1. FINANCIAL BEHAVIOR OF SMALL AND LARGE FIRMS

An image of small business that has appeared in the popular media in recent years is one of entrepreneurs starved for capital. According to this image, recent banking legislation reduced the flow of bank loans to small firms. At the same time, venture capital provision of equity financing fell from the peaks it achieved in the middle of the last decade. Without access to external financing, small firms have been limited in their ability to grow and contribute to employment.

Parts of the above image are no doubt accurate. Most measures of the flow of external finance to small firms show a decline in recent years. Such numbers, however, must be understood in the proper context. Has the recent experience of small firms been qualitatively different from that of larger firms? By at least some measures, the answer is no. For instance, commercial and industrial bank loans to all firms, large and small, fell in 1991.[4]

To gain greater perspective on the recent experience of small and large firms, one might ask whether there are any systematic differences in the financial behavior of firms of different sizes. One approach to such a question is to examine the balance sheet characteristics of small firms. The Census Bureau's Quarterly Financial Report provides aggregate balance sheet data for all manufacturing firms and for small manufacturing firms (firms with less than $25 million in assets). These data give rise to a few observations. Most notably, small manufacturing firms use more bank debt, as a percent of assets, than do larger firms. From 1986 to the first quarter of 1993, small firms' loans from banks have averaged about 20 percent of total assets, while the corresponding figure for all firms has been less than 10 percent. The difference in the reliance on bank loans is particularly pronounced in long-term debt (with a maturity of greater than one year). While smaller firms have fewer long-term liabilities (about 40 percent of total liabilities compared to almost 60 percent for all firms), more than half of all long-term debt of small firms is in the form of bank loans. For all firms, bank loans constitute less than one-third of all long-term debt.

The observations above on the reliance of small firms on banks are consistent with findings from earlier periods. Andrews and Eiseman (1981) find

[4] The Federal Reserve Bulletin provides figures on commercial and industrial loans.

the same pattern in data from the 1970s and from 1958. The importance of banks for small firms is also apparent in survey evidence, such as the Federal Reserve's National Survey of Small Business Finance. In an analysis of that survey's data, Elliehausen and Wolken (1990) uncover the additional result that the smaller the firm, the greater the importance of local rather than distant banks. This result suggests the importance to small firms of having a close relationship with suppliers of funds. Correspondingly, small firms are less likely to raise funds in public securities markets.

Since the set of firms that have not issued public securities tends to consist of firms smaller than those in the set of public corporations, it should not be surprising that those firms issuing securities for the first time are often small relative to those already public. Most often, a firm's first public issue is of common stock equity (an initial public offering, or IPO). While the size distribution of firms undertaking IPOs varies from year to year, it typically includes many small firms (assets less than $10 million). In 1984, virtually all IPOs were by small firms, while in 1985 and 1986, small firms conducted about half of all offerings.[5]

Even within the population of only public corporations, there are differences across firm size categories. In addition to the same tendencies cited above, it is worth noting the covariation of firm size and dividend behavior among public firms. Fazzari, Hubbard, and Petersen (1988), in their study of the investment behavior of a panel of firms, divide their sample into three classes based on dividend behavior: firms with a dividend to income ratio persistently less than 0.1; those with a dividend to income ratio between 0.1 and 0.2; and those who persistently paid out at least 20 percent of their income in dividends. The average size (measured by 1970 capital stock) of the highest dividend-paying group was more than four times that of the middle group and more than ten times that of the lowest group.

Another way in which smaller firms seem to differ systematically from larger firms is in the relationships between financial variables and real economic decisions. Most notably, there appear to be differences in the determinants of investment. A useful benchmark for thinking about investment and its relation to financial conditions is the irrelevance result of Modigliani and Miller (1958). The "Modigliani-Miller Theorem" states that a firm's financial policy (capital structure, payment of dividends, etc.) has no effect on its real decisions, including investment. Technological and product market opportunities determine investment and other real decisions. The firm's financial choices, for instance, of debt versus equity financing, should have no bearing on its real opportunities.

The Modigliani-Miller result applies to a frictionless world of perfect markets in which all market participants are always fully informed about firms'

[5] Small Business Administration (1992).

opportunities. Empirically, the result seems to fail frequently. Financial characteristics are correlated with firm behavior, and such relationships are most apparent for smaller firms.

One focus in the literature on financial characteristics and real behavior has been on the relationship between cash flow and investment. In the frictionless world of the Modigliani-Miller theorem, the two should be unrelated. A firm with good investment opportunities should be able to fund its investment either out of its own cash flow or by raising external funds. In a world of perfect information, a firm with good opportunities will face no barrier in raising funds from outside investors or financial institutions. Hence, unless the size and quality of the firm's investment opportunity set is correlated with current cash flow performance, there is no reason to expect a correlation between cash flow and investment. Contrary to this theoretical perspective, there is considerable evidence that for at least some firms, cash flow does help determine investment.

The evidence on investment and cash flow comes in two forms, corresponding to two standard approaches to the empirical study of investment behavior. The first of these is based on the Tobin's q theory of investment.[6] Under this theory, the ratio of a firm's market value to the replacement cost of its assets (Tobin's q) serves as a measure of the firm's investment opportunities. The theory suggests a regression equation of the following nature:

$$I_{it} = \beta_{0i} + \beta_{0t} + \beta_1 q_{it} + \beta_2 CF_{it} + \epsilon_{it}, \tag{1}$$

where I_{it} is firm i's investment in fixed capital in time period t (as a fraction of current fixed capital input), q_{it} is the Tobin's q ratio and CF_{it} is cash flow (as a fraction of current fixed capital input). The null hypothesis is that $\beta_2 = 0$. This approach is followed by Fazzari, Hubbard, and Petersen (1988). They reject the null hypothesis, estimating positive values of β_2 on a sample of public corporations. In particular, when the sample is divided into subsamples according to dividend behavior, cash flow is most strongly related to investment for the subsample of firms paying the lowest dividends.

A central focus in interpreting the results on cash flow and investment is the extent to which, conditional on other variables included in the analysis, cash flow provides information on the firm's investment opportunities. If cash flow does provide such information, then the empirical findings are not necessarily contrary to the Modigliani-Miller results. This issue is the concern of much of the next section. With this concern in mind, there have been some recent studies that have supplemented the evidence on cash flow and investment. One such study is by Fazzari and Petersen (1993). They augment equation (1) to estimate

$$I_{it} = \beta_{0i} + \beta_{0t} + \beta_1 q_{it} + \beta_2 CF_{it} + \beta_3 \Delta W_{it} + \epsilon_{it}, \tag{2}$$

[6] Tobin (1969).

where ΔW_{it} is the change in firm i's working capital in period t (as a fraction of current fixed capital input).[7] Like cash flow, working capital can serve as an internal source of funds for fixed investment. For a sample of firms paying low dividends, Fazzari and Petersen estimate a statistically significant negative value for β_3. They interpret this result as further suggesting the importance of internal finance to these firms; holding cash flow constant, a firm finances increasing investment by drawing down its holdings of liquid assets. A similar finding was obtained by Whited (1991) who examined the tendency of firms to accumulate liquid financial assets before undertaking a program of fixed investment.

The second approach used in studying investment behavior involves the direct estimation of the "first-order condition" in a firm's value-maximizing choice of investment. A simplified version of such a condition for a typical firm can be expressed as

$$E_t[mpk_{t+1}] = \rho_t, \tag{3}$$

where E_t denotes expectation conditional on information available at time t, mpk_{t+1} is the marginal product of the capital input, and ρ_t is the "user cost of capital," which, in its simplest form, includes the rates of interest and capital depreciation between times t and $t+1$. Equation (2) determines the desired amount of capital in the next period (period $t+1$), and (net) investment is simply the change in capital input from the current to the next period. Gilchrist (1990) and Whited (1992) are among the authors using this approach, the so-called Euler equation approach. The findings tend to parallel that of Fazzari, Hubbard, and Petersen. Equation (2) fits the data well for a sample of firms that regularly pay dividends but not for firms with low, irregular, or no dividend payment histories. While both approaches outlined above divide the samples of firms according to dividend policy, it should be noted that this procedure also tends to divide firms by size. As mentioned above, Fazzari, Hubbard, and Petersen provide evidence on the correlation between size and dividend policy.

The evidence suggests distinct differences in financial behavior across firms in different size classes. Smaller firms tend to make considerably less use of public securities markets for raising external funds. Accordingly, when they do raise external funds, they are more likely to borrow from a bank or other financial institution. Lastly, smaller firms seem to rely more on internally generated funds to finance their investment activities.

[7] Working capital is current assets (primarily inventories, cash, and accounts receivable) less current liabilities (short-term debt and accounts payable).

2. TWO THEORETICAL PERSPECTIVES ON FIRM SIZE AND FINANCE

While the empirical studies reviewed above provide a picture of how small and large firms differ, they give little insight into why they differ. Providing such insight is the role of economic theory. This section provides two theoretical perspectives that might be used to interpret the empirical picture painted above. The focus of the first is on imperfections in financial markets. The second focuses on the causes of variations in firm sizes in a dynamic, competitive economy.

Informational Market Failures

The apparent rejections of Modigliani-Miller results have led many economists to seek out the market imperfections, or sources of market failure, that cause financial behavior to differ from the idealized model. One imperfection on which much attention has been focused is the problem of incomplete or asymmetric information. A transaction is made under incomplete information when one party to the transaction has information that is relevant to the other party's decision. For instance, a seller may know details about the quality of the product or service being sold. It may be difficult for the buyer to perfectly discern all these details on inspection, or even upon receiving the product or service. In such a situation, a seller of a truly high-quality product may be unable to receive a price which fully reflects the product's quality. If high quality is more costly to provide, then the inability to extract a higher price may serve to drive high-quality providers out of the market. This problem, first analyzed in some detail by Akerlof (1970), is known as the "lemons" problem or "adverse selection" problem.

Another variety of asymmetric information problem is the "moral hazard" problem. The term "moral hazard" refers to the fact that the observable performance of one party to a transaction often depends partly on that party's unobservable actions and partly on random events. Hence, the contract governing the transaction cannot directly prescribe the "morally hazardous" action. Desired actions must be indirectly induced through the payment incentives in the contract.

An extensive theoretical literature has examined the implications of private-information problems for financial markets. The focus, here, will be on that part of the literature which finds that asymmetric information can raise a firm's cost of obtaining external finance. If the cost is raised enough, the firm may be forced to rely entirely on internal funds to finance its investment projects. One line of this research examines the implications of adverse selection for the ability of firms to raise funds through the issuance of debt to a competitive market of investors or institutions.[8] The key insight in this line of work is that, as in the lemons problem, a high-quality borrower (that is, one with a low probability of default) may have difficulty credibly conveying credit quality information to lenders. Hence, even a good borrower will have to pay an interest rate that compensates for the probability that any borrower might be a bad borrower (with a high probability of default). In some cases examined in this work, the problem becomes so severe that some (high-quality) borrowers are unable to obtain funds at any interest rate. Stiglitz and Weiss (1981), among others, have argued that such a credit rationing result is to be expected in financial markets subject to incomplete information.

There also has been work that has argued that moral hazard can impair a firm's access to external funds. A notable example is Gertler (1992). In such models, outside investors are unable to directly monitor all of the resource allocation decisions made inside the firm. An insider (manager) may have an incentive to misallocate resources for personal benefit. This incentive is reduced when the manager's own resources are put at risk in the enterprise.

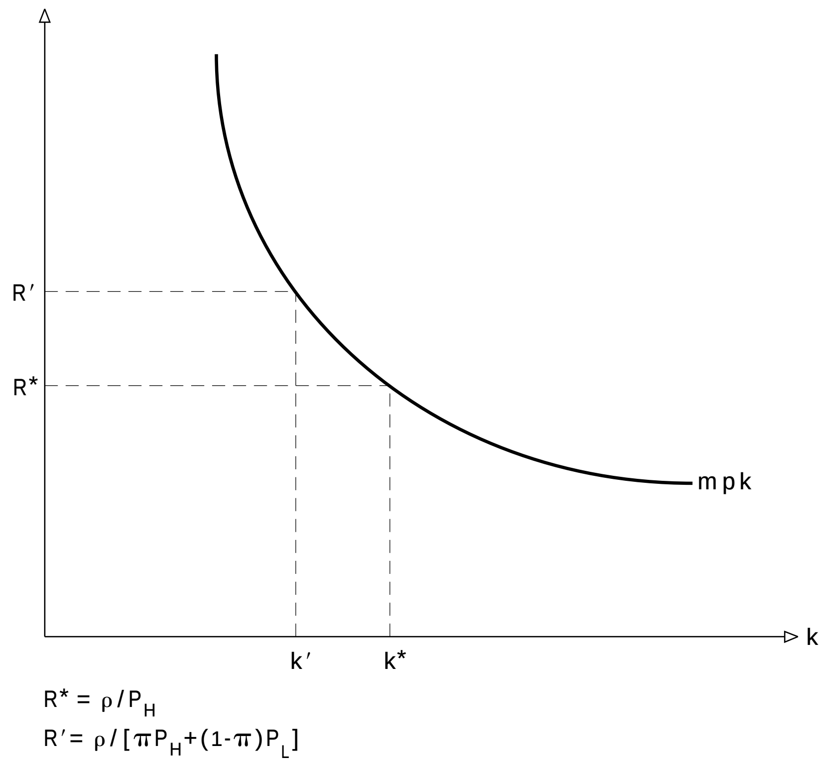
When viewing financial markets through the lens of asymmetric information theory, financial intermediaries often emerge as institutions that can partially resolve the problems of adverse selection and moral hazard by spending resources on information production. A bank or other intermediary might, for instance, invest resources in evaluating a borrower prior to lending, as in Boyd and Prescott (1986). Alternatively, such an institution might engage in costly monitoring of the borrower's performance after a loan has been made, as in Diamond (1984). This perspective is consistent with the popular view of banks and other intermediaries as institutions that specialize in information-intensive financial arrangements.

When asymmetric information affects the availability or cost to a firm of securing external funds, then the Modigliani-Miller results on the independence of financial behavior and real investment may not hold. A simple example may be useful.[9] Consider a firm that initially has no assets, either in the form of fixed capital or in the form of more liquid assets. The firm chooses its investment in fixed capital, k (in nominal value), and funds its purchase in a competitive credit market. If it is successful, the firm will produce output according to a production function, $f(k)$ (giving output in nominal value). Corresponding to this production function is a downward-sloping marginal product curve, as in Figure 1. If unsuccessful, the firm produces nothing and defaults on its

[8] Lacker provides a thorough and critical review of this line of research in this issue of the *Economic Quarterly*.

[9] The analysis of this example is admittedly incomplete, for a number of reasons. The purpose is not to give a complete model of financial markets but to give a sense of the directions in which asymmetric information can move financial behavior away from the benchmark case of full information.

Figure 1 Demand for Capital by a High-Quality Firm



loan. There are two possible types of firm. High-quality firms succeed with probability P_H and low-quality firms succeed with probability $P_L < P_H$.

Consider the problem facing a high-quality firm. If quality is known to all participants in the credit market, then the high-quality firm can borrow at an interest rate R per unit borrowed such that $P_H R = \rho$, where ρ is the rate of return available to lenders from an alternative risk-free investment. In this case, the firm's choice of k would be determined by equating the (expected) marginal product of capital to its (expected) marginal cost, as in equation (2). This choice is given by k^* in Figure 1.

Suppose now that only a firm's insiders know the firm's true quality. Lenders know only that some fraction, π, of all firms are high-quality. If the financial market cannot discriminate and must lend to all on equal terms, then the interest rate on loans, R, must be such that $[\pi P_H + (1-\pi)P_L]R = \rho$. Facing such a rate, a high-quality firm chooses an amount of capital given in Figure 1 by $k' < k^*$.

The presence of low-quality borrowers who cannot be screened out might be said to impose an externality on the high-quality borrowers. Note, however, that this externality is only relevant to a high-quality borrower without internal resources. If, before making its investment decision, the firm received a windfall of cash, it would make the higher investment k^*. Hence, this simple example suggests how, in the presence of asymmetric information, a firm's investment decision can be sensitive to random shocks to cash flow. It is also worth noting that the example suggests conditions under which a firm might find it worthwhile to utilize the type of costly information production provided by a bank. If we think of this information production as providing a "stamp of approval" or certification of true quality, then the value of obtaining such certification depends on the premium resulting from asymmetric information. This premium, the difference between R' and R^* in Figure 1, is decreasing in π, the fraction of high-quality borrowers in the population. Hence, if the role of financial intermediaries is to produce information that counteracts problems of adverse selection, then the services of intermediaries will have greater value the more severe the adverse selection problem faced by high-quality borrowers.

Under the asymmetric information view of financial markets, some firms will undoubtedly be more subject to the problems of adverse selection than others. Some firms will have a track record of past performance that will make it difficult to hide flaws and overstate virtues. Others, particularly young firms, will come to financial markets as relatively unknown entities. Hence, if one looked at a cross section of firms, one might expect deviations from the benchmark of frictionless finance to be inversely related to a firm's age and experience. The empirical evidence summarized above suggests an inverse relationship between such deviations and firm size. Therefore, the results of the asymmetric information approach will best conform to observed behavior if firm size and age are correlated. It is probably not surprising that age and size are, in fact, positively correlated in large cross sections of firms. One might imagine, then, a life cycle theory of the firm: as firms grow, they acquire publicly observed experience that enables them to loosen the bounds of financial constraints. Occasionally, as a result of changes in technology, preferences, or personnel, a firm's past experience becomes irrelevant for its future performance. At this stage, a firm either ceases to exist or returns to an earlier stage in the life cycle.

Life cycle models like that suggested above have, in fact, been used in analyzing the distribution of firm sizes in markets and economies. As will be discussed in the next subsection, the examination of such a model reveals that many of the empirical facts outlined above can be explained simply by the life cycle features of the model, without the additional feature of asymmetric information. This finding should prompt caution in considering the possible public policy implications of analyses based on informational market failures.

A Life Cycle Approach to Firm Size and Behavior

Analyzing differences in financial behavior among firms of different sizes is a bit like reading a book from the middle onward. You find characters reacting to a situation, but you do not know how they got into that situation. Similarly, in understanding differences between large and small firms, it may be useful to have a notion of what determines firm size. In other words, it may be useful to have a theory of the size distribution of firms in a market or an economy. Such a theory should be broadly consistent with empirical facts about size distributions.

The industrial organization literature has established a number of facts about size distributions. Simon and Bonini (1958) observed many of these facts, and more recent studies have provided some confirmation and some revision.[10] The first such fact is that there are, indeed, persistent differences in firm size within industries as well as across industries. Size distributions, either at the industry or aggregate level, tend to be skewed, with relatively small numbers of the largest firms and a large mass of firms in the smaller size ranges. Earlier studies concluded that rates of growth were independent of firm size, but more recent work, such as Evans (1987) and Hall (1987), has found this to be true only among larger firms. Overall, there is a negative correlation between size and growth. In addition, firm size is positively correlated with firm age, as found, for instance, by Evans (1987) and Dunne, Roberts, and Samuelson (1988). This last fact strongly suggests that life cycle effects may be important for understanding differences between the average behavior of small and large firms.

What the facts outlined above suggest is that there is a considerable amount of heterogeneity among firms. A model of a competitive economy that recognizes these facts of industrial organization should incorporate some form of heterogeneity into the fundamentals of the model economy. One such model has been provided by Lucas (1978). In a simplified version of that model, there is a generic technology available for using capital input to produce an output. Productivity, however, also depends on the ability of the entrepreneur or manager using the input.[11] Hence, the manager-specific technology can be represented by $y = \theta f(k)$, where y is output, k is capital input, and θ is the ability of the manager. Choice of inputs is like that represented in Figure 1, in which marginal product of capital is set equal to ρ, the market cost of capital. The curve *mpk* is higher the greater is the parameter θ. Accordingly, for any market cost of capital ρ, firms managed by managers with higher θs will be bigger than those with lower θs.

[10] For instance, see Evans (1987) and Hall (1987).

[11] Lucas' model also considers labor input and the division of the economy's population between workers and manager-entrepreneurs.

In the Lucas model, the underlying distribution of ability in the population determines the size distribution of firms. As a static model, however, it cannot directly address facts concerning the growth of firms. A related model, first studied by Jovanovic (1982), adds a dynamic learning process to an environment similar to that of Lucas. A firm begins its lifetime uncertain of the value of θ, its firm-specific productivity parameter. Output has a stochastic component, so that experience provides imperfect information about ability. As a firm accumulates more experience over time, uncertainty about the parameter, θ, declines.

In both the Lucas and Jovanovic models, there is an opportunity cost to the manager of continuing to produce. This might be, for instance, the value of working for the market wage or the value of starting a new productive endeavor. In the static model of Lucas, the existence of such an opportunity cost simply means that there is a "marginal" level of ability θ_0. Anyone with $\theta > \theta_0$ becomes a manager and hires inputs, while anyone with $\theta < \theta_0$ pursues the alternative activity. More precisely, if the value of not being a manager is C (independent of ability), then the marginal ability level is determined by

$$\theta_0 f(k(\theta_0)) - \rho k(\theta_0) = C. \tag{4}$$

In equation (4), the notation $k(\theta)$ indicates that the optimally chosen level of capital input is a function of managerial ability. The determination of θ_0 is depicted in Figure 2. In that figure, $v(\theta)$ is the return to being a manager with ability θ. Figure 3 shows how the determination of θ_0 serves to truncate the distribution of abilities in the population. Hence, even if the underlying distribution is symmetric, as in the figure, the distribution of ability among those who operate firms will be skewed. This skewness carries over to the distribution of sizes, because size rises with ability.

In the Jovanovic model, the marginal ability level would be determined exactly as in equation (4) if managers were fully aware of their abilities from the outset. With initial uncertainty and learning through experience, a manager with *expected* ability less than θ_0 may find it worthwhile to continue to produce on the chance that, through favorable experience, he will learn that he is able enough to remain a manager in the long run. In other words, a firm may be willing to take an operating loss, because production has *informational value*.

A manager's willingness to incur a short-term loss in exchange for information depends on two things: the current expected value of θ and the age of the firm. The lower the manager's expected ability, the greater the expected operating loss from continuing to operate and the smaller the probability that the next observation will be good enough to raise expected θ above θ_0. The older the firm, the more experience it has accumulated. This experience serves to reduce the remaining uncertainty about θ. Less uncertainty about θ, in turn, implies a lower probability of experiencing output much greater than expected.

Figure 2 The “Marginal” Firm

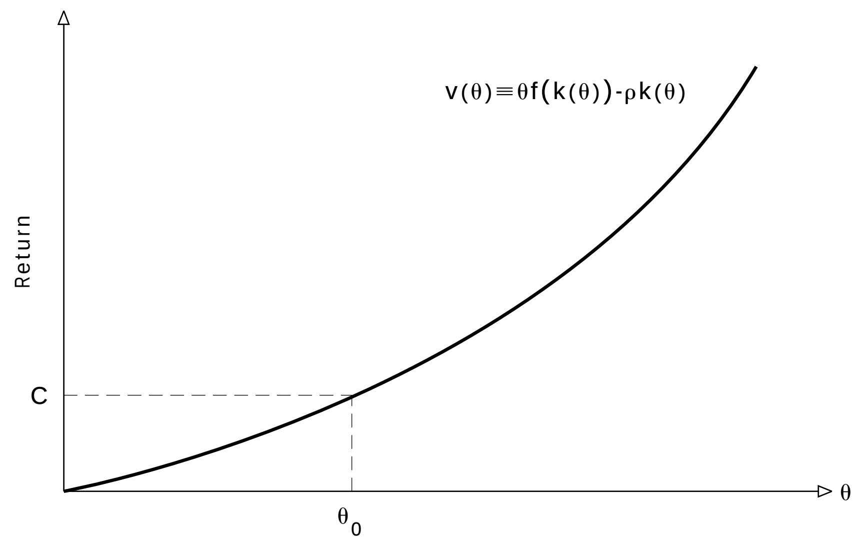
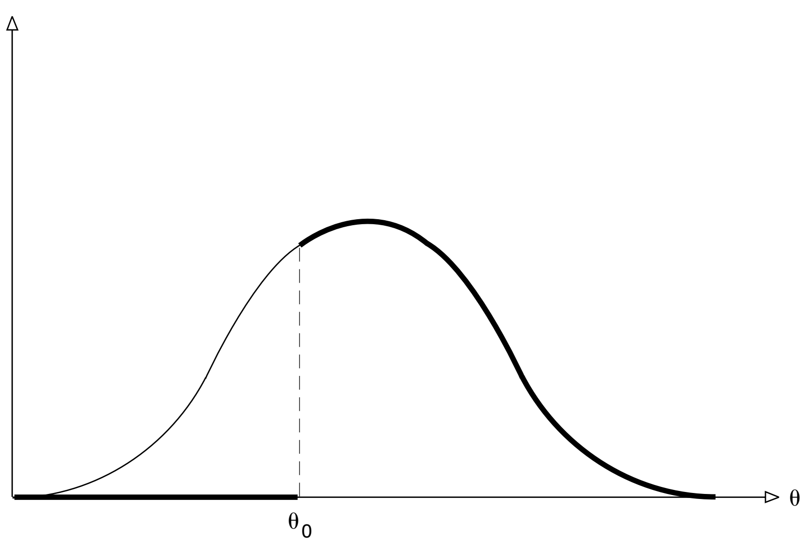


Figure 3 The Distribution of Abilities Is Truncated



Consequently, the probability of a substantial shift in expectation is reduced. In the learning model, then, a manager will continue to produce as long as expected ability is greater than some marginal value, θ_{0n}, where n is the age of the firm (the number of periods for which it has been operating). Hence, there is a sequence of thresholds for firms to continue operating. This sequence has two notable properties. First, $\theta_{0n} < \theta_0$, indicating that firms will be willing to take losses in the short run. Second, $\theta_{0n+1} > \theta_{0n}$, stating that older firms will be less willing to take such losses.

Since expected ability determines size, the learning model predicts a positive correlation between size and age; the further below θ_0, the smaller the firm and the less experienced it is likely to be. A very stark version of this model appears in Weinberg (1993). In that version, a firm starts with a prior expectation of its productivity. This prior might come from the manager's past experiences in other activities or from pre-production research and development work. Hence, there are a variety of prior expectations in the population. By producing for a fixed amount of time (one period), the firm learns its true ability with certainty. In this way, the population of firms can be separated into two classes: young firms, who are in the process of learning, and mature firms, who have already learned their types. If each firm, young or old, faces an exogenous probability of disappearing (due to exogenous shocks to its technology or personnel), there will tend to be a steady-state mixture of young and mature firms in the economy. Young firms will be smaller, on average, than mature firms. They will also face a higher probability of exit, since they can exit either because of exogenous shocks or because they learn that their ability is not great enough to merit continued operation.

The simple, two-class version of the learning model makes it quite easy to examine differences in investment behavior. The investment of mature firms is very simple. Since they have learned their firm-specific abilities, their investment (acquisition of capital for the next production period) will not respond to current output. In fact, their investment will, on average, merely replace depreciation (unless there are other sources of firm growth). Young firms, on the other hand, learn about their abilities from their current output. Hence, conditional on initial size, better performance implies a higher realized ability level, which, in turn, implies greater investment.

Notice that the relationship between investment and current performance is very similar to the empirical relationship discussed in Section 1, where cash flow was used as the measure of current performance. In the models discussed in this section, there are no imperfections in the capital markets; firms face no purely financial constraints. The authors of studies that found an effect of cash flow on investment certainly recognize that cash flow *could* be serving as an indicator of investment opportunities. What they overlooked, perhaps, was that economic theory should give us a strong a priori reason to believe that, in such regressions, cash flow *is* playing that role, for small firms in particular.

Comparing the Theoretical Approaches

The two perspectives sketched above represent the two most common explanations of findings of a cash flow effect in investment behavior of small, growing firms; an unexpected boost to cash flow might loosen the financial constraints arising from asymmetric information, or it might provide a signal of enhanced profitability and thereby shift investment demand. Notice that information plays a central role in both of these stories. In one, problems arise from the inability of some market participants to credibly convey private information to other participants. In the other story, information accumulates over time, but in a public way. While either one of these approaches can potentially explain the relationship between investment and cash flow, how do they compare in addressing some of the other facts outlined in Section 1? This section examines that question.

In the asymmetric information approach, cash flow affects investment, because firms subject to adverse selection pay a premium for external funds. Some of the evidence seems to support this notion. The firms for whom the cash flow effect is the greatest are firms that pay very little in dividends to shareholders. For these firms, working capital, which consists of short-term, liquid assets, can serve as an additional source of internal investment funds.

In a full information, Modigliani-Miller world, a firm would be indifferent between the use of internal and external funds. If, as in the learning model, current income served as a signal of profitable investment opportunities, then paying the income out as dividends and raising investment funds externally would be equivalent to using the income to fund investment internally. Hence, the Modigliani-Miller framework makes *no* prediction about the choice between internal and external funds. Suppose that, in an otherwise frictionless environment, there were a *small* transactions cost associated with raising external funds.[12] Firms would then have sufficient reason to prefer internal funds. That is, rather than paying dividends and raising funds externally as needed, a young firm with good growth prospects will retain earnings to fund its likely investment needs. Hence, problems of asymmetric information are sufficient but not necessary for a preference for internal funding.

The learning model, then, is consistent with the observations on investment behavior and the use of internal funds. Small firms are more likely to be young firms and engaged in learning. For these firms, the presence of favorable investment opportunities is correlated with the presence of ample internal funds, generated from current and recent favorable performance. Larger firms are more likely to be mature. For these firms, investment opportunities are less tied to firm-specific learning from experience. They are correspondingly more likely

[12] The type of cost considered here might be the cost of negotiating with an individual investor or the cost of making the public aware of an issue of public securities.

to have opportunities arise in times of low internal resources, requiring them to go to external sources for funds.

Other than the observations on investment behavior, the key facts discussed in Section 1 concerned where firms go for external funds. Most significantly, small firms go to banks for more of their financing than do large firms. Under the asymmetric information approach, one might suppose that asymmetric information problems are more severe for small firms, so that the value of using bank evaluation and monitoring services is greater for small firms than for large firms. Diamond (1991) develops a model in which such monitoring is provided to firms with mid-level reputations. If such a firm enjoys good performance, it can improve its reputation and raise public funds. While firm size is not directly incorporated in that model, it is not difficult to imagine a direct link between reputation and size. A similar line of reasoning can be followed under the life cycle approach. Small, young firms are likely to face the greatest uncertainty about their own long-run productivities. Again, the value of the information production services of banks will be greatest for these firms. In both approaches, banks are seen as producers of information. In the former case, they produce information in an attempt to undo the effects of asymmetric information, while in the latter, they produce new information that is useful to the firm in making its resource allocation decisions. In either case, once a firm has accumulated enough information to know (or to convince others) that it is profitable enough to continue producing, it enters the class of more mature firms that utilize public debt and equity markets for their external financing needs.

In summary, a theoretical perspective based on asymmetric information that produces financial constraints is capable of explaining observed deviations from the type of behavior predicted by the frictionless framework of Modigliani and Miller. By itself, however, this perspective cannot fully explain how those deviations tend to be more apparent for smaller than for larger firms. Some explanation of why the asymmetric information problems weigh more heavily on some firms is needed. Such an explanation can be found in a life cycle perspective. As firms age and grow, they acquire a public reputation that can partially undo the constraints imposed by informational frictions. One finds, however, that the life cycle perspective is capable of explaining a great deal of the observed behavior by itself.

Clearly the two theoretical approaches discussed herein are not mutually exclusive. Firms that are young and still accumulating knowledge about themselves are likely to be firms about which insiders are better informed than outsiders. Knowledge of self precedes public reputation. However, the presence of financial constraints seems not to be necessary for explaining the empirical facts discussed above. Since the magnitude of asymmetric information problems is inherently difficult to measure, it would be discomforting to rely on a theory that draws its explanatory power from informational frictions. The life cycle approach provides an attractive alternative.

3. SOME PUBLIC POLICY IMPLICATIONS

There has been a great deal of concern in recent years about the difficulties that small firms face in securing funds from financial markets and institutions. A number of regulatory and legislative initiatives have been put forward to address the financial needs of small firms.[13] Some of these proposals seek to expand credit to small firms by easing regulations. The federal agencies with regulatory responsibilities for depository institutions have jointly developed a plan to allow well-capitalized banks to make some small business loans with reduced documentation requirements. Similarly, the Small Business Incentive Act would exempt small issuers from some of the registration and disclosure requirements for issuing public debt and equity securities. A third regulatory approach is represented by the Small Business Loan Securitization and Secondary Market Enhancement Act. This measure would ease banking and securities regulations to facilitate the establishment of a secondary market in small business loans, similar to that which exists for home mortgage loans. The establishment of such a secondary market is also the aim of the Small Business Credit Act, which would create a government-sponsored enterprise to buy and securitize small business loans. Hence, under this proposal, the federal government would play a more direct role in intermediating between loan originating banks and the secondary market. Finally, there have been proposals to provide direct government subsidies to small business lending. The Small Business Capital Enhancement Act would create a loan loss reserve fund with contributions from the government as well as from lenders and borrowers.

While the proposed approaches vary in how they would expand credit to small firms, they all share a fundamental premise: if faced with the same terms and rules as other firms, small firms would be underserved by the financial markets. Such a premise is consistent with the conclusions that have been drawn by some from the asymmetric information perspective. In this view, financial constraints impose inefficient limitations on the operations of small firms. Some have argued that such inefficiency can be countered by government intervention in financial markets. Even within the asymmetric information framework, however, the case for efficiency-enhancing intervention is weak.[14] Briefly, there is no reason to suppose that the practices we observe in financial markets and institutions are not efficient responses to the informational frictions present in the economic environment. Since government intervention cannot remove those frictions, there is no reason to suspect that the government can improve on the responses developed by market participants. Under the life cycle approach, there is no market failure and, therefore, no reason to suspect

[13] Humes and Samolyk (1993) describe the proposals mentioned here.

[14] A critique of the case for intervention in the presence of asymmetric information is given by Lacker in this issue of the *Economic Quarterly*.

that the allocation of financial capital can be improved upon by government intervention.

As noted above, a number of the recent proposals have taken the form of easing regulatory requirements as opposed to directly or indirectly subsidizing the financing of small firms. These proposals might be based less on the notion of informational market failure than on the idea that financial markets and institutions face an excessive regulatory burden. If regulation is excessive, however, why should its easing be targeted to small firms? Again, there must be some reason why small firms are underserved. One possibility is the presence of informational market imperfections. Another is that the regulatory burden may be excessive for the financing of small firms but not for larger firms. This possibility could arise if, for instance, the costs of complying with regulations had a sizeable fixed component. This line of thinking probably lies behind proposals to allow small-firm exemptions from documentation and disclosure requirements for bank lending and issues of public securities.

Government intervention in favor of small firms, then, can be viewed as partially offsetting the effects of existing government intervention. Desirability of such a move depends on the reasons for the original intervention and on the judgment of how much regulation is excessive. Consider the case of easing bank regulations for small-firm lending. Suppose that financial behavior follows a version of the life cycle model in which banks provide information production services that aid firms (younger firms in particular) in their productive decisions. In this model, the population of potential firms is divided into three groups, depending on their priors: those that raise funds in public securities markets; those that receive bank funding and information services; and those that do not receive funding. Regulations on bank lending can be interpreted as increases in the costs of producing these information services. This increase in costs does two things. On the "high end," firms with sufficiently favorable priors will be induced to forgo bank services and raise more of their funds in public markets. These firms will be larger than the average bank client but smaller than the average public firm. On the "low end," firms with marginal priors will find themselves priced out of the market for bank lending. They will be among the smallest firms. Recent years have seen just such a coincidence of reduced bank lending with increasing numbers of initial public offerings.

A small-firm exemption to some bank regulatory requirements will reverse the low-end effect and, depending on the cut-off size, possibly the high-end effect. Is such a reversal desirable? Suppose that the original regulations were put in place to counter the perceived incentives for excessive risk taking induced by (implicit or explicit) government guarantees to bank depositors. The effects of such guarantees are similar to the effects of reducing the cost of bank information services. Hence, the various policies and counter policies serve to shift the margin between those firms that rely on bank financing and those that use public markets as well as the margin between those that are able to obtain bank financing and those that are priced out of the market. Choosing the "best" setting for those margins is a difficult judgment.

The question of choosing the best setting of bank regulations has arisen in discussions of recent legislative and administrative changes in bank regulatory policy. Some have argued that stricter examination standards in the Federal Deposit Insurance Corporation Improvement Act (FDICIA) of 1991 and risk-based capital requirements in the Basel Accord have driven the cost of bank lending so high as to contribute to a "credit crunch." Such arguments have been made, for instance, by Bizer (1993) and others, on the editorial pages of *The Wall Street Journal*. On the other hand, with only a limited time since the Act's implementation, it is difficult to disentangle the effects of FDICIA from other influences on aggregate credit market behavior.[15] While it does seem to be the case that financing of small firms has been particularly slow since the implementation of FDICIA, it is also true that small-firm financing and productive activity is generally more volatile and responsive to business cycle fluctuations than that of larger firms.[16] This greater volatility is consistent with the life cycle approach; while the responses of large firms to a change in market conditions are likely to be mostly "movements along demand curves," the responses of small firms are more likely to include changes in decisions to enter or exit from markets.

In summary, neither the asymmetric information approach nor the life cycle approach provides a definitive justification for a tilt toward small firms in financial market policy. One might argue for a policy favoring small firms on other grounds. Since small firms account for a large share of employment growth and since many small firms engage in highly innovative activities, one might argue that small-firm activity generates external benefits that contribute to the long-run growth of our economy. If such an argument is used to justify policies favoring small firms, it is not clear why such policies should work through financial market manipulation. A simpler approach might come in the form of targeted tax breaks.

4. CONCLUDING REMARKS

Financial behavior should not be viewed in a vacuum. If we observe systematic financial differences across firm sizes, or across some other firm characteristic, we should seek to understand those differences in the proper context. This article has asked the question, "What does economic theory have to say about

[15] For a discussion of the problem of identifying credit crunches, see Owens and Schreft (1993).

[16] The generally greater volatility of small-firm behavior is found, for instance, by Gertler and Gilchrist (1991).

the *joint* determination of firm size and financial behavior?" By contrast, the interpretations of financial behavior leading to conclusions of market failure have been conducted out of context, lacking an explicit theory of the determination of firm size. While the market failure interpretation might suggest a positive role for government intervention in financial markets, this conclusion is less tenable when the empirical facts are viewed in the context of a theory of the size distribution of firms.

By taking size differences as given in interpreting financial differences, the market failure approach amounts to partial equilibrium analysis; one market (the financial market) is examined in isolation from other markets in the economy. Attempting to understand the joint determination of size differences and financial behavior is a step toward general equilibrium analysis. Hence, the arguments presented in this article might be viewed as contributions to the case for the benefits of conducting applied economic analysis within a general equilibrium framework.

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M2 and Monetary Policy: A Critical Review of the Recent Debate

Michael Dotsey and Christopher Otrok

Recently the question of whether a monetary aggregate, and in particular M2, is a useful intermediate target for monetary policy has been the subject of intense debate. The most striking feature of this debate, which has been largely empirical, is that the central issues that are relevant for analyzing M2's usefulness in the conduct of monetary policy have been neglected. Issues involving the controllability of M2 and the structural relationship between M2 and economic activity have not been adequately addressed. Rather, much of the debate has focused on the notion of predictive content.

The argument expressed in much of the literature is that if money lacks predictive content, then it has no useful role as either an information variable, an intermediate target, or, when possible, an instrument of monetary policy.[1] This argument basically misses the point. In this article we argue that Granger-causality tests generally are not a proper test of the usefulness of money as an intermediate target. We also argue that evaluating the usefulness of any monetary aggregate in the conduct of monetary policy requires a structural model.

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[1] This view is expressed rather strongly in Friedman and Kuttner (1992) and seems at least to be implicit in most of the literature cited in this article. In what follows we use the terms *information variable, intermediate target,* and *instrument* in standard ways. An information variable is one that provides information about future economic activity and in particular about variables in the Fed's objective function. An intermediate target is a variable that the Fed explicitly tries to hit by altering its monetary instrument, which is a variable under direct control. That is, an instrument is either the federal funds rate or an element of the Fed's balance sheet.

The first section of this article reviews the empirical debate concerning M2's usefulness as an intermediate target. In particular we look at the result of Friedman and Kuttner (1992, 1993) which indicates that in the presence of financial market variables, M2 contains no predictive content for real income. We find that this result is fragile and that M2 does have significant predictive content for both real and nominal GDP when the statistical tests are properly specified. This agrees with similar evidence presented in Feldstein and Stock (1993), Hess and Porter (1992), Becketti and Morris (1992), and Konishi, Ramey, and Granger (1992). Thus under current operating procedures M2 provides useful information about the economy.

In Section 2 we take a deeper look at the notion of predictive content and its limitations in designing monetary policy. In particular, we show that a failure to find predictive content says very little about the potential usefulness of a monetary aggregate as an intermediate target. The lack of predictive content can arise as a result of operating procedures. It is entirely possible that the same monetary aggregate could serve as a reliable intermediate target or information variable under alternative operating procedures. Thus merely analyzing reduced-form relationships for the purpose of making theoretical arguments about the potential usefulness of M2, or any other measure of money, in formulating policy can be misleading.

Also, the presence of predictive content does not necessarily imply that M2 would make a good intermediate target. For that to be the case, M2 must be controllable and must have an effect on economic variables that the Fed ultimately wishes to influence. Feldstein and Stock (1993) realize that M2's usefulness as an intermediate target hinges on its controllability and assume that the Fed can perfectly control M2. In Section 3 we analyze the effects of relaxing this assumption and show that allowing for imperfect control weakens their argument substantially.

In Section 4 we look at another assumption that is crucial to the Feldstein and Stock analysis and to the entire recent empirical debate. That assumption involves the invariance of the estimated reduced-form structures to changes in Federal Reserve operating procedures. Here we show that the changes in operating procedures advocated by Feldstein and Stock should have substantial effects on the economy's reduced form. Thus, issues related to the Lucas critique cannot easily be dismissed and there is reason to question the validity of their policy experiments.

The combined analysis presented in Sections 2 and 4 indicates that the lines of research evaluated in this article are not likely to be productive from the standpoint of understanding and designing monetary policy. Granger-causality tests say very little about the usefulness of a variable as a monetary instrument or intermediate target. Further, the assumption that the Lucas critique is not measurably important in discussions concerning alternative operating procedures is rather heroic.

1. A REVIEW OF THE STATISTICAL EVIDENCE

In this section we look at the statistical evidence regarding the ability of M2 to help predict future movements in either real or nominal income. The key issue here is the treatment of cointegration. Engle and Granger (1987) show that proper estimation of a nonstationary system must explicitly account for any cointegrating relationships. Merely differencing nonstationary data and then performing statistical analysis does not properly account for long-run relationships, while leaving the data in levels omits relevant parameter restrictions. To highlight the differences that can occur with alternative specifications, we present Granger-causality tests results using differenced data with and without the inclusion of a cointegrating vector. The finding of Friedman and Kuttner that M2 has no predictive content is shown to be in part a result of an improper statistical representation.

Specifically we analyze equations of the following form:

$$\Delta y_t = \sum_{i=1}^{n} \alpha_{yi} \Delta y_{t-i} + \sum_{i=1}^{n} \alpha_{mi} \Delta M_{t-i} + \sum_{i=1}^{n} \alpha_{pi} \Delta p_{t-i} + \sum_{i=1}^{n} \alpha_{ri} \Delta r_{t-i} + \sum_{i=1}^{n} \alpha_{si} s_{t-i} + \sum_{i=1}^{n} \alpha_{\tau i} \tau_{t-i} + \beta z_{t-1} + \varepsilon_t \tag{1}$$

$$\Delta Y_t = \sum_{i=1}^{n} a_{yi} \Delta Y_{t-i} + \sum_{i=1}^{n} a_{mi} \Delta M_{t-i} + \sum_{i=1}^{n} a_{ri} \Delta r_{t-i} + \sum_{i=1}^{n} a_{si} s_{t-i} + \sum_{i=1}^{n} a_{ti} \tau_{t-i} + b z_{t-1} + e_t, \tag{2}$$

where the symbol "Δ" indicates first differencing, y (Y) is the log of real (nominal) GDP, M is the log of nominal M2, p is the log of deflator on GDP, r is either the three-month federal funds rate or the six-month commercial paper rate,[2] s is the spread between the six-month commercial paper rate and the three-month Treasury bill rate, τ is a term structure variable measuring the yield difference between the ten-year Treasury bond and the three-month funds rate, and z is the cointegrated vector between M2, the price level, income, and nominal interest rates implied by a stable money demand function.

The spread is included to take account of the financial effects emphasized by Friedman and Kuttner (1992), namely, that this spread reflects a risk premium that can vary cyclically. It is also influenced by changing liquidity needs since Treasury bills are more liquid than commercial paper. Thus the spread variable is a stand-in both for changes in the demand for financial liquidity

[2] We also experimented with the Treasury bill rate. The major difference is that the spread and the term structure are less significant (sometimes very much so) when the Treasury bill rate is employed.

and for changes in risk. Increases in risk or liquidity demands should have a negative effect on economic activity.

The term structure variable is included to portray the stance of monetary policy (see Bernanke and Blinder [1992]). An upward slope in the term structure indicates expectations of rising inflation and loose monetary policy. Thus the coefficients on this variable should be positive in the nominal GDP regressions and positive in the real GDP regressions if there are significant nominal rigidities in the economy. Alternatively, an upward-sloping yield curve could be associated with an upward-sloping term structure of real interest rates signaling expected consumption growth and thus has a positive association with future real output. If the term structure variable is largely reflecting the expected behavior of future real rates, then the effect on nominal GDP could be ambiguous since real output growth could result in lower inflation.

The regressions depicted in equations (1) and (2) are run in two different ways. One way is that of Friedman and Kuttner in which the cointegrating relationship is ignored (i.e., the constraints $\beta = b = 0$ are incorrectly imposed). The alternative methodology includes the cointegrating relationship among M2, the price level, real income, and nominal interest rates.[3]

The importance of including cointegration can be examined within the confines of a simple linear rational expectation model. Suppose the real part of the economy was exogenous and the nominal side could be depicted as

$$r_t = E_t p_{t+1} - p_t + w_t \tag{3}$$

$$M_t = p_t - cr_t + v_t \tag{4}$$

$$M_t = \mu + M_{t-1} + x_t, \tag{5}$$

where w_t, v_t, and x_t are white-noise disturbances to the nominal interest rate, money demand, and money supply, respectively. Equation (3) is the Fisher relationship relating nominal interest rates to expected inflation and a stochastic real rate of interest. The money demand disturbance, v_t, incorporates changes in real income and transactions costs, while x_t is a money control error. The model displays a cointegrating relationship between money and prices, with $M_t - p_t$ being stationary.

The reduced form for money and prices is

$$M_t = \mu + M_{t-1} + x_t \tag{6}$$

[3] We use a cointegrating vector similar to Feldstein and Stock (1993) in which $y_t + P_t - M_t - \alpha r_t$ is stationary. With interest rates multiplied by 100, α, the interest semi-elasticity of money demand, is equal to .0052 for commercial paper regressions and .0041 for regressions using the federal funds rate.

$$p_t = (1 + c)\mu + M_{t-1} + x_t + \frac{c}{1 + c} w_t - \frac{1}{1 + c} v_t. \tag{7}$$

Using equations (6) and (7) we can examine the importance of including cointegrating terms when testing if money growth helps predict future inflation. From the structure, it is obvious that money does help predict the future price level, but statistical tests will generally fail to confirm this feature of the model if the cointegrating relationship is ignored. To illustrate this point, we generated 2,000 samples of 100 observations each and tested for Granger-causality.[4] Without cointegration the lagged money growth was only significant at the 5 percent significance level 4.5 percent of the time, while with cointegration money Granger-caused prices 95 percent of the time.

Having illustrated the potential importance of including cointegrating vectors, we reinvestigate the Friedman-Kuttner results that M2 does not Granger-cause real output. The results are depicted in Table 1, where we report p-values or significance levels on Granger-causality tests. The sample period is 1960:1 through 1993:1 and four lags of each variable are included (i.e., $n = 4$ in equation [1]). Column 1 of Panel (a) basically replicates Friedman and Kuttner's result that the spread has significant predictive content while M2 does not. Replacing the commercial paper rate by the funds rate implies that M2 is significant at the 10 percent level, while adding a term structure term implies that M2 is significant at the 5 percent level. Like Feldstein and Stock (1993) we find that including a cointegrating term yields the result that M2 is highly significant in all specifications, even the one favored by Friedman and Kuttner, as is the spread and the term structure.[5]

Since the monetary authority may also be interested in the forecasts of nominal magnitudes when making policy decisions, we also look at the predictive content of M2 growth and the spread in regressions where nominal GDP is the dependent variable. The results are depicted in Table 2. Here both the spread and M2 are found to be highly significant predictors of nominal output.

Granger-causality tests are not the only way of examining predictive content. One may also wish to know if the effects of certain variables are long-lived or if they die out quickly over time. To address these issues, we look at impulse

[4] In the simulations both w and v are independently drawn from an N (0,1) distribution while $x_t \sim$ N (0, .1). The parameter $\mu = .05$ and $c = 2$ reflect an interest elasticity of approximately .10. The VARs were run with five lags of money growth and inflation.

[5] Friedman and Kuttner's results have been attacked on other grounds. Becketti and Morris (1992) find that eliminating the period October 1979–October 1982 when the Fed altered its operating procedures implies that M2 Granger-causes real output, while Konishi, Ramey, and Granger (1992) attribute most of the spread's predictive power to the inclusion of the 1971–1975 period. We were able to replicate the Becketti and Morris result but did not find the Konishi, Ramey, and Granger result to be robust to alternative specifications. Using equation (1) with $\beta \neq 0$, we still find the spread has predictive content for real GDP when using the funds rate, the commercial paper rate, or both the funds rate and the term structure.

Table 1 p-Values for Variables in Real Income Equations 1960:1–1993:1

Panel (a): No Cointegration

Independent Variable				
Δy	.5273	.6551	.5429	.6942
Δm	.1520	.0912	.0348	.0364
Δp	.0217	.0301	.0196	.0096
Δr_{ff}	na	.0264	na	.0095
Δr_{cp}	.0593	na	.0816	na
s	.0155	.0147	.0063	.0054
τ	na	na	.0650	.0167

Panel (b): With Cointegration

Independent Variable				
y	.0291	.0355	.0246	.0122
m	.0070	.0037	.0012	.0004
p	.0009	.0012	.0007	.0001
r_{ff}	na	.0010	na	.0001
r_{cp}	.0026	na	.0029	na
s	.0031	.0026	.0012	.0008
τ	na	na	.0476	.0044
zmd	.0025	.0022	.0019	.0005

Definition of variables: y = ln(real GDP), m = ln(nominal M2), p = ln(implicit price deflator for GDP), r_{ff} = quarterly average federal funds rate, r_{cp} = six-month commercial paper rate, s = six-month commercial paper rate minus the three-month Treasury bill rate, τ = ten-year Treasury bond rate minus the federal funds rate.

response functions. These results are displayed in Figures 1 and 2. Here we only use the specification that includes cointegration. The impulse response functions and the dashed lines that depict their 95 percent confidence band are displayed in Figure 1 and indicate that M2 has a short-lived effect on real output growth when ordered second in the orthogonalization procedure (panel A) but not much effect when ordered third (panel B). The spread, however, has a significant negative effect on real growth independent of ordering (panels C and D). The results for nominal income are depicted in Figure 2. Here a shock to M2 has a significant effect on nominal GDP that is quite long-lived (panels A and B), while the spread's effect is significant and surprisingly positive at business cycle frequencies.[6]

[6] We also tested if the sum of coefficients on the spread variable were significant and found that we could not reject this sum being equal to zero in either the real or nominal GDP regressions.

Table 2 p-Values for Variables in Nominal Income Equations 1960:1–1993:1

Panel (a): No Cointegration

Independent Variable				
Δy	.7074	.6172	.8817	.8975
Δm	.0261	.0204	.0065	.0053
Δr_{ff}	na	.0109	na	.0067
Δr_{cp}	.0313	na	.0756	na
s	.0803	.1046	.0390	.0309
τ	na	na	.2649	.0731

Panel (b): With Cointegration

Independent Variable				
y	.0739	.0520	.1048	.0416
m	.0020	.0013	.0005	.0001
r_{ff}	na	.0007	na	.0002
r_{cp}	.0024	na	.0059	na
s	.0402	.0490	.0246	.0152
τ	na	na	.2411	.0277
zmd	.0053	.0042	.0052	.0013

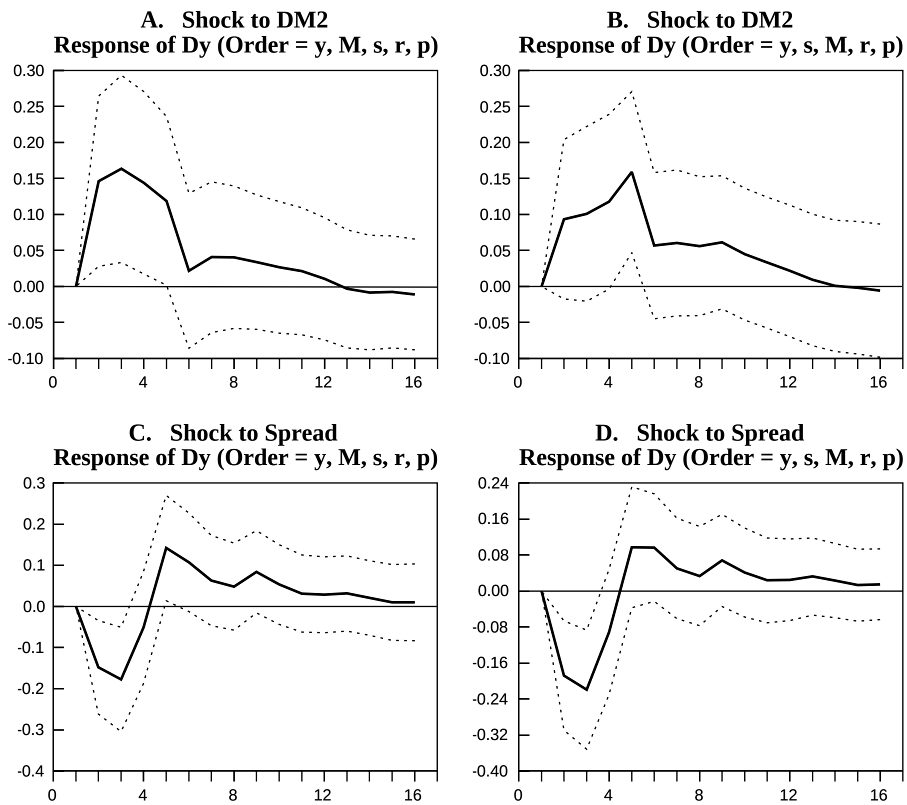
Definition of variables: y = ln(nominal GDP), m = ln(nominal M2), r_{ff} = quarterly average federal funds rate, r_{cp} = six-month commercial paper rate, s = six-month commercial paper rate minus the three-month Treasury bill rate, τ = ten-year Treasury bond rate minus the federal funds rate.

2. A DEEPER LOOK AT GRANGER-CAUSALITY

The analysis conducted in the previous section supports the results of a number of other studies that M2 has significant predictive content for future movements in both real and nominal GDP. Given the tremendous amount of effort exerted in analyzing this issue, it is important to ask whether Granger-causality is a relevant and essential property of a variable if that variable is to be useful in conducting monetary policy. In particular, does the absence of Granger-causality imply that a variable cannot be used as an intermediate target or instrument? The somewhat counterintuitive answer is no. Thus, for example, the fact that some studies show that the monetary base does not Granger-cause real economic activity provides little guidance concerning the potential role of the base in conducting monetary policy.[7]

[7] Examples depicting the usefulness of the base as an instrument of policy can be found in McCallum (1988), Judd and Motley (1991), and Hess, Small, and Brayton (1993).

Figure 1 Impulse Response Functions for Real Income



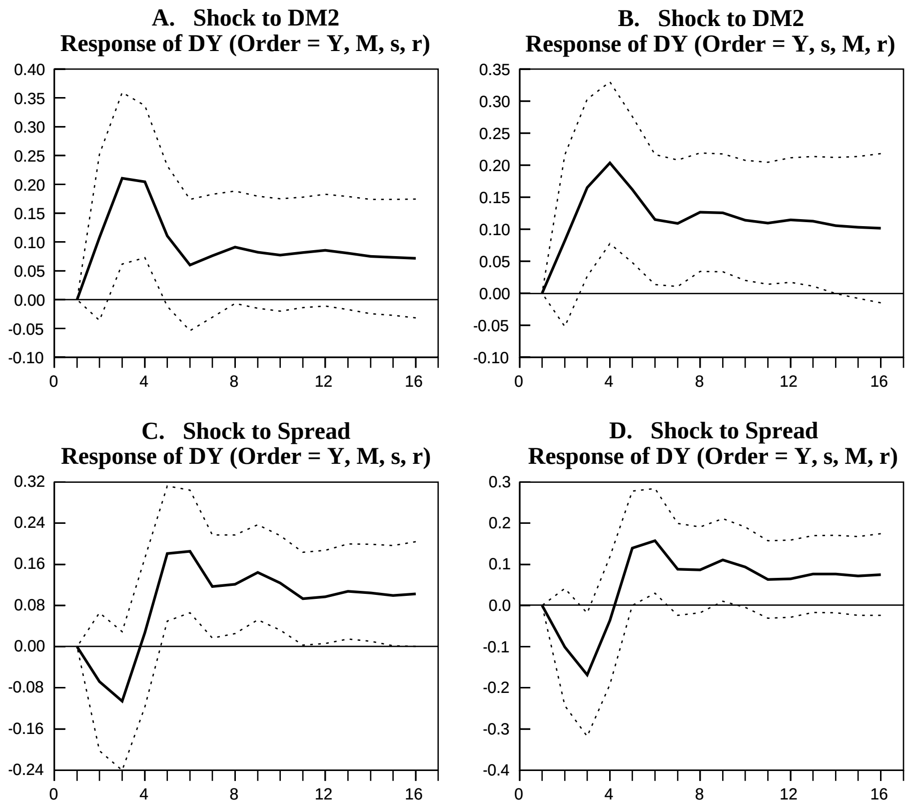
Symmetrically the observation of Granger-causality does not necessarily imply that a variable will be useful as an intermediate target or instrument. Issues of controllability and the ability of a variable to causally influence economic variables of primary concern must be addressed as well. Granger-causality, therefore, merely indicates that under existing policy a variable provides useful information about future economic activity.

In this section we examine by way of an illustration why the lack of Granger-causality may not be particularly relevant. In the next two sections we look at the other side of the coin and show that Granger-causality does not necessarily imply that a variable will be useful as an intermediate target.

To illustrate our point, we use the simple economic framework in the preceding example. Instead of using money as an instrument, the Fed uses an interest rate instrument whose behavior is given by

$$r_t = \mu_r r_{t-1} + \mu_p p_{t-1}. \tag{5'}$$

Figure 2 Impulse Response Functions for Nominal Income



Thus the economy is depicted by equations (3), (4), and (5′). The reduced form for this economy has the following ARMA (1, 1) representation:[8]

$$\begin{bmatrix} p_t \\ M_t \end{bmatrix} = \delta_1 \begin{bmatrix} 1 & 0 \\ 1 + c - c\delta_1 & 0 \end{bmatrix} \begin{bmatrix} p_{t-1} \\ M_{t-1} \end{bmatrix} + \begin{bmatrix} 1/\delta_2 & 0 \\ 1/\delta_2 & 1 \end{bmatrix} \begin{bmatrix} r_t \\ v_t \end{bmatrix}$$

$$+ \begin{bmatrix} \mu_r/\delta_2 & 0 \\ (1 + c - c\delta_1)\mu_r/\delta_2 & 0 \end{bmatrix} \begin{bmatrix} r_{t-1} \\ v_{t-1} \end{bmatrix}. \tag{8}$$

[8] As shown in Boyd and Dotsey (1993), equation (8) is the unique nonexplosive solution to this economic system. δ_1 and δ_2 are the eigenvalues of the matrix $\begin{bmatrix} 0 & 1 \\ -\mu_r+\mu_p & 1+\mu_r \end{bmatrix}$ with $|\ \delta_1\ | \leq 1$ and $|\ \delta_2\ | \geq 1$ for appropriate choices of μ_r and μ_p.

The reduced form of equation (8) can be written as an infinite order AR process

$$\begin{bmatrix} p_t \\ M_t \end{bmatrix} = \sum_{i=1}^{\infty} \Pi_i \begin{bmatrix} p_{t-i} \\ M_{t-i} \end{bmatrix} + \begin{bmatrix} 1/\delta_2 & 0 \\ 1/\delta_2 & 1 \end{bmatrix} \begin{bmatrix} r_t \\ v_t \end{bmatrix}, \tag{9}$$

where each upper right-hand element of each Π_i matrix is zero. Thus money will fail to Granger-cause prices. This failure says nothing about money's usefulness as a monetary instrument or intermediate target, since it is obvious that in this simple model economy controlling money will control prices.[9,10]

3. M2 AS AN INTERMEDIATE TARGET AND THE FELDSTEIN-STOCK ANALYSIS

As mentioned, the other side of this last result, that a lack of predictive content does not rule out the usefulness of a monetary aggregate in formulating monetary policy, is that predictive content does not necessarily imply that an aggregate should be an instrument or an intermediate target. Predictive content merely indicates that under current operating procedures a variable provides some useful information for forecasting future economic activity. In order to make the case that a variable would be a good instrument or intermediate target, one must show that a policy that incorporates the variable in either role improves economic performance in a welfare-enhancing way. Feldstein and Stock (1993) undertake such an exercise for M2.

They perform this exercise by estimating equations of the form (2), with a cointegrating vector included showing that M2 has significant predictive content for future nominal GDP. They also perform very sophisticated tests of the stability of the M2-nominal GDP relationship and find that it is indeed stable. The conclusion drawn from these results is that the reduced-form relationship they have estimated is likely to be invariant to changes in operating procedures, since the Fed changed operating procedures over their sample. The Fed, therefore, can profitably exploit the relationship between M2 and nominal GDP to reduce the variability of nominal GDP growth.

To see to what extent this variability can be reduced, they calculate the optimal M2 supply function, treating their reduced form as a structural relationship and assuming that M2 is perfectly controllable. They use the non-cointegrated system for this purpose. They find that optimally controlling M2 would result

[9] In particular, studies that show that the monetary base has little predictive content for future economic activity do not imply that the base would be an ineffective monetary instrument or intermediate target. McCallum (1993b) makes a similar argument with respect to stability of the base nominal GDP relationship.

[10] We also looked at some alternative policies. It appears that money's failure to Granger-cause output occurs whenever the Fed insulates the economy from money demand disturbances.

in quarterly growth rates of nominal GDP that are 88 percent as variable as they are now.[11] They then show that a simple feedback rule

$$M_t = -\lambda Y_{t-1} + (1 - \lambda)M_{t-1} \tag{10}$$

performs almost as well.

One of the critical assumptions in their analysis is that M2 is perfectly controllable. Taking for the moment the assumption that their reduced form is invariant to the change in operating procedures that they propose, we wish to see how their simple rule (for optimally chosen λ) would perform if M2 were not perfectly controllable. We use the cointegrated specification of equation (2) since our earlier results indicate that this is the preferred specification. Like Feldstein and Stock we drop the term structure and spread variable.

To see what the effect of using rule (10) has on the variance of nominal GDP, we conduct the same Monte-Carlo experiment that they do. First we generate 2,000 simulations of 40 quarters each using a four-variable vector autoregression that includes a cointegrating vector. The variables are nominal GDP, the price deflator on GDP, the three-month Treasury bill rate, and M2. More precisely, the first equation of this system looks like (2) with the term structure and spread terms omitted. In performing the simulations the random disturbances and coefficients are drawn from the appropriate distributions. We then replace the estimated M2 equation with (10) and perform the same exercise. Using the simulated data, ratios of the variances of nominal GDP growth can be constructed and analyzed. The results of the analysis are presented in Table 3.

For the case $\lambda = 0.3$ and perfect controllability, the mean of these ratios is .948, indicating that under the rule (10) nominal GDP's variance could be reduced to roughly 95 percent of its current value. Also 68 percent of the ratios are less than one, indicating that following (10) reduced variability most of the time. As the assumption of controllability is relaxed by adding to (10) a control error scaled by the percentage of M2's actual variance, the performance of the rule deteriorates. For example, if an attempt to control M2 as an intermediate target resulted in half the quarterly variability we now see, nominal output variance would only be reduced to .985 of its value under current procedures. Variability also only declines in 55 percent of the simulations. Thus the strength of the argument for using M2 as an intermediate target is intimately related to the issue of controllability. But the potential controllability of M2 cannot be answered by this exercise. In order to answer that question, one needs a

[11] They report a good deal more information. For example, they find that in 90 percent of their simulated decades, simulated GDP is less variable than actual GDP. Had they used the cointegrated system for this exercise, they would have found even greater improvement since including the cointegrating vector improves the R^2 of the model. (We thank Jim Stock for pointing this out to us.)

Table 3 The Predicted Reduction in the Variance of Nominal GDP Growth from Following a Simple Monetary Rule, $-\lambda Y_{t-1} + (1-\lambda)M_{t-1}$

Variance of M2	Value of λ	Mean	Standard Deviation	Median	Fraction <1
0	0	.913	.115	.914	.81
0	.1	.941	.121	.938	.72
0	.3	.948	.120	.954	.68
25% of actual	0	1.153	.268	1.085	.31
25% of actual	.1	.998	.119	.992	.51
25% of actual	.3	.965	.103	.972	.64
50% of actual	.3	.985	.098	.989	.55
75% of actual	.3	.999	.098	1.004	.48
100% of actual	.3	1.015	.101	1.015	.42

Note: These results were constructed by a Monte Carlo procedure that produced 2,000 draws of 40 quarters of predicted nominal GDP growth using the proposed money rule and random draws from the distribution of the reduced-form parameters and the reduced-form disturbances.

structural model since there is no period in which the Fed actually tried to control M2.

4. A DEEPER LOOK AT REDUCED-FORM INVARIANCE

Of equal if not greater importance than the issue of controllability is the assumption of reduced-form invariance to the change in operating procedures proposed by Feldstein and Stock. In this section we investigate the likely effects on reduced-form parameters if the Fed were to change its operating procedures from an interest rate feedback rule that responds to economic performance to a rule that targets M2. We do this for both an interest rate instrument and a total reserves instrument.

We use a simple log-linear rational expectations model for our investigation. Since monetary economics lacks an acceptable model, we choose to examine the issue of reduced-form invariance by examining a calibrated linear rational expectations model. While this model falls short of representing reality, it contains a number of key features found in many macroeconomic models and is useful for broadly illustrating the points we wish to make. The model is given by

$$y_t^s = y_{t-1} + a^s(p_t - E_{t-1}p_t) + u_t \tag{11}$$

$$y_t^d = a_0 + y_{t-1} - a^d(p_t + r_t - E_t p_{t+1}) + w_t \tag{12}$$

$$m_t^d = p_t - c_r r_t + c_y y_t + v_t \tag{13}$$

$$r_t = b_0 + b_p \Delta p_t + b_y \Delta y_t + b_r r_{t-1} + b_m m_{t-1} + x_t. \tag{14}$$

All variables with the exception of the nominal interest rate are in logs. Equation (11) is the standard Lucas supply curve relating real output to unexpected price-level movements, while (12) is an IS curve in which aggregate demand responds negatively to increases in the real rate of interest. Equation (13) is the demand function for M2 and (14) is the Fed's interest rate rule.[12] The Fed is modeled as responding to inflation, ΔP_t, and real output growth, Δy_t, while maintaining concern for some degree of interest rate smoothing. The Fed also responds to past M2 behavior using M2 as an information variable as opposed to using it as an intermediate target. (For a more complete discussion of models of this kind, see McCallum [1980].)

We can illustrate the extent to which the reduced form of this hypothetical economy is invariant to changes in operating procedures by examining how endogenous variables fluctuate around their expected value. A more complete analysis would present the entire reduced form, but the anticipated parts of the solution do not yield a simple analytical representation. We therefore present only the unanticipated portion of the reduced-form solution. For the system (11)–(14) these fluctuations are

$$\tilde{y}_t = (1/D)\{a^d(1 + b_p)u_t + a^s w_t + x_t\} \tag{15}$$

$$\tilde{p}_t = (1/D)\{-(1 + a^d b_y)u_t + w_t + x_t\} \tag{16}$$

$$\tilde{r}_t = (1/D)\{(a^d b_y - b_p)u_t + (a^s b_y + b_p)w_t + a x_t\} \tag{17}$$

$$\begin{aligned}\tilde{m}_t = (1/D)\{&[-(1 + a^d b_y) - c_r(a^d b_y - b_p) + c_y(a^d(1 + b_p))]u_t + v_t \\ &+ [1 - c_r(a^s b_y + b_p) + c_y a^s]w_t + [1 - c_r(a^s + a^d) + c_y]x_t\},\end{aligned} \tag{18}$$

where the "˜" notation indicates unexpected deviations (e.g., $\tilde{y}_t = y_t - E_{t-1}y_t$) and $D = a^s + a^d + a^d(b_p + a^s b_y)$.

If the Fed were to alter its policy rule (14) and use a noisy interest rate instrument, such as borrowed reserves, instead of directly controlling the funds rate, then the basic change in the economic system would be captured by an increased variance in x_t (the unexplainable part of policy). The solutions for the reduced-form parameters in terms of the structural parameters would be largely unchanged.[13]

[12] Fuhrer and Moore (1993) find a similar rule helps fit the data quite well when included in their contracting model.

[13] Dotsey (1989) shows that allowing banks to have private information does affect the reduced-form coefficients. For reasonable parameters, however, this effect is very small.

The changes in operating procedures over the period of the Feldstein and Stock analysis—the announced move to nonborrowed reserve targeting under lagged reserve requirements and the gradual emphasis placed on a borrowed reserve target later on—amounted to a noisy interest rate instrument. Also, as long as the Fed is using an interest rate instrument changes in reserve requirements, or the move from lagged reserve to contemporaneous reserve requirements, are largely inconsequential. Finally, the removal of Regulation Q ceilings should have very little impact on the interest elasticity of money demand if banks face fairly constant marginal costs of providing transactions services and if they price deposits competitively.[14] The stability that Feldstein and Stock find in their reduced-form estimates is, therefore, not surprising.

The change in operating procedures they contemplate, namely, directly targeting M2, may be an entirely different matter. To investigate the effect on the economies reduced form, we replace equation (14) by an equation that describes the Fed as targeting M2 with an interest rate instrument. This equation is given by

$$r_t = (1/c_r)[E_{t-1}p_t + c_y E_{t-1}y_t - m_t^*], \tag{14$'$}$$

where m_t^* is the target level of M2. Equations (15)–(18) would become

$$\tilde{y}_t = (a^d/a)u_t + (a^s/a)w_t \tag{15$'$}$$

$$\tilde{p}_t = (-1/a)u_t + (1/a)w_t \tag{16$'$}$$

$$\tilde{r}_t = 0 \tag{17$'$}$$

$$\tilde{m}_t = [(a^d - 1)/a]w_t + [(1 + a^s)/a]w_t + v_t, \tag{18$'$}$$

where $a = a^s + a^d$. This reduced-form system is quite different from the one shown previously, implying that the assumption of structural invariance is somewhat tenuous.

Alternatively, the Fed could attempt to control M2 by placing a uniform reserve requirement, η , on M2 balances and controlling M2 through the supply of total reserves. Under this policy, required reserves, *RR*, would then be equal to $\eta(\mathrm{M2}-C)$, where C is currency, and total reserve demand would equal *RR*

[14] If one thinks of the demand for money as responding to opportunity costs, then prior to the removal of Regulation Q money demand was influenced by the nominal rate, r. After removal of rate Q it was influenced by $r - r_M$, where r_M is the own rate. If marginal costs are fairly constant and the banking system is competitive, then $r_M = (1 - \lambda)r$ and the opportunity cost of holding money will be λr. One sees that $d \log M/d \log r$ is invariant to this regulatory change when money demand is of the constant elasticity form. If the demand for money is semi-logarithmic, then its interest elasticity would be scaled by λ. Since the elasticity is very small to begin with, stability tests may not be very sensitive to the removal of Regulation Q.

plus excess reserve demand, *ER*. A log-linear representation of total reserve demand would be

$$tr_t^d = \log\eta + m_t - \zeta_t + \varepsilon_t, \tag{13$''$}$$

where *tr* is the log of total reserves, m_t is the log of M2 balances, $\zeta_t = (c_t/\text{M2}_t)$ and $\varepsilon_t = ER_t/[\eta(\text{M2}_t - C_t)]$.[15] If the Fed supplied total reserves in an attempt to hit an M2 target, it could do so by setting $tr_t^s = \log\eta + m_t^*$. If total reserve control was exact then $m_t = m_t^* + \zeta_t - \varepsilon_t$ and M2 will vary with movements in currency and excess reserves. If the Fed instead controlled the monetary base, then movements between currency and deposits would generally change M2. Only if $\eta = 1$ and excess reserves were unimportant would strict M2 control be achievable. In this case M2 would equal the monetary base. Note, however, that although M2 is controllable, there is no longer a banking system since without fractional reserves banks have no assets with which to make loans. One suspects that such a policy would lead to financial changes that would considerably affect the correlation of nominal output and M2.

Again if we replace (13) with equation (13$''$) and (14) with

$$tr_t^s = tr_t^* + x_t, \tag{14$''$}$$

where $tr_t^* = \log\eta + m_t^*$ and x_t represents reserve control errors, then the reduced-form representation for unexpected changes in economic activity are

$$\tilde{y}_t = (1/DD)\{-(a^d c_y + c_r)u_t + c_r w_t - a^d(v_t - x_t - \zeta_t + \varepsilon_t)\} \tag{15$''$}$$

$$\begin{aligned}\tilde{p}_t = (1/DD)\{&-(a^d/a)(a^d c_y - 1)u_t - (a^d/a)(1 + a^s c_y)w_t \\ &- a^d(v_t - x_t - \zeta_t + \varepsilon_t)\}\end{aligned} \tag{16$''$}$$

$$\tilde{r}_t = (1/DD)\{(a^d c_y - 1)u_t + (1 + a^s c_y)w_t + a(v_t - x_t - \zeta_t + \varepsilon_t)\} \tag{17$''$}$$

$$\tilde{m}_t = x_t + \zeta_t - \varepsilon_t, \tag{18$''$}$$

where $DD = (a^s + a^d)c_r + a^d(1 + a^s c_y)$. Again, the reduced form is not invariant to this proposed change in operating procedures.

To investigate the extent of the reduced-form invariance, we calibrate the three distinct structural models and examine the implied variance-covariance matrices. In doing so, we set $a^s = 1.0$ and $a^d = .7$. The first value is taken from King and Plosser (1986) while the second comes from Fuhrer and Moore (1993).[16] We assume M2 has a unitary income elasticity, $c_y = 1$, and $c_r = 2$

[15] $tr = \log(RR + ER) = \log[RR(1 + \frac{ER}{RR})] = \log RR + \log(1 + \frac{ER}{RR}) \approx \log\eta + \log(\text{M2}-C) + \varepsilon_t = \log\eta + \log[M(\frac{1-C}{M})] + \varepsilon_t \approx \log\eta + m - \zeta + \varepsilon$.

[16] Fuhrer and Moore's coefficient is actually the impact effect of aggregate demand to a change in lagged value of the long-term real interest rate.

implies an interest elasticity of approximately $-.10$. Again following Fuhrer and Moore, the coefficients b_p and b_y are assumed to be .1 and we set $b_r = b_m = .1$ as well.

To produce numerical results, we also need to say something about the variances of the structural disturbances. We assume that the variance of the shocks to aggregate supply, aggregate demand, money demand, and Fed behavior are all of the same magnitude σ^2. The variances for the currency/M2 ratio, ζ, and the excess reserve/M2 ratio, ε, are assumed to be somewhat smaller. These are $(1/16)\sigma^2$ and $(1/1000)\sigma^2$, respectively. For example, a value of $\sigma^2 = .0001$ would imply that 95 percent of the shocks to quarterly output supply growth or output demand growth are ± 2 percent. The $(1/16)\sigma^2$ value for the variance of $\pm C$/M2 then implies that fluctuations in this ratio are generally no larger than .005 and the $(1/1000)\sigma^2$ value implies that fluctuations in *ER*/M2 seldom exceed .0006.

Under this parameterization the variance-covariance matrices for the three models are

$$\begin{bmatrix} .77 & & & \\ .35 & .93 & & \\ .55 & .57 & .87 & \\ .005 & .13 & -.60 & 1.54 \end{bmatrix} \sigma^2, \quad \begin{bmatrix} .52 & & & \\ .10 & .69 & & \\ 0.0 & 0.0 & 0.0 & \\ .61 & .80 & 0.0 & 2.42 \end{bmatrix} \sigma^2, \text{ and}$$

$$\begin{bmatrix} .51 & & & \\ -.04 & .07 & & \\ .10 & -.18 & .43 & \\ .15 & .15 & -.35 & 1.06 \end{bmatrix} \sigma^2,$$

respectively. The differences are noticeable, indicating that it is inappropriate to use a reduced-form structure from one type of policy rule to make inferences about the effects of an alternative policy rule. Of interest, however, is the fact that using a total reserves instrument to target M2 produces the lowest variance in prices and real output. Whether this result would carry over to more detailed structural models is unknown. Also, other types of rules, for example, those advocated by McCallum (1988, 1993a), may be better still. It is obvious that before jumping on an M2 bandwagon a lot of work remains to be done.

4. CONCLUSION

In this article we have critically examined the debate over using M2 as an intermediate target of monetary policy. We have done this by focusing on two largely empirical studies. We found that Friedman and Kuttner's central result that money does not Granger-cause real or nominal output is due to a model misspecification. When the cointegrating relationship among money, income, prices, and interest rates is accounted for, money does indeed Granger-cause output. We also found that Feldstein and Stock's main result, that a monetary policy that uses M2 as an intermediate target can substantially reduce the variance of nominal GDP growth, depends critically on their assumption that M2 is perfectly controllable. When this assumption is realistically relaxed, the ability of their policy to reduce the variance of nominal income growth is seriously diminished.

More generally, our results cast doubt on the idea that either empirical exercise is useful in analyzing alternative monetary policies. Studies, such as Friedman and Kuttner's, that base their conclusions solely on the use of Granger-causality and reduced-form models do not provide a firm basis for making a decision about the usefulness of a monetary aggregate under some alternative operating procedure. The absence of Granger-causality may provide little guidance for evaluating the usefulness of M2 or any other aggregate for monetary policy. All that the absence of Granger-causality tells us is that under current operating procedures some variable does not help forecast future economic activity.

Further, the presence of Granger-causality does not in and of itself imply that targeting the aggregate in question would be good monetary policy. In order to undertake that exercise, one needs a theory and the corresponding structural model. Simply using a reduced-form model as Feldstein and Stock do is inappropriate when that reduced form will not remain invariant to the contemplated changes in policy. There does not seem to us any shortcuts that will substitute for the hard and necessary work of building and analyzing structural models.

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Does Adverse Selection Justify Government Intervention in Loan Markets?

Jeffrey M. Lacker

Government involvement in loan markets in the United States is substantial. For example, federal government direct and assisted lending for 1980 through 1987 amounted to $1208.1 billion, or 25.3 percent of total net lending in nonfinancial credit markets over the period (Gale 1991). Only $115.5 billion of this amount represents direct federal lending; the rest is accounted for by guaranteed loans ($251.3 billion), lending through government-sponsored enterprises ($441.8 billion), and lending subsidized by tax-exemptions ($399.5 billion). Can such interventions be justified as welfare-improving corrections of market failures?

Some economists have argued that market failure is particularly likely in credit markets because of "adverse selection"—borrowers have unverifiable hidden knowledge about their likelihood of repayment.[1] There is a type of externality in loan offers, and this can sharply constrain loan market outcomes.

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[1] "The Federal government has played a central role in the allocation of credit among competing uses. This paper illustrates that this sort of government program can under plausible conditions improve on the unfettered market allocation. A necessary condition for efficient government intervention is unobservable heterogeneity among would-be borrowers regarding the probability of default. The greater is such heterogeneity, the greater is the potential for default" (Mankiw [1986], p. 469). See also de Meza and Webb (1987), Gale (1990), Greenwald and Stiglitz (1986), Innes (1991), and Smith and Stutzer (1989).

For example, a good borrower may not receive ideal loan terms, since an otherwise indistinguishable bad borrower would have an incentive to apply for that loan as well, making it unprofitable. The market failure literature argues that government credit guarantees can ease these constraints by improving loan terms for less creditworthy borrowers. The resulting improvement in loan terms for good borrowers leaves them willing to fund the subsidy to bad borrowers.

In a separate literature, some economists have argued that adverse selection can help explain the role of financial intermediaries.[2] In their models, financial intermediaries often emerge endogenously as part of equilibrium arrangements, attaining allocations that cannot be attained through direct lending alone. One notable result from these models is that the resulting financial arrangement cannot be improved upon by government intervention; private financial arrangements do as well as any government scheme.

How can we reconcile these two contrasting approaches? As I show in this article, both are based on virtually identical economic environments. They differ, however, in how they predict outcomes for given economic environments; each adopts a different definition of equilibrium. In the models rationalizing government intervention, equilibrium is defined by the way agents play a specific multi-stage game. The rules of the game have strong implications for how agents rationally play and what outcome emerges. In contrast, models of financial intermediation are careful not to impose any institutional arrangement on the agents in the economy, so that institutional structure can emerge endogenously.

I argue in this article that the different definitions of equilibrium yield contrasting policy conclusions because the market failure approach imposes ad hoc restrictions that prevent mutually beneficial contractual arrangements. In the models of market failure, a seemingly reasonable implication of the game agents play is that each type of loan contract must break even. This condition prevents lenders from offering a menu of contracts that breaks even on average but involves cross-subsidies across contracts. In this case, government tax and subsidy schemes, such as credit guarantees, can bring about the cross-subsidization that private agents cannot. Thus government intervention can make all people better off, even though the government is subject to the same informational constraints as private agents.

The same equilibrium condition rules out endogenous financial intermediaries in the market failure models. Intermediaries arise in adverse selection environments to reap the benefits of cross-subsidy; by subsidizing one borrower the incentive constraints impeding a better borrower can be relaxed, making both types better off. Since financial intermediaries are a prominent feature

[2] See Miyazaki (1977), Boyd and Prescott (1986), Boyd, Prescott, and Smith (1988), and Lacker and Weinberg (1993).

of loan markets, it seems desirable to adopt a model that allows financial intermediaries to emerge when they have a role to play. This suggests that the adverse selection justification for government intervention in loan markets is based on an overly restrictive definition of equilibrium. I conclude that based on the models now available, adverse selection does *not* justify government intervention in loan markets.

In this article I focus solely on situations of adverse selection, in which agents have relevant private information ex ante, that is, *before they first meet*. Situations of ex post private information, in which agents obtain hidden information *after* they first meet, do not present the same possibilities for market failure. It is well known that the standard theorems on the optimality of competitive equilibria continue to hold under ex post private information (Prescott and Townsend 1984). As a consequence, adverse selection has received far more attention as a potential source of market failure. There remain, of course, possible justifications on redistributive grounds, but these are beyond the scope of this article.[3]

1. AN ADVERSE SELECTION CREDIT ECONOMY

In this section I describe a simple economic environment with borrowing and lending under adverse selection. The central feature of the environment is that borrowers have private information about the risk and return on their investment projects. Lenders do not know as much as borrowers, but try to infer as much as they can from the repayment promises borrowers issue. Lenders' beliefs and borrowers' actions are linked in a delicate interdependence that is the hallmark of adverse selection environments. In order to make this interdependence manageable and understandable, I will work with a drastically simplified economy. Various versions of adverse selection credit economies have been studied by economists. However, there is a basic structure shared by virtually all adverse selection environments, and my argument carries over to more general settings.

The economy I examine contains one feature that is not standard in adverse selection credit market models. I assume that borrowers are able to costlessly hide the return to their project. This feature, along with the properties of the collateral good, implies that borrowers' repayment promises must take the form of collateralized debt, as I showed in an earlier paper (Lacker 1991). In most of the literature on adverse selection in credit markets, either debt contracts are

[3] Some government credit programs might be justified to ameliorate the effects of other government regulations that inhibit diversification by private financial intermediaries, such as legal restrictions on bank branching (Williamson 1993). The best solution, however, is to eliminate the legal restrictions themselves. Lang and Nakamura (1993) argue that lending can generate an informational externality via publicly disclosed appraisals.

imposed by the theorist or the equilibrium contracts are not debt at all.[4] This feature does not alter my argument in any way, but it makes the predicted financial arrangements somewhat more realistic and demonstrates that the argument does not depend on the ad hoc imposition of debt contracts.

To begin then, there are two periods and all consumption takes place in the second period. There are a large number of borrowers, each with a single investment project that requires exactly one unit of input in the first period and yields a random return in the second period. The return can take on one of two values: either R units of output (the "good state") or zero (the "bad state"). Borrowers' returns are independent of one another. In addition, each borrower has an amount K of a collateral good in the second period. This good is more valuable to the borrower than it is to any other agent. One interpretation of the collateral good is chattels—portable personal property such as clothing or furniture.

Borrowers are risk-averse. They have identical utility functions over second-period consumption, given by $u(c_1 + c_2)$, where c_1 is second-period consumption of output and c_2 is consumption of the collateral good. I assume that the function u is strictly concave.

There are two types of borrowers—good and bad. The good borrowers have a high probability of a good return, p_g, and the bad borrowers have a low probability of a good return, p_b. I assume $0 < p_b < p_g < 1$. A borrower's type is known only to that borrower; borrowers are observationally indistinguishable to all other agents. The number of good borrowers is N_g, and the number of bad borrowers is N_b, both of which should be thought of as large.

There are a large number of lenders, more than the number of borrowers. Each lender has one unit of input good in the first period. Like borrowers, lenders only desire to consume in the second period. Unlike borrowers, however, lenders have linear, risk-neutral utility functions. Their utility is given by $c_1 + \beta c_2$, where c_1 is second-period consumption of output and c_2 is consumption of a borrower's collateral good. I assume that the preference parameter β is positive but strictly less than one. This reflects the assumption that a collateral good is more valuable to a borrower, relative to the payment good, than it is to any lender. The difference in valuations could represent a special match between the borrower and the collateral good or the resource costs of transferring the good.

Lenders have an alternative investment opportunity available to them that yields ρ units of output in the second period for every unit of input good invested in the first period. Because they only want to consume in the second period, lenders will want to lend or invest all of their first-period input goods. Because of their alternative investment opportunity, a loan to a borrower will

[4] An exception is Boyd and Smith (1993).

have to provide at least as much expected utility as ρ. Because there are more lenders than there are borrowers, there will always be an elastic supply of loans on terms that provide lenders with at least as much expected utility as ρ.

A *loan contract,* or *contract* for short, could in general specify payments of output and collateral by the borrower for each possible return. In other words, a contract could consist of four numbers: payments of output and collateral when the return is high and payments of output and collateral when the return is low. We can restrict attention to simpler contracts without doing any harm, however. First, note that the low return is zero, so the payment of output when the return is low will always be zero. Second, consider the collateral payment when the return is high. It is easy to show that as long as R is large enough, it is never desirable to have a positive collateral payment in the good state since the collateral is more valuable to the borrower than to the lender. More precisely, any contract with a positive collateral payment in the good state is dominated by one with no collateral payment and commensurately larger payment of output in the good state.[5] Therefore, we can restrict attention to contracts that specify two numbers: r, a borrower's payment of output when the return is good, and C, a borrower's payment of collateral when the return is bad.

Because there are two types of borrowers and they might receive different contracts, we need a notation for each. Let (r_g, C_g) be the contract for a good borrower, and let (r_b, C_b) be the contract for a bad borrower. To be physically feasible, the output payment must not be greater than the return in the good state, R, and the collateral payment must be nonnegative and no greater than the borrower's collateral, K. I assume that R and K are large enough that these feasibility constraints never bind. Since they play no role in the analysis, from here on I will ignore them.

In the second period a borrower can hide the return R, making it appear that the return is zero. The hidden return can be consumed secretly by the borrower. This possibility constrains the contracts to which the borrower can credibly agree. For example, if a contract calls for no collateral payment when the return is low, but some positive payment r when the return is high, the borrower will always hide the return, pay nothing, and consume the entire return R in private; the alternative is to make the payment r and consume $R - r$. A collateral payment when the return is low can provide an incentive to make the required payment when the return is high. In this case the borrower compares paying r to hiding the return and transferring collateral with value C. If $C \geq r$, then the borrower has no incentive to hide the return. Therefore, contracts must satisfy the following.

[5] This is true under either of the definitions of equilibrium that appear below.

Incentive constraints:

$$r_h \leq C_h \qquad \text{for} \quad h = g, b. \tag{1}$$

Condition (1) ensures that the borrower has an incentive to repay the loan as agreed when the return is high, rather than hand over the collateral. The incentive constraints imply that loans must be "fully collateralized," meaning that the value of the collateral (to the borrower) is at least as large as the value of the promised repayment. If $C > r$, the loan is "overcollateralized." The only contracts that satisfy the incentive constraint (1) are collateralized debt contracts—noncontingent except when the return is insufficient to make the payment r.[6]

I can now describe the most crucial condition that contracts must satisfy in this environment. Suppose that the end result of the interactions between agents in this economy is that good borrowers receive contracts (r_g, C_g) and bad borrowers receive contracts (r_b, C_b). Since a borrower's type is private information, one type of borrower could conceivably participate pretending to be the other type of borrower, receiving the contract meant for the other type. All participants might be expected to be aware of this possibility. If the designation of contract (r_g, C_g) for good borrowers and contract (r_b, C_b) for bad borrowers is to correspond to reality, then it must not be in any borrower's interest to masquerade as the other type of borrower. This condition, which I call the *self-selection constraints*, must be satisfied by the outcome of any mechanism agents adopt. Stated formally, we have

Self-selection constraints:

$$\begin{aligned} &p_g u[(R - r_g) + K] + (1 - p_g)u(K - C_g) \\ &\qquad \geq p_g u[(R - r_b) + K] + (1 - p_g)u(K - C_b) \end{aligned} \tag{2}$$

$$\begin{aligned} &p_b u[(R - r_b) + K] + (1 - p_b)u(K - C_b) \\ &\qquad \geq p_b u[(R - r_g) + K] + (1 - p_b)u(K - C_g). \end{aligned} \tag{3}$$

Constraint (2) states that the expected utility of a good borrower is at least as high under contract (r_g, C_g) as under contract (r_b, C_b). Similarly, constraint (3) states that the expected utility of a bad borrower is at least as high under contract (r_b, C_b) as under the contract (r_g, C_g). Neither type of borrower has an incentive to pose as the other.

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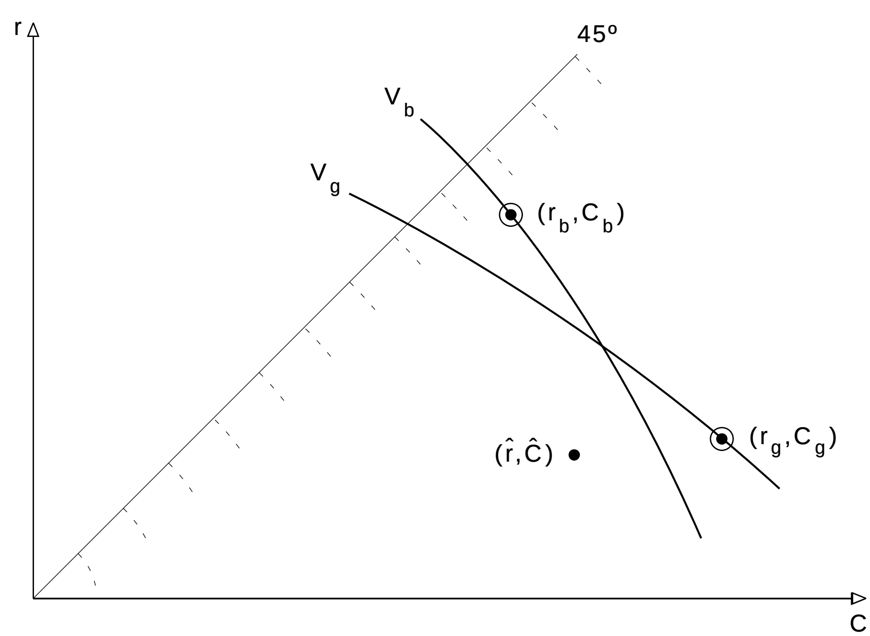
[6] The distinction between a risky debt contract and a more general contingent claim is blurred when there are only two returns. For example, one might just as well call a contract satisfying (1) a collateralized profit-sharing plan; the borrower promises to pay a fraction r/R of the return or else hand over collateral when the return is zero. When there are many possible returns, however, the distinction is quite meaningful.

The self-selection constraints are illustrated in Figure 1. The good state output payment r is measured on the vertical axis, while the bad state collateral payment C is measured on the horizontal axis. Any arbitrary contract (r, C) can be represented by a point on the graph. Borrower preferences over contracts are shown by means of indifference curves. The curve labeled V_g is the set of contracts that leaves a good borrower indifferent to the contract (r_g, C_g). Similarly, the curve labeled V_b is the set of contracts that leaves a bad borrower indifferent to the contract (r_b, C_b).

Borrowers would like smaller payments in either state, so indifference curves slope down and borrower utility is increasing toward the lower left corner of the graph. A contract like $(\hat{r}, \hat{C})$ is preferred over (r_g, C_g) by good borrowers, since it lies below V_g, and is preferred over (r_b, C_b) by bad borrowers, since it lies below V_b. The indifference curves of a bad borrower are everywhere steeper than the indifference curves of a good borrower. Because the probability of having to surrender collateral is larger for bad borrowers,

Figure 1 Self-Selection and Incentive Constraints



Notes: r is the loan repayment amount, and C is the collateral that is transferred in the event of default. V_b is a bad-borrower indifference curve through the contract (r_b, C_b). V_g is a good-borrower indifference curve through the contract (r_g, C_g). Utility is increasing to the lower left. Incentive constraints for voluntary repayment of the loan require that contracts lie below the 45° line.

they are more averse to collateral requirements than are good borrowers. As a result, it is always possible to find a pair of contracts that "separate" the two types of borrowers, as shown in Figure 1. Bad borrowers prefer their contract (r_b, C_b) to the good borrowers' contract (r_g, C_g), because the latter would place them on an inferior indifference curve. Similarly, good borrowers prefer their contract to the bad borrowers' contract.

The incentive constraints imply that contracts must lie below the 45° line; the collateral payment must be at least as large as the good state payment. If (1) is not satisfied ($r > C$), then the borrower would hide the return in the good state and transfer collateral rather than pay more.

Figure 2 shows "break-even lines" for each type of borrower. The line labeled π_g is the set of loans to good borrowers that earn no excess profits for lenders. (Throughout this article "profits" refers to the expected profits of lenders.) In other words, π_g is the set of contracts that satisfy

$$p_g r + (1 - p_g)\beta C = \rho. \tag{4}$$

Contracts above π_g earn positive profits for lenders and contracts below π_g earn negative profits. The line labeled π_b is similarly defined as the set of loans to bad borrowers that earn no excess profits for lenders.

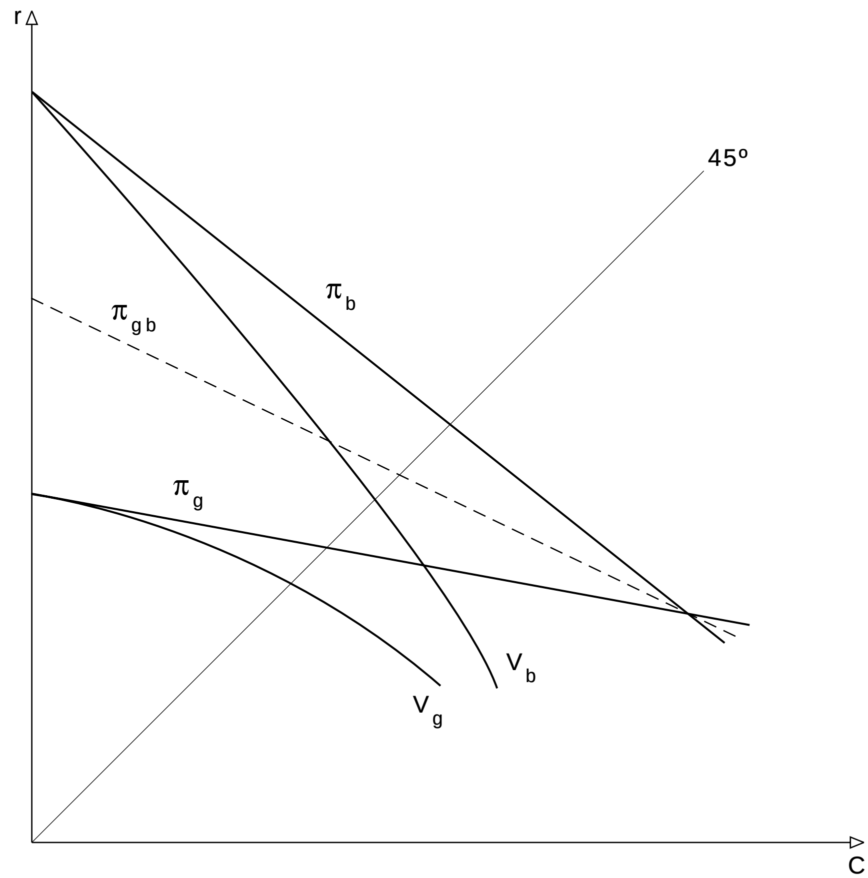
$$p_b r + (1 - p_b)\beta C = \rho. \tag{5}$$

The break-even line for bad borrowers is steeper than the break-even line for good borrowers because the probability of default and collateral transfer is larger for bad borrowers. Contracts above π_g but below π_b (to the left of their intersection) earn excess profits on good borrowers but negative profits on bad borrowers. Figure 2 also shows the "pooling break-even line," π_{gb}. This is the set of contracts that earn no excess profits when all borrowers apply, satisfying

$$[\,p_g r + (1 - p_g)C\,]\,N_g + [\,p_b r + (1 - p_b)C\,]\,N_b \geq \rho(N_g + N_b). \tag{6}$$

Overcollateralization is inefficient in this environment, ceteris paribus. As Figure 2 shows, a borrower's indifference curve is always steeper than the break-even line for that borrower. In the absence of the incentive and self-selection constraints, a borrower choosing among all of the contracts on the appropriate break-even line would prefer the one on the vertical axis, where collateral transfer is zero. There are two reasons for this. First, such a contract minimizes the risk borne by the borrower. Second, collateral is more valuable in the hands of the borrower, so better loan terms are available if the collateral transfer is minimized. The inefficiency of collateral transfer implies that contracts will attempt to minimize the collateral component, subject to the incentive and self-selection constraints.

Figure 2 Collateral Transfers Are Undesirable, Ceteris Paribus



Notes: π_g (π_b) is the set of contracts earning zero expected profits on good (bad) borrowers. π_{gb} is the set of contracts earning zero expected profits on the average borrower.

2. AN ARGUMENT FOR GOVERNMENT INTERVENTION IN LOAN MARKETS

A Definition of Equilibrium: The Wilson Equilibrium

I have described an economic environment, in other words, the preferences, endowments and technologies (including information technologies) of an artificial economy. An economic model also requires a means of selecting a predicted outcome from among the many possible outcomes that are feasible for any given environment—in other words, a definition of "equilibrium." The usual candidate is the competitive equilibrium in which agents take prices as given and select utility- or profit-maximizing quantities.

The standard notion of a competitive equilibrium is problematic in adverse selection environments, however. In frictionless environments, the value of a commodity is known to the buyer and so the perceived desirability of a transaction depends only on the preferences of the buyer and the price. In an adverse selection environment, buyers' beliefs about the value of the item—a financial claim, in our case—hinge on the actions of sellers, which in turn may depend on the entire array of options available to sellers. Thus the desirability of a given transaction may depend on all of the other transactions taking place. In our environment, for example, a lender's beliefs about which borrowers have applied for a loan depend on what other loan contracts are available. Another lender could offer a contract that takes away the best borrowers, leaving behind high-risk borrowers.

A number of definitions of equilibrium have been proposed for adverse selection economies. Many have defined equilibrium as the outcome of some game agents are assumed to play. Formally, a *game* consists of a sequence of moves and countermoves available to agents, along with a specification of the payoffs they receive for any particular sequence of chosen moves. Players adopt *strategies,* functions determining their choice of move in various circumstances. The outcome of the game is presumed to be a *Nash equilibrium,* in which agents take other agents' strategies as given and choose a strategy that maximizes their expected payoff. In a Nash equilibrium, each player's strategy is a "best response" to other players' strategies.

The simplest version of this approach to adverse selection economies is a two-stage game. In the first stage lenders simultaneously offer loan contracts, and in the second stage borrowers choose which contracts to accept. Accepted contracts are then executed, determining payoffs. A lender decides on a loan offer, taking as given the loans offered by other lenders and the way in which borrowers select from the available loans. Unfortunately, as Rothschild and Stiglitz (1976) showed in a closely related environment, there often is no equilibrium for this game. The problem is that "pooling" contracts, in which all borrowers receive the same contract, are always vulnerable to contracts that "cream-skim" the best borrowers away, while separating contracts can be vulnerable to pooling contracts that make both types of borrowers better off. Thus in some cases this notion of equilibrium makes no prediction at all!

One alternative that has been proposed is a particular four-stage game. The first two stages are as before, with lenders making offers and borrowers accepting. In the third stage lenders can withdraw any loan offer made in the first stage, but no contracts can be added. Lenders cannot precommit to not withdraw a contract in the third stage. In the final stage borrowers choose contracts again, the game ends, and contracts that have been accepted are executed. This game always has an equilibrium, so it avoids the serious existence problem of the two-stage game. This definition of equilibrium, which I describe more explicitly below, was first proposed by Charles Wilson in 1977 and is widely known as the "Wilson equilibrium." As I will show, there is a rationale for government loan market intervention in models adopting the Wilson equilibrium.[7]

Many other definitions of equilibrium have been proposed for adverse selection environments, and models adopting some of them have been used to justify government intervention in loan markets. The rationale for government intervention under these other equilibria is similar to that of the Wilson equilibrium, and I will briefly comment on them at the end of this section. One advantage of the Wilson equilibrium is that it always exists.

To formally define a Wilson equilibrium, let S be a set of contracts. The set S could be a pair of separating contracts or a single pooling contract.

Definition (defeats): Given a set of contracts S and another set of contracts S', suppose borrowers self-select among both sets of contracts. If any contracts in S earn negative profits, delete the smallest number of contracts in S such that the remaining contracts are all profitable after borrowers again self-select. If all of the contracts in S' now earn nonnegative profits and at least one earns strictly positive profits, then the set of contracts S' *defeats* the set of contracts S.[8]

Definition: A *Wilson Equilibrium* is a set of contracts S satisfying the following conditions:

(i) the incentive constraints (1);
(ii) the self-selection constraints (2) and (3);
(iii) each contract earns nonnegative profits for lenders; and
(iv) no other set of contracts S' exists that defeats the set of contracts S.

The first two conditions require that contracts be consistent with the informational imperfections of the environment. Condition (iii) states that each individual contract must at least break even. The essential idea in condition (iv) is that a set of equilibrium contracts cannot be trumped by some other contracts earning excess profits. The critical component of the definition concerns the conjectures of lenders contemplating introducing the deviating contracts. A new contract might attract good borrowers from other lenders and might earn excess profits, but some of the original contracts may then earn negative profits. If the

[7] Innes (1991) describes the case for government intervention in loan markets based on the Wilson equilibrium. Crocker and Snow (1985a) prove the existence of Pareto-improving government tax schemes in the Rothschild-Stiglitz insurance model.

[8] This definition, following Wilson, does not rely on an explicit formal definition of a game. Wilson viewed these conditions as defining a competitive equilibrium. As is typical, the game has multiple equilibria. One could view the definition as selecting a particularly plausible equilibrium. Hellwig (1987) conjectures that recently proposed equilibrium "refinements" select the Wilson equilibrium.

original contracts now earning negative profits are withdrawn, borrowers will reallocate themselves among the remaining contracts and some new contracts may now earn negative profits. Such contracts do not defeat the equilibrium. If the new contracts remain profitable, then they have defeated the original set of contracts, which could not have been an equilibrium.

Condition (iii) is crucial. It is sometimes called the "type-wise break-even" condition, since it requires that each contract earn nonnegative profits on its own. This condition is derived from the ability of lenders to withdraw any unprofitable contracts at the third stage of the game. Furthermore, lenders cannot precommit to *not* withdraw unprofitable contracts. As we will see below, condition (iii) implies a welfare-enhancing role for government intervention.

What Does the Wilson Equilibrium Look Like?

There is a unique set of contracts that constitutes a Wilson equilibrium. Depending on parameter values, the Wilson equilibrium is one of two types.[9] One type, the *separating equilibrium*, is shown in Figure 3. The bad borrower receives the contract (r_b^*, C_b^*), where the bad-type break-even line, π_b, intersects the 45° line. Of all the contracts that break even on bad borrowers and satisfy the incentive constraint (1), the contract (r_b^*, C_b^*) is the one most preferred by bad borrowers. The good borrower's contract has to lie on or above V_b^*, the bad borrower's indifference curve through (r_b^*, C_b^*), in order to satisfy the self-selection constraint (3). Since it must at least break even, it must also lie on or above π_g. Of all the contracts satisfying (3) and the good-type break-even condition, the contract (r_g^*, C_g^*) is the one most preferred by good borrowers.

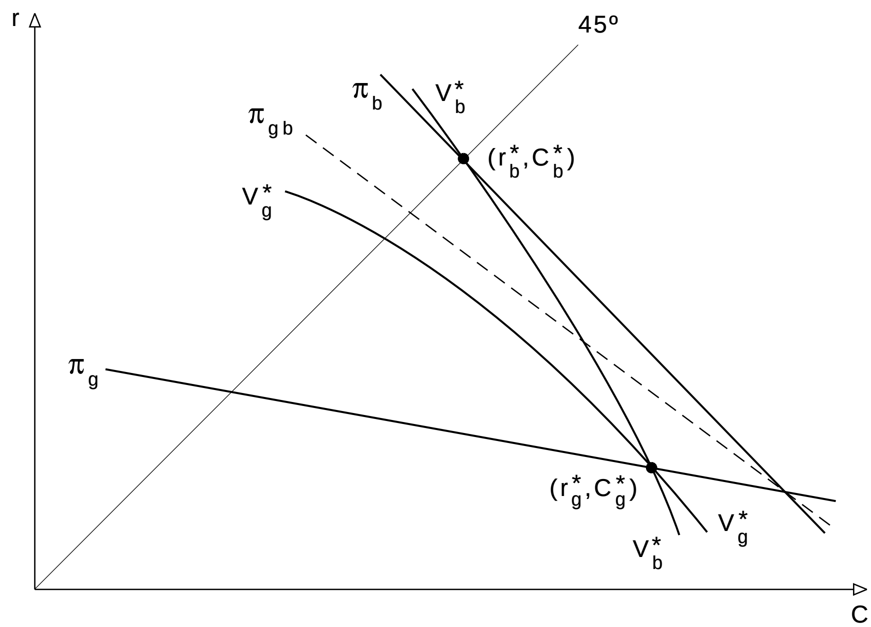
It is easy to see why this is an equilibrium. First, imagine trying to attract good borrowers without attracting the bad borrowers. To do so the new contract would have to lie below the good-type indifference curve V_g^* but above V_b^*, to the southeast of (r_g^*, C_g^*) in Figure 3. But such contracts earn negative profits since they lie below π_g. Similarly, there is no contract that attracts only the bad borrowers, satisfies the incentive constraint, and earns nonnegative profits. Finally, imagine introducing a pooling contract that attracts both good and bad borrowers. Such a contract would have to lie on or above the pooling break-even line, π_{gb}. No such contract would succeed in attracting the good borrowers, since π_{gb} lies everywhere above V_g^*.[10]

The other type of Wilson equilibrium is a *pooling equilibrium*. Both types of borrowers receive the same loan contract, (r^{**}, C^{**}) in Figure 4. This contract lies at the tangency of the pooling break-even line, π_{gb}, and a good borrower's

[9] There is a knife-edge case of a single set of parameter values for which both types of equilibria coexist, which I will ignore.

[10] In this case the Wilson equilibrium is the same as the equilibrium of the two-stage game analyzed by Rothschild and Stiglitz (1976).

Figure 3 The Wilson Equilibrium When N_b/N_g Is Large: Type-Wise Break-Even Separating Contracts



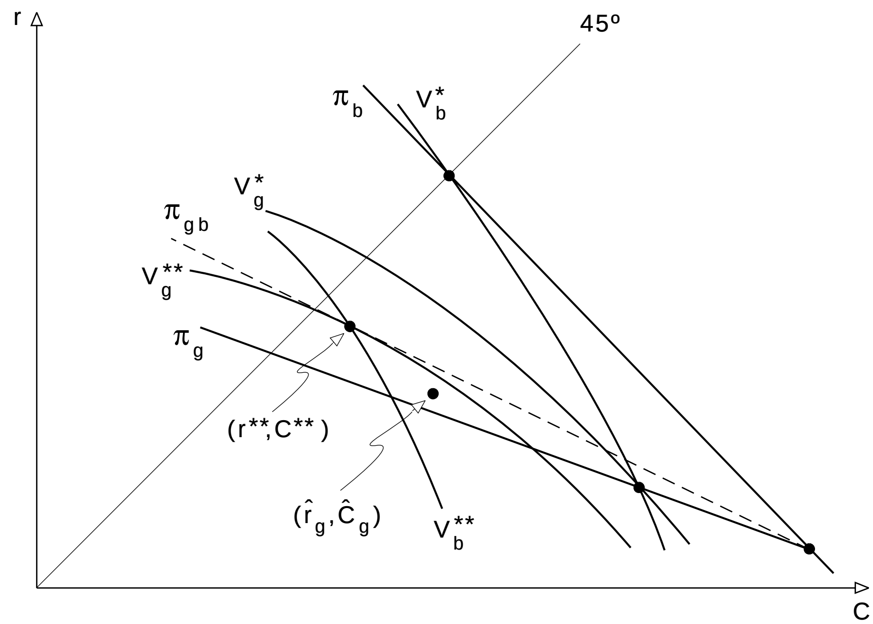
Notes: Bad borrowers receive the contract (r_b^*, C_b^*), where the bad-borrower break-even line, π_b, intersects the 45° line. Good borrowers receive the contract (r_g^*, C_g^*), where the good-borrower break-even line intersects the bad borrower's indifference curve through (r_b^*, C_b^*); the bad borrower is indifferent between (r_b^*, C_b^*) and (r_g^*, C_g^*). Good borrowers prefer (r_g^*, C_g^*) to any contract on the pooling break-even line, π_{gb}. This type of equilibrium occurs for *high* and *very high* levels of N_b/N_g in Table 1.

indifference curve, V_g^*. This contract provides higher expected utility for a good borrower than the separating equilibrium, since it lies below the indifference curve through the separating allocation, V_g^*. Of all of the pooling contracts, (r^{**}, C^{**}) is most preferred by the good borrowers.[11]

To see why this is an equilibrium, consider how a lender might try to attract good borrowers by offering a contract like $(\hat{r}_g, \hat{C}_g)$ in Figure 4. This would indeed attract good borrowers and it would make positive profits as well, since it lies above the good-type break-even line, π_g. But now the contract (r^{**}, C^{**}) would lose money, since it would only be selected by bad borrowers. It would

[11] Note that the pooling equilibrium might lie on the 45° line. This occurs if there is no point below the 45° line on π_{gb} tangent to a good borrower's indifference curve.

Figure 4 The Wilson Equilibrium When N_b/N_g Is Small: A Pooling Contract



Notes: The Wilson equilibrium contract (r^{**}, C^{**}) is the pooling contract that maximizes the expected utility of the good borrower. The rival contract $(\hat{r}_g, \hat{C}_g)$ would attract all of the good borrowers, but fails to defeat (r^{**}, C^{**}) because the latter would then lose money on just bad borrowers and be withdrawn, forcing all borrowers to take $(\hat{r}_g, \hat{C}_g)$, which would then lose money. This type of equilibrium occurs for *intermediate, low,* and *very low* levels of N_b/N_g in Table 1.

be withdrawn in the third stage of the game, leaving only the new contract $(\hat{r}_g, \hat{C}_g)$. The new contract would now attract both types of borrowers, and since it lies below π_{gb} it would earn negative profits. Such a contract thus fails to defeat (r^{**}, C^{**}). It should be clear that no other pooling contract is able to defeat (r^{**}, C^{**}) either, since none would break even *and* attract just the good borrowers after (r^{**}, C^{**}) is withdrawn.[12]

Which equilibrium occurs depends on whether π_{gb}, the pooling break-even line, intersects V_g^*, the good borrower's indifference curve that passes through the good-type separating contract. If it does, the equilibrium is a pooling

[12] In this case the Rothschild and Stiglitz equilibrium does not exist because the contract $(\hat{r}_g, \hat{C}_g)$ *would* defeat the candidate equilibrium (r^{**}, C^{**}); their equilibrium does not allow subsequent withdrawal of contracts earning negative profits.

contract like (r^{**}, C^{**}) in Figure 4. If it does not, the equilibrium is the set of break-even separating contracts shown in Figure 3. This depends on whether π_{gb} lies closer to π_g or π_b, which in turn depends on the ratio N_b/N_g. If there are many bad borrowers relative to good borrowers, pooling allocations are unattractive to the good borrower, so the type-wise break-even separating allocation is the equilibrium. If there are few bad borrowers relative to good borrowers, then the good borrower does well in a pooling allocation. As N_b/N_g approaches zero and the bad borrowers become a negligible portion of the market, the equilibrium allocation approaches the intersection of π_g and the 45° line, the loan that the good borrower would receive if there were no bad borrowers.

Is the Wilson Equilibrium Pareto-Optimal?

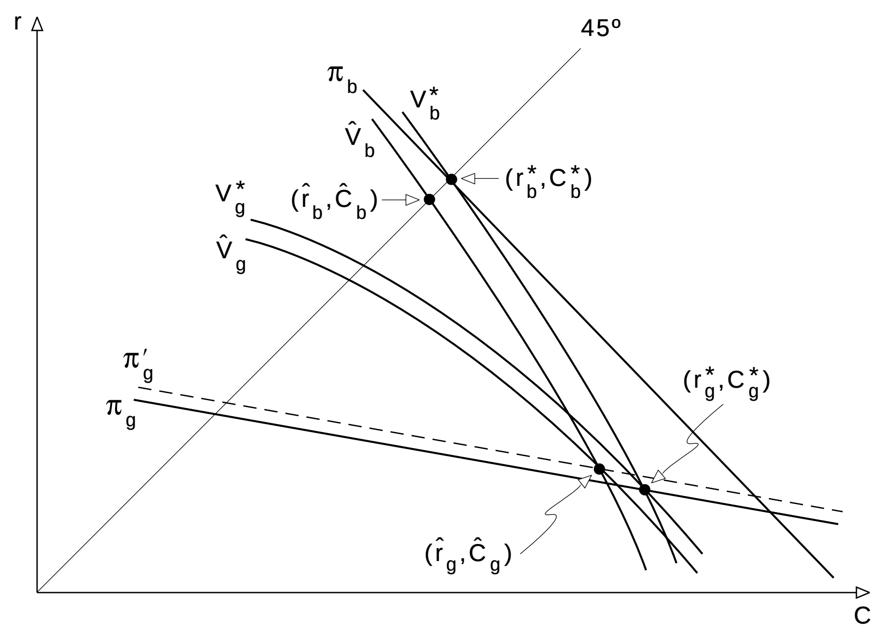
Are there any alternative allocations that make no agents worse off and make at least one agent strictly better off? If the answer is no, the given allocation is Pareto-optimal. The only relevant alternative allocations to check, of course, are those that are attainable—allocations that respect the resource, incentive, and self-selection constraints of the environment.

Is the Wilson equilibrium Pareto-optimal? Often the answer is no. Figure 5 shows why. Suppose the set of contracts $\{(r_g^*, C_g^*), (r_b^*, C_b^*)\}$ is a separating Wilson equilibrium, as before. (This occurs when the ratio of bad to good borrowers is above a certain threshold.) Now replace the bad borrowers' contract with the contract $(\hat{r}_b, \hat{C}_b)$, down and to the left along the 45° line. This new contract makes bad borrowers better off, but earns negative profits since it lies below π_b. In order to maintain resource feasibility, the new contract for good borrowers must earn excess profits. As a result, the good borrowers' new contract must lie on or above a line parallel to (but above) π_g, shown as a dashed line in Figure 5. The new contract for bad borrowers relaxes the self-selection constraint, which now requires that $(\hat{r}_g, \hat{C}_g)$ lie on or above $\hat{V}_b$. Among the contracts that satisfy the two constraints, the contract $(\hat{r}_g, \hat{C}_g)$, at the intersection of the dashed line and $\hat{V}_b$, is the one most preferred by good borrowers.

As shown in Figure 5, the good borrowers' new contract lies on an indifference curve that is superior to V_g^*, the indifference curve through the Wilson equilibrium contract.[13] The new set of contracts makes both types of borrowers better off, and by construction, lenders receive just as much expected consumption (and therefore expected utility) as before. In addition, the new contracts have been constructed to satisfy incentive and self-selection constraints. Therefore, the set of contracts $\{(\hat{r}_g, \hat{C}_g), (\hat{r}_b, \hat{C}_b)\}$ Pareto-dominates the separating Wilson equilibrium contracts.

[13] The new contract gives the good borrower a consumption pattern that is less risky than under the original contract. In addition, the good borrower benefits from reduced collateralization.

Figure 5 The Wilson Equilibrium Is Pareto-Dominated: The Separating Case



Notes: Bad borrowers prefer the contract $(\hat{r}_b, \hat{C}_b)$ to the equilibrium contract (r_b^*, C_b^*). Because $(\hat{r}_b, \hat{C}_b)$ lies below π_b, the resource feasible contracts for good borrowers now lie along π_g'. The good borrower can now obtain the contract $(\hat{r}_g, \hat{C}_g)$, where the bad borrower's indifference curve, $\hat{V}_b$, intersects π_g'. As shown, $(\hat{r}_g, \hat{C}_g)$ yields greater expected utility than (r_g^*, C_g^*).

The Wilson equilibrium *is* Pareto-optimal when N_b/N_g is very large. Whenever N_b/N_g is above some critical threshold, the dashed good-borrower resource feasibility line lies so far above π_g that no improvement for good borrowers is possible. This might even be true for any possible choice of alternative bad-borrower contract along the 45° line. If N_b/N_g is below the critical threshold the separating equilibrium is Pareto-dominated.

When the Wilson equilibrium is a pooling contract and does *not* lie on the 45° line, it is easy to show that it is not Pareto-optimal. The equilibrium allocation is dominated by a pair of separating contracts lying along V_b^{**}; the alternative contract for bad borrowers is above π_{gb} and the contract for good borrowers is below. Thus bad borrowers are indifferent and good borrowers are made strictly better off. If the Wilson equilibrium is the 45° line pooling contract, then it *is* Pareto-optimal. This occurs for values of N_b/N_g below some threshold. To summarize then, for a range of intermediate values of N_b/N_g the

Wilson equilibrium is *not* Pareto-optimal. For values of N_b/N_g above or below this range, the Wilson equilibrium *is* Pareto-optimal.[14]

Government Intervention Can Be Pareto-Improving

A crucial feature of the alternative allocations that Pareto-dominate the Wilson equilibrium is that they involve *cross-subsidy*. A pair of feasible contracts involve cross-subsidy if they do *not* lie on the individual break-even lines π_g and π_b; in other words, one earns positive expected profits while the other earns negative expected profits. In the allocations that Pareto-dominate the Wilson equilibrium, the good borrowers subsidize the bad borrowers, loosening the self-selection constraint and allowing good borrowers a less risky consumption pattern and reduced collateral transfer. Such allocations cannot be Wilson equilibria because they violate the type-wise break-even condition. When the Wilson equilibrium is not Pareto-optimal, government intervention can help by performing the cross-subsidization that is ruled out in equilibrium. Tax and subsidy schemes can provide bad borrowers with better loan terms, relaxing the bad borrower's self-selection constraint and allowing more desirable loan terms for good borrowers. Good borrowers are better off, even though they bear the tax burden.

Government intervention in this credit market can take many forms. One method is a subsidy for high-interest (bad-type) loans. The government could fund the subsidy through taxes levied on lenders' returns. This would relax the bad-borrower break-even line faced by lenders, making them willing to offer subsidized loan terms. The net tax on loans to good borrowers would shift upward the good-type break-even line. Tax and subsidy rates can be selected so that the resulting Wilson equilibrium Pareto-dominates the no-intervention equilibrium.[15]

One difficulty with a subsidy scheme of this sort is that it must be applied only to the loan contracts selected in equilibrium by the bad borrowers. A simpler alternative is a government loan guarantee applicable to all loans, funded by a tax on lenders' interest income. The government would guarantee a fraction δ of the stipulated loan repayment r, where $\beta < \delta < 1$. If the collateral transfer yielded $\beta C < \delta r$, the government would pay the lender $\delta r - \beta C$. This could be funded by a tax, τ, on lenders' net interest earnings, $(r - \rho)$. The parameter β can be set so that only bad borrowers are subsidized in equilibrium. The break-even lines for loans to type h borrowers $(h = g, b)$ is now

$$p_h[r - \tau(r - \rho)] \ + \ (1 - p_h)\mathrm{MAX}[\beta C, \delta r] \ = \ \rho. \tag{7}$$

[14] For a complete welfare analysis of the closely related Rothschild-Stiglitz insurance environment, see Crocker and Snow (1985b).

[15] Crocker and Snow (1985a) consider such tax/subsidy schemes.

The government budget constraint is

$$\tau p_g(r_g - \rho)N_g + \tau p_b(r_b - \rho)N_b \geq (1 - p_g)N_g\text{MAX}[0, \delta r_g - \beta C_g] + (1 - p_b)N_b\text{MAX}[0, \delta r_b - \beta C_b]. \quad (8)$$

The effect of the tax is to rotate both break-even lines in a clockwise direction around the point at which they intersect. The effect of the guarantee is to make the lines flat to the left of where $\delta r = \beta C$. The combined effect is illustrated in Figure 6.

The allocation $\{(\hat{r}_g, \hat{C}_g), (\hat{r}_b, \hat{C}_b)\}$ can be attained by setting τ so that $(\hat{r}_g, \hat{C}_g)$ satisfies (7), and then setting δ so that $(\hat{r}_b, \hat{C}_b)$ satisfies (7). The feasibility of the new set of contracts implies that the government budget constraint is satisfied.[16] In the case of the pooling Wilson equilibrium, parameters could similarly be set to achieve a Pareto-dominating separating allocation.

Other welfare-enhancing schemes are easy to imagine, but all share the same principle. The government is able to cross-subsidize loan contracts in a way that is ruled out in the Wilson equilibrium. Cross-subsidies are inconsistent with rational strategies in the multi-stage game that agents are assumed to play. A natural question that arises is: Why would agents play this particular game?

Other Definitions of Equilibrium

As I mentioned earlier, other definitions of equilibrium in adverse selection models have been used to justify government intervention in loan markets. Some authors select the Rothschild-Stiglitz equilibrium (type-wise break-even separating contracts) and restrict attention to cases in which it exists (Smith and Stutzer 1989; Gale 1990). Some authors adopt pooling allocations and note that such allocations are sometimes Pareto-dominated (Greenwald and Stiglitz 1986; de Meza and Webb 1987; Mankiw 1986). John Riley (1979) proposed an equilibrium very similar to Wilson's, in which lenders cannot withdraw contracts in the third stage (as they can under the Wilson setup) but *can* propose new contracts if they wish.[17]

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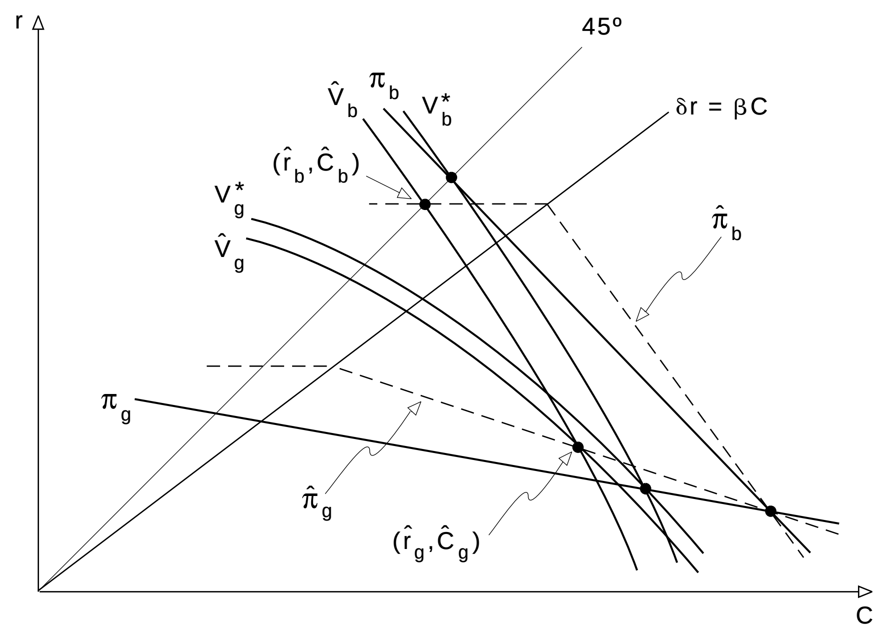
[16] This scheme would be affected by the possibility that the new pooling break-even line may now intersect the good borrower's indifference curve through $(\hat{r}_g, \hat{C}_g)$. If it did, the Wilson equilibrium in the presence of this government guarantee is a pooling contract on the 45° line. If the tax and subsidy parameters are set to balance the budget at the separating contracts, they may violate the budget constraint at the pooling equilibrium. This problem might limit the magnitude of the Pareto-improvement. Adding a fixed lump-sum component to the tax schedule can get around the problem. See Crocker and Snow (1985a).

[17] A vast literature studies adverse selection environments as "signaling games," in which the informed agents (our borrowers) move first by taking some irrevocable action or making a contract offer; see Cho and Kreps (1987). This approach has not yet been applied to policy analysis.

Figure 6 A Pareto-Improving Government Credit Guarantee



Notes: $\hat{\pi}_g$ ($\hat{\pi}_b$) is the set of contracts that break even after taxes when accepted by good (bad) borrowers. The tax on net interest income rotates the break-even lines, while the guarantee flattens them out to the left of the line $\delta r = \beta C$, where the guarantee just pays off.

All of these other definitions of equilibrium impose a particular structure on the way agents interact, some through explicit games, some in an ad hoc fashion. All share the feature that “equilibrium” allocations can fail to be Pareto-optimal, providing a role for government intervention. Under all definitions, equilibrium is Pareto-dominated in all the cases in which the Wilson equilibrium is Pareto-dominated. Under some definitions, equilibrium is Pareto-dominated in other cases as well. In a sense, the Wilson equilibrium provides the strongest case for government intervention because, of the equilibria that have been proposed, the laissez-faire Wilson equilibrium is least likely to be Pareto-dominated; if government intervention is warranted for the Wilson equilibrium, it is warranted under other definitions as well. In any event, the Wilson equilibrium is representative of definitions that give rise to market failure in adverse selection environments, and my remarks apply with equal force to all.

What About Credit Rationing?

Adverse selection models of credit markets are often associated with the notion of "credit rationing" (Stiglitz and Weiss 1981). The parameter values I have assumed for my economy imply that credit rationing never occurs.[18] It should be clear that the adverse selection justification of government intervention in loan markets does not depend on the existence of credit rationing (Smith and Stutzer 1989; Gale 1990). The justification relies on the effects of self-selection constraints, and these perturb equilibrium whether or not credit rationing occurs.

3. ADVERSE SELECTION MODELS OF FINANCIAL INTERMEDIARIES[19]

Financial intermediaries such as banks, pension funds, and insurance companies surely play an important role in loan markets. And yet standard frictionless models have little to say about financial intermediaries. Either organizations such as banks or firms are taken as primitive elements, or they are economically inessential because equilibrium allocations can be achieved without them. Financial intermediaries can be viewed as large multilateral arrangements that arise to overcome the problems of asymmetric information that are absent in the standard frictionless models. Much recent effort has gone into the search for environments in which "realistic" multilateral arrangements, or at least aspects of them, are in some sense endogenous outcomes rather than imposed constraints. Much of this effort has focused on environments in which information is limited in some way, either being asymmetrically distributed or costly to obtain.

Adverse selection environments have been the basis for a number of prominent recent models of financial intermediation.[20] In this section I will describe a simple model of financial intermediaries using the economic environment laid out in Section 1. In Section 2 I took the same environment, adopted a particular definition of equilibrium—the Wilson equilibrium—and showed that government loan market intervention could be Pareto-improving. In this section I adopt a different definition of equilibrium; this is the only difference between the two models. Under the definition adopted here, financial intermediaries can emerge endogenously in equilibrium. Furthermore, there is no welfare-enhancing role for government intervention, since equilibrium allocations turn out to be Pareto-optimal.

[18] Insufficient collateral—a low value of K—often gives rise to borrowing constraints.

[19] The results presented in this section are due to joint ongoing work with John Weinberg.

[20] See Boyd and Prescott (1986), Boyd, Prescott, and Smith (1988), and Lacker and Weinberg (1993). One should add Hajime Miyazaki (1977), who interprets cross-subsidizing wage-employment contracts as an "internal labor market," in other words, a firm. Adverse selection is not the only possible approach; Diamond (1984) and Williamson (1986) present models of endogenous financial intermediaries based on costly verification and delegated monitoring.

Financial Intermediaries Are Inhibited Under the Wilson Equilibrium

One hallmark of financial intermediaries is that almost all of their assets and liabilities are financial claims, as opposed to physical assets. Because financial intermediaries hold large portfolios, they do not necessarily need to break even on each individual claim. In contrast, when individual claims are sold directly by borrowers to ultimate lenders, equilibrium requires that each claim at least break even. Cross-subsidization thus appears to be inconsistent with nonintermediated lending. Therefore, financial intermediaries should be expected to arise whenever allocations require cross-subsidization. Adverse selection models of financial intermediaries are based on just such reasoning.[21]

If we want to allow for the possibility of financial intermediaries, the equilibrium notion adopted in the previous section is clearly inadequate. The Wilson equilibrium assumes that lenders and borrowers can only enter into *bilateral* financial contracts. Multilateral financial arrangements are precluded by assumption. For simplicity, lenders in our environment have only one unit each to lend, exactly the amount each borrower wants to borrow. Thus no lender offers more than one contract. It would make no difference for the models, however, if each lender was large relative to borrowers and made many loans.

More to the point, the Wilson equilibrium imposes a particular *game* on the agents in the economy. Agents are assumed to interact through a specific sequence of moves and countermoves governed by a specific set of rules. In particular, the game underlying the Wilson equilibrium specifies that in the third stage lenders are able to withdraw *individual* loan contracts. This prevents a lender from offering a menu of contracts as a whole in the first stage and precommitting not to drop any single contract. This feature gives rise to the break-even constraint, which implies a welfare-enhancing role for government intervention. The same feature rules out the cross-subsidizing allocations associated with financial intermediaries.

In many instances, participants in real world economies interact within highly structured institutions, governed by rules, laws, customs, and so forth. A wide variety of market institutions come to mind, from decentralized search markets, to trading fairs, to auctions, to highly centralized (and organized) open-outcry markets. Many of these institutional arrangements can easily be cast as games since they impose binding restrictions on the interaction of participants. Game theory is obviously quite useful for analyzing the implications of alternative institutional and market structures.

However, when we are interested in predicting institutional arrangements, when we want a model of *which* game agents will play, we need a different

[21] The situation is analogous to a multiproduct firm with economies of scope across products. In a sustainable equilibrium one product might be subsidized in the sense that the price is less than the stand-alone marginal cost.

approach. Indeed, outcomes in adverse selection environments are known to be particularly sensitive to the assumed "market convention," as Wilson's subsequent (1979) research demonstrated. He showed that equilibrium can be very different depending on whether the informed agents (the borrowers in our environment) or the uninformed agents (the lenders) propose contracts. Wilson's 1979 results stand as a strong warning about the reliability of predictions from adverse selection models in which equilibrium is identified as the outcome of one particular game.

A Different Definition of Equilibrium: The Sustainable Equilibrium[22]

A different definition of equilibrium is needed then, a different way of selecting a predicted outcome for this environment, one that allows for the possibility of financial intermediaries. Three ideas guide the definition described below. First, I want to be agnostic about the game agents might play to implement the resulting allocation, since imposing a particular game could arbitrarily restrict the allocations agents can achieve. Second, there should be some notion of competition between rival financial intermediaries. If a financial intermediary is part of an equilibrium, there must be no other rival financial intermediary that "beats" it by doing better for the agents involved. Third, for a rival financial intermediary to beat a candidate intermediary, the rival must be "credible" in the sense that it cannot be beaten by any other (credible) rival intermediary. If a rival intermediary is itself vulnerable to another rival, it cannot be taken seriously as a threat to overturn the candidate allocation. It is important to note that the credibility requirement is imposed on *any* subsequent proposed rival intermediary.

While the definition of the Wilson equilibrium was stated in terms of contracts, the definition of the sustainable equilibrium can be stated more clearly in terms of *coalitions* and *allocations*. A *coalition* is simply a collection of some or all of the agents in the economy. Let n designate a typical coalition; n is a list of the names of each agent in the coalition. Let N designate the coalition consisting of every agent in the economy, that is, the *coalition of the whole*. An *allocation* for a given coalition is a list of the consumption plans of all agents in a coalition, together with their investment decisions. An allocation is equivalent to specifying all of the contracts among agents in a coalition. Let a designate a typical allocation.

The central ingredient in the definition of a sustainable equilibrium is the idea of *blocking*, which captures the notion of competition between rival

[22] The equilibrium described here was introduced in Lacker and Weinberg (1993) and is related to the idea of "coalition-proof Nash equilibrium" formulated by Bernheim, Peleg, and Whinston (1987) and Greenberg (1989). Kahn and Mookherjee (1991) independently developed a closely related equilibrium notion for games in adverse selection environments also based on the coalition-proof idea, but their approach differs enough in certain details that their results have a very different flavor.

coalitions. Intuitively, an allocation for a given coalition can be blocked by a subcoalition if the subcoalition can feasibly make all its members at least as well off and some strictly better off. In an adverse selection environment this idea must be specified with some care. A key consideration is that allocations for a subcoalition are limited by the incentive and self-selection constraints, as are all allocations. An additional consideration arises, however. If a subcoalition is proposed, will any of the agents left behind in the original coalition wish to misrepresent themselves in order to gain entry into the deviating subcoalition? If so, the self-selection constraints for the subcoalition will be undermined, making the proposed deviation infeasible. The following definition of blocking takes these considerations into account.

Definition: An allocation a for coalition n is *blocked* by a subcoalition n', together with an allocation a', if:

(i) the blocking allocation a' satisfies the incentive and self-selection constraints and is resource feasible for n';
(ii) all agents in n' are at least as well off under a' as they would be under a, and at least one agent is made strictly better off; and
(iii) no agents that the subcoalition leave behind in the original coalition could make themselves better off by joining the subcoalition, including by claiming to be a different type.

Conditions (i) and (ii) are standard. Condition (iii) implies that if one type of agent is made strictly better off, the coalition attracts all of that type of agent. Condition (iii) also implies that if a deviating subcoalition wants to attract some, but not all, of a given type of agent, they must make that type of agent indifferent between joining the subcoalition (truthfully) and receiving the original allocation. Also, that type of agent must have no incentive to join the subcoalition by claiming to be another type of agent in the subcoalition. Condition (iii) merely extends the self-selection constraints to cover potential blocking subcoalitions; it recognizes a subcoalition's vulnerability to strategic behavior.

I am now ready to define a sustainable equilibrium. In order to do so I must define the sustainable allocations *for each possible subcoalition*, as well as for the coalition of the whole. The sustainable equilibrium is then just the sustainable allocation for the coalition of the whole. Let $s(n)$ denote the set of sustainable allocations for coalition n. The definition is then simple: an allocation is sustainable if it is not blocked by any subcoalition together with a sustainable allocation for that subcoalition. The mapping $s(n)$ is defined formally as follows.

Definition: The mapping $s(n)$ is the set of *sustainable allocations* for each coalition n if it satisfies the following properties:

(i) allocations a in $s(n)$ satisfy the incentive and self-selection constraints and are resource feasible for the coalition n and

(ii) an allocation a is in $s(n)$ if and only if there does not exist a subcoalition n' together with an allocation a' in $s(n')$ such that (a', n') blocks a.

Condition (i) merely states that sustainable allocations must satisfy resource and informational constraints. Condition (ii) captures the notion of credibility. An allocation is sustainable if it is not blocked by any subcoalition together with an allocation that is sustainable for that subcoalition. If an allocation *is* blocked by such a subcoalition and allocation, then it is *not* sustainable.

A *sustainable equilibrium*, then, is any allocation that is sustainable for the population as a whole.[23]

What Does the Sustainable Equilibrium Look Like?

It turns out that there is a simple way to find the sustainable equilibrium for our economy. Solutions to a particular maximization problem, shown below, are sustainable allocations.

The Miyazaki Problem:

$$\text{MAX} \quad p_g u(R - r_g + K) \ + \ (1 - p_g)u(K - C_g)$$

$$\begin{aligned} \text{s. t.} \quad & p_b u(R - r_b + K) \ + \ (1 - p_b)u(K - C_b) \\ & \geq \ p_b u(R - r_g + K) \ + \ (1 - p_b)u(K - C_g) \end{aligned} \tag{10}$$

$$[p_g r_g + (1 - p_g)\beta C_g]N_g \ + \ [p_b r_b + (1 - p_b)\beta C_b]N_b \ \geq \ \rho(N_g + N_b) \tag{11}$$

$$r_h \ \leq \ C_h \qquad h = g, b \tag{12}$$

$$p_b u(R - r_b + K) \ + \ (1 - p_b)u(K - C_b) \ \geq \ V_b^0, \tag{13}$$

[23] The sustainable equilibrium is closely related to the *core*—the set of allocations that are simply unblocked. The core is empty in the cases in which the Rothschild-Stiglitz equilibrium does not exist—that is, the cases in which the Wilson equilibrium is a pooling allocation. It should be clear that the set of sustainable equilibria always contains the set of core allocations, when they exist, because the latter allows "easier" blocking. Townsend (1978) studies the core in a perfect information economy with fixed costs of bilateral exchange. There, intermediaries are required to overcome the nonconvexity. Interestingly, he describes a noncooperative game that allows contract proposals to include multilateral financial arrangements. The equilibrium of the noncooperative game attains the core allocation, thus bridging the gap between the game-theoretic and cooperative approaches. Boyd and Prescott (1986), Boyd, Prescott, and Smith (1988), and Marimon (1988) also study core-like equilibria in adverse selection environments. Given the definition of blocking, the core is the set of unblocked allocations. Unfortunately, the core is often empty in our economy, as it is in many adverse selection economies.

where

$$V_b^0 \equiv \text{MAX} \quad p_b u(R - r_b + K) + (1 - p_b)u(K - C_b)$$

$$\text{s. t.} \quad p_b r_b + (1 - p_b)\beta C_b \geq \rho$$

$$r_b \leq C_b.$$

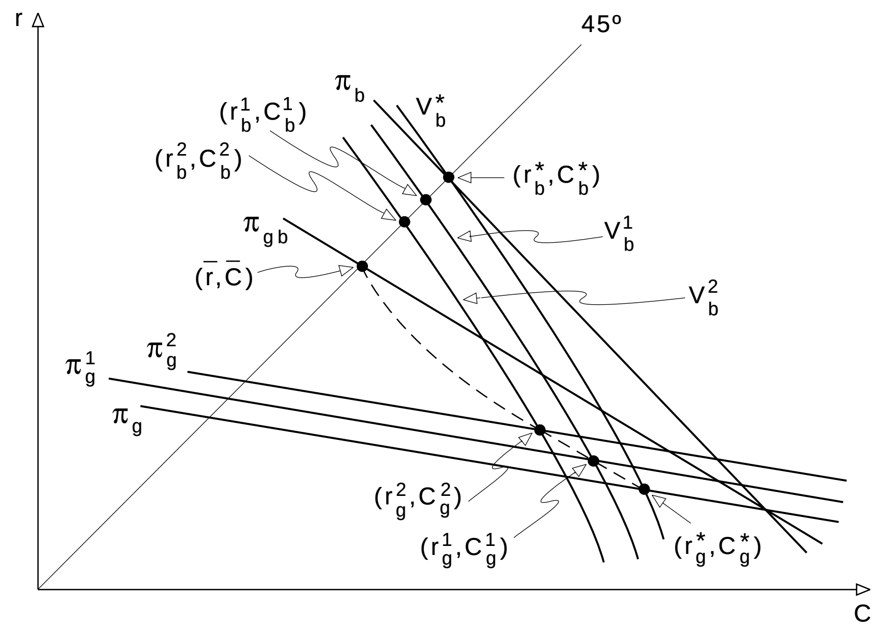
The Miyazaki Problem maximizes the expected utility of the good borrowers. The first constraint (10) states that bad borrowers have no incentive to pretend to be good borrowers. The second constraint (11) is just resource feasibility. The third constraint (12) ensures repayment incentives. The fourth constraint (13) states that the bad borrowers receive no less expected utility than V_b^0, the expected utility they would receive if they were on their own. V_b^0 is the maximum expected utility for bad borrowers under a contract that breaks even and respects the incentive constraint. It should be apparent that V_b^0 is equal to V_b^*, the expected utility under the Wilson equilibrium separating contract, (r_b^*, C_b^*) in Figure 3.

Hajime Miyazaki, in a 1977 paper in the *Bell Journal of Economics,* proposed that equilibrium be defined as solutions to an analogous problem in an adverse selection labor market economy. He argued that employers (analogous to lenders in our economy) are able to offer cross-subsidized wage-employment schedules, a situation he identified as an "internal labor market"—in other words, a multilateral financial arrangement. The "Miyazaki equilibrium," as it has come to be called, has been neglected in the adverse selection literature because cross-subsidization seemed hard to reconcile with a narrow conception of competitive behavior.

Using a few key properties of the sustainable equilibrium, there is a simple procedure that finds it. One important property is that bad borrowers receive contracts on the 45° line, minimizing the risk they bear and the collateral they transfer. Any other contract providing the same expected utility for the bad borrowers would use more resources and would thus make good borrowers worse off.

The first step in the procedure to find a sustainable equilibrium is to trace out the set of contracts that are feasible for the good borrower, shown as a dashed line in Figure 7. This set is constructed by varying the bad borrower's contract along the 45° degree line between (r_b^*, C_b^*), the separating Wilson equilibrium contract, and $(\overline{r}, \overline{C})$, the pooling contract on the 45° line. Start by taking the contract (r_b^*, C_b^*) for the bad borrower as given. Then the best possible contract for the good borrower is (r_g^*, C_g^*), where both the self-selection and the resource constraints bind. Now consider the contract (r_b^1, C_b^1) for the bad borrower, a short distance down along the 45° line from (r_b^*, C_b^*). Since (r_b^1, C_b^1) lies below π_b, the overall resource constraint is tightened; now contracts along π_g^1 are feasible for the good borrower. Because the bad borrower's self-selection

Figure 7 The Feasible Allocations

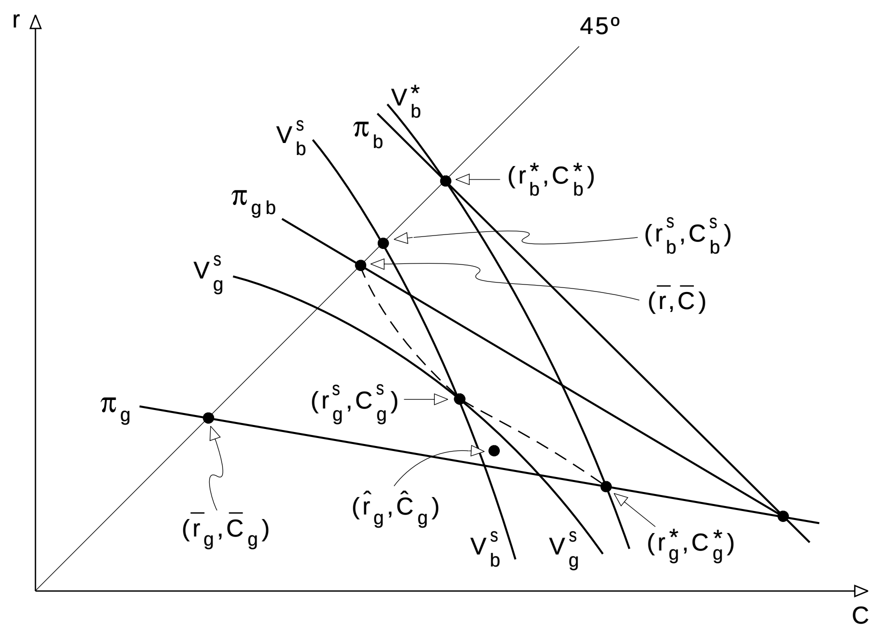


Notes: This figure shows the construction of the dashed line—the set of the best feasible contracts for the good borrower. Each point on the dashed line corresponds to a particular bad-borrower contract along the 45° line. For the bad-borrower contract (r_b^1, C_b^1), the best contract for the good borrower is (r_g^1, C_g^1), where the bad-borrower indifference curve V_b^1 intersects the break-even line π_g^1. Similarly, for bad-borrower contract (r_b^2, C_b^2), the best feasible contract for the good borrower is (r_g^2, C_g^2).

constraint is relaxed, the best possible contract for the good borrower is now (r_g^1, C_g^1), up and to the left of (r_g^*, C_g^*). Continuing this procedure for every bad-borrower contract between (r_b^*, C_b^*) and $(\bar{r}, \bar{C})$ traces out the dashed line, the set of the best possible good-borrower contracts for various levels of bad-borrower utility.

The second step is to select the contract along the dashed locus that maximizes the good borrower's expected utility; the associated allocation is the sustainable equilibrium. The best contract for the good borrower is shown as (r_g^s, C_g^s) in Figure 8, where the dashed locus is tangent to a good-borrower indifference curve. The bad borrower receives (r_b^s, C_b^s). Depending on the ratio of bad borrowers to good borrowers, the sustainable equilibrium could instead be at either of the endpoints of the dashed line. If the ratio of bad borrowers to good borrowers is relatively large (the range labeled "very high" in Table 1), the dashed line is very steep and the sustainable equilibrium is the set of

Figure 8 The Sustainable Equilibrium

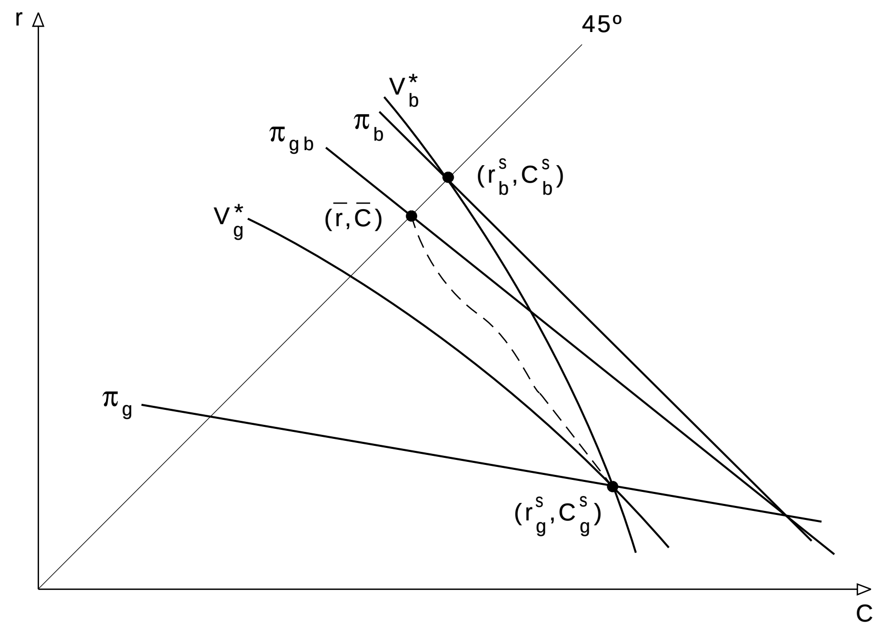


Notes: The contract along the dashed line that maximizes the expected utility of the good borrower is the sustainable equilibrium: (r_g^s, C_g^s). The associated contract for the bad borrower is (r_b^s, C_b^s). The contract $(\hat{r}_g, \hat{C}_g)$ for the good borrowers fails to credibly block the sustainable equilibrium because it in turn is credibly blocked by $(\bar{r}_g, \bar{C}_g)$, the sustainable allocation for the coalition of just good borrowers.

break-even separating contracts, the same as the Wilson separating equilibrium. This case is shown in Figure 9. If there are few bad borrowers (the range labeled "very low" in Table 1), the dashed line is relatively flat and the pooling contract on the 45° line is the sustainable equilibrium, the contract $(\bar{r}, \bar{C})$ in Figure 10. Table 1 summarizes the different types of sustainable equilibria for various values of the ratio of bad borrowers to good.

What prevents lenders from skimming off the good borrowers, offering a contract they prefer and which earns excess profits (a contract like $[\hat{r}_g, \hat{C}_g]$ in Figure 8)? Such a deviation lacks credibility because it does not meet the sustainability requirement defined above. If such a coalition were to form, it would consist entirely of good borrowers, but it would be vulnerable to the sustainable allocation for that coalition—the contract $(\bar{r}_g, \bar{C}_g)$ at the intersection of the good-type break-even line, π_g, and the 45° line. In other words, agents would anticipate that if the proposed deviation $(\hat{r}_g, \hat{C}_g)$ were to occur, it would itself be blocked by a subcoalition proposing $(\bar{r}_g, \bar{C}_g)$. Since the latter is

Figure 9 The Sustainable Equilibrium for N_b/N_g "Very High"



Notes: When N_b/N_g is very high, the dashed line is steep and the best contract for the good borrower lies at the lower endpoint. In this case, sustainable equilibrium is identical to the separating Wilson equilibrium and is Pareto-optimal, and financial intermediaries are unnecessary.

sustainable, that threat is credible and succeeds in blocking the cream-skimming deviation. There is no sustainable allocation that attracts the good borrowers away from the equilibrium contract (r_g^s, C_g^s). Attracting just the bad borrowers is unsuccessful, since any contract that they alone prefer earns negative profits. Finally, there is no pooling contract that would succeed in attracting the good borrowers, since every feasible pooling allocation gives them utility lower than V_g^s.

Government Intervention Is Never Pareto-Improving

The sustainable equilibrium is always Pareto-optimal. The Miyazaki Problem maximizes the expected utility of the good borrowers subject to resource, incentive, and self-selection constraints, and a participation constraint for the bad borrowers. No other feasible allocation yields higher expected utility for good borrowers without violating the bad borrower's participation constraint. The sustainable equilibrium is not necessarily the best possible allocation for the bad borrowers, but any other feasible allocation that provides higher expected

Table 1 Properties of Equilibria as N_b/N_g Varies

	Ratio of Bad to Good Borrowers, N_b/N_g				
	Very Low	**Low**	**Intermediate**	**High**	**Very High**
Wilson equilibrium	pooling, 45° line	pooling, 45° line	pooling, below 45° line, Fig. 4	separating, break-even, Fig. 3	separating, break-even, Fig. 3
Is the Wilson equilibrium Pareto-optimal?	yes	yes	no	no	yes
Can government intervention be Pareto-improving?	no	no	yes	yes	no
Sustainable equilibrium	pooling, 45° line, Fig. 10		separating, cross-subsidizing, Fig. 8		separating, break-even, Fig. 9
Is the sustainable equilibrium Pareto-optimal?	yes		yes		yes
Are financial intermediaries necessary?	no		yes		no

utility for the bad borrower must provide lower expected utility for the good borrower.[24]

Government intervention in whatever form it takes must respect the resource, incentive, and self-selection constraints of the environment. Since the sustainable equilibrium is Pareto-optimal with respect to those constraints, there are no allocations that the government can feasibly achieve that Pareto-dominate the sustainable equilibrium. In contrast, sometimes Wilson equilibrium allocations are not Pareto-optimal with respect to resource, incentive, and self-selection constraints; in exactly these cases government intervention can make all agents better off (see Table 1).

When Do Financial Intermediaries Arise?

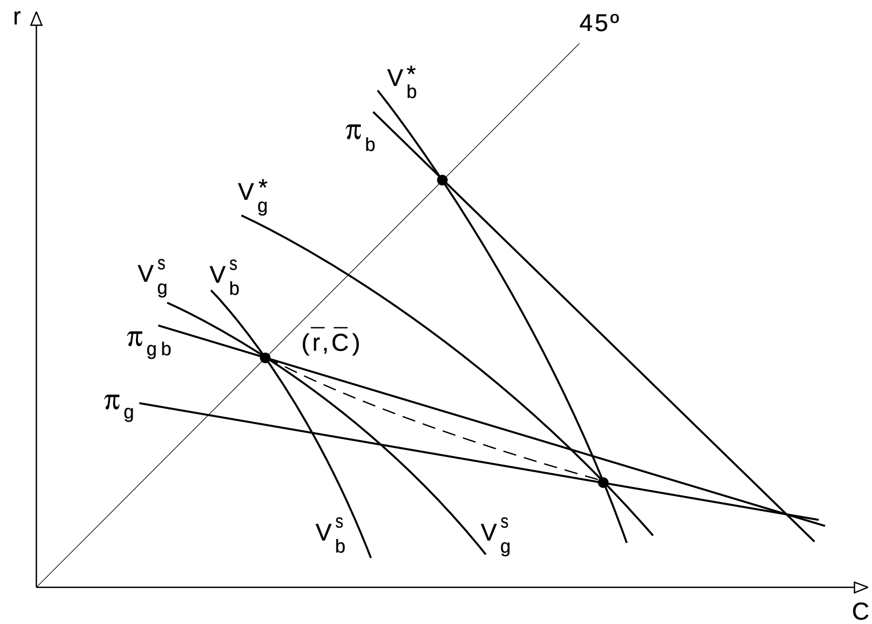
In some cases the sustainable equilibrium involves cross-subsidization across contracts. This occurs whenever the sustainable equilibrium is a pair of distinct contracts that do *not* lie on the individual break-even lines, π_g and π_b. In these cases the sustainable equilibrium is somewhere along the dashed line, as in Figure 8. When the ratio of bad to good borrowers is very high, the sustainable equilibrium is a pair of contracts that each break even, as in Figure 9; no cross-subsidization occurs in this case. When the ratio of bad to good borrowers is very low, as in Figure 10, the sustainable equilibrium is a single pooling contract and so cross-subsidization occurs.

Financial intermediaries are required whenever the sustainable equilibrium involves cross-subsidy across contracts. In this case a financial intermediary can break even on a portfolio of loans to both good and bad borrowers even though individual contracts do not break even; the bad contract earns positive expected profits while the good contract earns negative expected profits. Direct lending, with each investor making a single loan, is inconsistent with cross-subsidized contracts, since no lender would make a single loan earning negative profits. The allocation that *can* be achieved by direct bilateral lending, the Wilson equilibrium, cannot be a sustainable equilibrium in this case because it can be blocked by a financial intermediary offering contracts preferred by both borrowers.

For extreme values of the ratio of bad to good borrowers, financial intermediaries are not necessary to achieve the sustainable equilibrium. When the ratio is very high, each contract breaks even in the sustainable allocation. Individual lenders know they will break even on the borrowers that request the loans they offer. When the ratio of bad to good borrowers is very low, lenders offering the

[24] All of the allocations corresponding to contracts along the dashed line between the sustainable equilibrium and the pooling contract on the 45° line are Pareto-optimal. For a very high ratio of bad borrowers to good borrowers, as in Figure 9, all of the dashed line corresponds to Pareto-optimal allocations. For a very low ratio of bad borrowers to good borrowers, as in Figure 10, only the pooling contract on the 45° line is Pareto-optimal.

Figure 10 The Sustainable Equilibrium for N_b/N_g "Very Low"



Notes: When N_b/N_g is very low, the dashed line is relatively flat and the best contract for the good borrower is at the upper endpoint; both borrowers receive the contract $(\bar{r}, \bar{C})$. In this case, the sustainable equilibrium is identical to the Wilson equilibrium and is Pareto-optimal, and financial intermediaries are unnecessary.

pooling contract make excess profits on good borrowers and negative profits on bad borrowers. Lenders do not know which type of borrower accepts their loan, but if they believe that the probability that a given borrower is of a given type is the same as that type's representation in the population, then ex ante expected profits are zero.[25]

Financial intermediaries arise in all cases in which the Wilson equilibrium is *not* Pareto-optimal. This occurs for ranges of the ratio of bad to good borrowers labeled "intermediate" and "high" in Table 1. In these situations the Wilson equilibrium can be improved upon by government intervention. For the same reason government intervention is Pareto-improving, the Wilson equilibrium allocation is unsustainable because it is vulnerable to a financial intermediary offering a Pareto-improving set of contracts. Thus whenever the Wilson equilibrium suggests a role for government intervention, the sustainable equilibrium

[25] Note that financial intermediaries *could* be operative in this equilibrium, but they are not *required*.

suggests a role for financial intermediaries and no role for government intervention. The welfare-enhancing role of government intervention in the Wilson equilibrium is the direct result of restrictions that prevent the emergence of financial intermediaries.

4. CONCLUDING REMARKS

In this article I examined a single economy under two different definitions of equilibrium. The Wilson equilibrium assumes that agents interact by playing a specific four-stage game. Equilibrium allocations are often not Pareto-optimal under this definition of equilibrium, and a government tax/subsidy scheme can be Pareto-improving. Under the other equilibrium, agents are free to communicate and propose alternative arrangements, and outcomes are required to be sustainable in a certain sense. The sustainable equilibrium is Pareto-optimal and implies no welfare-enhancing role for government intervention. The sustainable equilibrium also gives rise to financial intermediaries, a widely observed phenomenon in loan markets. By contrast, conditions implicit in the Wilson equilibrium prevent intermediaries from playing any role. This observation suggests that the Wilson equilibrium, and others like it, are too restrictive and that models based on them are unreliable guides to policy. Thus, on the basis of these considerations, I conclude that adverse selection does *not* justify government intervention in loan markets. Intervention could, of course, be desirable on redistributive grounds.

One might wonder if the approach advocated here is somehow rigged to minimize the potential efficiency role of the government. The notion of sustainability places only minimal restrictions on agents' interactions. Does this approach give private agents an unrealistic capacity to coordinate their activities to achieve the best of all possible allocations? Are these assumptions Panglossian?

This is a legitimate question to raise. To put the question another way, Under what conditions would such an approach ever predict that government intervention is welfare-improving? One response is to give the models a normative rather than positive interpretation. In other words, treat the model as if it were telling us the best allocation. If we are confident the primitive assumptions on preferences, endowments, and technologies match well with the actual economy and we observe that the recommended allocation is not being attained, then government intervention to achieve the optimal allocation is warranted. The difficulty with this approach, however, is that without a positive model of why the observed allocation falls short of the one recommended by the economist, we can have little confidence that we have accurately identified all of the relevant impediments to trade. Without such confidence, we are forced to rely on ignorance or irrationality to explain out-of-equilibrium observations.

An alternative response is to view government intervention as a potential outcome, an endogenous component of the equilibrium multilateral arrangement. Indeed, in many models it is hard to distinguish between endogenous financial intermediaries and government-mandated reallocations. A rationale for government intervention would require a model in which government actions and private contracts are clearly distinguishable, perhaps in the methods of enforcing contracts. A case for government intervention could then be made if a plausible model predicted allocations that could not be achieved through private arrangements alone, but instead required identifiably governmental arrangements. I know of no such model at the present time that justifies government intervention in loan markets.

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