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Simple Rules for Monetary Policy*

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How effective are "simple" monetary policy rules at stabilizing the economy? This paper explores the characteristics and performance of monetary policy rules designed to minimize fluctuations in inflation, output, and interest rates using the Federal Reserve Board's large-scale FRB/US macroeconometric model. I find that a smoothed measure of inflation, the output gap, and the lagged funds rate are sufficient statistics for the setting of monetary policy. Efficient simple rules that respond to these three variables perform nearly as well as fully optimal policies that respond to the hundreds of variables in the model, and the simple rules are more robust to model misspecification. Efficient policies smooth the interest rate response to shocks and use the feedback from anticipated policy actions to stabilize inflation and output and to moderate movements in short-term interest rates. These results hold in a wide range of macro models but are sensitive to the assumption of rational expectations.

1. Introduction

This paper explores two key questions regarding the design and performance of efficient simple monetary policy rules. First, what are the basic features of efficient simple rules? In particular, to what variables should policy respond and by how much? Second, how well do simple rules perform compared to more complicated rules that respond to a larger information set? Or, in other words, what is the cost, measured in terms of stabilizing the economy, of following a simple rule when the best possible policy incorporates a wide range of information?

My approach to evaluating monetary policy rules follows in the tradition dating to Phillips (1954), where one computes a policy that minimizes the magnitude of fluctuations of a set of target variables based on simulations of a macroeconomic model. By the early 1970s, application of optimal control techniques to traditional macroeconometric models appeared to provide a precise answer to this problem, one that was based on a concrete description of policymakers' preferences and the law of motion of the economy. But, then this methodology came under attack from two sides, causing a fundamental reassessment of the approach to policy evaluations. First, Lucas (1976) decried the fact that the structural parameters of the macroeconomic models used for policy evaluation were assumed to be invariant to policy, contradicting the notion of optimizing agents. Second, Kydland and Prescott (1977) argued that the optimal policies are likely to be time inconsistent in that a policymaker would find it advantageous to deviate from the policy. During the past decade there has been a resurgence in research on the design and performance of monetary policy that has responded, at least partially, to these criticisms. In response to the Lucas critique, much of the recent research has been conducted using macroeconomic models that feature explicit optimization-based microeconomic foundations and rational expectations. In addition, research has tended to focus on "simple" policy rules such as the Taylor (1993a) rule in which the interest rate is determined by a small set of variables. Arguably, the transparency of simple rules may help the policymaker commit to the rule by increasing the visibility of discretionary policy actions and thereby reducing the incentive to deviate from the rule.[1]

Much of the research on monetary policy rules has been conducted using small- to medium-scale models. Because

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1. This argument was put forth by Currie and Levine (1985). Dennis and Söderström (2002) examine the magnitude of the stabilization bias resulting from the time inconsistency problem by comparing performance under optimal discretionary policies and under commitment to a simple rule.

these models contain only a small number of variables they provide little scope for an evaluation of the performance of simple vs. optimal rules. In this paper, I conduct my analysis using the Federal Reserve Board of Governor's large-scale FRB/US model that contains a far richer description of the determinants of output and prices than the small-scale models typically used for monetary policy evaluation. Optimal monetary policy in FRB/US responds to literally hundreds of inputs, including asset prices, foreign variables, and disaggregated spending, price, and labor market variables. In the past, the computational cost associated with solving and simulating such a large-scale rational expectations model was prohibitive, and policy evaluation was limited either to comparing small sets of policies in large-scale models, as in Bryant, et al. (1989, 1993) and Taylor (1993b), or to using small-scale models, as in Fischer (1977), Phelps and Taylor (1977), Taylor (1979), and Fuhrer (1997). Recent increases in computer speed and the development of more efficient model solution algorithms have made the detailed evaluation of monetary policies in large-scale rational expectations models such as FRB/US feasible.

Although the policymaker faces a complicated world in FRB/US, I find that simple policy rules perform nearly as well as more complicated or even fully optimal policies and that simple rules are more robust to model misspecification. A key characteristic of successful policies under rational expectations is a strong degree of persistence in movements in the federal funds rate. Efficient rules smooth the interest rate response to shocks and use the feedback from anticipated policy actions to stabilize inflation and output and to moderate movements in short-term interest rates. These results hold in a wide range of rational expectations macroeconomic models but are sensitive to the assumption of rational expectations.

The remainder of the paper is organized as follows. Section 2 presents a brief description of the FRB/US model. Section 3 analyzes the characteristics of efficient simple monetary policy rules in the model. Section 4 compares the performance of optimized simple policy rules to fully optimal rules. Section 5 then explores the robustness of these results to various assumptions. Section 6 concludes.

2. The FRB/US Model

FRB/US is a large-scale rational expectations two-country macroeconometric model that was developed by the staff of the Federal Reserve Board of Governors in the early 1990s as a replacement for the MPS model. Each period of time in the model corresponds to one-quarter of a year. The U.S. economy is modeled in considerable detail, while a small set of reduced-form equations is used for aggregate measures of foreign GDP, prices, and interest rates. The model's dynamic properties accord reasonably well with those of the data. For example, model impulse responses generally match those of small-scale VAR models, and model second moments are reasonably close to those of the data. For more detailed accounts of the model's design and properties, see Brayton, Mauskopf, et al. (1997), Brayton, Levin, et al. (1997), and Reifschneider, et al. (1999).[2]

In the model, households are assumed to maximize lifetime utility and firms are assumed to maximize the present discounted value of expected profits, subject to adjustment costs that hinder instantaneous adjustment of quantities following a change in fundamentals. The supply side of the economy is described by a three-factor (capital, labor, and energy) production function. GDP is disaggregated into more than a dozen categories of household, business, and government spending as well as trade. Tinsley's (1993) generalized adjustment cost model is used to capture the inertia evident in many categories of spending and labor inputs. This specification differs from the simple quadratic adjustment model in that it allows for the appearance of lagged growth rates in the estimated decision rules.[3]

The model's wage-price block contains separate equations for the prices for domestic output, consumption goods, crude energy, non-oil import goods, oil imports, and labor compensation. Price inflation is determined by the level of the markup of prices over factor (labor and energy) costs, recent past inflation, expected future growth in factor costs, and the expected unemployment gap (the difference between the unemployment rate and the NAIRU), with a positive unemployment gap putting downward pressure on prices. Labor compensation growth is determined by the level of the productivity-adjusted real wage, past compensation growth, expected future growth in prices and productivity, and the expected unemployment gap, with a positive unemployment gap putting downward pressure on compensation growth. The specification of price dynamics in FRB/US yields intrinsic inertia in the inflation rate, similar to that resulting from the staggered price model introduced by Buiter and Jewitt (1981) and empirically implemented by Fuhrer and Moore (1995), and the indexing assumptions used by Galí and Gertler (1999) and Christiano, et al. (2001). It contrasts with that of the staggered price-setting models of Taylor (1980) and Calvo (1983), and the quadratic adjustment cost model of

2. To take advantage of powerful computational methods, I have linearized the model equations; because the model's structure is already nearly linear, the linearization has little effect on the model's properties.

3. The dynamic specification is similar to that used by Fuhrer (2000) for consumption and by Christiano, et al. (2001) for investment.

Rotemberg (1982), each of which generates intrinsic inertia in the price level but not the inflation rate, in the absence of serially correlated shocks.

Overall, the FRB/US model can be characterized as a hybrid model that incorporates more intrinsic persistence in prices and output than "optimizing" rational expectations models such as those developed by Kerr and King (1996), Rotemberg and Woodford (1997), McCallum and Nelson (1999), and Clarida, et al. (1999), but significantly less intrinsic persistence than in traditional backward-looking models developed by Fair and Howrey (1996), Ball (1999), and Rudebusch and Svensson (1999). As such, it occupies the potentially instructive middle ground. Given the controversies regarding the specification of output and price dynamics, I explore the robustness of the results from FRB/US to different model specifications below.

Given the sluggish adjustment of prices, monetary policy influences the real short-term rate through changes in the nominal federal funds rate. Movements in the real federal funds rate affect real long-term rates, the real value of wealth, and the real exchange rate according to standard no-arbitrage conditions. In addition to the interest rate channel of the monetary policy transmission mechanism, spending by households and firms also depends directly on current income and cash flow, respectively, reflecting the effect of credit constraints consistent with the evidence from Carroll (1997) and Gilchrist and Himmelberg (1995).

3. The Characteristics of Optimized Simple Rules

I assume that the monetary policymaker's objective is to minimize a weighted average of the unconditional variances of the output gap (the percent deviation of real GDP from potential output), y, and the deviation of the annualized one-quarter personal consumption expenditure (PCE) price inflation rate, π, from a target level, π^*, subject to an upper bound on the unconditional variance of the nominal federal funds rate, r.[4] Specifically, the minimization problem is given by

$$\min \quad \lambda\sigma_y^2 + (1-\lambda)\sigma_{\pi-\pi^*}^2 \tag{1}$$

$$\text{s.t.} \quad \sigma_r^2 \leq k^2, \tag{2}$$

where $\lambda \in [0, 1)$, k^2 is the constraint on interest rate variability, and σ_x^2 is the unconditional variance of variable x. The numerical method of solving the model and computing the asymptotic variances of model variables is discussed in the appendix. If $\lambda = 0$, the policymaker places no weight on output gap variability; at the other extreme, when λ is nearly unity, the policymaker places virtually no weight on deviations of inflation from its target.

I adopt the constraint on interest rate variability in the policy objective because in the absence of such a limitation, the optimized monetary policy rules would generate wild swings in the funds rate with an unconditional variance of several hundred percent. The model itself imposes no restrictions on or costs to interest rate variability. However, there are a number of reasons why such highly variable short-term rates are likely to be highly undesirable in practice, and the ad hoc constraint on interest rate variability attempts to capture this. One problematic aspect of highly variable interest rates is the zero lower bound, which constrains how variable interest rates can be in practice (see Rotemberg and Woodford 1999). A second argument is that the term premium paid on bonds may be positively related to the variance in expected short-term rates, implying the existence of a long-run tradeoff between the volatility of short-term interest rates and potential output through the effect of the term premium on the cost of capital that is absent from the model (Tinsley 1998).[5] A third argument has a more political economic nature: Policymakers may wish to avoid reversals in the direction of policy out of the fear that such actions may be misinterpreted as "mistakes," which may eventually have consequences for central bank independence and credibility. Finally, the hypothesized invariance of model parameters to changes in policy rules is likely to be stretched to the breaking point under policies that differ so dramatically in terms of funds rate variability from those seen historically. Note that in this paper interest rate variability is measured by the variance of the *level* of the funds rate, as suggested by Rotemberg and Woodford (1999). The basic results from the FRB/US model reported in this paper are unchanged if interest rate variability instead is measured by the variance of the one-quarter *change* in the funds rate, as in Rudebusch and Svensson (1999), Levin, et al. (1999), and others.

I refer to the set of best obtainable pairs of the unconditional variances of the inflation rate and the output gap corresponding to the range of values of λ between zero and one as a "policy frontier," and refer to the policies that underlie these frontiers as "efficient" or "optimized" policies. By varying k, I can draw the three-dimensional surface that

4. The specification and parameterization of the policy objective in this analysis are admittedly ad hoc but are common to much of the literature on policy rule evaluation. In principle, the explicit treatment of household preferences in FRB/US enables one to evaluate monetary policy rules on the basis of consumer welfare, as in Ireland (1997), Rotemberg and Woodford (1999), Amato and Laubach (2001), and others. I leave the analysis of consumer welfare-maximizing monetary policies in the context of the FRB/US model to future work.

5. Similarly, extremely volatile interest rates may induce or exacerbate fragility in financial markets.

represents the constraints the model places on the policymaker in terms of the policy objectives of stabilizing inflation, output, and short-term interest rates. Note that my approach differs from a common practice found in the literature (for example, Rudebusch and Svensson (1999)) where interest rate variability is included directly in the policy objective. The advantage of my approach is that it allows me to plot frontiers in two-dimensional space.

Throughout the following, I assume that the federal funds rate is always set according to the specified policy rule and that the public knows the full specification of the rule. That is, I study policy under commitment. I also assume that private agents and the monetary policymaker have full knowledge of the model and observe all variables in real time.[6] Note that from time to time such policy rules will prescribe negative nominal interest rates. In this paper, I do not explicitly incorporate the non-negativity constraint on nominal rates in the analysis, but the efficient simple rules computed here lose little of their effectiveness if the non-negativity constraint is imposed even with an inflation target of zero, as shown in Reifschneider and Williams (2000).

The first step in evaluating simple policy rules is to choose the specification of the rule, that is, select the variables that determine the policy instrument, the federal funds rate. As shown by Svensson and Woodford (2003) and Giannoni and Woodford (2002), the fully optimal policy with a quadratic objective and a linear model can be described by a policy rule in which the federal funds rate depends only on leads and lags of the variables in the objective function. I start by limiting the rule to having three free parameters. In this case, a natural specification for a simple policy rule is one in which the nominal interest rate depends on some weighted moving average of the inflation rate, the output gap, and the interest rate. I assume policy responds only to current and lagged values of variables, but below I consider policies that respond to forecasts of future variables. I further restrict the analogues to rules that yield a unique rational expectations equilibrium. In practice, the model yields a unique solution for a wide range of values of θ_r and θ_y as long as θ_π exceeds about 0.04. See Levin, et al. (2003) for a detailed discussion of the determinacy conditions in this model.[7]

Experimentation within this class of three-parameter policy rules leads to the following specification:

$$r_t = \theta_r r_{t-1} + (1-\theta_r)(rr_t^* + \bar{\pi}_t) + \theta_\pi(\tilde{\pi}_t - \pi^*) + \theta_y\, y_t\,, \tag{3}$$

where rr^* is the long-run equilibrium real interest rate, $\bar{\pi}$ is the average inflation rate over the past year and $\tilde{\pi}$ is the average inflation rate over the past three years. The degree of policy inertia is measured by θ_r. Rules in which $\theta_r = 0$ are termed "level" rules because the level of the funds rate responds to the level of the output gap and the inflation rate (the Taylor rule and the Henderson-McKibbin (1993) rules are examples of this class). Rules with $0 < \theta_r < 1$ are said to exhibit "policy inertia." The special case of $\theta = 1$ is often termed a "difference rule" or "derivative control" (Phillips 1954). The case of $\theta_r > 1$ is termed "super-inertial policy" by Rotemberg and Woodford (1999).

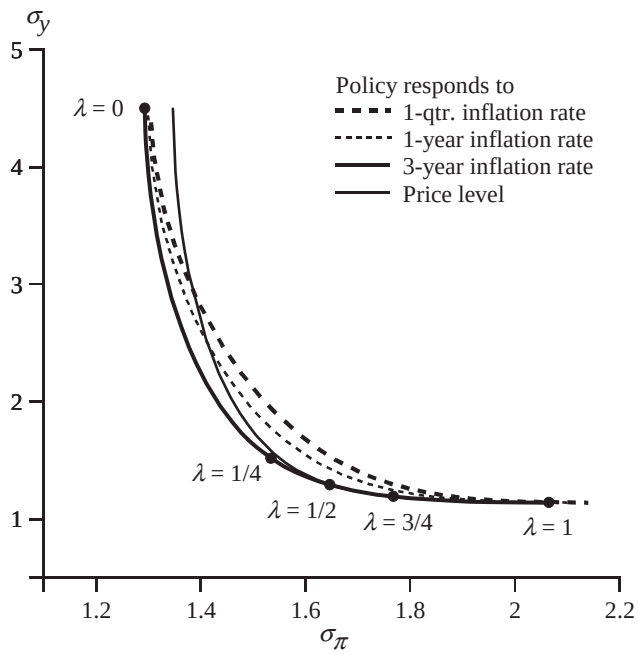
Although the policy objective is written in terms of the variance of the one-quarter inflation rate, the best-performing simple rule responds to the three-year average inflation rate that filters out high frequency noise. By contrast, in the literature, policy is assumed to respond either to the one-quarter inflation rate or the four-quarter inflation rate. I experimented with a range of measures of the inflation rate in the policy rule, including the annualized one-quarter inflation rate and the one-, two-, three-, and four-year average rates of inflation.[8] I also tried a variant of the rule in which the policy responds to the deviation of the price level from a predetermined target path, instead of the inflation rate implying that past deviations from the inflation target must be reversed. Figure 1 shows four representative policy frontiers corresponding to policy rules differing by the measure of inflation used. These frontiers are computed with the standard deviation of the funds rate constrained to be less than or equal to 4 (the constraint is binding in each case), which is about the historical average of the nominal funds rate in the postwar period. Reference values of λ are indicated for the frontier corresponding to frontier rules that respond to the three-year inflation rate.

6. Staiger, et al. (1997), Orphanides and van Norden (2002), Laubach and Williams (2003), and others have documented the difficulties in estimating the NAIRU, the output gap, and the equilibrium real interest rate, respectively. A number of authors, including Smets (1999), Orphanides, et al. (2000), McCallum (2001), and Rudebusch (2001, 2002), have investigated the effects of output gap uncertainty on the coefficients of simple policy rules. The results from this analysis suggest muting the response to the output gap but not eliminating it. Orphanides and Williams (2003) examine the implications of imperfect knowledge on the part of the public on efficient monetary policy rules.

7. Note that the "Taylor Principle," as described by Woodford (2003), which implies that for $\theta_y = 0$, stability is achieved for any $\alpha_\pi > 0$, does not strictly apply here because the specifications of the model and the policy rule differ from that analyzed by Woodford. Nonetheless, the stability condition in FRB/US is nearly the same.

8. I also experimented with different moving averages of the output gap. Policy rules that respond to a two-quarter moving average of the output gap or the lagged output gap performed worse than those that respond to the current gap.

Figure 1
Policy Frontiers and the Measure of Inflation in the Policy Rule



As seen in the figure, the frontier resulting from the rule that responds to the three-year inflation rate lies inside the other frontiers, indicating that it offers the best performance. These results are not sensitive to the particular value of the constraint on interest rate variability underlying this chart. Interestingly, the performance of optimized price-level targeting rules is nearly as good as rules that respond to inflation; in fact, in terms of *inflation* and output stabilization, such price-level targeting rules outperform rules that react to the one-year inflation rate for values of $\lambda > 0.1$.[9]

Starting from a frontier policy corresponding to a moderate amount of interest rate variability, further increases in interest rate variability yield modest stabilization benefits. Panel A of Figure 2 shows three policy frontiers, computed for values of $k = 3$, 4, and 6. As the constraint on interest rate variability is relaxed, the frontiers move slightly inward toward the origin. However, the incremental improvement in stabilization performance becomes progressively smaller as k increases.

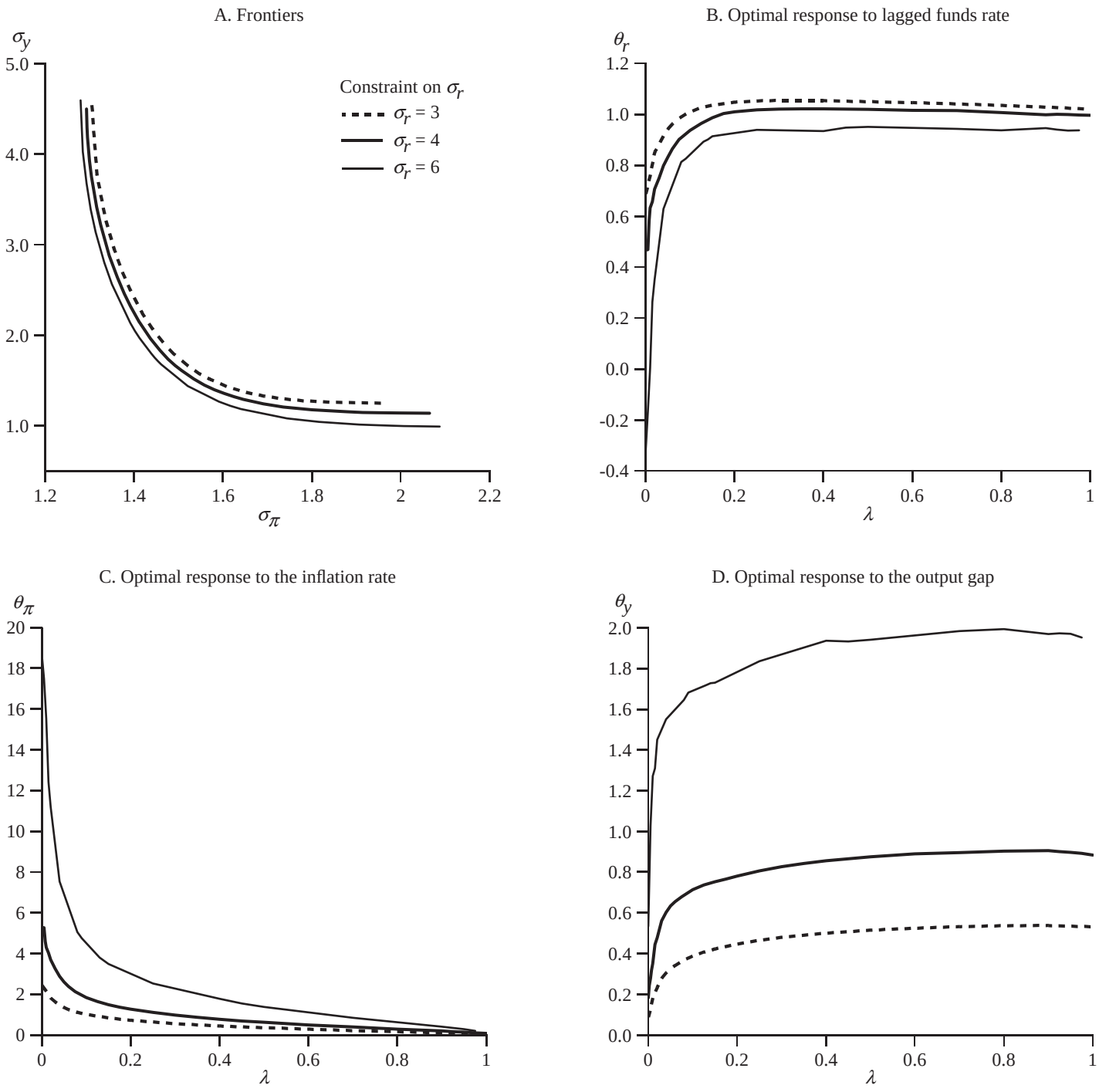
The most striking result regarding efficient policies is the large value of θ_r, the coefficient relating the current funds rate to last period's funds rate, for most values of λ and k. Panel B of Figure 2 shows the optimized values of θ_r for the range of values of λ and the three values of k. When λ is close to zero, the optimal value of θ_r is small or even negative. Evidently, in that case, the optimal response to an unwanted movement in inflation is to act quickly and aggressively with the funds rate. In all other cases, however, θ_r is very close to and in some cases exceeds unity. In such cases, the policy response to movements in the output gap and the inflation rate is initially modest but then grows in magnitude as long as the deviations from the target levels persist.

The result that efficient rules incorporate a great deal of inertia stems from the penalty on the variability of the short-term interest rate. The optimal degree of policy inertia, as measured by θ_r, declines as the constraint on interest rate variability is relaxed. Because the expectations theory of the term structure determines bond rates in FRB/US, a small but sustained rise in the funds rate achieves the same change in the current bond rate as a large but short-lived increase in the funds rate but with far less variability in short-term interest rates. Given the desire to avoid fluctuations in short-term rates, the efficient response to an undesired increase in output or inflation is to hold the funds rate at an elevated level for an extended period of time (Goodfriend 1991). This high level of policy inertia in optimized simple rules holds in a wide variety of rational expectations models in which output is determined by a long-term bond rate (Rotemberg and Woodford 1999, Woodford 1999, Levin, et al. 1999).

The optimized response to the output gap is very small when λ is near zero, that is, when the policymaker cares only about the variability of inflation; the response to deviations of the inflation rate from target, in contrast, is very large. As shown in the last two panels of Figure 2, as the weight on output variability rises, the optimized coefficient on the output gap rises and that on inflation declines. When the policymaker places nearly all weight on output gap variability, the optimized value of θ_π is the minimum value sufficient to assure a unique stable equilibrium. Not surprisingly, both the inflation and output gap coefficients increase as the constraint on interest rate volatility is relaxed. The upper bound constraint on interest rate variability is strictly binding for the values of k considered here (recall that in the absence of the constraint the optimized rule would entail a variance of the interest rate greater than 100), so an increase in k allows more vigorous responses to output and inflation.

9. See also Svensson (1999), who finds that price-level targeting can be more effective at stabilizing inflation and unemployment than inflation targeting if the monetary authority cannot commit to its actions in advance.

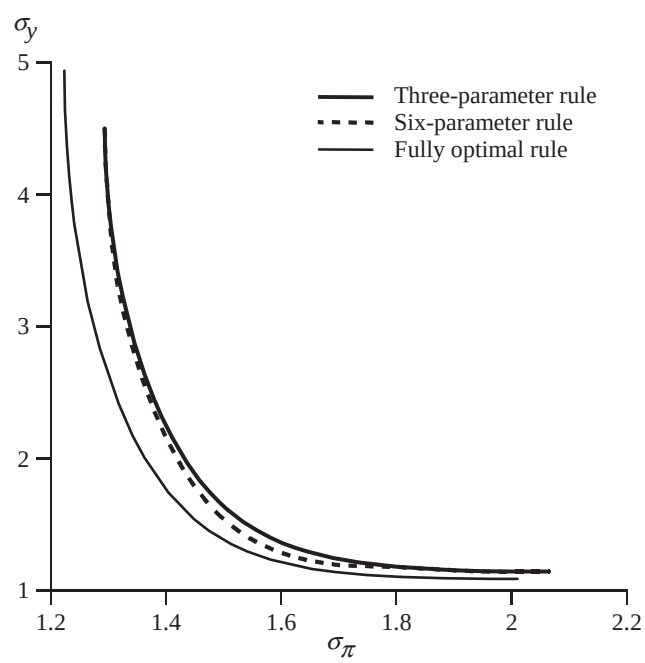
Figure 2
Policy Frontiers and Frontier Policies



4. The Relative Performance of Simple and Complicated or Fully Optimal Rules

The simple rules studied in the previous section ignore a large amount of information about the economy: FRB/US contains hundreds of variables representing prices and quantities in the goods, labor, financial, and foreign markets. Abstracting from the claimed benefits of parsimony in the specification of the policy rule, the cost to following a simple rule is the inability to take advantage of this information. There has been relatively little study of the magnitude of this cost, mainly because most monetary policy evaluation exercises usually take place using small-scale models for which a simple rule is optimal or nearly so by default. Levin, et al. (1999), Rudebusch and Svensson (1999), Dennis (2002), and Levin and Williams (2003) compare the performance of simple rules to that of more complicated or fully optimal rules in small- to medium-scale macro models. These studies typically find only small improvements in performance moving from simple three-parameter rules to complicated or fully optimal rules. However, these studies may underestimate the costs of following simple rules because they use models that understate the true complexity of the economic environment. Indeed, Finan and Tetlow (1999) compare simple rules to fully optimal policies using FRB/US and find larger losses in performance from following simple rules than in small-scale models.

Figure 3
Performance of Simple versus Complicated Rules



I first consider the performance of a more complicated policy rule that responds to six variables: two lags of the funds rate and the output gap, the current one-quarter inflation rate, and the three-year average inflation rate. The frontier resulting from this six-parameter rule, computed with $k = 4$, is shown by the dashed line in Figure 3; for comparison, the frontier resulting from the three-parameter rule is shown by the thick solid line. I repeated this experiment numerous times trying a wide range of variables in the policy rule, including stock prices, spending components, and the unemployment rate, and the result was always the same: moderately more complicated optimized rules yield only trivial stabilization gains over optimized three-parameter rules. Similarly, as shown in Levin, et al. (2003), including forecasts of inflation and output—which embody information on hundreds of variables in the model economy—yields only trivial stabilization gains in FRB/US over simple three-parameter rules based on current and lagged variables. In fact, in FRB/US the optimal forecast horizon for inflation is zero quarters and that for output is only two quarters.

Even if policy responds optimally to *all* the variables in the economy, the improvement in macroeconomic performance over the optimized three-parameter rule is still fairly small, with the reduction in the weighted average of output and inflation variances averaging only about 10 percent. The frontier corresponding to the fully optimal policy is shown by the thin solid line in Figure 3.[10] For a policymaker who cares only about inflation ($\lambda = 0$), moving from the optimized three-parameter simple rule to the fully optimal rule reduces the standard deviation of inflation by less than 0.1 percentage point. The difference in performance is about the same all along the frontier. With balanced preferences ($\lambda = 1/2$), the standard deviations of both output and inflation are less than 0.1 percentage point apart between the frontiers. And, for the policymaker who cares only about stabilizing output, switching to the fully optimal policy reduces the standard deviation of the output gap by less than 0.1 percentage point.

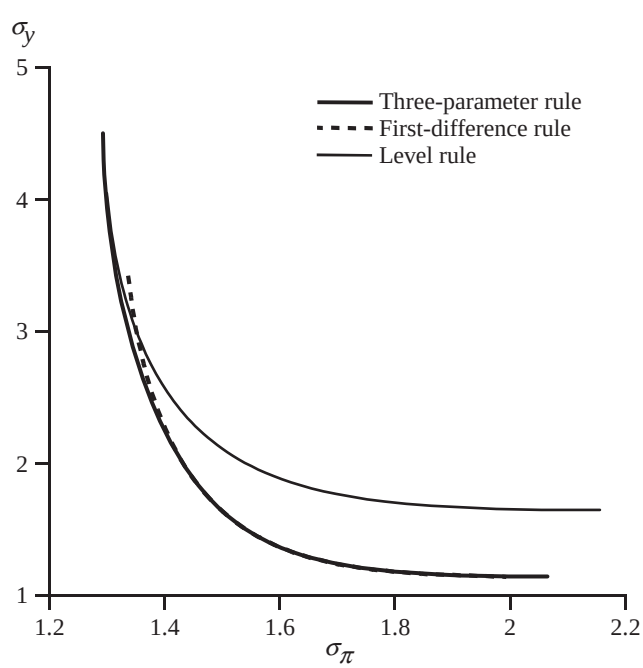
Why are the gains to adding more information to the policy rule so small? According to the FRB/US model, the lagged interest rate, the current output gap, and a smoothed measure of the inflation rate constitute sufficient statistics

10. I use the Finan and Tetlow (2001) procedure to solve for the fully optimal policy under commitment. This algorithm takes a mere four minutes on a personal computer equipped with a 1.2 Mhz Pentium III to solve the optimal policy and compute the associated unconditional moments for one value of policy preferences. Their method assumes a quadratic loss function which differs from my setup where frontiers are computed with a constraint on interest rate variability. To derive the frontiers, for a given value of λ, I computed optimal policies for a range of penalties on interest rate variability. I then interpolated the results to find the best point subject to the constraint on interest rate variability.

for setting monetary policy. Other variables generally are highly correlated with the three variables already in the rule and thus provide little additional information. In addition, the expectations channel assists simple rules in stabilizing the economy. Even if the policymaker does not respond immediately to all available information, the public knows that policy will respond to any deviations of inflation or output from target levels. Expectations of these future actions and their consequences help contain unwanted movements in inflation and output before the policy action takes place. For example, consider a disequilibrium increase in wages. Although the simple rule does not respond directly to this movement in wages, the knowledge that policy will respond to the ensuing increase in inflation causes bond rates to rise immediately, thus dampening output and inflationary pressures. In such instances, the expectations channel substitutes for a more complicated policy response.

The loss from simplifying the policy rule further by constraining the value of θ_r to equal unity is generally trivial, while constraining θ_r to zero can have somewhat more deleterious effects on macroeconomic performance. Figure 4 compares the frontier from first-difference rules where $\theta_r = 1$ to the three-parameter rule frontier. In both cases, the frontiers are computed under the constraint that $\sigma_r \leq 4$. The two frontiers differ by an imperceptible amount except where the policy objective places very little weight on the variability of the output gap. In such cases, the optimal value of θ_r is well below unity and the restriction causes a small deterioration in stabilization performance. The figure also shows the frontier for policies where θ_r is constrained to equal zero. Except for cases where λ is near zero, such "level" rules perform moderately worse than the three-parameter rules. For a policymaker who cares mostly about inflation variability, the level rules perform nearly as well as the three-parameter rules and slightly better than the first-difference rules.

Figure 4
Performance of Simple
Two- and Three-Parameter Rules



5. Robustness

A frequent criticism of model-based policy evaluation is that it is by its nature model-specific (McCallum 1988). Considerable uncertainty exists regarding parameter estimates and the appropriate specification of model equations. In this section I consider the robustness of the main results of this paper to alternative assumptions regarding the model.

The basic results about the characteristics and performance of simple rules presented above have been found to generalize to a wide range of rational expectations macroeconomic models. Levin, et al. (1999) examine the effects of different features of model design and specification by computing policy frontiers for FRB/US, the Fuhrer and Moore (1995) model, Taylor's (1993b) multicountry model, and the Monetary Studies Research model of Orphanides and Wieland (1998). Each of these models assumes rational expectations on the part of the public. The results from these other models confirm those from FRB/US. Indeed, a striking result is that simple frontier rules from FRB/US are found to be highly efficient in the three other models. Levin, et al. (2003) extend this analysis to include the New Keynesian model and show that the same characteristics and properties of optimal rules carry over to this model, which incorporates no intrinsic inertia in inflation and output. In all of these models, optimized simple rules incorporate a great deal of inertia, with the optimal value of θ_r near or above unity in many rational expectations models where there is a penalty on interest rate variability. Furthermore, Orphanides and Williams (2002) show that difference rules are less susceptible to mismeasurement of the long-run equilibrium real interest rate. Finally, as noted above, the finding that complicated or even fully optimal rules yield relatively small gains over simple policy rules is common to many estimated macro models.[11]

11. For example, as shown in Levin and Williams (2003), the optimized simple rule yields performance within 15 percent of the first-best in each of the three models.

Although simple policy rules have been found to be robust to model uncertainty, complicated policy rules and fully optimal policies tend not to be, as demonstrated in Levin, et al. (1999) and Levin and Williams (2003). Complicated rules and fully optimal rules are fine-tuned to the particular details of a model's specification. These details tend to differ across models, reflecting the uncertainty modelers face in specifying macroeconomic relationships.[12] This fine-tuning can be counterproductive when the details differ substantially across models. A concern for robustness argues against complicated or fully optimal policies, which even in the best circumstances yield small performance benefits over simple rules. The more basic features of how monetary policy affects inflation and output, however, are similar across the models, and as a result, simple rules tend to be more robust.

The finding that optimized policy rules exhibit considerable policy inertia, however, is sensitive to the assumption of rational expectations, that is, that expectations are consistent with the model structure and the policy rule in place. If expectations are backward-looking, as in the models of Fair and Howrey (1996), Ball (1999), and Rudebusch and Svensson (1999), the expectations channel is cut off. As a result, as demonstrated in Rudebusch and Svensson (1999), high values of θ_r are associated with poor performance and can even be destabilizing owing to the instrument instability problem where the gradualism in the policy response causes explosive oscillations in the economy. This outcome was noted first by von zur Muehlen (1995), who used a simple macro model to show that interest rate smoothing policy rules that are stabilizing if expectations are forward-looking can be destabilizing if inflation expectations are backward-looking. As shown in Levin and Williams (2003), policy rules that are robust to the assumption of backward-looking expectations are characterized by moderate policy inertia, with θ_r around 0.5.

6. Conclusion

In this paper, I evaluate monetary policy rules using the Federal Reserve Board's FRB/US model. I find that simple policy rules are very effective at minimizing the fluctuations in inflation, output, and interest rates. Although the policymaker faces a complicated world in FRB/US, rules that respond to large sets of variables yield relatively modest stabilization benefits over efficient simple rules. In addition, simple rules tend to be more robust to model uncertainty than complicated rules that are fine-tuned to a particular model's features. A key characteristic of successful policies under rational expectations is a strong degree of persistence in movements in the federal funds rate. Efficient rules smooth the interest rate response to shocks and use the feedback from anticipated policy actions to stabilize inflation and output and to moderate movements in short-term interest rates. These results are robust across a range of rational expectations models.

12. Currie and Levine (1985) make this argument but do not test it.

Appendix

Computing Unconditional Variances and Optimized Simple Rules

Much of the analysis of this paper involves computing unconditional second moments of aggregate variables. In order to make this computationally feasible, the model is log-linearized around sample means; the relevant dynamic properties of the model are virtually unaffected by this approximation. In its companion form, the linearized system is given by

$$E_t \sum_{j=-1}^{1} H_j x_{t+j} = Ge_t ,$$

where x_t is the vector of endogenous variables, and e_t is a mean-zero vector of serially uncorrelated random disturbances with finite second moments, $E(ee') = \Omega$. I estimate Ω using the equation residuals from 1966 to 1995. The information set for expectations formation differs across sectors; expectations in the financial sector incorporate knowledge of the current state of the economy, while expectations in the other sectors are based on information that is lagged one quarter.

One equation in this system corresponds to the monetary policy rule, described by a vector of parameters, θ. For a given specification of the policy rule, I solve for the saddle point rational expectations solution, if it exists, using the AIM algorithm developed by Anderson and Moore (1985). The reduced-form representation of the solution is given by

$$x_t = A_\theta x_{t-1} + B_\theta e_t ,$$

where the elements of the matrices A and B depend on the policy rule parameter vector θ. For notational convenience, I set all constants to zero so that the unconditional expectation of all variables is zero, $E(x) = 0$.

Given the reduced-form solution, I compute an approximation to the unconditional variance-covariance matrix for x, $V_\theta \equiv E(xx')$,

$$V_\theta = \sum_{j=0}^{\infty} A_\theta^j B_\theta \Omega B_\theta' A_\theta'^j ,$$

using the doubling algorithm of Hansen and Sargent (1998). This approach is more efficient at computing highly accurate answers than the standard method of stochastic simulations. Using a personal computer with an Intel Pentium III 1.2 Mhz processor, computation of the saddle path solution and the unconditional covariance matrix for a given policy rule takes about 20 seconds.

To compute optimized simple rules, I use a minimization routine that varies the rule parameters to minimize the weighted variances of the inflation rate and the output gap and 10,000 times the squared difference between the standard deviation of the interest rate and the specified value of k. Inclusion of this final term assures that the interest rate variability constraint is satisfied. The minimization routine takes between 20 minutes and 2 hours to compute a single point on the simple rule frontier. This compares to about four minutes to compute the fully optimal policy using the Finan and Tetlow (2001) procedure.

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Productivity Shocks and the Unemployment Rate*

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Productivity grew noticeably faster than usual in the late 1990s, while the unemployment rate fell to levels not seen for more than three decades. This inverse relationship between the two variables also can be seen on several other occasions in the postwar period and leads one to wonder whether there is a causal link between them. This paper focuses on technological change as the common factor, first reviewing some recent research on the effect of technological change on the unemployment rate and then presenting some empirical evidence on the issue. While theoretical models make conflicting predictions about the effects of a technology shock on the unemployment rate, the empirical evidence presented here shows that a positive technology shock leads to a reduction in the unemployment rate that persists for several years.

1. Introduction

The economy boomed in the second half of the 1990s, with output and productivity growing rapidly. At the same time, unemployment fell to levels that had not been seen since the 1960s, leading to concerns that inflationary pressures were likely to build and suggesting to some (especially early in the boom) that policymakers might need to take action to prevent an acceleration of inflation.[1]

One aspect of this boom that was hard to miss was the large role that was being played by changes in technology. For one thing, these changes made themselves felt in the explosive growth of things like computers, the Internet, and cellular phones. Accompanying this growth was a dramatic decline in the prices of these products, which underlined the role that technical change appeared to be playing during this period. These price declines may have helped to exert downward pressure on the aggregate inflation rate as well; in any case, there was little evidence to suggest that inflation was picking up even after several years of rapidly growing output and record low unemployment.

This combination of circumstances led other observers to suggest that the "new economy" had a new "speed limit." More specifically, these observers suggested that because of technical change the economy could grow faster or operate at lower unemployment rates without experiencing higher inflation. Thus, they argued, there was no need for monetary policymakers to tighten policy.

While the subsequent recession put an end to the debate about whether policy needed to be any tighter (as policymakers began to worry about rising unemployment and falling output), it did little to answer the underlying question of how policy should react to a technology-driven boom. The appropriate response obviously depends upon how the effects of technical change make themselves felt in the economy. For instance, one possibility is that rapid technological change leads to a reduction in inflation independent of the prevailing unemployment rate. In this case, a return to unemployment rates that prevailed in the late 1990s without a pickup in the pace of technical change seen during that period would tend to be accompanied by a pickup in inflation. Another possibility is that improvements in technology lead to a permanently lower unemployment rate, in which case we could see a return to low unemployment in the near future without any pickup in inflation. Yet another possibility, which is incongruent with the U.S. boom of the 1990s but which cannot be ruled out a priori, is that rapid technological change destroys the job skills of some types of workers and leads to long-term unemployment for them. This would tend to raise the unemployment rate and to change the relationship between the unemployment rate and inflation as well.

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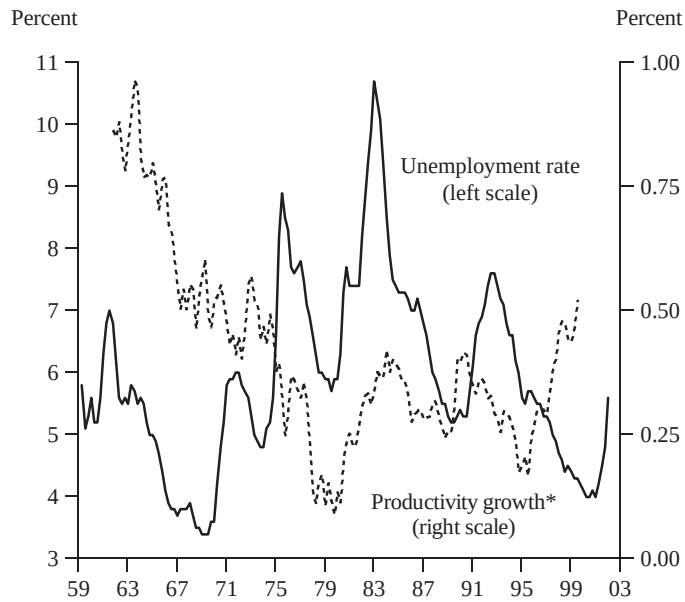
1. Such a relationship is implied by the Phillips curve, as discussed, for example, in Mankiw (1992). According to Mankiw, the inflation rate depends on (among other things) "the deviation of unemployment from the natural rate, called *cyclical* unemployment" (p. 303). Thus, the concern in the second half of the 1990s was that cyclical unemployment had fallen too low, which would cause the inflation rate to go up. Also see Ball and Mankiw (2002).

This paper attempts to shed some light on this issue by focusing on what effects productivity shocks are likely to have on the unemployment rate. It seems useful to start by looking at the historical relationship between productivity and unemployment, which is shown in Figure 1. As mentioned above, during the 1990s the unemployment rate fell to levels that had not been seen for three decades. At the same time, productivity grew faster than it had at any time since the 1960s. More importantly, the figure reveals that this is not the only time that one can see such a pattern. Thus, the 1960s were a period of high productivity growth and relatively low unemployment as well. The same relationship can be seen in the 1970s, except that unemployment was rising while productivity growth languished. While some of the observed correlation is obviously short-run in nature, the evidence suggests that there is a long-run relationship between the two series as well. Stock and Watson (2001), for instance, construct measures of the trend (or long-run) components of unemployment and productivity growth and show that they are negatively related.

These comovements between the two variables suggest that there may be a causal relationship between them. This paper focuses on the causation running from (exogenous) changes in productivity to unemployment.[2] It begins by reviewing a theory of unemployment in Section 2 and goes on in Section 3 to discuss recent research that has made use of this theory to explain how changes in productivity can affect the unemployment rate. In Section 4 it discusses some other models that use changes in productivity to explain changes in the unemployment rate. This is followed by a discussion in Section 5 of the relatively limited empirical evidence on the issue. The paper then goes on to present some new estimates of the effects of productivity shocks on both the economy-wide unemployment rate and the unemployment rate of workers with different education levels. Section 6 concludes.

Figure 1
Productivity Growth and Unemployment



*Centered 5-year moving average.

2. The Search Theory of Unemployment

Since much of the recent research on the relationship between productivity growth and unemployment is based on the search theory of unemployment, it is useful to begin with a simple overview of this theory. It starts with the assumption that workers have different skills and jobs have different skill requirements. Workers need to find desirable jobs at the same time that firms need to find the most productive workers. Neither firms nor workers have all the information they need about the options available to them, so they must engage in search. Since search is costly and time-consuming, both firms and workers must use some of their resources to find a good match.

Workers are assumed to search only when they are unemployed. They face an uncertain environment (just as firms do). When a worker gets a wage offer, for instance, she must decide whether to accept it or continue searching for a better offer. Accepting the offer means forgoing the chance of a higher wage offer later, while continuing the search means losing the wages she would have earned if she had accepted the offer and started working. The wage at which the worker is indifferent between continuing the search and accepting the current job is called the "reservation wage." The worker accepts all job offers above this wage and rejects all offers below it.

When a search is successful, that is, when there is a match between the needs of the worker and the firm, the worker leaves unemployment. However, existing matches sometimes fall apart, which leads to workers becoming unemployed. At the equilibrium unemployment rate, the number of workers leaving unemployment equals the number of workers becoming unemployed. The equilibrium unemployment rate moves around over time; it is often argued, for instance, that the equilibrium unemployment rate went up in the 1970s because a large number of workers with little or no experience entered the labor force.

2. Unemployment rates could have an effect on productivity as well. For instance, it has been argued that the unemployed tend to lose skills and become less productive. While this is a reasonable hypothesis, it is not obvious that it can be used to explain changes in economy-wide productivity levels over time.

The relative level of the reservation wage is obviously a crucial determinant of the level of unemployment in the economy. If the typical worker's reservation wage is significantly higher than the typical wage offer, she will tend to turn down more offers and spend more time searching for a job. Consequently, the unemployment rate will tend to be higher.

The wage offered by the firm is directly related to the worker's productivity. Assume, now, that there is an economy-wide increase in productivity that workers are not aware of. The higher productivity makes it more attractive for the firm to increase employment and allows it to do so by increasing the wage it offers to workers. This, in turn, increases the likelihood that the average worker will find an acceptable job offer and reduces the time she is likely to spend searching. Thus, the unemployment rate will decline in response to the increase in productivity.

This drop in the unemployment rate is unlikely to be permanent, however, even if there is no decrease in productivity. This is because workers will come to realize that all firms are offering higher wages than before and, consequently, their reservation wage will adjust gradually to the higher level of wage offers in the economy. As this occurs, the level of unemployment gradually will go back to the level that prevailed prior to the increase in productivity. Of course, the reservation wage could adjust slowly, and so it could take a while for the unemployment rate to return to its original level. Even so, the key implication is that a change in the level of productivity cannot have a permanent effect on the level of the unemployment rate. We now turn to a discussion of how recent research has used elements from this story to explain the recent behavior of the unemployment rate.

3. Models with Homogenous Labor

Ball and Moffitt (2001) present a variation on the process described above to explain the decline in unemployment in the second half of the 1990s.[3] Instead of reservation wages, they conduct their analysis in terms of "aspiration wages," which is defined as wages that workers consider to be fair. Research by Akerlof and Yellen (1990), for instance, shows that workers are likely to reduce the amount of effort they put in on the job if they perceive the wages they receive to be unfair. However, it is hard to come up with an operational definition of "fair wages," especially when one is dealing with aggregate data. Ball and Moffitt assume that workers use past wages to determine fair wages. As a consequence, an increase in the rate of productivity growth does not show up as an increase in the aspiration wage at once and so leads to an increase in employment and a fall in the unemployment rate. As the aspiration wage adjusts to the increase in productivity, the unemployment rate rises back up.

In Mankiw and Reis (2001), the target nominal wage depends upon the price level, productivity, and employment. One way to motivate this relationship is from the standpoint of a union that sets a target for the real wage depending upon productivity but also varies its demand in response to the level of employment in the economy. The crucial assumption in their model is that the target wage is set using less-than-perfect information. It takes time and effort to collect and process information, so individuals update their decisions gradually over time. It is important to distinguish this approach from another closely related approach that is more common in the literature, which assumes that it is costly to change wages (or prices). Under the Mankiw-Reis assumption, firms are free to change prices every period. Thus, faced with an annual inflation rate of 4 percent, they could decide to change wages by 1 percent every quarter (or as often as they wished). However, if the inflation rate unexpectedly drops to 3 percent, firms will take a while to detect this change and to alter the rate by which they change prices every period.

Consider what happens in this model when there is an increase in the rate of growth of productivity. Under the authors' assumptions, it will take a while for the target wage to catch up to this increase. Higher productivity implies higher output even if employment were to remain unchanged. However, employment rises as well because firms find that they can get more output per worker but do not have to pay workers any more than before. Prices fall as firms pass on the lower costs to customers. Of course, the target wage does adjust at some point. Note that this wage is subject to two influences: the increase in productivity will push it up, while the fall in prices will push it down. Under certain conditions, it is possible for these two influences to offset exactly so that the target wage stays at the level needed to maintain full employment.

While these papers focus on the effects of a slowly adjusting reservation wage, Pissarides (2000) emphasizes a different mechanism, one that causes the equilibrium unemployment rate to decline in response to an increase in the rate of technical change. He points out that a firm's decision to hire a worker involves balancing the costs of hiring that worker against the profits that will accrue once the worker is hired. The hiring costs are incurred now while the profits are realized over time. Other things equal, an in-

3. The ultimate aim of the Ball and Moffitt paper is to use the change in productivity growth to explain why inflation stayed low in the late 1990s even though the unemployment rate fell to unusually low levels. See Grubb, et al. (1982) for a similar explanation of the stagflation of the late 1970s.

crease in the trend rate of growth raises future profits and makes it attractive to increase hiring today. Thus, an increase in the trend growth rate will lead to a decrease in unemployment, while a decrease in the trend growth rate will lead to an increase in unemployment. As the increase in future profits implies an increase in the present value of the job, this is known as the "capitalization effect."

Aghion and Howitt (1998) point out that technological progress tends to destroy old jobs at the same time that it creates new ones. Thus, it creates the need for workers to move across jobs. An increase in the rate of technological progress leads to an increase in the pace at which worker skills as well as jobs embodying specific technologies become obsolete, which leads to an increase in the rate at which worker-firm matches are broken up. As a consequence, frictional unemployment goes up, in contrast to Pissarides.

Mortensen and Pissarides (1998) show that either of these results can be obtained depending upon what one assumes about the cost of adopting new technology. Firms are assumed to lock in the existing technology when they create a new job. Because of technical progress, the technology embodied in a particular job becomes obsolete over time. The firm then must choose whether to spend the money to update the technology in the existing job (which may involve retraining the worker) or to destroy the job. If updating costs are prohibitively high, the firm will choose to destroy the job; in this case, faster technical progress (which makes existing capital obsolete faster) leads to greater job destruction. Note that because job creation and destruction depend upon job updating costs, which are likely to vary by firm and by industry, the model does not provide an unambiguous prediction about the relationship between economy-wide productivity growth and unemployment in the data.

One way an improvement in technology would lead to an unambiguous reduction in the equilibrium unemployment rate is if it led to a permanent increase in the rate at which searching firms and workers "find" the right match. This is exactly what Gomme (1998) suggests that the Internet has done. Firms now routinely post vacancies on the Internet so that workers can look for jobs in multiple (perhaps remote) locations at almost no cost. Saving (2000) notes that several million resumes are now online and that the Internet is available to roughly half the U.S. population. At this point in time, though, the Internet has not been around long enough to allow economists to measure the magnitude of this effect.

Some other authors have focused on the effect of anticipated changes in technology on the unemployment rate. In Phelps (1999) and Phelps and Zoega (2001) an anticipated improvement in technology tends to lower the unemployment rate temporarily. In earlier work (see Phelps 1994), Phelps has argued that the value of firms' assets (which include physical capital as well as employees and customers) is the proximate force driving the demand for labor. In more recent work, he discusses how changes in productivity can affect firm valuations. After defining a structural boom as a wholly, or largely, temporary expansion in employment (which is not caused by aggregate demand), the argument proceeds as follows. The starting point of the boom is "the unanticipated arrival of the *prospect* of new opportunities for profitable use of capital beginning at some point in the medium-term future, perhaps several years ahead" (Phelps and Zoega 2001, p. 93). Entrepreneurs realize that the jump in productivity will increase the return on their assets in the future, which, in turn, raises the value of their assets today without raising the cost of acquiring them. Thus, firms engage in anticipatory investment including the hiring of more workers. When, and if, the anticipated productivity jump materializes, the cost of investment in workers and equipment goes up (for instance, the value of labor in other uses is raised) and investment and employment fall off. Thus, the news of an increase in productivity sometime in the future leads to a boom in the economy, which dissipates (perhaps gradually) once the productivity increase materializes. Since the stock market reflects changes in the valuation of the firm (though not, perhaps, the change in the valuation of a job, which is the key variable here), the empirical analysis the authors conduct focuses on the relationship between the unemployment rate and the stock market.

Specifically, Phelps and Zoega present results from a multicountry study of the relationship between unemployment and lagged values of the stock market. (Recall that the stock market is hypothesized to go up following news of a future increase in productivity.) Using data over the 1960–1999 period for the G-7 (excluding Japan) as well as six other OECD countries, they show that there is a negative relationship between the unemployment rate and share prices which are normalized by productivity.

By contrast, Manuelli (2000) argues that an anticipated improvement in technology is likely to lead to a long-lived (but not permanent) increase in the unemployment rate. In his model, an anticipated (but not yet realized) improvement in technology reduces the market value of existing firms, which causes firms to cut back on investment and job creation.[4] New firms are unwilling to enter at this time as well, because doing so would mean that they would have to adopt a technology that soon would become obso-

4. See Greenwood and Yorukoglu (1997) for an early statement of the hypothesis that the productivity slowdown in the 1970s and the acceleration during the 1990s were part of the same phenomenon.

lete. Thus, investment and job creation go down and the unemployment rate goes up. Once the new technology becomes available, firms begin to increase investment and create more jobs, causing the unemployment rate to fall. Manuelli argues that stock markets fell and unemployment rose in the mid-1970s partly because markets realized that new technologies were coming that would make existing ones obsolete. These new technologies (relating to computers and information technology) began to mature sometime in the 1980s, causing unemployment to fall and productivity to rise over time. Thus, his paper links both the increase in unemployment in the 1970s and the decrease in unemployment in the 1990s to an exogenous change in technology. His model does not predict a productivity slowdown in the 1970s, though others have proposed similar models that do.

Galí (1999) also presents a model in which positive productivity shocks lead to temporary declines in worker hours (and, by implication, in employment), although the negative effect here is much shorter lived than the one in Manuelli's paper. Prices are assumed to be sticky and aggregate demand depends upon the amount of real money balances in the economy. In addition, it is assumed that the monetary authority does not vary the money supply in response to technology shocks—so that aggregate demand is unchanged.[5] Since neither aggregate demand nor prices can be varied in response to the technology shock, firms respond by reducing the number of worker hours that they employ to produce the same amount of output as before. In the next period, when they are free to adjust prices, they reduce them; output and worker hours go up as a consequence. Galí also presents empirical evidence consistent with this hypothesis. Using a number of different specifications and data for the U.S. over the 1948–1994 period, he shows that a positive technology shock leads to an increase in productivity but a temporary decrease in worker hours.[6]

For our purposes the key question is whether the positive technology shock will cause unemployment to go up as well. In terms of the theory, the answer depends upon how workers are assumed to respond to the higher productivity. Wen (2001) shows that the positive income effect arising from a positive technology shock can lead to a decrease in labor supply (i.e., a withdrawal from the labor force) under fairly general conditions. A similar effect is present in one of the models in Francis and Ramey (2002). The net effect on unemployment then will depend upon the size of this effect relative to the decrease in labor demand emphasized by Galí. The issue of the empirical relationship is addressed below.

To sum up the discussion so far, positive productivity shocks tend to lower unemployment in the short run to the extent that the reservation wage tends to adjust slowly to changes in productivity (as argued by Ball and Moffitt as well as by Mankiw and Reis). But there are other channels in play as well, and here the effects are not so clear-cut. Phelps and Zoega argue that news of a future increase in productivity can cause investment and employment to increase and unemployment to fall in the short run; however, Manuelli argues the opposite. Galí argues that positive technology shocks lead to a temporary contraction in the demand for labor. The effect on the unemployment rate is not unambiguous; it could go up as a result but may not if labor supply contracts by more than demand, as pointed out by Wen. The long-term effects of changes in the rate of productivity growth appear to be even more ambiguous. As Mortensen and Pissarides point out, the net effect depends upon firm- or industry-specific variables such as the cost of updating a job. Of course, to the extent that technological change affects the process of search directly (as some have argued the Internet has done), predictions are easier to make: lower search frictions should lead to lower unemployment.

4. Models with Heterogeneous Labor

The models we have looked at in the previous section have involved a fairly high level of aggregation and, in particular, have ignored heterogeneity across the labor force. In models with different kinds of labor, technology (and other) shocks may be more likely to raise unemployment in the short run than in single sector models, often because in these models both firms and households must search harder to make the right match.

Acemoglu (1998) presents a model in which an increase in technology or the skill level of the labor force "splits" an economy with homogenous jobs into one with jobs that require different levels of skills and pay different levels of wages. In his model, firms make irreversible decisions about capacity (that is, about the amount of physical capital) before hiring labor; these decisions are meant to repre-

5. The assumption about monetary policy is not innocuous. Dotsey (1999) shows that if the monetary authority is assumed to follow the rule estimated in Clarida, et al. (2000), positive technology shocks lead to an increase in both productivity and employment in the same model in which Galí's assumption of exogenous money supply leads to a negative correlation between the two variables.

6. Galí's analysis has led to considerable debate about whether technological shocks do, in fact, reduce labor input. Basu, et al. (1999) show that technology shocks reduce input use and, in particular, labor hours upon impact, using annual data and a methodology that is very different from that used by Galí. By contrast, Shea (1998) finds that technology shocks tend to increase input use in the short run and lower it in the long run. Using Galí's identification condition, Francis and Ramey (2002) find that technology shocks do reduce labor hours, while Altig, et al. (2002) find that they do not.

sent the choices firms make about the type of business to run and the types of jobs to create. There are two kinds of workers: high-skilled and low-skilled. The search process is random; for instance, low-capacity and high-capacity firms are equally likely to meet high-skilled workers. Upon meeting, firm-worker pairs decide whether to enter into an employment agreement or to continue the search for a new partner.

Different types of equilibria are possible in this model. In a "pooling" equilibrium both high-skilled and low-skilled workers do the same kind of job (in the model this means that they work with the same amount of capital). It is profitable for the firm to offer the same kind of job to all workers if the productivity differential between the two kinds of labor is small. In this equilibrium, low-skilled workers work with a greater amount of capital relative to the level of their skills than do high-skilled workers, and wage differentials are small. In a "separating" equilibrium firms create separate jobs for high-skilled and low-skilled workers. High-skilled workers work with more capital than low-skilled workers, so the ratios of physical capital to human capital in the two kinds of jobs are equalized. High-skilled workers earn more than they would in the pooling equilibrium, while low-skilled workers earn less. Thus, the dispersion of wages is higher under the separating equilibrium. Unemployment is higher as well, because high-skilled workers prefer to keep searching until they find the job that is right for them while firms that have a large amount of physical capital refuse to hire low-skilled workers. There also exist equilibria in which the unemployment rates of low-skilled workers go up by more than those of high-skilled workers.

If technical progress is skill biased (which means that it raises the productivity of high-skilled workers relative to that of low-skilled workers), it can push the economy from the pooling equilibrium to the separating equilibrium. In other words, technical progress can be accompanied by rising wage dispersion and rising unemployment.[7] According to Acemoglu, his model provides an explanation for the labor market patterns observed in the U.S. in the 1970s and 1980s, which include falling wages for low-skilled workers, rising unemployment rates for all workers, and a change in the composition of jobs in the economy.[8]

Blanchard and Katz (1997) discuss another reason why technical progress may raise the unemployment rate in a world with heterogeneous labor. They postulate that low-skilled workers are paid a wage that is very close to their reservation wage, while high-skilled workers are paid a wage that is substantially above their reservation wage. Consider, now, what would happen if there were a shift in technology that raised the demand for high-skilled workers but reduced the demand for low-skilled workers. The supply curve for low-skilled labor is relatively flat, which means that the inward shift of the demand curve will lead to a relatively large increase in the unemployment rate for those workers. By contrast, the supply curve for high-skilled labor is relatively steep, which means that the increase in demand will lead to a relatively small decrease in the unemployment rate for those workers. As a consequence, the overall unemployment rate will go up.

Baumol and Wolff (1998) focus on the costs of learning and argue that an increase in the rate of technical progress implies that workers will have to be retrained and plants will have to be retooled more often. Workers will be unemployed while plants are being retooled. Further, because older workers are harder to train than younger ones, the hypothesized adverse effects of faster technical progress should be more evident in older cohorts.

Using multivariate regressions, the authors show that the mean duration of unemployment is positively related to productivity growth over the previous five years. In addition to a measure of productivity (and other variables), their regressions also include investment in office, computing, and accounting equipment. This variable is positive and statistically significant in all regressions as well. In other words, the mean duration of unemployment goes up when investment in high-tech equipment goes up. They go on to repeat their regressions by age group and gender and show that the coefficients associated with both productivity growth and investment in high-tech equipment become larger as the age of the worker increases. The effects of these variables do not depend upon the gender of the worker. Overall, then, their evidence is consistent with the hypothesis that older workers will be more (adversely) affected by technical progress because they are harder to retrain.[9]

Mincer and Danninger (2000) conduct some tests on the effects of technological change on unemployment that explicitly account for differences in worker skill levels. Using annual data over the 1970–1995 period, they show

7. An increase in the size of the high-skilled labor force can have the same effect, as it can make it more profitable for firms to create different kinds of jobs.

8. A related literature looks at how technical change may have affected the wages of high-skilled workers relative to those of low-skilled workers; see, for instance, Greenwood and Yorukoglu (1997) and Krusell, et al. (2000). These papers say little, if anything, about the unemployment rate.

9. Changes in the relevant surveys over time have led to changes in the measures of duration used by the authors. See Abraham and Shimer (2001) for a discussion of these changes, as well as for a discussion of other factors affecting duration.

that technical progress leads to a contemporaneous increase in the unemployment rate of low-skilled workers *relative* to that of high-skilled workers.[10] This finding is robust to the use of four alternate measures of technical change: total factor productivity growth, the number of computers per worker, research and development expenditures per worker, and computers as a fraction of total capital equipment. Interestingly, they find that this effect is reversed after five years; according to them, the reversal represents a labor supply response to the initial change in the relative unemployment rates.[11]

Turning to the aggregate unemployment rate, Mincer and Danninger find that an increase in any of their four technology variables leads to a synchronous decrease in unemployment, though the effect is not significant for two of the four cases. The negative effects turn out to be stronger in the long run (after five years), when three of the four variables they consider become significant.

The theoretical research reviewed in this section suggests that unemployment should worsen after a positive technology shock, and also that less-skilled workers should suffer more than high-skilled workers. The empirical findings are more mixed. Of the two studies discussed above, one finds that the aggregate unemployment rate falls in response to positive technology shocks. The results from both studies suggest that workers who find it harder to learn new skills will be hit harder by technological change, though the two studies tend to classify workers in different ways.

5. Empirical Estimates of the Effects of Technology Shocks on Unemployment

In the discussion above, we have seen that different papers emphasize different channels through which technology shocks can affect the unemployment rate, and these channels lead to different predictions about how the unemployment rate will respond. Given these often contradictory predictions, it is natural to ask which one dominates in the data. As we also have seen above, the limited empirical research available on this issue does not provide a clear-cut answer either. Accordingly, this section presents some new evidence on this issue using data on U.S. unemployment and productivity and some related variables. The evidence presented here will be obtained by estimating models in the spirit of Galí (1999), who identifies technology shocks by assuming that these are the only shocks that can have a permanent effect on the level of productivity. Before doing so, it is worth mentioning one other antecedent to the empirical analysis below. Blanchard and Quah (1989) estimate a two-variable model containing output and the unemployment rate in which the underlying structure is identified by assuming that certain shocks do not have a permanent effect on the economy. These shocks are labeled "demand shocks," while shocks that have a permanent effect on the level of output are labeled "supply shocks." Blanchard and Quah show that while a positive supply shock raises output permanently it also raises unemployment in the short run. (Demand shocks raise output and lower unemployment in the short run.) This result appears to echo Galí's, though it is useful to keep in mind that the Blanchard-Quah assumption does not really distinguish between different kinds of shocks that have a permanent effect on output. A permanent increase in labor supply, for instance, would also increase output permanently and could lead to a temporary increase in unemployment.

The measure of productivity included in the model is obtained by deflating output by total labor hours, as in Galí (1999). The sample period extends from 1959:Q1 to 2001:Q4, with the starting date dictated by the availability of the output data. Before estimating the model it is important to determine whether the two variables to be included are stationary. It turns out that one cannot reject the null that the productivity process contains a unit root (after taking logs), but one can easily reject the null that the first difference of this process contains a unit root. In the case of the log of the unemployment rate, the augmented Dickey-Fuller test statistic is –2.87, which in absolute terms is slightly smaller than the 5 percent significance level of –2.89.[12] While one cannot reject the null of a unit root in this case, it turns out that one also cannot reject the null that the unemployment rate is stationary. Specifically, the KPSS test yields a value of 0.16, which is well below the 5 percent critical value of 0.46.[13]

Based on these results, the analysis below will be carried out under the assumption that the unemployment rate is stationary. Note that this assumption is not innocuous since it automatically rules out any permanent effect of a productivity shock on the unemployment rate (such as that associated with the Internet, for example). Because of that, it is worth discussing what alternative assumptions

10. Education levels are used to proxy for skill levels; see the discussion below.

11. This interpretation is consistent with the analysis of Murphy and Topel (1997), who show that low-skilled workers have reacted to the prolonged decline in their wages by gradually withdrawing from the labor force. This allows the unemployment rate for these groups to come back down, even though employment does not recover fully.

12. See Maddala and Kim (1998), pp. 74–76, for a discussion of the tests and tables containing critical values.

13. See Maddala and Kim (1998), pp. 120–122, for a description of the test.

might imply. One possibility is to assume that the unemployment rate contains a unit root. A look at the data (in Figure 1) suggests that the unemployment rate does possess some of the characteristics of a unit root process. Like a unit root process, it shows a lot of persistence. It was relatively low in the 1960s and early 1970s but then seemed to be on an upward trend over the next decade or so. The unemployment rate tended to remain around 6 percent from the mid-1980s to the mid-1990s but then declined dramatically during the second half of the 1990s. Yet the assumption of a unit root appears too extreme; it implies, for instance, that the unemployment rate could move anywhere, given enough time. A perhaps more reasonable assumption is that the unemployment rate is mean-reverting, but that this mean shifts over time. For instance, it is possible that the mean of the unemployment process shifted up during the 1970s and then down again in the 1990s. Tests developed by Bai and Perron (1998) were used to examine this possibility. These tests allow for one or more shifts in the mean of a series without the user having to specify the date or dates at which these shifts may have occurred. Neither of the two tests recommended by them rejects the null of no breaks in the series, though one of the other tests finds evidence of five breaks (which is the maximum number of breaks that was allowed in the test). These findings may reflect the fact that the unemployment rate is a very persistent series, a situation in which the tests may have trouble detecting breaks according to Bai and Perron (2000).

Given these results, it seems best to stay with the assumption that the unemployment rate is stationary. As mentioned above, output per hour appears to contain a unit root, so it is differenced before being included in the vector autoregression (VAR). The identification condition employed here is taken from Galí (1999), who in turn employs a version of the long-run restriction developed by Blanchard and Quah (1989). Specifically, the assumption is that "only technology shocks can have a permanent effect on the level of labor productivity" (Galí 1999, p. 256). Note that under this identification scheme even though the second shock to the VAR is nominally identified, it really serves as a catchall since it contains some linear combination of shocks to labor supply, monetary policy, etc.

Figure 2 shows how the unemployment rate and productivity react to the productivity shock in the two-variable system. A positive, permanent shock to productivity lowers the unemployment rate on impact and continues to push it down further for about a year and a half (Panel A); thereafter, the unemployment rate returns gradually to its original level. While the effect is not statistically different from zero in the first few quarters, it does become significant for about three years after that.[14] Panel B shows that output per hour ultimately ends up a little bit higher than it was upon the initial impact of the productivity shock.

Before going further, it is useful to examine how sensitive this result is to changes in model specification. Consider, first, what happens when we change the identification assumption used here. Panel A of Figure 3 shows how the unemployment rate reacts to a productivity shock in a system in which identification is achieved by means of a Choleski decomposition. Specifically, we assume that productivity shocks have a contemporaneous effect on the unemployment rate but that shocks to the unemployment rate do not have a contemporaneous effect on productivity. The impulse response function is quite similar to that shown in Figure 2. In particular, a positive productivity shock tends to push the unemployment rate down for a while, and the estimated effect is statistically significant for the first few years.

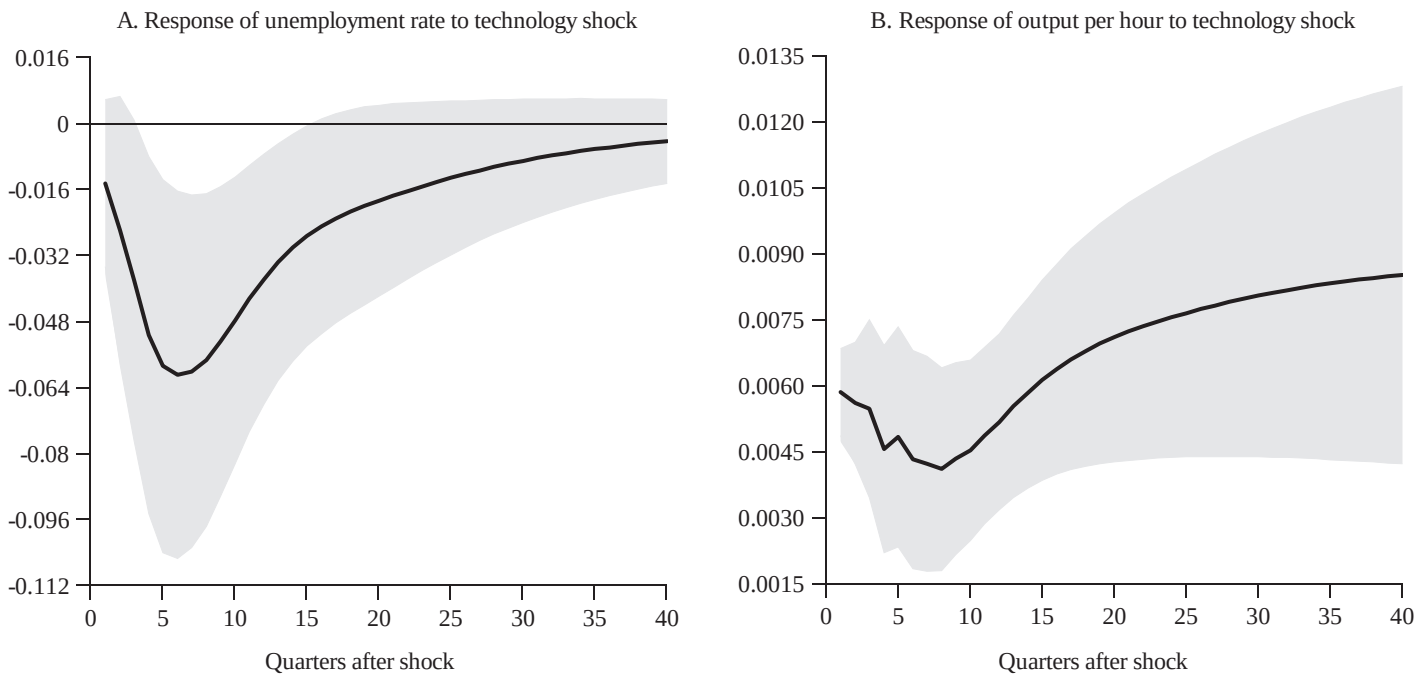
Second we ask what happens to the estimated response when additional variables are included in the VAR. To answer this question we add the three variables used by Galí in the five-variable version of his VAR; the additional variables are the real interest rate, the quantity of real balances, and the inflation rate. The technology shock is identified using Galí's identification restriction (just as in Figure 2), and the effect of this shock on the unemployment rate is shown in Panel B of Figure 3. The unemployment rate actually rises a little bit in the first period in this system but falls below its original level one quarter later. The initial response is not really distinguishable from zero, however, and it is only around the two-year mark that the decline in the unemployment rate becomes statistically significant.

Overall, the results in Figures 2 and 3 suggest that the unemployment rate may fall a little bit immediately after a technology shock hits the economy, but that this effect is not very large. However, roughly a year after a positive technology shock the unemployment rate is lower than it was when the shock hit, and it stays significantly lower than the initial value for three to four years after that. Thus, this evidence offers little support for theories implying that a positive technology shock raises the unemployment rate and instead tends to favor theories that predict that the unemployment rate will decline in response to a positive technology shock.

How important are technology shocks for the behavior of the unemployment rate on average? To answer this question, Table 1 shows the variance decomposition of the unemployment rate associated with the impulse responses shown in Figure 2 (which, in turn, are from a two-variable

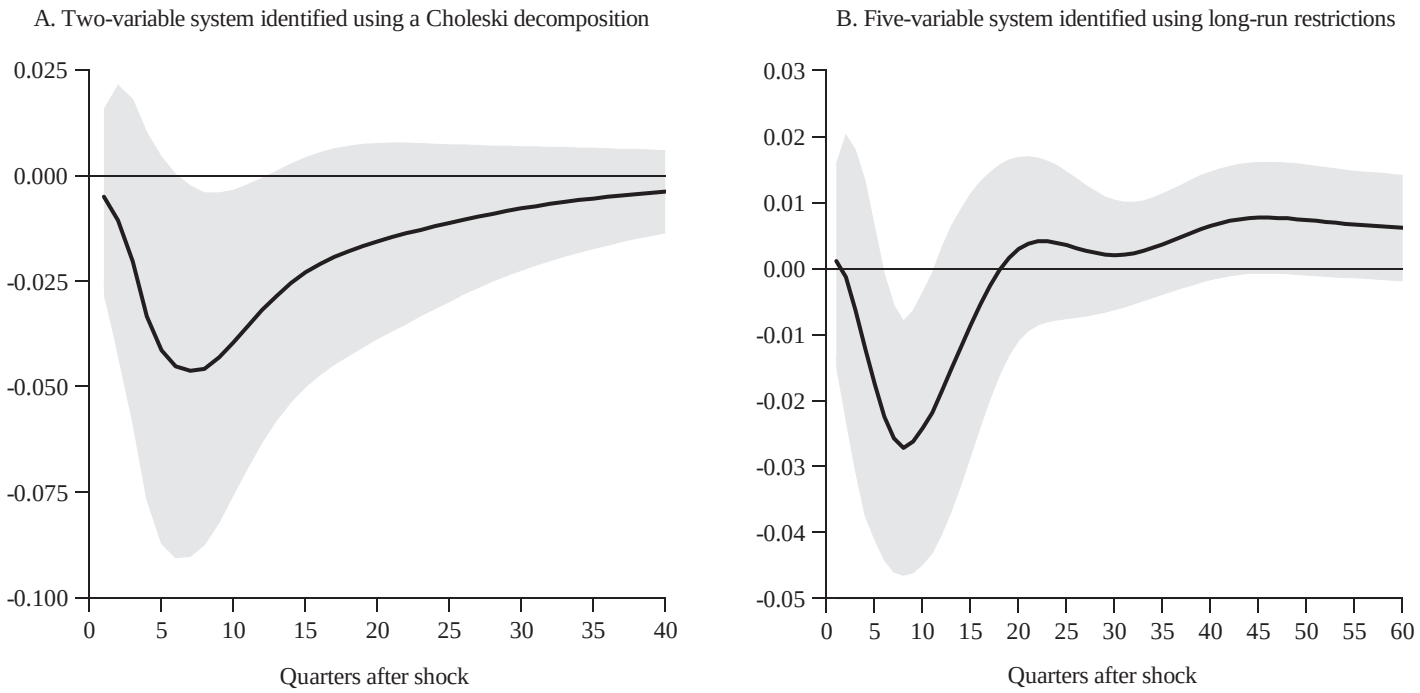
14. The 95 percent confidence bands shown here and in all figures below are based on 500 simulations.

FIGURE 2
EFFECT OF TECHNOLOGY SHOCKS: 1959:Q1–2001:Q4



Note: 95 percent confidence bands are based on 500 simulations.

FIGURE 3
EFFECT OF TECHNOLOGY SHOCKS ON UNEMPLOYMENT UNDER ALTERNATIVE SPECIFICATIONS



Note: 95 percent confidence bands are based on 500 simulations.

system that contains the unemployment rate and output per hour). Technology shocks do not have much of an impact on the unemployment rate initially, but their importance grows over time; they explain about a quarter of the forecast-error variance of the unemployment rate two years out and about one-third three years out. In the long run, their share of the variance settles to a little bit under 40 percent. For comparison purposes, it is worth noting that in the five-variable system the technology shock accounts for less than 1 percent of the variance of the unemployment rate after a year but for over 50 percent in the long run.

It is also interesting to compare the results in Figure 2 and Table 1 with the results for the Blanchard and Quah two-variable system, which contains real output and the unemployment rate. A key difference is that in their system (both in the original paper and when estimated over the sample period of this paper) supply shocks raise the unemployment rate for a relatively long time, while here technology shocks tend to lower the unemployment rate. Recall that in the Blanchard-Quah system, supply shocks are identified as having permanent effects on the level of output (and not just on productivity). So it is possible that the supply shocks identified by them also include the effects of shifts in labor supply, such as the increases in the labor force that took place when the baby boomers began to enter the labor force in the 1970s. The results from the variance decompositions are also consistent with this interpretation, as the supply shocks obtained under their identification account for a larger proportion of the variance of unemployment than the technology shocks identified here do. In their system (estimated over the sample period of this paper) supply shocks account for 26 percent of the variance of unemployment after four quarters and for 43 percent after two years. In the long run, the share of supply shocks rises to a little more than 50 percent.

To see how the estimated technology shocks have influenced the evolution of the unemployment rate over time, we construct a measure of how the unemployment rate would have evolved if the only shock hitting the economy were the technology shock and compare this measure to the actual unemployment rate over the 1961–2001 period. The results from this exercise are shown in Figure 4. The figure shows that the technology shock-driven unemployment rate moves fairly closely with the actual unemployment rate. Almost all of the decline through the late 1960s is explained by the supply component, as is much of the increase over the 1970s. Even so, technology shocks do not explain the peaks in the unemployment rate during the mid-1970s and early 1980s. The role of the technology shocks during the 1990s is especially interesting; the actual unemployment rate remains noticeably below the component that can be explained by technology shocks over this period, even though technology shocks were exerting constant downward pressure on the unemployment rate.

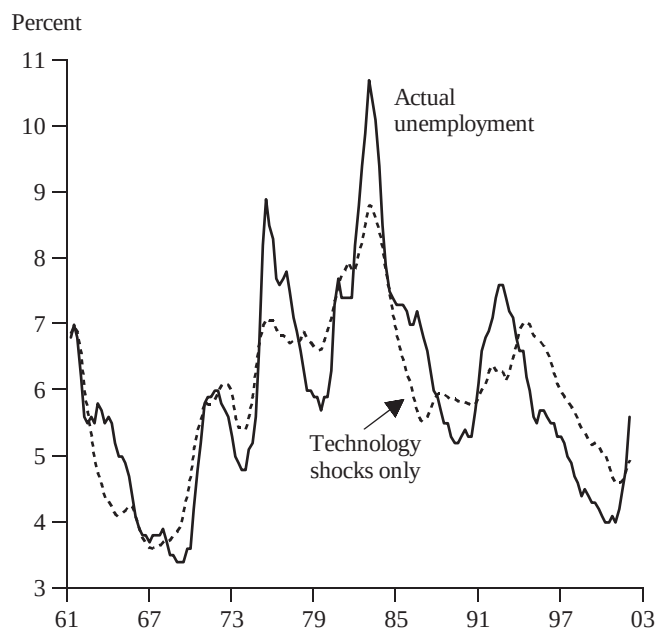
Table 1
Variance Decomposition of the Unemployment Rate
(Sample: 1961:Q1 to 2001:Q4)

Quarters Ahead	Technology Shocks (percent)	Other Shocks (percent)
1	1.4	98.6
2	2.7	97.3
4	10.1	89.9
8	25.2	74.8
12	33.3	66.7
20	37.5	62.5
30	38.4	61.6
40	38.7	61.3

5.1. High-skilled versus Low-skilled Workers

As discussed above, a substantial body of research suggests that technology shocks should affect different kinds of labor in different ways. Blanchard and Katz (1997), for instance, argue that positive technology shocks lower the unemployment rate of high-skilled workers while raising that of low-skilled workers, while some of the arguments put forward by Acemoglu (1998) suggest that the

Figure 4
Actual and Simulated Unemployment Rate



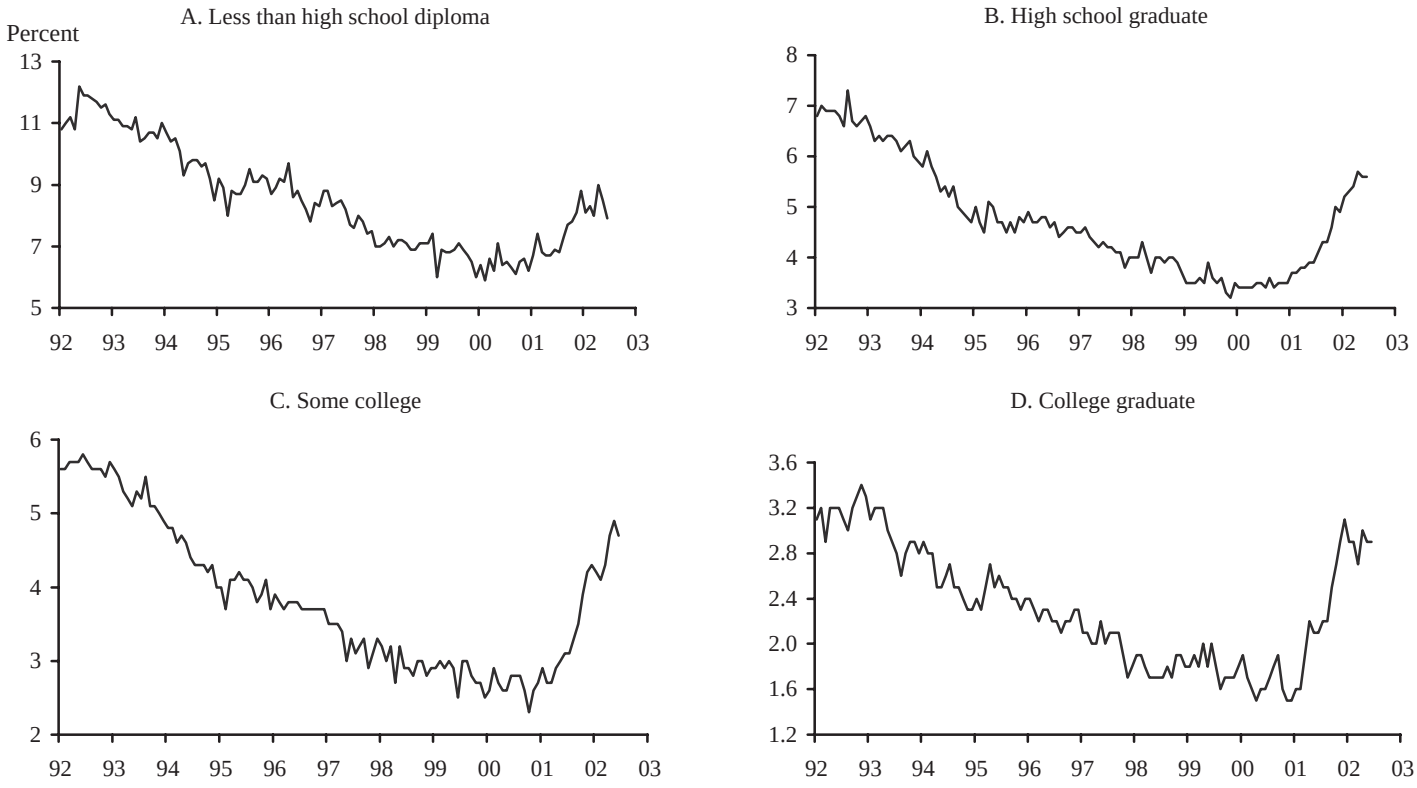
unemployment rate of low-skilled workers should go up more than that of high-skilled workers. This section attempts to determine what kind of evidence there is for such hypotheses.

Data on labor skills are extremely hard to get, particularly if one is looking for data on the entire economy over a reasonable length of time. The usual response is to use data on education as a proxy for labor skills, even though it is well understood that the two are not the same. It turns out that there are severe limitations on the availability of unemployment data by education levels as well. At a monthly frequency, data on unemployment rates by education levels are available since 1993 for workers 25 years and older. This sample is clearly too short to undertake the kind of analysis we have performed in the previous section. One can get annual unemployment data for workers with four different levels of education over the 1970–2000 period. However, these data are not consistent over time. For one thing, in the early 1990s the categories were redefined to focus on completed degrees rather than years in school. Other changes in the survey used to collect data also make it difficult to compare data after 1993 with earlier data. These data limitations mean that it will be difficult to get conclusive evidence on the impact of technology shocks on the unemployment rate across different kinds of workers using either data set. Nevertheless, in order to provide some sense of what the relationship might be like, this section will present the results from some simple analysis of both kinds of data.

Figure 5 shows monthly data on unemployment rates by education level since 1992. Broadly speaking, all four unemployment rates have fallen over most of this period. Unemployment rates were high at the beginning because the economy was emerging from a recession; they fell over the 1990s as the economy experienced a long expansion and rose towards the end as another recession hit. Note that in relative terms the recent recession has hit the most educated the hardest. For those with college degrees, unemployment rates are close to where they were in the early 1990s; this is not the case for those with lower education levels.

How are these changes related to changes in productivity over this period? The available sample of monthly data is clearly too small to allow the estimation of VARs similar to those in the previous section; for one thing, the sample is too small to impose a long-run restriction. Consequently,

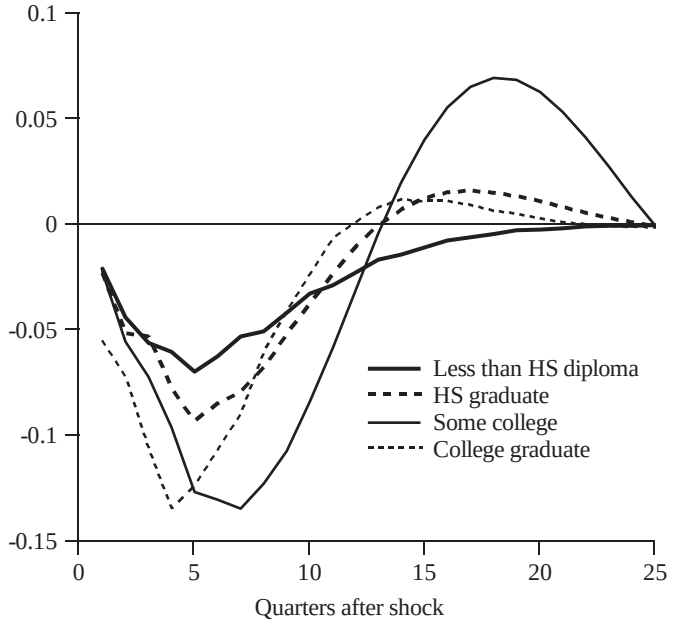
Figure 5
Unemployment Rates by Education Level



the analysis of the short sample here will take the technology shocks identified in the previous section as given and examine the effect that they have on the unemployment rates of different kinds of workers. An important benefit of this exercise, relative to the alternative of estimating separate VARs for each unemployment rate, is that the technology shock does not change across specifications.

For the first exercise, we simply regress each of the unemployment rates on its own lags and lags of the technology shock variable. To avoid the problems raised by the redesign of the survey, we estimate these regressions over the 1994:Q1–2001:Q4 period. From each of these regressions we can compute how the relevant unemployment rate will behave over time in response to a technology shock. The four resulting impulse response functions are shown in Figure 6. Note, first, that all four unemployment rates decline immediately in response to a positive technology shock and that the unemployment rates continue to fall further for at least another year afterward. The impulse response functions are also similar enough that there is little hope of distinguishing them statistically from each other, especially in light of the small sample size. Even so, it is worth noting that the unemployment rate for workers without a high school degree falls least in response to a positive technology shock, followed by the unemployment rate for workers who have finished high school; in addition, the unemployment rates for workers with the two highest levels of schooling fall roughly twice as much as those for workers who did not finish high school. Finally, note that the impulse response function for workers with some college damps out very slowly; more likely than not, this is a reflection of the small sample size.

Figure 6
Response of Unemployment Rate to Technology Shocks: Quarterly Data from 1994:Q1 to 2001:Q4



One way to judge whether the productivity shocks defined above affect different unemployment rates differently is to define a variable that measures the spread of the four different unemployment rates at each point in time and see if the technology shocks identified above make a difference to that variable. Variance-type measures come naturally to mind. One problem, however, is that such measures contain no information about the direction in which various unemployment rates change in response to a technology shock. For instance, a positive technology shock could lead to an increase in the dispersion of these four unemployment rates either because the unemployment rate of the workers with more education decreased more than that of workers with less education or because the former increased more than the latter. Consequently, we also construct a variable for the difference between the unemployment rate of the workers who have not finished high school and the unemployment rate of workers who have completed a college degree and see how this variable reacts to the technology shocks we have constructed. The results of these exercises are shown in Table 2.

The first column shows the results when the variance-based measure (called UDisperse) is regressed on the contemporaneous value of the difference of the log of real GDP (DGDP) and six quarterly lags of the technology shock variable from the exercise in Section 5 above. This specification was selected by starting with contemporaneous and lagged values of GDP and the technology shocks and eliminating insignificant lags, following the general-to-specific strategy recommended by Hendry (1995). Lagged values of UDisperse were included as well but were found to be insignificant. The results indicate that the dispersion of the unemployment rate goes up when real GDP growth picks up.[15] Dispersion also goes up in response to a technology shock, with some of this decrease being reversed in the long run.[16] The variables in the equation explain about half of the movement in the dispersion variable, and the chi-squared tests indicate that the technology shock variables are significant at the 1 percent level.

15. The standard errors shown in the table are robust to the existence of heteroskedasticity and autocorrelation.

16. In both equations shown here, lags 7 and 8 of the technology shock variable turn out to have negative coefficients when included in the equation; however, these lags are not significantly different from zero.

TABLE 2
TECHNOLOGY SHOCKS AND THE DISPERSION OF UNEMPLOYMENT (SAMPLE 1994:Q1 TO 2001:Q4)

	UDisperse	URange
Constant	0.20[1]	1.23[1]
	(0.01)	(0.03)
$DGDP_t$	3.10[1]	9.54[1]
	(0.82)	(2.59)
$Techshock_{t-1}$	0.96	2.92
	(0.60)	(1.80)
$Techshock_{t-2}$	1.42[1]	4.06[1]
	(0.49)	(1.47)
$Techshock_{t-3}$	1.11[5]	3.37[10]
	(0.58)	(1.81)
$Techshock_{t-4}$	0.35	0.62
	(0.37)	(1.09)
$Techshock_{t-5}$	1.06[5]	2.59[5]
	(0.43)	(1.33)
$Techshock_{t-6}$	–0.80[5]	–2.86[1]
	(0.33)	(1.05)
R^2	0.51	0.52
$\chi^2(6)$ [a]	19.90[1]	18.70[1]

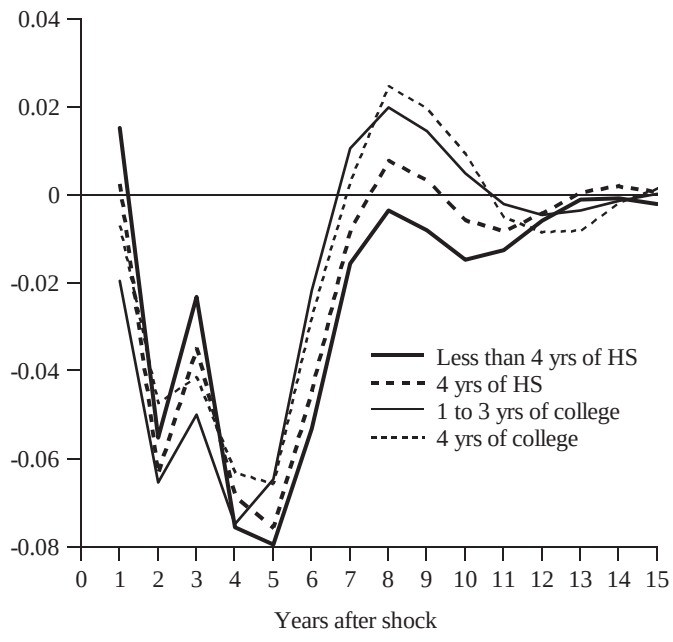
Note: Standard deviations are in parentheses.
[1] denotes significance at 1 percent.
[5] denotes significance at 5 percent.
[10] denotes significance at 10 percent.
[a]The null is that the techshock variable can be excluded from the equation.

The second column presents the results for the URange variable, which is defined as the difference between the unemployment rate of workers with the least education and the unemployment rate of workers with the most education. These results are similar to those in the first column. The advantage here is that one can see that (the increase in dispersion observed in the first column comes about because) the technology shock actually raises the unemployment rate of less-educated workers relative to those with more education. (The shortcoming of the second measure is that it ignores information about workers with intermediate skill levels.) Combined with the results in Figure 5, which shows us that the unemployment rates of both kinds of workers fall in response to a positive technology shock, the implication is that such a shock pushes down the unemployment rate of high-skilled workers by significantly more than it pushes down the unemployment rate of low-skilled workers.

As mentioned above, annual data on unemployment by education levels also are available over the 1970–2000 period. We carried out the same analysis using annual data with one important difference. Instead of using data on output per hour, we used data on multifactor productivity.[17] The advantage of using these data is that they are likely to be more closely related to technology shocks than are the data on average output per hour. These data were used, along with annual data on the aggregate unemployment rate, to derive a series of technology shocks, exactly as was done for the quarterly data.[18] Each of the four series of unemployment by education level then was regressed on the technology shock and its own lags. (Four lags were used.)

Figure 7 shows how each of the unemployment rates reacts to the technology shock. All four decline following a positive technology shock, though the initial response is positive for those who did not finish high school as well as for those who finished high school but did not attend college. The responses of the four unemployment rates are extremely close to each other and, given the small number of observations, there is not much point in trying to distinguish these responses from one another. An attempt was made to determine if these differences were statistically significant by constructing a spread variable similar to that for the quarterly data. However, the spread turns out to be

FIGURE 7
RESPONSE OF UNEMPLOYMENT RATE TO TECHNOLOGY SHOCKS: ANNUAL DATA FROM 1970 TO 2001



17. These data have been obtained from the Bureau of Labor Statistics website and are available only at an annual frequency.

18. Neither slope nor intercept dummies that were meant to control for the effects of the changes in surveys discussed above turned out to be significant in the equations estimated on annual data.

nonstationary,[19] and after one accounts for this nonstationarity it is hard to find any role for the technology shocks.

To sum up, disaggregating the data by education levels shows that positive technology shocks tend to lower the unemployment rates of workers across all skill levels. This result seems to be true whether we use quarterly data since the early 1990s or annual data since 1970. Quarterly data for the last eight years also suggest that the unemployment rates of high-skilled workers tend to fall by more than those of low-skilled workers. However, the small sample size argues against putting a lot of weight on this finding. Further, annual data do not provide evidence of a significant difference across categories (even though the point estimates are consistent with the quarterly results).

6. Conclusions

This paper has looked at some recent research on the effects of changes in productivity growth on the unemployment rate. Models that postulate that the reservation wage adjusts sluggishly to changes in productivity (and that assume homogeneity of labor and ignore the increase in job destruction that is likely to come about as a result of a higher pace of technical progress) make an unambiguous prediction: high productivity growth implies that unemployment falls. A more complex picture emerges as some of these restrictions are relaxed. To the extent that rapid technical change leads to more job destruction, it raises frictional unemployment as more workers and firms must spend time looking for the right match. This effect will be amplified if technical change increases heterogeneity, since each individual must spend more time on search as well. There is also some ambiguity about how firms respond to news about higher productivity (or new technology) in the future. Some models also suggest that productivity shocks are likely to have different effects on workers with different skill levels; generally speaking, workers with relatively low skill levels are not likely to do as well as workers with high skill levels.

There has been relatively little empirical research on these issues. The results from two of the studies discussed above suggest that technology shocks lead to lower unemployment, while another study finds that the duration of unemployment goes up in response to technology shocks. The empirical results in this paper are relatively unambiguous. Specifically, positive shocks tend to lower unemployment, with effects that build up over several years before damping out. This effect appears to be robust to a classification of workers by skill levels, in that the unemployment rate of each of four groups of workers (differentiated by the Bureau of Labor Statistics on the basis of education levels) declines in response to a positive technology shock. There is some evidence that the unemployment rates of highly educated workers decline by more than those of workers with lower education levels, though available sample sizes are too small to place a lot of weight upon this finding.

These findings are consistent with the predictions of models that emphasize sluggish adjustment of the reservation wage and with models that predict an economic boom when news about improved technology arrives. And they are certainly consistent with the boom observed in the second half of the 1990s, when a surge in productivity growth was accompanied by a sharp decline in the unemployment rate. This does not mean that models which stress job destruction and worker as well as job heterogeneity are wrong in some way, but empirically the effects working through these channels appear to be dominated by the positive effects of technology shocks on the unemployment rate.

19. The unemployment rate of workers who did not finish high school goes up over the 1970s and stays relatively high throughout the sample, while the unemployment rates of other workers tend to fall back.

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How Might Financial Market Information Be Used for Supervisory Purposes?*

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Bank supervisory monitoring, both on-site and off-site, generates a wealth of information with which to judge the safety and soundness of banks and bank holding companies (BHCs). For BHCs with publicly traded securities, the monitoring efforts of investors generate additional information that may complement the supervisory information set. In this paper, we address three public policy questions related to how supervisors might use this financial market information. First, can financial markets detect changes in BHC risk characteristics? To address this question, we summarize the academic literature on the topic and present our own empirical results using BHC stock returns and bond spreads. We find that securities prices signal changes in supervisory ratings of BHC condition up to a year prior to their assignment. Second, do securities prices provide information that complements supervisory information? Using forecasts generated by an off-site monitoring model developed by Krainer and Lopez (2001), we find that securities prices do improve forecasts of supervisory ratings changes, although the improvement is not statistically significant. Third, what is an appropriate level of accuracy to demand of financial market signals and off-site monitoring models more generally? We examine this question by studying the model's ratio of correct forecasts to incorrect forecasts.

1. Introduction

Banks are thought to play a special role in the economy as monitors of investment projects and aggregators of borrower information. Banks also provide households and firms with sources of liquidity and allegedly play a role in the transmission of monetary policy. Without exception, countries with modern economies have developed banking sectors to help finance real activity. But the types of functions that banks carry out—taking deposits from households and investing them in illiquid and difficult-to-evaluate projects—necessarily expose them to risks of failure. For example, economic shocks that raise depositor demand for additional liquidity can cause banks' funding to dry up and potentially lead to decreased bank lending or the inefficient liquidation of existing projects.

To guard against such systemic risks, countries have created public safety nets and established banking supervisory authorities of various forms. In the United States, deposit insurance and the Federal Reserve's discount window are intended to protect both depositors and banks from systemic shocks. In addition, multiple government agencies supervise and regulate the banking sector to ensure that it is not overly vulnerable to systemic shocks.

Currently, most bank supervisory agencies conduct on-site examinations to monitor the health of banking institutions and look closely at bank financial conditions and operational processes. However, it is increasingly obvious that a banking institution's condition can deteriorate rapidly, and, if banks are examined relatively infrequently, then supervisory assessments can become outdated quickly.[1] Thus, supervisors also have developed off-site

*We thank Rob Bliss for sharing his bank holding company debt database with us. We thank Fred Furlong and Simon Kwan for extensive comments and suggestions, Anita Todd for editorial assistance, and Judy Peng, Paul Schwabe, Ryan Stever, and Chishen Wei for research assistance.

1. Note that for large, complex banking organizations, the Federal Reserve now maintains a continuous supervisory presence. See DeFerrari and Palmer (2001) for further discussion.

monitoring methods to augment their on-site exams. These methods are appealing because they provide predictive information that can identify problems at an early stage when it should be easier and cheaper for supervisors to deal with them.

An interesting development in bank supervision has been the attempt to harness financial market data, such as bank holding company (BHC) debt and equity prices, for the monitoring effort. For example, the Basel Committee on Banking Supervision (2001) proposed a new international accord on commercial bank capital requirements, one pillar of which focuses on market discipline of banks. A joint study by the Board of Governors of the Federal Reserve System and the U.S. Department of the Treasury (2000) concluded that subordinated debt issuance could be a way to encourage market discipline at depository institutions. The report further states that the U.S. bank supervisory agencies will continue to use and should enhance their application of financial market data to evaluate current and future BHC conditions.[2]

Financial market participants and the information they produce can aid supervisors in two distinct ways. The debt markets can impose *direct* discipline on banking organizations by demanding high prices for the financing of risky activities. Thus, the appropriate pricing of risk may discourage banks from taking on risk profiles that supervisors would discourage. *Indirect* discipline—potentially more useful to supervisors—refers to the signals derived from the banking organization's traded securities. Investors, like regulators, have much to gain from learning about the condition of a banking institution. Thus, market prices for bank debt and equity should reflect a consensus opinion among investors about the value of the firm. If market prices are accurate, then these prices presumably could give supervisors an alternative, reliable assessment of the condition of a banking institution.

In the U.S., supervisors monitor an array of financial market variables, such as changes in stock prices, expected default probabilities, and spreads on subordinated notes and debentures, as part of their off-site monitoring.[3] Researchers, meanwhile, have been trying to quantify the usefulness of financial market data for the supervisory process and to discover the best ways to use the information. In this paper, we examine this research as it relates to BHCs, which in the United States are supervised by the Federal Reserve.

We do so by addressing three specific policy questions. First, we ask the basic question of whether changes in BHC risk characteristics get incorporated into BHC securities prices. The consensus in the academic literature is that the market pricing of debt and equity securities reflects BHC risk. We extend this literature by presenting our own empirical results that changes in BHC stock returns and bond spreads anticipate (i.e., lead) changes in supervisory BHC ratings.

Second, we ask whether financial market prices can provide complementary information not already in the supervisory information set. We explore this question using an off-site monitoring model proposed by Krainer and Lopez (2001). Using data from the 1990s, we find that incorporating BHC financial market variables into the model improves its in-sample fit. However, including financial market variables in the model does not produce ratings forecasts that are statistically different from forecasts based on supervisory data alone.

While financial markets correctly signal changes in condition that our benchmark model fails to identify, the problem is that markets also incorrectly signal changes in condition that do not occur. This finding leads naturally to our third policy question: What degree of accuracy should supervisors demand of financial market signals and of off-site monitoring models more generally? We examine this question by studying our model's ability to forecast supervisory rating downgrades correctly and weighing the number of correct signals against the number of signals that incorrectly forecast a ratings change. We show that the model that includes financial market variables produces a different set of correct forecasts than the core model without these variables. These differences, we argue, can be exploited since this extended model is relatively better than the core model at forecasting ratings changes for publicly traded BHCs.

In conclusion, we provide empirical evidence on the question of how useful financial market information could be for supervisory off-site monitoring. The evidence suggests that using BHC financial market data certainly should not hinder the monitoring effort. The financial market variables we study do not provide unambiguously better forecasts of BHC condition when combined with supervisory variables in our model. Upon closer inspection, though, we see that financial market variables help identify ratings changes at publicly traded BHCs that otherwise would not be flagged by our benchmark core model. Therefore, it should be beneficial to combine forecasts from the two models, especially since this benefit can be achieved at a fairly low cost.

The paper is organized as follows. In Section 2, we survey the academic literature on the topic. In Section 3, we

2. See also Board of Governors (1999).

3. For a more complete discussion of how Federal Reserve supervisors monitor financial market information, see Supervisory Letters 95-03 and 02-01 (Board of Governors 1995, 2002).

provide a brief summary of the supervision of bank holding companies in the United States. In Section 4, we present our event studies regarding supervisory assessments, known as BOPEC ratings, as they relate to BHC stock returns and debt yields. In Section 5, we examine two sets of BOPEC forecasts generated from different specifications of the model: a core model based on a set of supervisory variables, and an extended model that incorporates both equity and debt market variables into the core model. We also examine the BOPEC forecast accuracy trade-offs implied by these two models. We present our conclusions in Section 6.

2. Literature Review

Many researchers have examined how financial markets anticipate or respond to different types of events. For the purpose of this paper, we are interested in two related questions in the academic literature. First, can financial markets accurately assess the conditions of financial firms, especially BHCs, or are their assets too opaque for investors? Second, in what ways might financial market information be of use for supervisory monitoring?

2.1. Literature on Bank Opacity

Modern theories of financial intermediation, such as Diamond (1984), stress the special role of banks as monitors and processors of information. That is, banks specialize in gathering and monitoring balance sheet information from their borrowers, whose assets otherwise would be too opaque for other institutions to evaluate. An important strand of empirical work that has flowed from this model of banking seeks to determine whether banks, as specialists in solving problems of asymmetric information between firms and investors, are themselves opaque to investors. In other words, can financial market investors accurately assess the value of bank assets given their opacity?

To our knowledge, the first academic paper to explore the relationship between BHC conditions and the responses of their financial market securities was written by Pettway (1976). The author found that BHC debt yields and stock returns were not sensitive to variations in BHC capital ratios in the early 1970s. Subsequent to this work, many studies have examined whether investors in bank securities respond to changes in bank default risk.

With respect to bank debt, the evidence regarding bank opaqueness has been mixed depending on both the type of debt instrument and the sample period, but the overall conclusion is that investors in debt securities do price changes in bank risk. As surveyed by Gilbert, et al. (2001), studies of the market for large, uninsured certificates of deposit (CDs) in the 1970s generally found no evidence that investors in these instruments responded to changes in bank risk. However, studies based on data from the 1980s found that investors responded to such changes. For example, Hannan and Hanweck (1988) found that CD rates were sensitive to the volatility of banks' returns on assets and capital ratios during the 1980s.

Interestingly, the empirical relationship between the yields on bank subordinated notes and debentures, which are typically less senior and longer term than CDs, and measures of bank risk has been harder to establish; see the survey by the Board of Governors (1999). Studies of these debt yields from the mid-1980s by Avery, et al. (1988) as well as Gorton and Santomero (1990) found no evidence of sensitivity to measures of bank risk. However, as argued by Flannery and Sorescu (1996), this supposed failure by investors to price different bank risks could be due to investor perception of a real or implicit government guarantee of bank liabilities. In fact, they found that, following the passage of the 1991 Federal Deposit Insurance Corporation Improvement Act and its stated retreat from a "too-big-to-fail" policy, spreads on traded bank debt securities became more responsive to risk measures. Several other studies, such as Jagtiani, et al. (2000) and Morgan and Stiroh (2001), found similar results for the latter half of the 1990s.[4]

With regard to investors in bank equities, the evidence regarding bank opacity, as derived from many studies, suggests that stock market investors do price changes in bank risk. As summarized by Flannery (1998), this empirical literature provides broad support for the hypothesis that bank equity investors incorporate risk-related information into BHC stock prices. For example, Kho, et al. (2000) found that the degree to which BHC stock prices were affected by currency crises in emerging market economies in the late 1990s depended on the degree of the BHC's exposure to these economies. Furthermore, Dahiya, et al. (2003) found that stock prices of lead lending BHCs fall significantly when a major corporate borrower announced its default or bankruptcy. When the BHCs were ranked according to their exposures to such distressed borrowers, the stock price decline for the low exposure banks was insignificant, while that for the high exposure banks was large and significant.

4. A recent study by Covitz, et al. (2002) found that the bank subordinated debt premiums (over similar maturity Treasury securities) used in these studies are biased due to the risk-sensitive nature of the managerial decision to issue such debt. That is, we can assume that the issuers of bank subordinated debt before and after 1991 were sufficiently different so as to be subject to important sample selection issues. After adjusting for this sample selection bias, the authors found that bank subordinated debt prices were sensitive to changes in bank risk prior to the Federal Deposit Insurance Corporation Improvement Act.

Another branch of the literature regarding bank opacity has sought to determine whether banks are more opaque to investors relative to comparable nonbank firms. Flannery, et al. (2002) used stock market data to address this question, based on the premise that compared to more transparent firms, opaque firms' stocks should exhibit different market microstructure properties. Opaque firms' earnings also should be more difficult to forecast. They found that larger BHCs traded on the New York and American Stock Exchanges were as easy for investors to evaluate as similarly sized nonbanks. In addition, smaller BHCs traded on the NASDAQ were relatively easier to assess than similarly sized nonbanks. They concluded that asset opacity is not a prominent feature of bank holding companies. In contrast, Morgan (2003) found that credit rating agencies were more likely to disagree on debt ratings for financial intermediaries, such as banks and BHCs, and that these disagreements mainly arose from assets, such as loans, that are harder for outside monitors to assess. These seemingly contradictory results could be due to differing incentives facing stock investors and rating agencies or different research methodologies. Further research into this topic is necessary.

2.2. Literature Linking Market and Supervisory Assessments

Given that financial markets have been shown capable of providing information on bank conditions, we now turn to the question of whether this information might be of use to supervisors. The academic literature most related to this paper examines the correlation between market evaluations of bank conditions and supervisory assessments, which are summarized by supervisory ratings. Note that market participants are not actively trying to guess what supervisory ratings will be, nor do they officially learn the outcomes of supervisory inspections. Instead, this literature tests whether there is an alignment between investor and supervisory assessments that could allow supervisors to use market data for their own purposes.

Most studies in this area have examined equity market or debt market information separately, although a few recent studies have examined both. With respect to equity market information alone, Berger and Davies (1998) used an event study framework to examine whether daily BHC stock prices react to changes in their subsidiary banks' supervisory ratings. Even though these ratings are confidential, they found that BHC stock prices respond to these changes, implying that supervisory assessments provide valuable information that the equity market can detect. The authors conjectured that market participants view supervisory ratings as both certifications of bank financial statements and indicators of future regulatory treatment.[5] Several recent studies have provided complementary evidence. Gunther, et al. (2001) and Hall, et al. (2001) found that equity market signals provide useful information that supplements supervisory assessments. Elmer and Fissel (2001) as well as Curry, et al. (2001) further supported this conclusion by finding that equity market variables add value to supervisory models of bank failure.

Similar studies have been conducted using debt market information. DeYoung, et al. (2001) found that supervisory information significantly affects contemporaneous and subsequent changes in the spreads of bank debentures over the corresponding Treasury rates. Specifically, they found that the private information component of bank supervisory ratings affects debt spreads several months after their assignments. Gilbert, et al. (2001) found that default risk premia for jumbo CDs, as derived from financial statement variables, do not predict bank supervisory downgrades as well as a standard early warning model.

Since the interests of bank subordinated debt holders and bank supervisors generally are considered to be aligned, several studies have advocated that subordinated debt prices be incorporated into the supervisory process.[6] Evanoff and Wall (2001) examined this proposition directly by testing the degree to which subordinated debt spreads provide supervisors with additional information. In their study, they modeled changes in the supervisory ratings of banks and BHCs that have outstanding subordinated debt over the period 1990 to 1999 as a function of lagged subordinated debt spreads and regulatory capital ratios. They found that subordinated debt spreads do as well as or better than any of the capital ratios at explaining supervisory rating changes.

A few recent studies have examined the relationship between securities market information, both equity and debt, and bank ratings. Gropp and Richards (2001) found that changes in agency ratings for European banks have little impact on bond prices and a strong effect on equity prices in the case of rating downgrades. Extending this work, Gropp, et al. (2002) examined the ability of equity and debt market variables for European banks to signal changes in

5. Note that Allen, et al. (2001) do not find evidence that supervisory ratings affect equity market assessments when the supervisory ratings of bank management actually become public knowledge. However, since these results are tied to the special case of changes in bank charter status, it is not clear how general these results are.

6. Hancock and Kwast (2001) provide support and additional guidance for the use of subordinated debt spreads in supervisory monitoring and highlight difficulties with currently available data sources. Bliss (2000) objects to this viewpoint, arguing that supervisory interests may diverge from bondholder interests in that the parties may disagree on the relative riskiness of different bank portfolios.

bank financial conditions. Using ordered logit models at several horizons and a proportional hazard model, they found that both equity-based measures of bank default and subordinated debt spreads are useful for detecting changes in bank agency ratings. Interestingly, they found that equity-based default measures are less useful when banks are closer to default and that subordinated debt spreads have signal value only close to defaults.

Bongini, et al. (2002) found different patterns among equity and debt market indicators with respect to signaling financial distress at individual Asian banks during the East Asia crisis of 1997. The authors found that information based on stock prices or on agency ratings did not improve upon the historical information contained in balance sheet data. However, stock prices responded more quickly to changing financial conditions than did agency ratings.

Turning to U.S. supervisory BHC ratings, Berger, et al. (2000) found that financial market and supervisory assessments appear to focus on different aspects of BHC performance. Supervisory BHC ratings are most closely related to agency ratings, as indicated by the finding that supervisory ratings Granger-cause agency bond ratings, and vice versa. However, this type of interrelation is not apparent between supervisory ratings and equity market assessments; that is, the authors found very little Granger-causality from equity market variables to supervisory ratings. Furthermore, they found that, after accounting for equity and debt market assessments, supervisory ratings do not contribute substantially to the modeling of future indicators of BHC performance, such as changes in nonperforming loans. Our study is most closely related to this study, although our sample periods and empirical methods differ. Overall, however, both of our studies find that monitoring by supervisors, bond market investors, and equity market investors all produce complementary information on BHC performance.

In summary, the broad consensus from these empirical studies is that financial market investors do conduct reasonable monitoring of BHCs and that the information they generate is different from that generated by supervisors. As shown in Krainer and Lopez (2001, 2003) and as will be shown below, financial market information can complement supervisory monitoring, especially with regard to off-site monitoring models.

3. Supervision of Bank Holding Companies

In the United States, the Federal Reserve is the supervisor of BHCs as well as financial holding companies, which were created by the Gramm-Leach-Bliley Act of 1999. Full-scope, on-site inspections are a key element of the supervisory process. These inspections generally are conducted on an annual basis, particularly in the case of large and complex BHCs.[7]

Although the inspection process also includes limited and targeted inspections that may or may not be conducted on-site, we focus our analysis on full-scope, on-site inspections since they provide the most comprehensive supervisory BHC assessments.

At the conclusion of an inspection, the supervisory team assigns the institution a numerical rating, called a composite BOPEC rating, that summarizes its opinion of the BHC's overall health and financial condition.[8] The BOPEC acronym stands for the five key areas of supervisory concern: the condition of the BHC's **B**ank subsidiaries, **O**ther nonbank subsidiaries, **P**arent company, **E**arnings, and **C**apital adequacy. BOPEC ratings are assigned according to an absolute scale ranging from 1, indicating strong performance, to 5, indicating very poor performance. BOPEC ratings of 1 or 2 indicate that the BHC is not considered to be of supervisory concern. Note that BOPEC ratings are highly confidential and are not made available to the public.

Between on-site inspections, when private supervisory information cannot be gathered as readily, supervisors monitor BHCs using a well-specified off-site monitoring system; see Board of Governors (1995, 2002) for further discussion. Of particular importance to our analysis are the three primary sources of information used in the surveillance process. One source, known as the BHC Performance Report, is a detailed summary of BHC quarterly regulatory reporting forms; see Board of Governors (2001) for a complete description. As of March 1999, the report summarized approximately 800 BHC variables across several years. From this report, certain variables are selected as key performance criteria, and if a BHC fails to meet these criteria in a given quarter, this is noted as a supervisory exception that requires further monitoring.

A second source of information for off-site BHC monitoring is the supervisory CAMELS ratings assigned to banks within a bank holding company. As with BOPEC ratings, CAMELS ratings are assigned after bank examinations and are not made public. The CAMELS acronym refers to six key areas of concern: the bank's **C**apital adequacy, **A**sset quality, **M**anagement, **E**arnings, **L**iquidity, and **S**ensitivity to risk. The composite CAMELS ratings

7. A complex BHC has nonbank subsidiaries that extend credit or have debt outstanding to the general public. See DeFerrari and Palmer (2001) for an overview of the supervisory process for large, complex banking organizations. Note that the frequency of such inspections for BHCs with less than $1 billion in assets has been reduced, as described in Board of Governors (2002).

8. For an overview of supervisory rating systems in the U.S. and the rest of the world, see Sahajwala and Van der Bergh (2000).

also range from 1 to 5, with banks assigned lower ratings for better performance. Since BHC conditions are closely related to the conditions of their subsidiary banks, the off-site BHC surveillance process includes monitoring recently assigned CAMELS ratings.

As with on-site BHC inspections, on-site bank examinations occur at approximately an annual frequency, which is long enough for the gathered supervisory information to decay and become less representative of the bank's condition.[9] To address this issue, the Federal Reserve instituted an off-site monitoring system for banks, known as the System for Estimating Examiner Ratings (SEER), in 1993.[10] The SEER system consists of two separate models, one that forecasts bank failures over a two-year horizon and one that forecasts CAMELS ratings for the next quarter. The model that we are most interested in here is the latter, which is an ordered logit model with five categories corresponding to the five possible values of the CAMELS rating. The model is estimated every quarter in order to reflect the relationship between selected financial ratios and the two most recent quarters of CAMELS ratings. Significant changes in a bank's CAMELS rating as forecasted by the SEER model could be sufficient to warrant closer monitoring of the bank. The off-site BHC surveillance program also explicitly monitors the SEER model's forecasted CAMELS ratings.

A third information source is BHC financial market information, when available. Supervisors monitor BHC securities prices at various horizons. For example, as stated in Board of Governors (1995), supervisory staff at the Federal Reserve Banks are expected to monitor stock prices for BHCs. If a BHC exhibits irregular stock price movements, this can be noted as an exception that requires closer monitoring during the regular surveillance process.

To examine the contribution of BHC financial market information to the supervisory process statistically, we construct a data set that combines BOPEC ratings, BHC variables collected during the supervisory process, and BHC financial market variables.[11] The complete data set spans the period from 1990 to 1999 and consists of 3,399 BOPEC assignments. Note that we will make use of different subsamples of this larger data set, depending on the application, throughout the paper.

To underscore the point that BOPEC ratings are absolute ratings and not relative ratings, Table 1 reveals a clear trend in assigned ratings that is tied to the broader U.S. economy. In 1990, over 30 percent of the BOPEC assignments were ratings of 3 or worse, and just 18 percent of the ratings were 1. However, by 1999, when the economy and the banking sector were in better condition, less than 7 percent of the BOPEC assignments were 3 or worse, and 43 percent of the ratings were 1.

4. Univariate Event Studies

This section addresses the first policy question, namely whether changes in BHC risk characteristics are incorporated into BHC security prices. We examine this question by conducting two sets of event studies to determine whether BHC financial market variables anticipate BOPEC assignments. The event studies focus on firm-specific variations in financial market variables that could be useful to supervisors.

There are several issues that arise in the process of conducting these event studies. First, as mentioned, BOPEC ratings are confidential and are not made public. Hence,

Table 1
BOPEC Ratings in the Sample, 1990–1999

	BOPEC ratings				
	1	2	3	4–5	Total observations
1990	46	135	54	27	262
% of total	17.6	51.5	20.6	10.3	
1991	48	140	76	36	300
% of total	16.0	46.7	25.3	12.0	
1992	55	194	75	52	376
% of total	14.6	51.6	19.9	13.8	
1993	96	216	56	28	396
% of total	24.2	54.5	14.1	7.1	
1994	136	211	32	22	401
% of total	33.9	52.6	8.0	5.5	
1995	143	210	31	18	402
% of total	35.6	52.2	7.7	4.5	
1996	194	195	21	3	413
% of total	47.0	47.2	5.1	0.7	
1997	176	178	16	1	371
% of total	47.4	48.0	4.3	0.3	
1998	113	108	14	1	236
% of total	47.9	45.8	5.9	0.4	
1999	104	122	12	4	242
% of total	43.0	50.4	5.0	1.7	
Total	1,111	1,709	387	192	3,399
%	32.7	50.3	11.4	5.6	

9. See Cole and Gunther (1998) as well as Hirtle and Lopez (1999) for further discussion of this issue.

10. For a complete description of the SEER system, see Cole, et al. (1995). The statistical analysis of supervisory bank ratings within the Federal Reserve System dates back to Stuhr and Van Wicklen (1974); see also Korobow, et al. (1977).

11. Throughout our analysis, we differentiate between "supervisory" variables, which are generated during BHC inspections or from mandatory supervisory reporting, and "financial market" variables derived from securities prices. This terminology unfortunately obscures the fact that supervisors also monitor financial market variables.

equity and debt market variables cannot directly anticipate BOPEC ratings. Instead, we must assume that changes in BHC conditions and investor expectations of their future profitability will lead to changes in both BHC securities prices and BOPEC ratings. Detecting such a leading relationship between market variables and BOPEC ratings would support the notion that market signals could be useful to BHC supervisors. Failure to detect such a relationship could be interpreted as evidence that BHC assets are too opaque, thus rendering financial market signals of little use from a supervisory standpoint. Alternatively, failure to detect a leading relationship could imply that investors are indifferent to BOPEC rating changes.

Second, the timing convention used in the event study is critical. If investors receive information about a change in BHC condition before the beginning of our defined event window, then the event study will miss the market signal. To guard against this possibility, our event window begins one year before the BOPEC assignment. Additionally, we limit our analysis to events where there is at least one year between a BHC's inspections.

Third, care must be taken in interpreting signals extracted from market prices. For the case of subordinated debt spreads, market illiquidity and infrequent trading can make reported prices unreliable. These problems would tend to bias the results against finding a significant relationship between supervisory ratings and changes in spreads. For equity market data, our focus on stock returns abstracts from problems of disentangling changes in stock returns due to changes in the market value of BHC assets and those due to changes in BHC asset volatility.[12] These distinctions are important when trying to forecast events such as BHC default, especially in light of the public safety net for banks.

Finally, market signals can be interpreted as significant or abnormal only with the aid of a model. Thus, as with all event studies, the hypotheses tested below are actually joint hypotheses of whether market investors anticipate an event and whether the pricing model is correct. For our equity market event studies, we used a standard model. For our debt market event study, however, there is no commonly accepted model of bond spreads that allows a clear identification of BHC-specific variation. Rather, we look for significant deviations in BHC debt spreads from reasonable benchmarks.

The focus in this section on abnormal changes in security prices is based on the ease with which certain hypotheses can be tested in a univariate setting. This approach does not, of course, make use of the full potential of market data. If a common shock, such as a recession, affects all securities prices, our focus on abnormal returns would ignore this shock. Yet, the fact that all securities prices, including BHC security prices, have changed may be useful information to the supervisors. We address this issue of systematic variation in securities prices in our multivariate analysis in Section 5.

In both sets of event studies, we define the event date to be the inspection exit date, which is the day that examiners conduct their final meeting with BHC management. The first set of event studies is based on BHC stock returns and uses standard methods, as in Campbell, et al. (1997). In the second set, we examine whether changes in subordinated debt spreads anticipate changes in BOPEC ratings.

4.1. Equity Market Event Studies

For our equity market event study, we use monthly stock return data to investigate whether market investors anticipate BOPEC changes.[13] We define the event window as beginning twelve months prior to the exit date and ending three months after the exit date. We assume that stock returns follow a simple two-factor model, where the factors are the return on a broad market portfolio and the change in the federal funds rate; see Box 1 for further details. The model is estimated using monthly returns for up to 60 months prior to the beginning of the event window. In the event window, we compute *abnormal returns,* or deviations of actual returns from the model's predicted return. Cumulative abnormal returns (CARs) are formed by summing abnormal returns across the event window and are standardized using their estimated variances. The resulting standardized CARs (SCARs) are characterized well by the standard normal distribution and are used to test our event study hypotheses.

The event study is conducted using BOPEC ratings assigned from 1990 to 1999. A BHC inspection qualifies for the event study if it meets three criteria: there is enough stock return data to estimate the two-factor model; we can identify the BHC's lead bank and its prior BOPEC rating; and at least one year has elapsed since the previous inspection. The sample for this exercise consists of 813 BOPEC assignments for publicly traded BHCs, of which 139 (17 percent) are upgrades and 85 (10 percent) are downgrades.

In Figure 1, we plot the average CARs and SCARs for the BOPEC upgrades, downgrades, and no changes. The average CAR is meant to convey a sense of the economic impact of a BOPEC assignment on stock returns, while the average SCAR is meant to gauge whether this effect is sta-

12. We analyze this distinction explicitly in Krainer and Lopez (2001).

13. Note that we actually used four-week returns, but we use the term "monthly" for convenience.

Box 1
An Event Study Model of BHC Stock Returns

We structure our equity market event studies using a two-factor model of BHC stock returns; see Campbell, et al. (1997) for a general overview of event study methodology. We define R_{it} to be the four-week (or "monthly") stock return for BHC i at time t. R_{it} is assumed to take the form

$$R_{it} = \alpha + \beta R_{mt} + \gamma f_t + \varepsilon_{it} ,$$

where R_{mt} is the monthly return on the value-weighted portfolio of all NYSE, AMEX, and NASDAQ stocks at time t, f_t is the monthly change in the federal funds rate, and ε_{it} is a normally distributed error term.

In the banking literature, two-factor models are by far the most common specification used for event studies, and virtually all of these models incorporate the overall market return as a factor. There is less uniformity in the choice of the second factor. Some authors have used the return on a portfolio of bank stocks, as per Berger and Davies (1998). Other studies let the second factor capture changes in the interest rate environment. For example, Kwan (1991) used holding period returns on short-term and long-term constant maturity Treasury bonds as the second factor, and Hirtle (1997) used the percentage change in yield on a 10-year Treasury security. Following Kho, et al. (2000), we use the change in a short-term interest rate as the second factor.

We define the event window as beginning twelve months prior to the exit date of the BHC inspection and ending three months after the exit date. The model's parameters are estimated using monthly returns for up to 60 months prior to the beginning of the event window. Within the event window, the abnormal return is defined as

$$AR_{it} = R_{it} - \hat{\alpha}_i - \hat{\beta}_i R_{mt} - \hat{\gamma}_i f_t ,$$

and the cumulative abnormal return from time $t-j$ to time t is defined as

$$CAR_{i,t-j,t} = \sum_{s=t-j}^{t} AR_{is} .$$

The standardized cumulative abnormal return for this period is calculated as

$$SCAR_{i,t-j,t} = \frac{CAR_{i,t-j,t}}{\sqrt{\text{var}(CAR_{i,t-j,t})}} ,$$

which has a t-distribution with degrees of freedom based on the size of the model's estimation window. These *SCAR* variables are the ones used to test our event study hypotheses.

Note that we use the fitted systematic returns from our two-factor model in our multivariate analysis. The fitted systematic return is defined as

$$SR_{it} = \hat{\alpha}_i + \hat{\beta}_i R_{mt} + \hat{\gamma}_i f_t ,$$

and the cumulative systematic return from time $t-j$ to time t is defined as

$$CSR_{i,t-j,t} = \sum_{s=t-j}^{t} SR_{is} .$$

The standardized cumulative systematic return for this period is calculated as

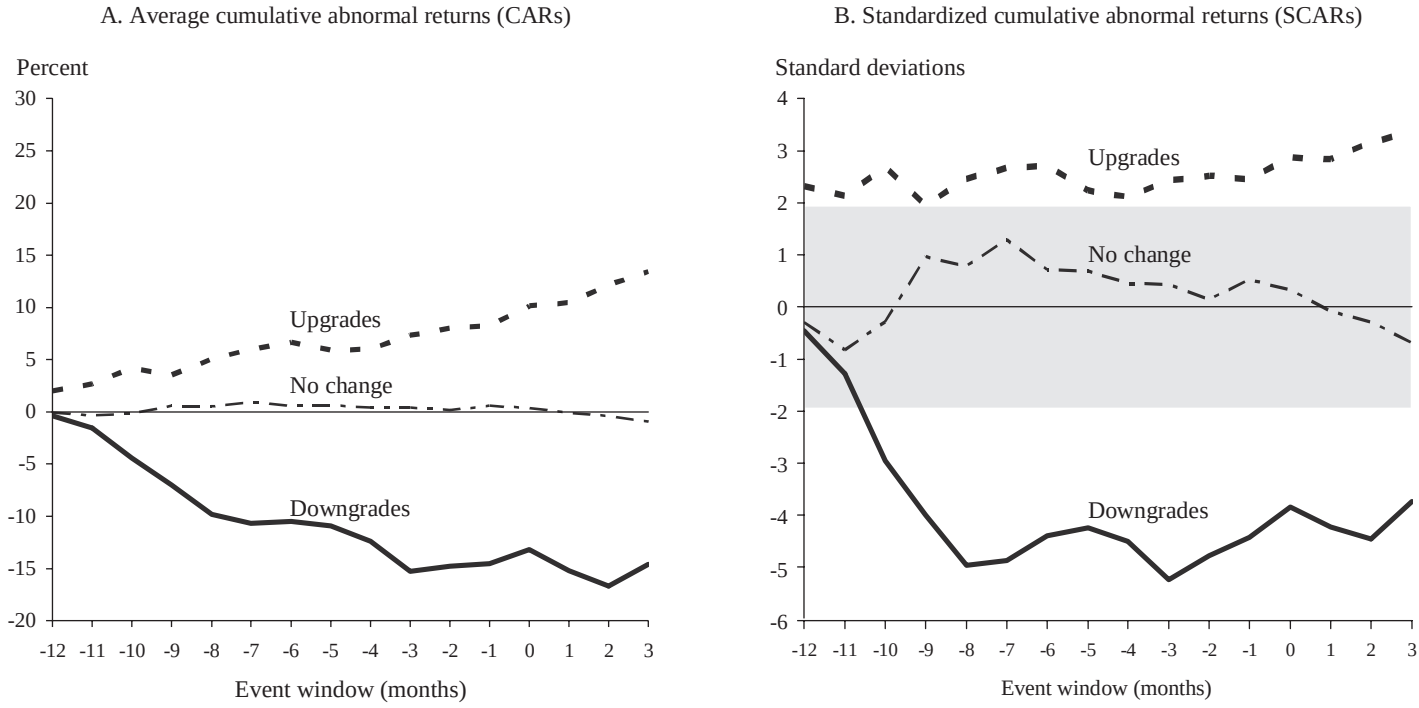
$$SCSR_{i,t-j,t} = \frac{CSR_{i,t-j,t}}{\sqrt{\text{var}(CAR_{i,t-j,t})}} .$$

tistically significant. Note that average SCARs with an absolute value greater than 1.96 are statistically significant at the 5 percent confidence level.

The figure clearly shows that equity market participants anticipate BOPEC changes well in advance of their actual assignments. For the BOPEC upgrades, the average CARs increase as we approach the event date, growing to over 13 percent by the end of the event window. The SCARs are significantly positive as early as twelve months prior to the inspection. For the BOPEC downgrades, the average CAR was –15 percent by the end of the event window, and the average downgrade SCARs are statistically significant as early as ten months prior to the exit date. Additionally, on average, the market does not appear to send false signals of approaching changes. The average CARs for inspections with no change in BOPEC rating are generally positive yet quite small and never statistically significant. By the end of the event window, the average CAR for no change inspections is approximately –1 percent. These results confirm the hypothesis that equity markets are capable of anticipating BOPEC changes.

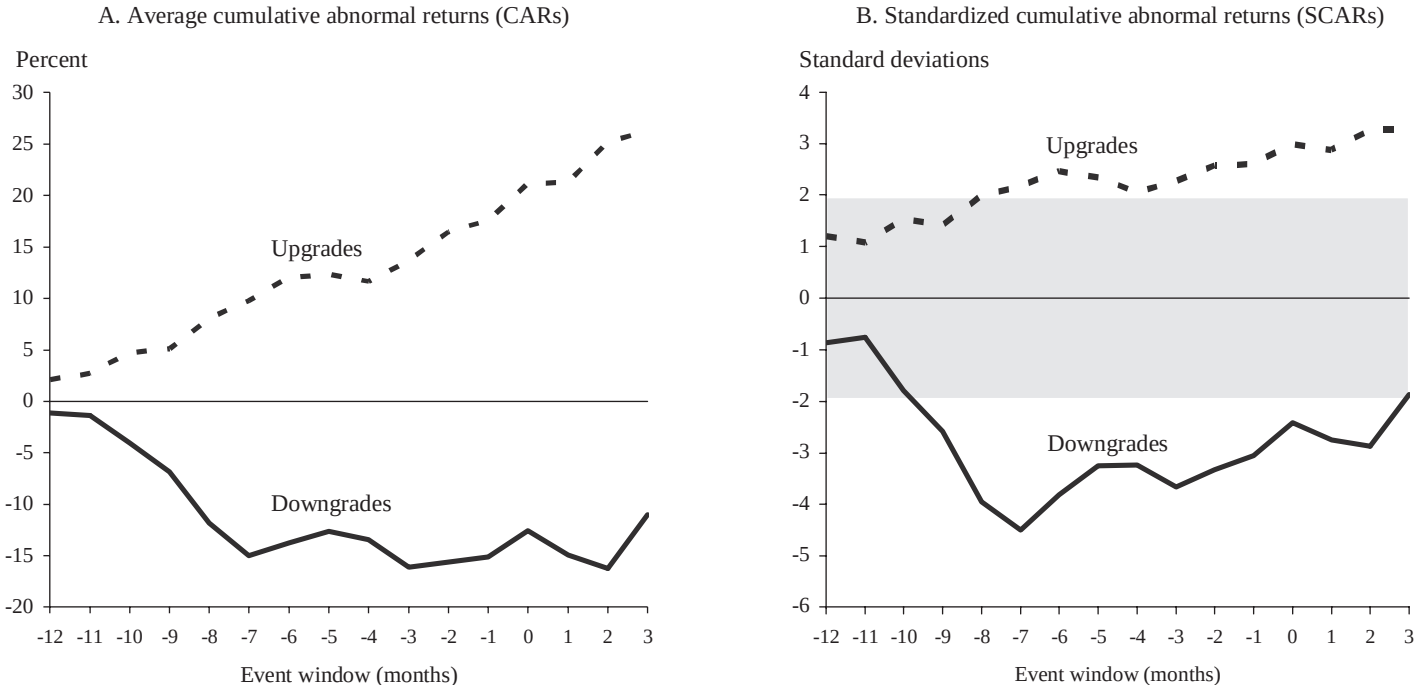
A change over the threshold between BOPEC ratings 2 and 3 is of particular concern to supervisors, and our event study focusing on these occasions is summarized in Figure 2. Note that crossings of this regulatory threshold are relatively rare events (about 11 percent of the sample) and, thus, the average CARs and SCARs are measured with more error. Nevertheless, the stock market behavior prior to these events is broadly similar to our earlier results. For the 39 downgrades below the threshold, the market sends a statistically significant signal nine months prior to the exit date, approximately the same time as for the case of all downgrades. Over the event window, the average CAR for downgrades below the threshold is –11 percent.

FIGURE 1
EQUITY MARKET EVENT STUDY FOR BOPEC CHANGES



Note: Inspection exit date occurs at month 0. Sample consists of 813 inspections, of which 139 are upgrades, 85 are downgrades, and 589 show no change. Shaded band shows the 95 percent confidence interval.

FIGURE 2
EQUITY MARKET EVENT STUDY FOR BOPEC CHANGES CROSSING THE THRESHOLD BETWEEN RATINGS 2 AND 3



Note: Inspection exit date occurs at month 0. Sample consists of 50 upgrades and 39 downgrades over the BOPEC 2 and BOPEC 3 threshold. Shaded band shows the 95 percent confidence interval.

For the sample of 50 upgrades above the threshold, the average CAR is 21 percent at the event date and 26 percent by the end of the event window. The equity market appears to anticipate BOPEC upgrades moving above the threshold by seven months. This more focused event study confirms that equity markets are capable of anticipating BOPEC changes and that equity market variables could be useful for supervisory BHC monitoring.

4.2. Debt Market Event Study

In this section, we investigate whether changes in BHC bond yields anticipate changes in supervisory BOPEC ratings. The debt market variables used in this study are taken from the Warga/Lehmann Brothers Corporate Bond Database and are the same as those used by Bliss and Flannery (2001).[14]

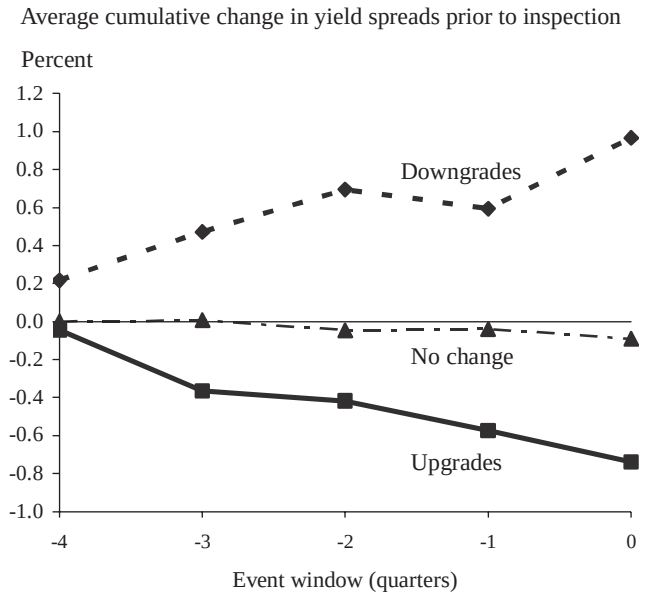
There are two unique empirical issues regarding bond data that must be addressed. First, in cases where a BHC has multiple outstanding bonds, we must compress these multiple market signals into a single observation. When confronted with this problem in our data set, we use a weighted average change in bond yields, where the weights are the bond amounts outstanding in each quarter. Second, as with the equity market variables, it is necessary to have some measure of whether a change in bond yield is abnormal. Following Bliss and Flannery (2001), we create BHC yield spreads by subtracting from a BHC's yield the yield on an index of bonds with similar terms-to-maturity and agency ratings. We use indices based on eleven categories corresponding to Moody's and S&P ratings and on three term-to-maturity categories.[15] This adjustment, however, still leaves open the possibility that the yield spread contains information common to all BHCs. Therefore, we further adjust the yield spread by subtracting off the median yield spread of BHC bonds with similar BOPEC ratings. The resulting variable is our "adjusted yield spread."

Due to data availability, the sample used in this event study is smaller than the one used in the equity event studies. This loss of observations reflects the relative scarcity of BHCs with publicly traded debt compared to those with publicly traded equity. This subsample contains 315 BOPEC assignments for 63 unique BHCs, 57 (18 percent) of which are upgrades and 30 (10 percent) of which are downgrades. The sample period ranges from the first quarter of 1990 to the second quarter of 1998.

In anticipation of a BOPEC downgrade, we would expect an increase in the BHC's adjusted yield spread, and in anticipation of an upgrade, we would expect a decrease in the adjusted yield spread. As shown in Figure 3, the data appear to move in accordance with these expectations. For the BOPEC downgrades, the average cumulative increase in adjusted yield spreads is about 100 basis points (i.e., 1%) by the time of the exit date. For the BOPEC upgrades, adjusted yield spreads drop by about 75 basis points by the exit date. Using the nonparametric sign test, the cumulative change in adjusted yield spreads for the BOPEC upgrades and downgrades are significantly different from zero at the 5 percent confidence level. For the no-change inspections, the average cumulative change in adjusted yield spread is about –5 basis points and is not statistically significant.

In conclusion, both sets of event studies suggest that, on average, changes in BHC stock returns and subordinated debt yields are consistent with the supervisory BHC assessments summarized by BOPEC ratings. These financial market signals can be observed as statistically significant from about twelve to nine months prior to the BOPEC assignments, and thus these data could be of use for supervisory off-site monitoring. What remains to be seen, however, is whether the financial variables add information to that which is already available to supervisors from their own information sources. We turn to this question in the next section.

Figure 3
Debt Market Event Study for BOPEC Changes



Note: Sample consists of 315 inspections, of which 57 are upgrades, 30 are downgrades, and 228 show no change.

14. We thank Rob Bliss for sharing these data with us.

15. As in Bliss and Flannery (2001), the qualifiers attached to the basic agency ratings are suppressed, and the three maturity categories are less than five years, five to ten years, and greater than ten years.

5. Multivariate Analysis Using the BOPEC Off-Site Monitoring Model

The second policy question that we address is whether financial market data provide supervisors with information above and beyond the balance sheet and supervisory ratings data that they already possess. Unlike the event studies where we looked at the behavior of securities prices leading up to BOPEC assignments of known outcomes, here we formally model the supervisory BOPEC ratings themselves. While models must abstract from the real decisionmaking process that takes place in an inspection, they have the advantage of offering a relatively easy way to evaluate the potential contribution of different data.

5.1. Model Description

Following Krainer and Lopez (2001, 2003), we use a multivariate model that allows BOPEC ratings to depend on both supervisory variables and financial market data. Not only does this approach allow us to study the marginal value of financial market data relative to supervisory data, but we are also free to use a larger array of financial market data than is possible in a univariate framework; specifically, we can incorporate both equity and debt market data in the same model. We also now can examine the influence of systematic changes in financial market variables (i.e., variation across all BHCs and not limited to a specific BHC) on BOPEC ratings.

The BOPEC off-site monitoring (BOM) model that we use is an ordered logit; see Box 2 for further details. In the model, the BOPEC rating assigned to a BHC depends on supervisory data available two quarters prior to the inspection and on financial market variables available one quarter prior to the inspection. We would prefer to use more up-to-date supervisory variables for this exercise, but, as a practical matter, supervisory data are not widely available for about 60 days after the end of the quarter. Since we conduct a forecasting exercise, we err on the conservative side and use supervisory data from two quarters prior to the inspection so as to best mimic the information supervisors actually would have if they were generating the forecasts in real time.[16]

Supervisors collect hundreds of financial variables in the course of routine BHC monitoring and, for the case of the largest BHCs where examiners are continuously present, they collect data more often than the quarterly frequency that we use here. To build a parsimonious off-site monitoring model, we condense the list of potential explanatory variables to just eight variables that correspond to the main areas of concern in BHC inspections.

To capture the supervisory concerns regarding bank subsidiaries summarized in the "B" component of the rating, we use the CAMELS rating of the BHC's lead bank; the ratio of the sum of BHC nonperforming loans, nonaccrual loans, and other real estate owned to its total assets; and the ratio of BHC allowances (or provisions) for losses on loans and leases to its total loans. To measure a BHC's nonbank activities that are captured in the "O" component of the rat-

16. As a robustness check, we verify that the results change little when the supervisory data are lagged by only one quarter.

Box 2
The BOPEC Off-Site Monitoring (BOM) Model

As proposed by Krainer and Lopez (2001), an ordered logit model is used to construct the BOPEC off-site monitoring (BOM) model. Within this structure, BOPEC ratings are modeled as a continuous variable BP_{it}^*, which is a linear function of supervisory and financial market variables. Specifically, $BP_{it}^* = \beta x_{it-2} + \theta z_{t-1} + \varepsilon_{it}$, where x_{it-2} is a vector of supervisory variables unique to BHC i observed two quarters prior to the inspection, $z_{i,t-1}$ is a vector of financial market variables specific to BHC i observed one quarter prior to the inspection, and the disturbance term ε_{it} has a standard logistic distribution. Note that this is a forecasting model, so all the independent variables are lagged relative to BP_{it}^*. We would prefer to use more up-to-date supervisory variables for this exercise, but, as a practical matter, supervisory data are not widely available for about 60 days after the end of the quarter. Thus, we must use supervisory data from two quarters prior to the inspection.

Since BOPEC ratings only take integer values between 1 and 5, the model's estimation procedure also must find the four points, denoted α_1 through α_4, that cut the support of BP_{it}^* into five non-overlapping regions. That is,

$$BP_{it} = 1 \text{ if } BP_{it}^* \in (-\infty, \alpha_1],$$

$$BP_{it} = 2 \text{ if } BP_{it}^* \in (\alpha_1, \alpha_2],$$

$$BP_{it} = 3 \text{ if } BP_{it}^* \in (\alpha_2, \alpha_3],$$

$$BP_{it} = 4 \text{ if } BP_{it}^* \in (\alpha_3, \alpha_4],$$

$$BP_{it} = 5 \text{ if } BP_{it}^* \in (\alpha_4, \infty).$$

The model is estimated using maximum likelihood methods. The estimation results are available in Krainer and Lopez (2001, 2003).

ing, we use an indicator of whether the BHC engages in securities underwriting via a Section 20 subsidiary and the ratio of its trading assets to total assets. These nonbank activities could affect BHC condition in a number of different and competing ways. For example, if a BHC's expansion into nonbanking activities affords it revenue diversification, the expansion could improve the BOPEC rating, holding all other things equal. Alternatively, such activities could increase overall BHC risk, in which case the BOPEC rating would be harmed.

The health of the parent company, as reflected in the "P" component of the rating, is captured by the ratio of the lead bank's equity capital to the BHC's equity capital—the so-called "double leverage" ratio. The earnings (or "E") component of the rating is captured using the BHC's return on average assets, defined as the ratio of the four-quarter average of a BHC's net income to the four-quarter average of its assets. The BHC's capital position, which is the "C" component of the rating, is summarized by the ratio of BHC equity capital to its total assets.

We also include two BHC control variables in the regression. We include the natural log of total BHC assets as a size control. We also include the BHC's last assigned BOPEC rating as a way to summarize any relevant supervisory information not captured by the other eight variables.

For financial market variables, we use the equity and debt variables from the event studies. For the equity variables, we use the SCAR variables over the six-month window at one quarter prior to the BOPEC assignment. We also include a measure of the overall equity market variation within the BHC stock returns. This latter variable is used within the model to capture broad economic shocks that likely will affect all BHC securities prices.[17] The debt market variable is calculated as the three-month change in the adjusted yield spread ending one quarter prior to the exit date.

The full estimation sample contains 2,940 inspections beginning in the first quarter of 1990 and ending in the second quarter of 1998, of which 643 (22 percent) are upgrades and 344 (12 percent) are downgrades. We consider two specifications of the BOM model. The first model has only supervisory variables and is known as the "core" model. The second model is an extension of the core model that includes the three financial market variables. When estimating the extended model, the data are pooled to include all BHCs, regardless of whether they have publicly traded equity or publicly traded debt.[18]

5.2. In-Sample Estimation Results

In-sample estimates of the BOM model's coefficients over the full estimation sample are discussed in great detail in Krainer and Lopez (2001, 2003) and are summarized briefly in Box 3. Key supervisory variables, such as the lagged BOPEC rating, the bank subsidiary's CAMELS rating, problem loans, provisions, returns on assets, and equity capital, all have coefficients with the expected signs and are statistically significant. Thus, using the BOM model, the variables meant to proxy for the "B," "E," and "C" components of the BOPEC ratings are significant for describing actual ratings. However, our measures of the "O" and "P" components are not.

The financial market variables all have the expected sign and are statistically significant. Thus, both equity and debt market information appear to be useful for describing past BOPEC ratings, suggesting that both sets of market participants have information that could be useful to supervisors. For the equity market variables, both the BHC-specific return and the systematic return are significantly different from zero. Thus, as hypothesized, systematic changes in stock prices that would accompany common shocks, such as changing economic conditions, contain information that could be useful to supervisors. Large abnormal changes in stock prices and debt yields again are shown to contain useful information, as was found in the event studies.

5.3. Out-of-Sample Forecast Accuracy

Although the in-sample estimation results are of interest, what is of most interest for an off-site monitoring model is its out-of-sample forecast accuracy. That is, given a model fitted to historical data, what percentage of its forecasted BOPEC ratings correctly anticipate the BOPEC ratings eventually assigned? To address this question, we generate BOPEC forecasts from the core and extended BOM models and assess their performance relative to the actual BOPEC assignments in our database. We do so by using a rolling estimation technique; that is, we estimate the two BOM models using just four quarters of data and then forecast BOPEC ratings for the next quarter. We roll through our sample period from the first quarter of 1990 through

17. By including these two equity market variables in the model, we effectively decompose the cumulative BHC stock returns into a fitted systematic component and an abnormal (or idiosyncratic) component; see Box 1 as well as Krainer and Lopez (2001) for further details.

18. We pool the data and adjust for the missing securities market information in order to increase our sample size and improve the precision of the coefficient estimates. See Krainer and Lopez (2001, 2003) for further methodological details.

Box 3
Explanatory Variables in the Extended BOM Model

Variables	An increase suggests
Supervisory variables:	
Lead bank CAMELS	worse rating*
Problem loans / total assets	worse rating*
Provisions / total loans	worse rating*
Section 20 indicator	unclear
Trading assets / total assets	unclear
Double leverage	improved rating
Return on assets	improved rating*
Equity capital	improved rating*
Log of total assets	unclear*
Prior BOPEC rating	worse rating*
Financial market variables:	
Six-month SCAR	improved rating*
Six-month fitted return	improved rating*
Three-month change in adjusted yield spread	worse rating*

*Indicates statistical significance at the 5 percent level.

the second quarter of 1998 and generate one-quarter-ahead forecasts for all 2,940 inspections in the database for each quarter. To analyze forecast accuracy, we look at the BOPEC forecasts generated four quarters prior to the BOPEC assignments.

The results are summarized in Tables 2 and 3, where a row describes the distribution of actual BOPEC ratings associated with a particular BOPEC forecast. As we can see along the tables' diagonals, both models do fairly well at forecasting future ratings even at four quarters prior to the inspection. For example, in Table 2, if the core model forecasts a BOPEC rating of 1 four quarters prior to an inspection, the actual BOPEC rating assigned is 1 about 80 percent of the time. The core model forecasts a BOPEC rating of 1 or 2 accurately 75 percent of the time. However, the model appears to be less accurate in forecasting inspection outcomes at the lower-rated BHCs at the four-quarter horizon. Given BOPEC forecasts of 3 or higher, these forecasts are correct about 40 percent of the time.

The extended BOM model generates forecasts with approximately the same degree of forecast accuracy. As shown in Table 3, if the extended BOM model generates a BOPEC forecast of 1, these forecasts again are correct 78 percent of the time. BOPEC forecasts of 1 or 2 again are correct about 75 percent of the time. Like the core model, the extended model's accuracy diminishes for lower rated BHCs. BOPEC forecasts of 3 are correct only 41 percent of the time and actually are BOPEC ratings of 2 approximately 47 percent of the time. BOPEC forecasts of 5 match the actual rating just 19 percent of the time and are actually 4 ratings 53 percent of the time.

This poor performance by both models at the lower end of the ratings distribution may be due to the fact that the bulk of the BOPEC ratings in our sample are 1 and 2 (recall

Table 2
Forecasting Accuracy of the Core Model at Four Quarters Prior to Assignment

	Actual rating					
Forecasted rating	1	2	3	4	5	Total
1	**619**	148	4	1	1	773
% of total	**80**	19	1	0	0	
2	302	**1,138**	116	26	1	1,583
% of total	19	**72**	7	2	0	
3	1	180	**153**	39	0	373
% of total	0	48	**41**	11	0	
4	0	16	70	**76**	11	173
% of total	0	9	41	**44**	6	
5	0	0	9	20	**9**	38
% of total	0	0	24	53	**24**	
Total	922	1,482	352	162	22	2,940

Note: Rows denote the distribution of actual BOPEC ratings given the model's forecast. The full estimation sample contains 2,940 inspections beginning in the first quarter of 1990 and ending in the second quarter of 1998, of which 643 (22 percent) are upgrades and 344 (12 percent) are downgrades. Bold denotes correct forecast.

Table 3
Forecasting Accuracy of the Extended Model at Four Quarters Prior to Assignment

	Actual rating					
Forecasted rating	1	2	3	4	5	Total
1	**605**	161	5	1	1	773
% of total	**78**	21	1	0	0	
2	316	**1,131**	116	22	0	1,585
% of total	20	**71**	7	1	0	
3	1	171	**152**	42	1	367
% of total	0	47	**41**	11	0	
4	0	19	69	**78**	13	179
% of total	0	11	39	**44**	7	
5	0	0	10	19	**7**	36
% of total	0	0	28	53	**19**	
Total	922	1,482	352	162	22	2,940

Note: Extended model includes supervisory data and debt market and equity market data as explanatory variables. Rows denote the distribution of actual BOPEC ratings given the model's forecast. The full estimation sample contains 2,940 inspections beginning in the first quarter of 1990 and ending in the second quarter of 1998, of which 643 (22 percent) are upgrades and 344 (12 percent) are downgrades. Bold denotes correct forecast.

Table 1). Another possible reason is that BOPEC ratings of 3 and 5 are important cusp points in the rating system and may be where supervisory concerns not captured by the models play a larger role.

A critical question is whether the extended model including both supervisory and financial market variables provides useful information about BOPEC ratings beyond what is obtained by the core model. A common way to make such an assessment is to compare the accuracy of the two sets of forecasts statistically, which in this case is comparing the percentages of BOPEC ratings that they accurately forecast. We formally test for differences between the forecasts in other research (Krainer and Lopez 2001, 2003) and we find little statistical difference between the two sets of forecasts. Hence, using this metric, the financial market variables do not appear to contribute to the supervisory information set.

This result, however, does not mean that the set of BOPEC ratings correctly forecasted by the two models are identical; in fact, the two models signal BOPEC changes for different, although overlapping, sets of BHCs. The forecasting literature has shown that combining forecasts from different models can improve certain aspects of forecast accuracy. Hence, another way to gauge the contribution of financial market information to the BOM model is to examine the additional forecast signals for publicly traded BHCs generated by the extended model relative to the core model's signals. Seen in this light, the marginal benefit of adding these signals to those from the core model is notable.

In the second column of Table 4, we focus exclusively on downgrade signals prior to assignment. We define a downgrade signal as a forecasted BOPEC rating that is greater than the current rating by one or more ratings.[19] Using the signals generated by both models, we ask, what is the percentage increase in correct signals when financial market data are used in the BOM model? For the extended model, 9 percent more correct signals are produced at the four-quarter horizon over and above those produced by the core model.[20] At the one-quarter horizon, the model produces 37 percent more signals.

Of course, the extended model produces incorrect signals over and above those produced by the core model. We look at this tradeoff more closely in the third column of Table 4, where we express the ratio of correct signals to incorrect signals. For example, the extended model produces one additional correct downgrade signal at the cost of four incorrect signals at the four-quarter horizon. At the one-quarter horizon, however, the accuracy tradeoff dramatically improves to four additional correct signals at the cost of only one extra incorrect signal. In summary, the marginal contribution of financial market variables to BOPEC forecasts generated by the extended BOM model is present, but not across all BOPEC forecasts. As presented in Table 4, the contribution is most clearly seen in the additional correct forecasts generated at the relatively low cost of incorrect forecasts.

Table 4
Forecast Analysis of the Combined Forecasts from the Core and Extended BOM Models

	Extended BOM Model	
	% increase in total correct downgrade forecast signals	Tradeoff of correct signals to incorrect signals
4 quarters	9	1 / 4
3 quarters	38	5 / 2
2 quarters	51	19 / 3
1 quarter	37	4 / 1

Notes: Downgrade signal is defined as (forecasted rating – current rating) > 1. Table reports the number of downgrades correctly signaled by the extended model and not identified by the core model, expressed as a percentage of downgrades correctly identified by the core model. Entries in the tradeoff column report the number of additional correct BOPEC downgrade signals from the extended BOM model over the core model, at the cost of additional incorrect downgrade signals.

This result leads us directly to our third public policy question about the degree of accuracy supervisors should demand of financial market signals and of off-site monitoring models more generally. Clearly, any model will generate correct and incorrect forecasts, and the aggregate value of these forecasts will depend on the supervisors' relative costs regarding these forecasts. The two types of errors that can be made by an off-site monitoring model are missed signals, which are occasions when observed BOPEC downgrades are not forecasted (i.e., type-1 error), and false positives, which are forecasted downgrades that do not occur (i.e., type-2 error). Supervisors should be aware of the tradeoffs between these two error types for a given set of forecasts and could incorporate the tradeoff costs directly into their forecast evaluation.

For our exercise in Table 4, at four quarters prior to assignment, we have one missed downgrade signal for every four false positives. The policy question regarding the use of financial market information is whether the benefit of catching an additional BOPEC downgrade one year before

19. We set our definition of a downgrade signal at a forecast difference of one rating for clarity. Weaker signals, such as a difference of 0.75, could be used with a concurrent increase in the total number of signals and in the number of incorrect signals.

20. Formally, we compute the number of correct extended BOM signals and subtract those downgrades that the core BOM also correctly identifies.

it happens is worth the cost of four additional on-site inspections that do not lead to downgrades. This tradeoff becomes more stark at one quarter prior to assignment. Without knowing these actual costs a priori, it is not possible to make this judgment for our example. However, given the potentially large costs of missed signals, it is clear that supervisors could find it useful to use the extended BOM model for off-site monitoring.

6. Conclusion

Banks and their holding companies are subject to government supervision and regulation to guard against systemic risk to the economy. These supervisory efforts use a wide variety of information sources, from on-site inspections to BHC securities prices. In this article, we address three public policy questions related to the use of financial market information for supervisory purposes and conclude that this information should be of use to supervisors, at least in their off-site monitoring efforts.

The first policy question is whether changes in BHC risk characteristics get incorporated into BHC securities prices, the primary source of financial market information. In agreement with much of the academic literature, we find that securities prices do incorporate these risk changes and that the financial markets anticipate supervisory rating changes by about nine to twelve months.

The second question is whether supervisors already capture the information content of financial market prices using other means. Using the BOPEC off-site monitoring (BOM) model proposed by Krainer and Lopez (2001), we find that both equity and debt market variables are statistically significant in explaining BOPEC rating assignments, even when a wide variety of supervisory variables are already in the model. This result is further evidence that supervisors could benefit from incorporating financial market information into their off-site monitoring efforts.

The final policy question is how best to evaluate the contribution of financial market variables to supervisory monitoring; that is, what degree of accuracy should supervisors demand of financial market signals and of off-site monitoring models more generally? To address this question, we focus on out-of-sample forecast accuracy. We find that the forecast accuracy of BOM models with and without financial market variables is not statistically different, but that the two sets of BHCs for which BOPEC changes are forecasted are not identical. Furthermore, we find that when the downgrade forecast signals from the two models are combined, we have a roughly 10 percent increase in the number of correct signals, although at the cost of increased false positive signals. The policy question regarding the use of financial market information is now whether the benefit of catching an additional BOPEC downgrade one year before it happens is worth the cost of four additional on-site inspections that do not lead to downgrades. Given the potentially large costs of missed signals of BOPEC changes, especially downgrades, we believe it is clear that supervisors could find it beneficial to use the extended BOM model and financial market information more broadly for off-site monitoring.

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WP 02-01

Operating Performance of Banks among Asian Economies: An International and Time Series Comparison

Simon H. Kwan, *FRB San Francisco*

Published in *Journal of Banking and Finance* 27(3) (March 2003) pp. 471–489.
See p. 61 for the abstract of this paper.

WP 02-02

Assessing the Lucas Critique in Monetary Policy Models

Glenn D. Rudebusch, *FRB San Francisco*

Empirical estimates of monetary policy rules suggest that the behavior of U.S. monetary policymakers changed during the past few decades. However, at the same time, statistical analyses of lagged representations of the economy, such as VARs, often have not rejected the null of structural stability. These two sets of empirical results appear to contradict the Lucas critique. This paper provides a reconciliation by showing that the apparent policy invariance of reduced forms is consistent with the magnitude of historical policy shifts and the relative insensitivity of the reduced forms of plausible forward-looking macroeconomic specifications to policy shifts.

WP 02-03

Investment, Capacity, and Uncertainty: A Putty-Clay Approach

Simon Gilchrist, *Boston University*
John C. Williams, *FRB San Francisco*

In this paper, we embed the microeconomic decisions associated with investment under uncertainty, capacity utilization, and machine replacement in a general equilibrium model based on putty-clay technology. We show that the combination of log-normally distributed idiosyncratic productivity uncertainty and Leontief utilization choice yields an aggregate production function that is easily characterized in terms of hazard rates for the standard normal distribution. At low levels of idiosyncratic uncertainty, the short-run elasticity of supply is substantially lower than the elasticity of supply obtained from a fully flexible Cobb-Douglas alternative. In the presence of irreversible factor proportions, an increase in idiosyncratic uncertainty about the productivity of an investment project typically reduces investment at the micro level, but it raises aggregate investment. Increases in uncertainty also have important dynamic implications, causing sustained increases in investment and hours and a medium-term expansion in the growth rate of labor productivity.

WP 02-04

Imperfect Knowledge, Inflation Expectations, and Monetary Policy

Athanasios Orphanides, *Federal Reserve Board*
John C. Williams, *FRB San Francisco*

Forthcoming in *Inflation Targeting*, ed. Michael Woodford. Chicago: University of Chicago Press.
See p. 68 for the abstract of this paper.

WP 02-05

The Empirical Relationship between Average Asset Correlation, Firm Probability of Default, and Asset Size

Jose A. Lopez, *FRB San Francisco*

Forthcoming in *Journal of Financial Intermediation*.
See p. 63 for the abstract of this paper.

WP 02-06

Macro Factors and the Affine Term Structure of Interest Rates

Tao Wu, *FRB San Francisco*

I formulate an affine term structure model of bond yields from a general equilibrium business cycle model with observable macro state variables of the structural economy as the factors. The factor representing monetary policy is strongly mean-reverting, and its influence on the term structure is primarily through changing the slope of the yield curve. The factor representing technology is more persistent, and it affects the term structure by shifting the level of the yield curve. The dynamic implications of the model for the macro economy and the term structure are consistent with the broad empirical patterns. From simulation studies of the macro factor model I can extract the "level" and "slope" factors, similar to the ones extracted from the empirical term structure estimations. Simulation studies also show that the movement of the "slope" factor is primarily driven by the monetary policy innovations, and the changes of the "level" factor are more closely associated with the aggregate supply shocks from the private sector.

WP 02-07

Monetary Policy and the Slope Factor in Empirical Term Structure Estimations

Tao Wu, *FRB San Francisco*

This paper examines the empirical relationship between the movement of the slope factor in term structure of nominal interest rates and exogenous monetary policy shocks in the U.S. after 1982. Using first a six-variable VAR model and then a GMM estimation model of the "Taylor rule," I estimate the exogenous monetary policy shocks implied by each of them in the U.S. during this period. Meanwhile, a two-factor model is used to extract the underlying slope factor of the term structure. Results from the correlation study suggest that there is strong correlation between the slope factor and the exogenous monetary policy shocks. Moreover, monetary policy shocks can explain a large part of variability of the slope factor. This study provides strong evidence in support of the Knez, Litterman, and Scheinkman (1994) conjecture on the relation between the slope factor and Federal Reserve policy and is also consistent with the results of the general equilibrium-based simulation study in Wu (2001a).

WP 02-08

Stylized Facts on Term Structure and Business Cycles: An Empirical VAR Study

Tao Wu, *FRB San Francisco*

Forthcoming in *Applied Economics*.
See p. 70 for the abstract of this paper.

WP 02-09

A Gravity Model of Sovereign Lending: Trade, Default, and Credit

Andrew K. Rose, *University of California, Berkeley*
Mark M. Spiegel, *FRB San Francisco*

One reason why countries service their external debts is the fear that default might lead to shrinkage of international trade. If so, then creditors should systematically lend more to countries with which they share closer trade links. We develop a simple theoretical model to capture this intuition, then test and corroborate this idea.

WP 02-10

How Important Is Precommitment for Monetary Policy?

Richard Dennis, *FRB San Francisco*
Ulf Söderström, *Sveriges Riksbank*

Economic outcomes in dynamic economies with forward-looking agents depend crucially on whether or not the central bank can precommit, even in the absence of the traditional "inflation bias." This paper quantifies the welfare differential between precommitment and discretionary policy in both a stylized theoretical framework and in estimated data-consistent models. From the precommitment and discretionary solutions we calculate the permanent deviation of inflation from target that in welfare terms is equivalent to moving from discretion to precommitment, the "inflation equivalent." In the estimated models, using a range of reasonable central bank preference parameters, the "inflation equivalent" ranges from 0.05 to 3.6 percentage points, with a midpoint of either 0.15 or 1 to 1.5 percentage points, depending on the model. In addition to the degree of forward-looking behavior, we show that the existence of transmission lags and/or information lags is crucial for determining the welfare gain from precommitment.

WP 02-11

A Theory of Endogenous Nontradability and Its Implications for Intertemporal Trade

Paul R. Bergin, *University of California, Davis*
Reuven Glick, *FRB San Francisco*

This paper analyzes how trading frictions in the goods market limit intertemporal trade by creating endogenously nontraded goods. We formulate a small open economy two-period model in which goods switch endogenously between being traded or nontraded depending on relative transportation costs, endowments, and preferences. Our model nests together special cases analyzed by Dornbusch (1983), where some goods are nontraded in all periods, and Obstfeld and Rogoff (2000), where a good may be nontraded in one period but not in both. We show how endogenous nontradability affects intertemporal prices and the costs of borrowing, and hence may limit the magnitude of current account imbalances. In contrast to other recent work, our more general model implies that these borrowing costs are likely to rise dramatically even for relatively small current account imbalances.

WP 02-12

Estimating the Euler Equation for Output

Jeffrey C. Fuhrer, *FRB Boston*
Glenn D. Rudebusch, *FRB San Francisco*

New Keynesian macroeconomic models generally have emphasized that expectations of future output are a key factor in determining current output. The theoretical motivation for such forward-looking behavior relies on a straightforward generalization of the well-known Euler equation for consumption. In this paper, we use maximum likelihood and generalized method of moments (GMM) methods to explore the empirical importance of output expectations. We find little evidence that rational expectations of future output help determine current output, especially after taking into account the small-sample bias in GMM.

WP 02-13

Statistical Nonlinearities in the Business Cycle: A Challenge for the Canonical RBC Model

Diego Valderrama, *FRB San Francisco*

Significant nonlinearities are found in several cyclical components of macroeconomic time series across countries. Standard equilibrium models of business cycles successfully explain most first and second moments of these time series. Nevertheless, this paper shows that a model of this class cannot replicate nonlinear features of the data. Applying the Efficient Method of Moments (Gallant and Tauchen 1996, 2000) methodology to build an algorithm that searches over the model's parameter space establishes the parameterization that best allows replication of all statistical properties of the data. The results show that this parameterization captures nonlinearities in investment but fails to account for observed properties of consumption.

WP 02-14

The X-Efficiency of Commercial Banks in Hong Kong

Simon H. Kwan, *FRB San Francisco*

This paper uses the stochastic econometric cost frontier approach to investigate the cost efficiency of commercial banks in Hong Kong. On average, the X-efficiency of Hong Kong banks is found to be about 16 to 30 percent of observed total costs, which is comparable to the findings in the U.S. banking industry. X-efficiency is found to decline over time, indicating that banks in Hong Kong are now operating closer to the cost frontier than before. This is consistent with technological innovation that might have occurred in the Hong Kong banking industry. Furthermore, the average large bank in Hong Kong is found to be less efficient than the average small bank, particularly during the earlier time periods. Finally, X-efficiency is found to be related to certain bank characteristics. Specifically, X-efficiency is found to decline with bank size, deposit-to-asset ratio, loan-to-asset ratios, provision for loan loss, and loan growth, and to increase with off-balance sheet activities.

WP 02-15

The Impact of Financial Frictions on a Small Open Economy: When Current Account Borrowing Hits a Limit

Diego Valderrama, *FRB San Francisco*

The evidence of the last 20 years of recurring output busts and rapid reversals of the current account in emerging markets indicates that domestic agents may not be able to borrow in international capital markets to fully insure themselves against internal and external shocks. This paper models this phenomenon as a form of excess volatility by introducing a financial friction into a stochastic model of a small open economy. The financial friction limits the current account deficit to a fixed fraction of gross domestic product. The paper shows that conditional volatility and asymmetry are significant statistical characteristics of the GDP and current account that reflect the excess volatility and the current account reversals. The economic model can explain the conditional volatility and asymmetry of Mexican GDP and the current account.

WP 02-16

Network Externalities and Technology Adoption: Lessons from Electronic Payments

Gautam Gowrisankaran, *FRB San Francisco*
Joanna Stavins, *FRB Boston*

We seek to analyze the extent and sources of network externalities for the automated clearinghouse (ACH) electronic payments system using a quarterly panel data set on individual bank adoption and usage of ACH. We provide three methods to identify network externalities using this panel data. The first method identifies network externalities from the clustering of ACH adoption. The second method identifies them by examining whether banks in areas with higher market concentration or larger competitors are more likely to adopt ACH. The third method identifies them by examining whether the ACH adoption by small branches of large banks affects the adoption by local competitors. Using fixed effects and panel data these methods separately identify network externalities from technological advancement, peer-group effects, economies of scale, and market power. We find evidence that the network externalities are moderately large.

WP 02-17

Learning and the Value of Information: The Case of Health Plan Report Cards

Michael Chernew, *University of Michigan*
Gautam Gowrisankaran, *FRB San Francisco*
Dennis P. Scanlon, *The Pennsylvania State University*

We estimate a Bayesian learning model in order to assess the value of health plan performance information and the extent to which the explicit provision of information about product quality alters consumer behavior. We take advantage of a natural experiment in which health plan performance information for HMOs was released to employees of a Fortune 50 company for the first time. Our empirical work indicates that the release of information had a small but statistically significant effect on health plan choices, causing 3.1% of employees to switch health plans. Although consumers were willing to pay an extra $267 per year per below-average rating avoided, the average value of the information per employee was only $10 per year. The relatively small impact of the ratings arises because the ratings were estimated to be very imprecise measures of quality. More precise measures of quality could have been more valuable.

WP 02-18

Bayesian Inference for Hospital Quality in a Selection Model

John Geweke, *University of Iowa*
Gautam Gowrisankaran, *FRB San Francisco*
Robert J. Town, *University of Minnesota*

This paper develops new econometric methods to infer hospital quality in a model with discrete dependent variables and nonrandom selection. Mortality rates in patient discharge records are widely used to infer hospital quality. However, hospital admission is not random, and some hospitals may attract patients with greater unobserved severity of illness than others. In this situation the assumption of random admission leads to spurious inference about hospital quality. This study controls for hospital selection using a model in which distance between the patient's residence and alternative hospitals are key exogenous variables. Bayesian inference in this model is feasible using a Markov chain Monte Carlo posterior simulator and at-

taches posterior probabilities to quality comparisons between individual hospitals and groups of hospitals. The study uses data on 74,848 Medicare patients admitted to 114 hospitals in Los Angeles County from 1989 through 1992 with a diagnosis of pneumonia. It finds the smallest and largest hospitals to be of the highest quality. There is strong evidence of dependence between the unobserved severity of illness and the assignment of patients to hospitals, whereby patients with a high unobserved severity of illness are disproportionately admitted to high-quality hospitals. Consequently a conventional probit model leads to inferences about quality markedly different than those in this study's selection model.

WP 02-19

Exploring the Role of the Real Exchange Rate in Australian Monetary Policy

Richard Dennis, *FRB San Francisco*

Forthcoming in *Economic Record*.
See p. 59 for the abstract of this paper.

WP 02-20

The Supplemental Security Income Program

Mary C. Daly, *FRB San Francisco*
Richard V. Burkhauser, *Cornell University*

Forthcoming in *Means-Tested Transfers in the U.S.*, ed. Robert Moffitt. Cambridge, MA: NBER.
See p. 57 for the abstract of this paper.

WP 02-21

United States Disability Policy in a Changing Environment

Richard V. Burkhauser, *Cornell University*
Mary C. Daly, *FRB San Francisco*

Published in *Journal of Economic Perspectives* 16(1) (Winter 2002) pp. 213–224.
See p. 57 for the abstract of this paper.

WP 02-22

Self-Reported Work Limitation Data: What They Can and Cannot Tell Us

Richard V. Burkhauser, *Cornell University*
Mary C. Daly, *FRB San Francisco*
Andrew J. Houtenville, *Cornell University*
Nigar Nargis, *Cornell University*

Published in *Demography* 39(3) (August 2002).
See p. 57 for the abstract of this paper.

WP 02-23

Nonlinearities in International Business Cycles

Diego Valderrama, *FRB San Francisco*

This paper documents the dynamic properties of national output, its components, and the current account for five OECD countries. There is strong evidence of conditional volatility for almost all time series as well as significant deviations from normality. The deviations are detected particularly in GDP, net exports, and investment time series.

WP 02-24

Employment Declines among People with Disabilities: Population Movements, Isolated Experience, or Broad Policy Concern?

Mary C. Daly, *FRB San Francisco*
Andrew J. Houtenville, *Cornell University*

We look beyond the overall decline in employment among working-age people with disabilities in the 1990s to track the importance of three factors on the observed changes: (1) trends among key subgroups, especially those with employment-risk factors other than disability; (2) population shifts towards subgroups with lower-than-average employment rates; and (3) changes in self-reported health status. Our analysis is based on cross-sectional data from the Current Population Survey. Our results suggest that the decline was broad-based, present in a wide range of demographic and educational subgroups. In terms of population shifts, we find no evidence that compositional changes in the population with disabilities account for the average employment decline during the 1990s. In contrast, we find that compositional changes were important to the increase in employment among those with disabilities during the 1980s. Finally, we show that self-reported health among those with disabilities remained relatively stable in the latter half of the 1990s, making changes in health status an unlikely cause of declining employment rates.

Center for Pacific Basin Studies Working Papers Abstracts

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PB 02-01

The Disposition of Failed Japanese Bank Assets: Lessons from the U.S. Savings and Loan Crisis

Mark M. Spiegel, *FRB San Francisco*

This paper reviews the Japanese experience with "put guarantees" recently offered in the sale of several failed banks. These guarantees, meant to address information asymmetry problems, are shown to create moral hazard problems of their own. In particular, the guarantees make acquiring banks reluctant to accept first-best renegotiations with problem borrowers. These issues also arose in the U.S. savings and loan crisis. Regulators in that crisis turned to an alternative guarantee mechanism known as "loss-sharing arrangements," with apparently positive results. I introduce a formal debt model to examine the conditions determining the relative merits of these guarantees. The results show that both forms of guarantees reduce expected regulator revenues, but that the impact of economic downturns on the relative desirability of the two guarantees is ambiguous.

PB 02-02

How Bad Are Twins? Output Costs of Currency and Banking Crises

Michael Hutchison, *University of California, Santa Cruz*
Ilan (Neuberger) Noy, *University of California, Santa Cruz*

We investigate the output effects of severe banking and currency crises in emerging markets, focusing on whether "twin crises" (simultaneous occurrence of currency and banking crises) exist as a unique phenomenon and whether they entail especially large losses. Recent literature, mostly relating to the East Asian crisis, emphasizes the interplay and reinforcement between currency and banking crises, presumably making twin crises particularly damaging to the real economy. Using a panel data set over the 1975–1997 period and covering 24 emerging-market economies, we find that twin crises do not contribute any additional (marginal) negative impact on output growth. That is, twin crises do not adversely impact output over and above the independent effects associated with a currency and banking crisis taken together. We find that currency (banking) crises are very damaging, reducing output by about 5 to 8 (8 to 10) percent over a two- to four-year period. The cumulative output loss of both types of crises occurring at the same time is therefore very large, around 13 to 18 percent, and should alarm policymakers. However, twin crises are "bad" only in that they entail output losses associated with both currency and banking crises, not because there are additional feedback or interactive effects further damaging the economy. This result is robust to alternative model specifications, lag structures, and using IV and GMM estimation procedures that correct bias associated with simultaneity and estimation of dynamic panel models with country-specific effects.

PB 02-03

Sudden Stops and the Mexican Wave: Currency Crises, Capital Flow Reversals and Output Loss in Emerging Markets

Michael Hutchison, *University of California, Santa Cruz*
Ilan (Neuberger) Noy *University of California, Santa Cruz*

Sudden stops are the simultaneous occurrence of a currency/balance-of-payments crisis with a reversal in capital flows (Calvo 1998). We investigate the output effects of financial crises in emerging markets, focusing on whether sudden stop crises are unique phenomena and whether they entail an especially large and abrupt pattern of output collapse (a "Mexican wave"). Despite an emerging theoretical literature on sudden stops, empirical work to date has not precisely identified their occurrences nor measured their subsequent output effects in broad samples. Analysis of sudden stops may provide the key to understanding why some currency/balance-of-payments crises entail very large output losses, while others are frequently followed by

expansions. Using a panel data set over the 1975–1997 period and covering 24 emerging-market economies, we distinguish between the output effects of currency crises, capital inflow reversals, and sudden stop crises. We find that sudden stop crises have a large negative, but short-lived, impact on output growth over and above that found with currency crises. A currency crisis typically reduces output by about 2 to 3 percent, while a sudden stop reduces output by an additional 6 to 8 percent in the year of the crisis. The cumulative output loss of a sudden stop is even larger, around 13 to 15 percent over a three-year period. Our model estimates correspond closely to the output dynamics of the "Mexican wave" (such as seen in Mexico in 1995, in Turkey in 1994, and elsewhere), and out-of-sample predictions of the model explain the sudden (and seemingly unexpected) collapse in output associated with the 1997–1998 Asian crisis. The empirical results are robust to alternative model specifications, lag structures, and using estimation procedures (IV and GMM) that correct for bias associated with simultaneity and estimation of dynamic panel models with country-specific effects.

PB 02-04

On Discretion versus Commitment and the Role of the Direct Exchange Rate Channel in a Forward-Looking Open Economy Model

Alfred V. Guender, *University of Canterbury, Christchurch, New Zealand*

Irrespective of whether discretion or commitment to a binding rule guides the conduct of monetary policy, the existence of a direct exchange rate channel in the Phillips curve causes the behavior of the key economic variables in the open economy to be dramatically different from that in the closed economy. In the open economy, the policymaker can no longer perfectly stabilize real output and the rate of inflation in the face of IS and UIP shocks as well as shocks to foreign inflation. If the exchange rate channel in the Phillips curve is operative, then in the open economy the policymaker faces an output-inflation tradeoff that differs substantially from its counterpart in the closed economy.

Our analysis of the conduct of monetary policy reveals that the stabilization bias under discretion is weaker in the open economy relative to the closed economy. In the open economy, a "less conservative central banker" (one who attaches a smaller weight to the variance of inflation in the loss function) can be appointed to replicate the behavior of real output that eventuates under optimal policy. Evaluating the social loss function under discretion and commitment, we find that the existence of a direct exchange rate channel in the Phillips curve mitigates the pronounced differences between the two strategies that exist in case of high persistence in the stochastic shocks.

PB 02-05

Financial Structure and Macroeconomic Performance over the Short and Long Run

Jose A. Lopez, *FRB San Francisco*
Mark M. Spiegel, *FRB San Francisco*

Forthcoming in *Proceedings of the 2002 East-West Center/Korean Development Institute Conference on the Macroeconomic Implications of Post-Crisis Structural Change*.
See p. 64 for the abstract of this paper.

PB 02-06

Are Crisis-Induced Devaluations Contractionary?

Ramkishen S. Rajan, *University of Adelaide, Australia, and Institute of Southeast Asian Studies, Singapore*
Chung-Hua Shen, *National Chengchi University*

Why are some currency crises followed by economic contractions while others are not? This paper is an attempt to answer this query. In particular, we investigate two closely related questions. First, we explore whether there is a difference in the output effects of a devaluation during "normal" periods versus during crises; after all, during noncrisis periods, real exchange devaluation is seen as an important policy option for promoting exports and output growth. Yet, the literature has not made a distinction between crisis and noncrisis periods. To preview the main conclusion, we find that the contractionary effects tend to exist only during the crisis period. Building on this, we go on to explore the factors that cause a crisis-induced devaluation to be contractionary.

PB 02-07

Post-Crisis Exchange Rate Policy in Five Asian Countries: Filling in the 'Hollow Middle'?

Leonardo Hernández, *Central Bank of Chile*
Peter J. Montiel, *Williams College*

Following the 1997–1998 financial turmoil, crisis countries in Asia moved toward either floating or fixed exchange rate systems, superficially consistent with the bipolar view of exchange rate regimes and the "hollow middle" hypothesis. But some observers have claimed that, despite the changes in their de jure exchange rate regimes, the crisis countries' policies have de facto been very similar in the post- and pre-crisis periods. This paper analyzes the evidence and concludes that, except for Malaysia, which adopted a hard peg and imposed capital controls, crisis countries are floating more than before, though less than "real" floaters do. But the intermediate exchange rate policies pursued by most of the crisis countries during the post-crisis period can be justified on second-best arguments.

PB 02-08

The High Demand for International Reserves in the Far East: What's Going On?

Joshua Aizenman, *University of California, Santa Cruz*
Nancy Marion, *Dartmouth College*

This paper explores econometric and theoretical interpretations for the relatively high demand for international reserves by countries in the Far East and the relatively low demand by some other developing countries. Using a sample of about 125 developing countries, we show that reserve holdings over the 1980–1996 period seem to be the predictable outcome of a few key factors, such as the size of international transactions, their volatility, the exchange-rate arrangement, and political considerations. The estimating equation also does a good job of predicting reserve holdings in Asia before the 1997 financial crisis. After the crisis, the estimating equation significantly underpredicts the reserve holdings of several key Far East countries, as one might expect from the Lucas critique. This underprediction is consistent with models explaining the demand for international reserves by developing countries. Specifically, we show that sovereign risk and costly tax collection to cover fiscal liabilities lead to a relatively large demand for international reserves. In the aftermath of a crisis, countries that have to deal with higher perceived sovereign risk and higher fiscal liabilities (both funded and unfunded) will opt to increase their demand for reserves. The models also help us understand why some developing countries do not hold large precautionary reserve balances in the aftermath of crises. Countries with high discount rates, political instability, or political corruption find it optimal to hold much smaller precautionary balances. We also show that models that incorporate loss aversion predict a relatively large demand for international reserves. Hence, if a crisis increases the volatility of shocks and/or loss aversion, it will greatly increase the demand for international reserves. Consequently, we conclude that the "puzzling" pattern in international reserve holdings is reasonably explained by the extended models described in this paper.

PB 02-09

The Value of Banking Relationships during a Financial Crisis: Evidence from Failures of Japanese Banks

Elijah Brewer III, *FRB Chicago*
Hesna Genay, *FRB Chicago*
William Curt Hunter, *FRB Chicago*
George G. Kaufman, *Loyola University*

In this paper, we provide evidence on the value of banking relationships by examining the stock market valuation impact of three large bank failures in Japan in 1997 and 1998 on their clients and the clients of surviving banks. Bank failures are theorized to have adverse consequences for other firms in general and for customers of the failed institutions in particular. Firms that are customers of the failed institution may be adversely affected because they may lose an ongoing source of funding and need to incur the expense of search and providing financial and other information about themselves to new lenders. Firms that are not customers of the failed bank may be adversely affected because the failure may signal existing but yet unrecognized problems at other banks, ignite problems at other banks through spillover or contagion, or foretell adverse economic conditions for the economy in the region or nationwide.

Unlike previous studies of this type, we examine the impact of bank failure announcements on the market valuation not only of the client firms of the failed banks but on all firms including the clients of surviving banks. We find that, as in previous studies, the market value of customers of the failed banks is adversely affected at the date of the

failure announcements. Firms that have greater access to alternative sources of funding experience a less severe adverse impact from bank failure announcements. Similarly, clients of banks that are more profitable, better capitalized, and have lower loan loss reserves suffer less from the failure announcements. However, we also find that these effects are not significantly different from the effects experienced by all firms in the economy. That is, the bank failures represent "bad news" for all firms in the economy, not just for the customers of the failed banks.

PB 02-10

Financial Intermediation, Agency, and Collateral and the Dynamics of Banking Crises: Theory and Evidence for the Japanese Banking Crisis

Robert Dekle, *University of Southern California*
Kenneth Kletzer, *University of California, Santa Cruz*

We outline a model of an endogenously evolving banking crisis in a growing economy subject to either idiosyncratic or aggregate productivity shocks. The model incorporates agency problems at two levels: between firms and their banks and between banks and the banks' depositors and deposit insurers. In equilibrium, banks have an incentive to renegotiate loans to insolvent firms, leading to an increasing contingent liability of the government with deposit insurance and regulatory forbearance. The growth rate of output is endogenous, and we explain how the agency problems affect the qualitative dynamics of the economy in this framework. We find that the dynamics predicted by our model fit the recent behavior of the Japanese economy well. As Japan was hit by a succession of adverse aggregate shocks in the 1990s, bank portfolios continued to deteriorate and the market value of collateral (land) collapsed. The decline in collateral values led to a fall in bank lending, a decline in physical investment, and finally, a fall in GDP.

PB 02-11

Loans to Japanese Borrowers

David C. Smith, *Federal Reserve Board of Governors*

Though the Japanese banking system has been the focus of numerous empirical studies, there is scant empirical evidence on the characteristics of loan contracts between Japanese firms and their banks. This paper incorporates relatively new contract-specific data on bank loans to large borrowers to help fill this gap. Specifically, we examine how loans to Japanese companies compare with loans to similar non-Japanese companies and how loans to Japanese borrowers vary according to the nationality of the bank making the loan. We then gauge the value of bank loans to Japanese borrowers by estimating abnormal stock price returns around the announcement of new bank loans.

Abstracts of Articles Accepted in Journals, Books, and Conference Volumes*

The Supplemental Security Income Program

Mary C. Daly, with
Richard V. Burkhauser,
Cornell University

Forthcoming in *Means-Tested Transfers in the U.S.,* ed. Robert Moffitt. Cambridge, MA: NBER.

Supplemental Security Income (SSI) is a nationwide federal assistance program for aged, blind, and disabled individuals with low incomes. Rapid program growth, the changing composition of SSI beneficiaries, and increasing pressure to devolve federal responsibility for social programs to state governments, as well as to integrate traditional "nonworkers" into the labor market, all have raised questions about the role that SSI plays in the broader U.S. social welfare system. This paper provides the basic information necessary for SSI policymakers to make informed choices about its future.

United States Disability Policy in a Changing Environment

Mary C. Daly, with
Richard V. Burkhauser,
Cornell University

Published in *Journal of Economic Perspectives* 16(1) (Winter 2002) pp. 213–224.

In this paper we provide a broader perspective from which to evaluate current disability policy. We begin by reviewing the major aspects of the Disability Insurance and Supplemental Security Income programs. We then examine trends in employment and disability benefit receipt among those with disabilities, paying particular attention to the last 15 years. Within this framework we summarize the primary difficulties in crafting an efficient and equitable assistance program for a heterogeneous population that changes with its environment. Finally, we place disability policy in the context of the broader United States social welfare system and consider how changes in other social welfare programs likely will affect disability program usage in the future.

Self-Reported Work Limitation Data: What They Can and Cannot Tell Us

Mary C. Daly, with
Richard V. Burkhauser,
Cornell University
Andrew J. Houtenville,
Cornell University
Nigar Nargis, *Cornell University*

Published in *Demography* 39(3) (August 2002).

Data constraints make the long-term monitoring of the working-age population with disabilities a difficult task. Indeed, the Current Population Survey (CPS) is the only national data source that offers detailed work and income questions and consistently asked measures of disability over a 20-year period. Despite its widespread use in the literature, the CPS and surveys like it have come under attack of late, with critics discounting the results of any research obtained from such data. We put these criticisms in perspective by systematically examining what the CPS data can and cannot be used for in disability research. Based on comparisons with the National Health Interview Survey (NHIS), a data set with much more information on health than the CPS, we find that the work limitation-based definition of disability available in the CPS underestimates the size of the broader population with health impairments in the NHIS, but that the employment trends in these two populations in the NHIS are not significantly different from one another. We then show that the trends in employment observed for the NHIS population defined by self-reported work limitation are not statistically different from those found in the CPS. Based on these findings, we argue (1) that the CPS and other nationally representative employment-

*The abstracts are arranged alphabetically by FRB San Francisco authors, whose names are in boldface.

based data sets can be used to monitor trends in outcomes of those with disabilities and, (2) that the dramatic decline in the employment of people with disabilities we describe in the CPS during the 1990s is not an artifact of the data.

Black–White Wage Inequality in the 1990s—A Decade of Progress

Mary C. Daly, with
Kenneth Couch,
University of Connecticut

Published in *Economic Inquiry* 40(1) (January 2002) pp. 31–41.

Using Current Population Survey data, we find that the gap between the wages of black and white males declined during the 1990s at a rate of about 0.60 percentage point per year. Wage convergence was most rapid among workers with fewer than 10 years of potential experience, with declines in the gap averaging 1.40 percentage points per year. Using standard decomposition methods, we find that greater occupational diversity and reductions in unobserved or residual differences are important in explaining this trend. General wage inequality tempered the rate of wage convergence between blacks and whites during the 1990s.

Optimal Indicators of Socioeconomic Status for Health Research

Mary C. Daly, with
Greg J. Duncan,
Northwestern University
Peggy McDonough, *York University*
David R. Williams,
University of Michigan

Published in *American Journal of Public Health* 92(7) (July 2002) pp. 1,151–1,157.

This paper examines the relationship between various measures of socioeconomic status (SES) and mortality for a representative sample of individuals. We use data from the Panel Study of Income Dynamics, sampling 3,734 individuals aged 45 and older who participated in the 1984 interview and tracking them between 1984 and 1994 using Cox event-history regression models. We found that wealth and recent family income were the indicators that were most strongly associated with subsequent mortality. These associations persisted after we controlled for the other SES indicators and were stronger for women than for men and for nonelderly than for elderly individuals. We found that the economic indicators of SES were usually as strongly associated with mortality as, if not more strongly associated with mortality than, the more conventional indicators of completed schooling and occupation.

Population Movements: Isolated Experience or Broad Policy Concern?

Mary C. Daly, with
Andrew J. Houtenville,
Cornell University

Forthcoming in *What Is Causing the Decline in Employment of People with Disabilities,* Upjohn Institute for Employment.

Numerous researchers have shown that the decline in employment rates among working-age men and women with disabilities over the 1990s was not an artifact of measurement choices or research design, but robust across definitions of disability and data sources. Although this overall trend is disturbing, a greater understanding of what underlies it is needed before an appropriate policy response can be crafted. Specifically, policymakers need to know whether the recent employment decline was broad-based or concentrated among a few subgroups of the population, whether it reflects changes in the characteristics of the population with disabilities or changes in their behavior and/or labor market opportunities, and finally, whether it was associated with exogenous changes in health or changes in environmental factors. This paper addresses these issues. The results suggest that the decline in employment among those with disabilities was broad-based, present in a wide range of demographic and educational subgroups. In terms of population shifts, we find no evidence that compositional changes in the population with disabilities during the 1990s account for the average

employment decline during the period. In contrast, we find that compositional changes were important to the increase in employment among those with disabilities during the 1980s. Finally, we show that self-reported health among those with disabilities remained relatively stable in the latter half of the 1990s, making changes in health status an unlikely cause of declining employment rates.

Exploring the Role of the Real Exchange Rate in Australian Monetary Policy

Richard Dennis

Forthcoming in *Economic Record.*

An important issue in small open economies is whether policymakers should respond to exchange rate movements when they formulate monetary policy. Micro-founded models tend to suggest that there is little to be gained from responding to exchange rate movements, and the literature has largely concluded that such a response is unnecessary or even undesirable (Taylor 2001). This paper examines this issue using an estimated model of the Australian economy. In contrast to micro-founded models, according to this model policymakers should allow for movements in the real exchange rate and the terms-of-trade when they set interest rates. Further, taking real exchange rate movements into account appears even more important with price-level targeting than with inflation targeting.

Is Money Still Useful for Policy in East Asia?

Reuven Glick
Ramon Moreno

Published in *Inflation Targeting: Theories, Empirical Models, and Implementation in Pacific Basin Economies,* Proceedings of 14th Pacific Basin Central Bank Conference, Bank of Korea (2002).

Since the East Asian crises of 1997, a number of East Asian economies have allowed greater exchange rate flexibility and abandoned monetary targets in favor of inflation targeting, apparently because the perceived usefulness of money as a predictor of inflation (i.e., the information content of money) has fallen. In this paper, we discuss factors that are likely to have influenced the stability of the relationship between money and inflation, particularly in the 1990s, and then assess this relationship in a set of East Asian economies. We focus on (1) the stability of the behavior of the velocity of money; (2) the ability of money growth to predict inflation as measured by tests of Granger causality, and (3) the contribution of money to the variance of the forecast error of inflation. We find evidence that, with a few exceptions in which capital flows were particularly large, velocity remained generally stable, as did the relationship between money growth and inflation. However, the contribution of money to inflation forecast errors fell considerably in the 1990s, reducing its value as an information variable to monetary authorities.

Does a Currency Union Affect Trade? The Time Series Evidence

Reuven Glick, with
Andrew K. Rose,
University of California, Berkeley

Published in *European Economic Review* 46(6) (June 2002) pp. 1,125–1,151.

Does leaving a currency union reduce international trade? We answer this question using a large annual panel data set covering 217 countries from 1948 through 1997. During this sample a large number of countries left currency unions; they experienced economically and statistically significant declines in bilateral trade after accounting for other factors. Assuming symmetry, we estimate that a pair of countries that starts to use a common currency experiences a near doubling in bilateral trade.

Payer Type and the Returns to Bypass Surgery: Evidence from Hospital Entry Behavior

Gautam Gowrisankaran, with
Michael Chernew,
University of Michigan
A. Mark Fendrick,
University of Michigan

Published in *Journal of Health Economics* 21(3) (May 2002) pp. 451–474.

In this paper, we estimate the returns associated with the provision of coronary artery bypass graft (CABG) surgery by payer type (Medicare, HMO, etc.). Because reliable measures of prices and treatment costs are often unobserved, we seek to infer returns from hospital entry behavior. We estimate a model of patient flows for CABG patients that provides inputs for an entry model. We find that FFS provides a high return throughout the study period. Medicare, which had been generous in the early 1980s, now provides a return that is close to zero. Medicaid appears to reimburse less than average variable costs. HMOs essentially pay at average variable costs, though the return varies inversely with competition.

Equilibrium Valuation of Illiquid Assets

John Krainer, with
Stephen F. LeRoy,
University of California, Santa Barbara

Published in *Economic Theory* 19(2) (January 2002) pp. 223–242.

We develop an equilibrium model of illiquid asset valuation based on search and matching. We propose several measures of illiquidity and show how these measures behave. We also show that the equilibrium amount of search may be less than, equal to, or greater than the amount of search that is socially optimal. Finally, we show that excess returns on illiquid assets are fair games if returns are defined to include the appropriate shadow prices.

Incorporating Equity Market Information into Supervisory Monitoring Models

John Krainer
Jose A. Lopez

Forthcoming in *Journal of Money, Credit, and Banking.*

We examine whether equity market variables, such as stock returns and equity-based default probabilities, are useful to bank supervisors for assessing the condition of bank holding companies. Using an event study framework, we find that equity market variables anticipate supervisory ratings changes by up to four quarters and that the improvements in forecast accuracy arising from conditioning on equity market information are statistically significant. We develop an off-site monitoring model that easily combines supervisory and equity market information, and we find that the model's forecasts also anticipate supervisory ratings changes by several quarters. While the inclusion of equity market variables in the model does not improve forecast accuracy by much relative to simply using supervisory variables, we argue that equity market information should still be useful for forecasting supervisory ratings and should be incorporated into supervisory monitoring models.

Impact of Deposit Rate Deregulation in Hong Kong on the Market Value of Commercial Banks

Simon H. Kwan

Forthcoming in *Journal of Banking and Finance.*

This paper examines the effects of a series of events leading up to the deregulation of deposit interest rates in Hong Kong on the market value of banks. All the evidence suggests that banks earned rents from deposit interest rate rules and deregulation would lower these rents and hence bank market values. On average, the total abnormal return due to interest rate deregulation was around –4%. There is some evidence that large banks and banks with high deposit-to-asset ratios suffered a bigger drop in value, suggesting that these banks enjoyed a bigger subsidy under the interest rate rules.

Operating Performance of Banks among Asian Economies: An International and Time Series Comparison

Simon H. Kwan

Published in *Journal of Banking and Finance* 27(3) (March 2003) pp. 471–489.

Per unit bank operating costs are found to vary significantly across Asian countries and over time. The strong correlation between per unit labor cost and physical capital cost suggests that there exist systematic differences in bank operating efficiency across countries. The declining operating costs between 1992 and 1997 is consistent with improving operating performance. Since 1997, the run-up in operating costs coincided with the Asian financial crisis, suggesting that banks incurred additional costs to deal with problem loans while outputs declined simultaneously. Labor cost share is also found to decline significantly between 1997 and 1999, perhaps because banks were able to cut labor force faster than physical capital. Significant differences in labor cost share across countries suggest cross-country differences in bank production functions. The positive relation between labor cost share and wage rate indicates that banks using more labor is due to labor force productivity, rather than labor being cheap.

Market Evidence on the Opaqueness of Banking Firms' Assets

Simon H. Kwan, with
Mark J. Flannery,
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Forthcoming in *Journal of Financial Economics.*

We assess the market microstructure properties of U.S. banking firms' equity to determine whether they exhibit more or less evidence of asset opaqueness than similar-sized nonbanking firms. The evidence indicates that large bank holding companies (BHCs), traded on the NYSE, have very similar trading properties to their matched nonfinancial firms. In contrast, smaller BHCs, traded on NASDAQ, trade much less frequently despite having very similar spreads. We also find empirical support for the hypothesis that BHC asset categories differ in their opacity. Analysis of IBES earnings forecasts indicates that banking assets are not unusually opaque; they are simply boring. The implications for regulatory policy and future market microstructure research are discussed.

Hidden Cost Reductions in Bank Mergers: Accounting for More Productive Banks

Simon H. Kwan, with
James A. Wilcox,
University of California, Berkeley

Published in *Research in Finance* 19, ed. Andrew H. Chen. London: Elsevier Press, 2002, pp. 109–124.

The bank mergers of the 1990s often triggered upward adjustments in reported depreciation and goodwill amortization expenses, apart from any change in actual costs, due to the conventions of purchase accounting. Thus, conventional measurements underestimated the sizable and long-lasting reductions in noninterest costs achieved following mergers.

The largest reductions in reported post-merger bank costs occurred in labor expenses, which were not subject to accounting revaluations. Reported premises expenses fell considerably less than that of labor when buildings were revalued. Other noninterest expense rose, partly because amortization increased due to the additional goodwill generated by mergers.

Measuring the CRA Subsidy in Mortgage Markets

Elizabeth Laderman, with
Glenn B. Canner,
Federal Reserve Board of Governors
Andreas Lehnert,
Federal Reserve Board of Governors
Wayne Passmore,
Federal Reserve Board of Governors

Published in *Proceedings of the 38th Annual Conference on Bank Structure and Competition,* FRB Chicago (May 2002) pp. 429–441.

The Community Reinvestment Act (CRA) encourages lenders to make mortgage loans to certain classes of borrowers. However, the law does not apply to all lenders, and lenders do not necessarily receive credit for all loans made to borrowers of a particular class. Specifically, only commercial banks and savings institutions are subject to the CRA, while mortgage bankers are not. Further, CRA credit is given for loans made to higher-income borrowers who purchase homes in lower-income neighborhoods but not to other higher-income borrowers. We use this variation to test whether or not CRA-affected lenders cut interest rates to CRA-eligible borrowers; in other words, we test for the presence of a regulation-driven subsidy. Our theory suggests that loans made by commercial banks and savings associations ("relationship lenders") and mortgage companies ("transaction lenders") will differ from one another depending on borrower risk and home-ownership benefits. Empirically, we find that CRA-eligible loans at CRA-affected institutions do carry lower mortgage spreads compared with other loans at the same institution. However, once we control for risk and benefit effects suggested by our theory, these differences in mortgage spreads become economically and statistically insignificant.

Fiscal Policy, Increasing Returns, and Endogenous Fluctuations

Kevin J. Lansing, with
Jang-Ting Guo,
University of California, Riverside

Published in *Macroeconomic Dynamics* 6(5) (November 2002) pp. 633–664.

This paper examines the quantitative implications of government fiscal policy in a discrete-time one-sector growth model with a productive externality that generates social increasing returns to scale. Starting from a laissez-faire economy that exhibits local indeterminacy, we show that the introduction of a constant capital tax or subsidy can lead to various forms of endogenous fluctuations, including stable 2-, 4-, 8-, and 10-cycles, quasiperiodic orbits, and chaos. In contrast, a constant labor tax or subsidy has no effect on the qualitative nature of the model's dynamics. We show that the use of local steady-state analysis to detect the presence of multiple equilibria in this class of models can be misleading. For a plausible range of capital tax rates, the log-linearized dynamical system exhibits saddle-point stability, suggesting a unique equilibrium, whereas the true nonlinear model exhibits global indeterminacy. This result implies that stabilization policies designed to suppress sunspot fluctuations near the steady state may not prevent sunspots, cycles, or chaos in regions away from the steady state. Overall, our results highlight the importance of using a model's nonlinear equilibrium conditions to fully investigate global dynamics.

The Empirical Relationship between Average Asset Correlation, Firm Probability of Default, and Asset Size

Jose A. Lopez

Forthcoming in *Journal of Financial Intermediation.*

The asymptotic single risk factor (ASRF) approach is a simplified framework for determining regulatory capital charges for credit risk and has become an integral part of how credit risk capital requirements are to be determined under the second Basel Accord. Within this approach, a key regulatory parameter is the average asset correlation. In this paper, we examine the empirical relationship between the average asset correlation, firm probability of default, and firm asset size measured by the book value of assets. Using data from year-end 2000, credit portfolios consisting of U.S., Japanese, and European firms are analyzed. The empirical results suggest that average asset correlation is a decreasing function of probability of default and an increasing function of asset size. The empirical results suggest that several factors may impact average asset correlations within an ASRF framework, and these factors may need to be accounted for in the final calculation of regulatory capital requirements for credit risk.

Supervisory and Regulatory Concerns Regarding Bank Internal Ratings Systems

Jose A. Lopez, with
Marc R. Saidenberg, *FRB New York*

Published in *Credit Ratings: Methodologies, Rationale, and Default,* ed. M. Ong. London: Risk Books, 2002, pp. 305–314.

Internal rating systems are one of the oldest and most widely used credit risk measurement tools used by commercial banks. These systems distill the information on potentially thousands of borrowers into common ratings that summarize risk characteristics and permit comparisons across the entire loan portfolio. Many large banks use their ratings in several aspects of credit risk management, such as loan origination and pricing, credit portfolio monitoring, profitability analysis, and management reporting. Since internal ratings are such a key element of credit risk management systems, it is not surprising that they come under greater attention from international bank regulators and supervisors. In particular, the ongoing work of the Basel Committee on Banking Supervision to update international regulatory capital requirements, commonly referred to as the Basel II process, has brought internal ratings to the center of regulatory concerns. This increased emphasis and expanded use of internal ratings clearly should alert supervisory concerns since national bank supervisors will be faced with the task of implementing these regulatory requirements and monitoring bank adherence to them over time. In this paper, we discuss the supervisory con-

cerns that already exist and outline the regulatory issues arising from the Basel II process. We attempt to highlight where the Basel II process will affect supervisory concerns the most and discuss possible future directions for supervisory and regulatory concerns regarding internal rating systems.

Financial Structure and Macroeconomic Performance over the Short and Long Run

Jose A. Lopez
Mark M. Spiegel

Forthcoming in *Proceedings of the 2002 East-West Center/Korean Development Institute Conference on the Macroeconomic Implications of Post-Crisis Structural Change.*

We examine the relationship between indicators of financial development and economic performance for a cross-country panel over long and short periods. Our long-term results are consistent with much of the literature in that we find a positive relationship between financial development and economic growth. However, we fail to find a significant positive relationship after accounting for disparities in factor accumulation. These results therefore indicate that the primary channel for financial development to facilitate growth over the long run is through physical and human capital accumulation. We also identify a significant negative relationship between financial development and income volatility, suggesting that financial development does mitigate economic fluctuations in the long run.

We then turn to short-run analysis, concentrating on the period immediately surrounding the 1997 Asian financial crisis. Unlike our long-term results, our short-term panel analysis fails to find a significant relationship between financial development and economic performance during this period, both for a broad sample of countries and for a small sample of developing Asian nations.

Taken as a whole, our analysis appears to support a relatively new idea in the literature that while financial development is beneficial over the long run, it may exacerbate short-term volatility in isolated episodes. One reason for this discrepancy may be that financial liberalizations are typically only partial, resulting in increased financial market distortions. We analyze the Korean experience in the period surrounding the Asian financial crisis and argue that this experience supports the idea of distortionary partial liberalization.

Assessing Nominal Income Rules for Monetary Policy with Model and Data Uncertainty

Glenn D. Rudebusch

Published in *The Economic Journal* 112 (April 2002) pp. 1–31.

Nominal income rules for monetary policy have long been debated, but two issues are of particular recent interest. First, there are questions about the performance of such rules over a range of plausible empirical models—especially models with and without explicit rational inflation expectations. Second, there are questions about the performance of these rules in real time using the type of data that is actually available contemporaneously to policymakers rather than final revised data. This paper determines optimal monetary policy rules in the presence of such model uncertainty and real-time data uncertainty and finds only a limited role for nominal output growth.

Term Structure Evidence on Interest Rate Smoothing and Monetary Policy Inertia

Glenn D. Rudebusch

Published in *Journal of Monetary Economics* 49(6) (September 2002) pp. 1,161–1,187.

Numerous studies have used quarterly data to estimate monetary policy rules or reaction functions that appear to exhibit a very slow partial adjustment of the policy interest rate. The conventional wisdom asserts that this gradual adjustment reflects a policy inertia or interest rate smoothing behavior by central banks. However, such quarterly monetary policy inertia would imply a large amount of forecastable variation in interest rates at horizons of more than 3 months, which is contradicted by evidence from the term structure of interest rates. The illusion of monetary policy inertia evident in the estimated policy rules likely reflects the persistent shocks that central banks face.

Eurosystem Monetary Targeting: Lessons from U.S. Data

Glenn D. Rudebusch, with Lars E.O. Svensson, *Stockholm University*

Published in *European Economic Review* 46(3) (March 2002) pp. 417–442.

Using a small empirical model of inflation, output, and money estimated on U.S. data, we compare the relative performance of monetary targeting and inflation targeting. The results show monetary targeting to be quite inefficient, yielding both higher inflation and output variability. This is true even with a nonstochastic money demand formulation. Our results are also robust to using a P^* model of inflation. Therefore, in these popular frameworks, there is no support for the prominent role given to money growth in the Eurosystem's monetary policy strategy.

Sterilization Costs and Exchange Rate Targeting

Mark M. Spiegel, with Kenneth Kletzer, *University of California, Santa Cruz*

Forthcoming in *Journal of International Money and Finance.*

We examine the movements of exchange rates and capital inflows in an environment where an optimizing central bank pursuing the joint goals of inflation and output targeting engages in costly sterilization activities. Our results predict that when faced with increased sterilization costs, the central bank will choose to limit its sterilization activities allowing target variables, such as the nominal exchange rate, to adjust. We then test the predictions of a linearized version of the saddle-path solution to the model for a cross-country panel of developing countries. We use OLS, IV, and GMM specifications to allow for the endogeneity of capital inflows. Our results confirm that monetary policy does respond to sterilization costs.

The Evolution of Bank Resolution Policies in Japan: Evidence from Market Equity Values

Mark Spiegel, with
Nobuyoshi Yamori, *Nagoya University*

Forthcoming in *Journal of Financial Research.*

We examine the evidence in equity markets concerning bank regulatory policies in Japan from 1995 to 1999. Our results support the presence of information-based contagion in Japanese equity markets. When the failure of a bank of certain regulatory status was announced, it adversely affected excess returns on banks with equal or lower levels of regulatory protection. Market participants therefore initially behaved as if only Second Regional and smaller banks would be allowed to fail. As the situation deteriorated, however, banks that traditionally enjoyed greater regulatory protection also were perceived to lose their too-big-to-fail status.

Financial Turbulence and the Japanese Main Bank Relationship

Mark Spiegel, with
Nobuyoshi Yamori, *Nagoya University*

Forthcoming in *Journal of Financial Services Research.*

The Japanese "main bank" relationship, under which a bank holds equity in a firm and plays a leading role in its decisionmaking and financing, may leave a firm dependent on its main bank for financing due to its information advantage over other potential lenders. While alternative sources of finance may mitigate this dependency, it may resurface during episodes of financial turbulence. We examine the sensitivity of returns on portfolios of Japanese firm equity to the returns of their main banks using a three-factor arbitrage-pricing model. We find no significant dependence on main bank returns when coefficient values are constrained to remain constant over the entire sample. However, the data strongly suggest a structural break subsequent to the last quarter of 1997, a turbulent period for Japanese financial markets. When a structural break is introduced, main bank sensitivity increases after the break, usually to significantly positive levels.

The Impact of Japan's Financial Stabilization Laws on Bank Equity Values

Mark Spiegel, with
Nobuyoshi Yamori, *Nagoya University*

Forthcoming in *Journal of the Japanese and International Economies.*

In the fall of 1998, two important financial regulatory reform acts were passed in Japan. The first of these acts, the Financial Recovery Act, created a bridge bank scheme and provided funds for the resolution of failed banks. The second act, the Rapid Revitalization Act, provided funds for the assistance of troubled banks. While both of these acts provided some government assistance to the banking sector, they also called for reforms aimed at strengthening the regulatory environment. Using an event study framework, this paper examines the evidence in equity markets concerning the anticipated impact of the regulatory reforms. Our evidence suggests that the anticipated regulatory impact of the Financial Recovery Act was mixed, while the Rapid Revitalization Act was expected to disproportionately favor weaker Japanese banks. As such, it appears that the market was skeptical about the degree to which the new acts would lead to true banking reform.

Union Effects on Health Insurance Provision and Coverage in the United States

Rob Valletta, with
Thomas Buchmueller,
University of California, Irvine
John DiNardo, *University of Michigan*

Published in *Industrial and Labor Relations Review* 55(4) (July 2002) pp. 610–627.

During the past two decades, union density has declined in the United States and employer provision of health benefits has changed substantially in extent and form. Using individual survey data spanning the years 1983 to 1997 combined with employer survey data for 1993, the authors update and extend previous analyses of private-sector union effects on employer-provided health benefits. They find that the union effect on health insurance coverage rates has fallen somewhat but remains large, due to an increase over time in the union effect on employee "take-up" of offered insurance, and that declining unionization explains 20 to 35 percent of the decline in employee health coverage. The increasing union take-up effect is linked to union effects on employees' direct costs for health insurance and the availability of retiree coverage.

Measuring the Natural Rate of Interest

John C. Williams, with
Thomas Laubach,
Federal Reserve Board of Governors

Forthcoming in *Review of Economics and Statistics.*

The natural rate of interest—the real interest rate consistent with output equaling its natural rate and stable inflation—plays a central role in macroeconomic theory and monetary policy. Estimation of the natural rate of interest, however, has received little attention. We apply the Kalman filter to estimate jointly time-varying natural rates of interest and output and trend growth. We find a close link between the natural rate of interest and the trend growth rate, as predicted by theory. Estimates of the natural rate of interest, however, are very imprecise and subject to considerable real-time measurement error.

Robust Monetary Policy with Competing Reference Models

John C. Williams, with
Andrew T. Levin,
Federal Reserve Board of Governors

Forthcoming in *Journal of Monetary Economics.*

The existing literature on robust monetary policy rules has focused largely on the case in which the policymaker has a single reference model while the true economy lies within a specified neighborhood of the reference model. In this paper, we show that such rules may perform very poorly in the more general case in which non-nested models represent competing perspectives about controversial issues such as expectations formation and inflation persistence. Using Bayesian and minimax strategies, we then consider whether *any* simple rule can provide robust performance across such divergent representations of the economy. We find that a robust outcome is only attainable in cases where the objective function places substantial weight on stabilizing both output and inflation; in contrast, we are not able to find a robust policy rule when the sole policy objective is the stabilization of inflation. We analyze these results using a new diagnostic approach, namely, by quantifying the *fault tolerance* of each model economy with respect to deviations from optimal policy.

The Performance of Forecast-Based Monetary Policy Rules under Model Uncertainty

John C. Williams, with
Andrew T. Levin,
Federal Reserve Board of Governors
Volker Wieland,
Johann Wolfgang Goethe-University and European Central Bank

Forthcoming in
American Economic Review.

We investigate the performance of forecast-based monetary policy rules using five macroeconomic models that reflect a wide range of views on aggregate dynamics. We identify the key characteristics of rules that are robust to model uncertainty: such rules respond to the one-year-ahead inflation forecast and to the current output gap and incorporate a substantial degree of policy inertia. In contrast, rules with longer forecast horizons are less robust and are prone to generating indeterminacy. Finally, we identify a robust benchmark rule that performs very well in all five models over a wide range of policy preferences.

Imperfect Knowledge, Inflation Expectations, and Monetary Policy

John C. Williams, with
Athanasios Orphanides,
Federal Reserve Board of Governors

Forthcoming in *Inflation Targeting,* ed. Michael Woodford. Chicago: University of Chicago Press.

This paper investigates the role that imperfect knowledge about the structure of the economy plays in the formation of expectations, macroeconomic dynamics, and the efficient formulation of monetary policy. Economic agents rely on an adaptive learning technology to form expectations and to update continuously their beliefs regarding the dynamic structure of the economy based on incoming data. The process of perpetual learning introduces an additional layer of dynamic interaction between monetary policy and economic outcomes. We find that policies that would be efficient under rational expectations can perform poorly when knowledge is imperfect. In particular, policies that fail to maintain tight control over inflation are prone to episodes in which the public's expectations of inflation become uncoupled from the policy objective and stagflation results, in a pattern similar to that experienced in the United States during the 1970s. Our results highlight the value of effective communication of a central bank's inflation objective and of continued vigilance against inflation in anchoring inflation expectations and fostering macroeconomic stability.

Robust Monetary Policy Rules with Unknown Natural Rates

John C. Williams, with
Athanasios Orphanides,
Federal Reserve Board of Governors

Published in *Brookings Papers on Economic Activity* 2002(2) pp. 63–145.

We examine the performance and robustness properties of alternative monetary policy rules in the presence of structural change that renders the natural rates of interest and unemployment uncertain. Using a forward-looking quarterly model of the U.S. economy, estimated over the 1969–2002 period, we show that the cost of underestimating the extent of misperceptions regarding the natural rates significantly exceeds the costs of overestimating such errors. Naive adoption of policy rules optimized under the false presumption that misperceptions regarding the natural rates are likely to be small proves particularly costly.

Our results suggest that a simple and effective approach for dealing with ignorance about the degree of uncertainty in estimates of the natural rates is to adopt difference rules for monetary policy, in which the short-term nominal interest rate is raised or lowered from its existing level in response to inflation and changes in economic activity. These rules do not require knowledge of the natural rates of interest or unemployment for setting policy and are consequently immune to the likely misperceptions in these

concepts. To illustrate the differences in outcomes that could be attributed to the alternative policies we also examine the role of misperceptions for the stagflationary experience of the 1970s and the disinflationary boom of the 1990s.

Embodying Embodiment in a Structural, Macroeconomic Input-Output Model

Daniel J. Wilson

Forthcoming in *Economic Systems Research.*

This paper describes an attempt to build a regression-based system of labor productivity equations that incorporate the effects of capital-embodied technological change into IDLIFT, a structural, macroeconomic input-output model of the U.S. economy. Builders of regression-based forecasting models have long had difficulty finding labor productivity equations that exhibit the Neoclassical or Solowian property that movements in investment should cause accompanying movements in labor productivity. Theory dictates that this causation is driven by the effect of traditional capital deepening as well as technological change embodied in capital. Lack of measurement of the latter has hampered the ability of researchers to properly estimate the productivity-investment relationship. Wilson (2001a), by estimating industry-level embodied technological change, has alleviated this difficulty. In this paper, I utilize those estimates to construct capital stocks that are adjusted for technological change, which then are used to estimate Neoclassical-type labor productivity equations. It is shown that replacing IDLIFT's former productivity equations, based on changes in output and time trends, with the new equations results in a convergence between the dynamic behavior of the model and that predicted by Neoclassical production theory.

Is Embodied Technology the Result of Upstream R&D? Industry-Level Evidence

Daniel J. Wilson

Published in *Review of Economic Dynamics* 5(2) (April 2002) pp. 285–317.

This paper provides an exploratory analysis of whether data on the research and development (R&D) spending directed at particular technological/product fields can be used to measure industry-level capital-embodied technological change. Evidence from the patent literature suggests that the R&D directed at a product, as the main input into the "innovation" production function, is proportional to the value of the innovations in that product. I confirm this hypothesis by showing that the decline in the relative price of a good is positively correlated with the R&D directed at that product. The hypothesis implies that the technological change, or innovation, embodied in an industry's capital is proportional to the R&D that is done ("upstream") by the economy as a whole on each of the capital goods that a ("downstream") industry purchases. Using R&D data from the National Science Foundation, I construct measures of capital-embodied R&D. I find they have a strong effect on conventionally measured total factor productivity growth, a phenomenon that seems to be due partly to the mismeasurement of quality change in the capital stock and partly to a positive correlation between embodied and disembodied technological change. Finally, I find the cross-industry variation in empirical estimates of embodied technological change accord with the cross-industry variation in embodied R&D.

Stylized Facts on Nominal Term Structure and Business Cycles: An Empirical VAR Study

Tao Wu

Forthcoming in *Applied Economics*.

This paper examines the importance of various macroeconomic shocks in explaining the movement of the term structure of nominal bond yields in the post-war U.S., as well as the channels through which such macro shocks influence the yield curve, using a structural vector autoregressive model. The results show that the monetary policy and the aggregate supply shocks are important determinants of the nominal term structure. Moreover, the monetary policy innovations have a large but transitory effect on the nominal bond yields, primarily by changing the slope of the yield curve, and the aggregate supply shocks from the private sector have a more persistent effect on the level of the yield curve but have little effect on the slope of the yield curve.

Conferences

Macroeconomic Models for Monetary Policy

Financial Issues in the Pacific Basin Region

Technological Change

The San Francisco Fed's Research Department organized three conferences in 2002.

The first, cohosted with the Stanford Institute for Economic Policy Research, explored the use of macroeconomic models in guiding monetary policy. Issues discussed at the conference included the role of explicit expectations in models, the use of multiple models, the importance of judgmental adjustments to models, the identification of model structural change, and the appropriate size and amount of detail in models.

The second conference was cosponsored by the Department's Center for Pacific Basin Monetary and Economic Studies and the *Journal of the Japanese and International Economies*. The conference examined important financial issues of relevance to the Pacific Basin, focusing on Japan's banking sector problems and on exchange rate polices in the Pacific Basin region.

The third conference, cosponsored with the Stanford Institute for Economic Policy Research, focused on how changes in technology—particularly information technology—have affected productivity and the economy. A key focus was the concept of "embodiment" which is the reason why one has to buy a new computer to take advantage of the latest advances in technology. Various papers looked at how embodiment might explain the pattern of technological diffusion across the economy both in the information technology revolution as well as in earlier industrial revolutions. Other papers were concerned with the international diffusion of technology.

These conferences bring professional economists from the Federal Reserve System and from research institutions together with policymakers from the U.S. and abroad. Many of the papers presented are "works in progress" and therefore represent the latest research on policy-related issues.

Attendance at all of the conferences is by invitation only. In addition, the papers are chosen from submissions by a select group of noted researchers.

In this section are the conference agendas as well as summaries of the conferences that appeared in our *FRBSF Economic Letter*.

Macroeconomic Models for Monetary Policy

Federal Reserve Bank of San Francisco
March 1–2, 2002

Cosponsored by the Federal Reserve Bank of San Francisco and the Stanford Institute for Economic Policy Research

Papers presented at this conference can be found on the conference website http://www.frbsf.org/economics/conferences/0203/index.html

Keynote Speaker

Frederic Mishkin, *Columbia University*

Empirical Analysis of Policy Interventions

Eric Leeper, *Indiana University*
Tao Zha, *FRB Atlanta*

Discussants: Kevin Hoover, *University of California, Davis*
Sharon Kozicki, *FRB Kansas City*

Monetary Policy in an Estimated Stochastic Dynamic General Equilibrium Model of the Euro Area

Frank Smets, *European Central Bank*
Raf Wouters, *National Bank of Belgium*

Discussants: Peter Ireland, *Boston College*
Lars Svensson, *Princeton University*

An Optimizing Model of U.S. Wage and Price Dynamics

Argia Sbordone, *Rutgers University*

Discussant: Jeffrey Fuhrer, *FRB Boston*

Should Monetary Policy Target Labor's Share of Income?

Jeremy Rudd, *Federal Reserve Board of Governors*
Karl Whelan, *Federal Reserve Board of Governors*

Discussant: John Leahy, *Boston University*

Inflation Dynamics, Marginal Cost, and the Output Gap: Evidence from Three Countries

Katherine Neiss, *Bank of England*
Edward Nelson, *Bank of England*

Discussant: Robert Gordon, *Northwestern University*

Macroeconomic Switching

Christopher Sims, *Princeton University*
Tao Zha, *FRB Atlanta*

Discussants: James Hamilton, *University of California, San Diego*
Edward Leamer, *UCLA*

Panel: What Is a Good Macroeconomic Model for a Central Bank to Use?

Lawrence Christiano, *Northwestern University*
Adrian Pagan, *Australian National University*
Dave Stockton, *Federal Reserve Board of Governors*

Financial Issues in the Pacific Basin Region

Federal Reserve Bank of San Francisco
September 26–27, 2002

Cosponsored by the Center for Pacific Basin Monetary and Economic Studies, Federal Reserve Bank of San Francisco, and the Journal of the Japanese and International Economies

Papers presented at this conference can be found on the conference website http://www.frbsf.org/economics/conferences/0209/index.html

Keynote address: Growth Prospects in Asia

Brad DeLong, *University of California, Berkeley*

The Impact of Japan's Financial Stabilization Laws on Bank Equity Values

Mark M. Spiegel, *FRB San Francisco*
Nobuyoshi Yamori, *Nagoya University*

Discussant: Jim Wilcox, *University of California, Berkeley*

Loans to Japanese Borrowers

David Smith, *Federal Reserve Board of Governors*

Discussant: Anil Kashyap, *University of Chicago*

The High Demand for International Reserves in the Far East: What's Going On?

Joshua Aizenman, *University of California, Santa Cruz*
Nancy P. Marion, *Dartmouth College*

Discussant: Hali J. Edison, *International Monetary Fund*

Post-Crisis Exchange Rate Policy in Five Asian Countries: Filling In the 'Hollow Middle'?

Leonardo Hernández, *Banco Central de Chile*
Peter J. Montiel, *Williams College*

Discussant: Reuven Glick, *FRB San Francisco*

Roundtable discussion: Monetary Policy Coordination in Asia

Takeo Hoshi, *University of California, San Diego*
Menzie D. Chinn, *University of California, Santa Cruz*
Barry Eichengreen, *University of California, Berkeley*
Steven Kamin, *Federal Reserve Board of Governors*
Ronald McKinnon, *Stanford University*
Wataru Takahashi, *Bank of Japan*

Financial Intermediation, Agency, and Collateral and the Dynamics of Banking Crises: Theory and Evidence for the Japanese Banking Crisis

Robert Dekle, *University of Southern California*
Kenneth Kletzer, *University of California, Santa Cruz*

Discussant: Kenneth Kasa, *Simon Fraser University*

The Value of Banking Relationships during a Financial Crisis: Evidence from Failures of Japanese Banks

Elijah Brewer, *FRB Chicago*
Hesna Genay, *FRB Chicago*
William C. Hunter, *FRB Chicago*
George Kaufman, *Loyola University*

Discussant: James Harrigan, *FRB New York*

Technological Change

Federal Reserve Bank of San Francisco
November 14–15, 2002

Cosponsored by the Federal Reserve Bank of San Francisco and the Stanford Institute for Economic Policy Research

Papers presented at this conference can be found on the conference website http://www.frbsf.org/economics/conferences/0211/index.html

Productivity Growth in the Industrial Revolution: A New Growth Accounting Perspective

Nick Crafts, *London School of Economics*

Discussant: Brad DeLong, *University of California, Berkeley*

The Transition to a New Economy after the Second Industrial Revolution

Andy Atkeson, *UCLA*
Pat Kehoe, *FRB Minneapolis*

Discussant: John Williams, *FRB San Francisco*

The Baby Boom and Baby Bust: Some Macroeconomics for Population Economics

Jeremy Greenwood, *University of Rochester*
Ananth Seshadri, *University of Wisconsin, Madison*
Guillaume Vandenbroucke, *University of Rochester*

Discussant: Matthias Doepke, *UCLA*

Vintage Capital as an Origin of Inequalities

Andreas Hornstein, *FRB Richmond*
Per Krusell, *University of Rochester*
Giovanni Violante, *New York University*

Discussant: Chad Jones, *University of California, Berkeley*

Human Capital and Technology Diffusion

Jess Benhabib, *New York University*
Mark Spiegel, *FRB San Francisco*

Discussant: Rody Manuelli, *University of Wisconsin, Madison*

Importing Technology

Francesco Caselli, *Harvard University*
Daniel Wilson, *FRB San Francisco*

Discussant: Robert Feenstra, *University of California, Davis*

Macroeconomic Models for Monetary Policy

Federal Reserve Bank of San Francisco
March 1–2, 2002

Reprinted from FRBSF Economic Letter 02-11, April 19, 2002.

This *Economic Letter* summarizes the papers presented at the conference "Macroeconomic Models for Monetary Policy" held at the Federal Reserve Bank of San Francisco on March 1–2, 2002, under the joint sponsorship of the Federal Reserve Bank of San Francisco and the Stanford Institute for Economic Policy Research.

Models of the economy are valuable tools for monetary policymakers for at least two reasons. First, such models can help produce forecasts of future inflation, output, and other variables, which are crucial for a forward-looking central banker who takes into account lags in the effects of monetary policy. Second, macroeconomic models can help quantify the amount of uncertainty that central bankers face in making their policy choices—particularly through the use of alternative model simulations. The research and discussion at this conference considered which macroeconomic models would be most useful in guiding monetary policy. Some of the relevant issues included the role of explicit expectations in models, the use of multiple models, the importance of judgmental adjustments to models, identifying model structural change, and the appropriate size and amount of detail in models.

There are three broad categories of macroeconomic models currently being considered for monetary policy analysis, and this conference had examples and proponents of all three. One category contains calibrated or estimated general equilibrium (GE) models, which are closely based on a detailed theoretical structure that features explicitly optimizing businesses and consumers. The paper by Smets and Wouters formulates such a model with sticky prices and wages for the euro area to investigate business cycle fluctuations and optimal monetary policy.

The papers by Sbordone and by Neiss and Nelson also start with a dynamic stochastic GE model as motivation; however, their analyses focus on the single issue of the appropriate econometric specification of the determination of wages and prices, the subject of the paper by Rudd and Whelan as well. Such a focus on the empirical estimates of a structural equation is the hallmark of the second type of model used to analyze monetary policy: the structural macroeconometric model. As was made clear in the conference panel discussion by Adrian Pagan and David Stockton, such structural macroeconometric models are the most common type of model used at central banks. These models, which continue a line of research over 50 years old, have been updated during the past decade or so with explicit expectations and better long-run properties, but another panel discussant, Larry Christiano, suggested that GE models could be a useful alternative.

The third category of models contains those that are almost purely statistical in nature, particularly vector autoregressions (VARs). The paper by Leeper and Zha uses a VAR to consider the plausibility of various monetary policy actions, and the paper by Sims and Zha uses a VAR to examine changes in the variances of shocks that buffet the economy.

Monetary policy in an estimated GE model of the euro area

Smets and Wouters develop a dynamic stochastic GE model with sticky prices and wages for the euro area. The model is theoretically quite intricate, with features such as monopolistically competitive markets, costs to adjusting the capital stock, habit formation by consumers, and a variable rate of capacity utilization. Smets and Wouters attempt to estimate this model and analyze the relative contributions of eight different kinds of shocks to business cycle fluctuations in the euro area. They find that productivity shocks account for only 10 percent of the long-run variability in output, contrary to what so-called Real Business Cycle models would predict.

The estimated model is also used to show that historical monetary policy in the euro area has apparently deviated from the way an optimal monetary policy should have been set in response to various structural shocks. An important caveat to this analysis is that the unified euro area did not exist historically, so the analysis pertains to a synthetic history of reconstructed euro area data. (For a complementary analysis with a very simple macroeconometric model, see Rudebusch and Svensson 2002.)

An optimizing model of U.S. wage and price dynamics

The Phillips curve, which links inflation with an unemployment or output gap from trend, has provided perhaps the most popular empirical description of wage and price dynamics for the past half century; however, the theoretical foundations of this model are considered weak and have been the subject of almost constant debate. In her paper, Sbordone uses a GE optimizing model to derive a theoretical "New Keynesian" Phillips curve, which relates inflation to future expected inflation and marginal costs. The output gap in such a model should be measured as the deviation from potential output with a stochastic trend (i.e., incorporating actual aggregate demand and supply shocks) rather than the usual deterministic trend.

Sbordone also argues that incorporating labor cost dynamics is crucial to a model of price dynamics. She derives the joint dynamics of wages and prices implied by a sticky-price model with a perfectly competitive, flexible-wage labor market and, alternatively, with a monopolistically competitive, sticky-wage labor market. Sbordone compares the implied dynamics with actual postwar U.S. data, and concludes that the model performs quite well in predicting the inflation process using the real wage. The real output gap, when measured as deviations from a stochastic trend potential output, also performs well in matching inflation dynamics.

Should monetary policy target labor's share of income?

In a closely related paper, Rudd and Whelan challenge the empirical results in Woodford (2001) and Sbordone (2002), which also suggested that marginal costs or wages worked better in predicting inflation than the output gaps used in the traditional Phillips curve literature. Specifically, Woodford (2001) presented evidence that using real unit labor costs (labor's share of income) as a driving variable in the Phillips curve yields a superior fit for inflation than a model that uses deterministically detrended real GDP as the driving variable. For his empirical work, expectations of the driving variables were obtained from a reduced-form VAR. However, Rudd and Whelan find that Woodford's result is not robust and that the evidence in favor of using the labor's income share is highly sensitive to small changes in the specification of the VAR.

Rudd and Whelan also show that the principal reason for the good fit obtained by Sbordone (2002) is not the use of the labor income share as a driving variable, but rather an additional—and unrealistic—assumption that the nominal marginal cost evolves independently of the price level. Indeed, after imposing a similar assumption that nominal output evolves independently of the price level, Rudd and Whelan find that the New Keynesian Phillips curve with a traditional output gap (defined using a deterministically trended potential output) performs just as well as the labor income share version. Furthermore, the reason that both models obtain fairly good results is that both estimation equations include lagged inflation as one of the explanatory variables. Because inflation is highly persistent, the lagged inflation term helps explain a lot of the variation in inflation. Accordingly, the use of the labor income share does not improve the inflation prediction performance.

Inflation dynamics, marginal cost, and the output gap

The Neiss and Nelson paper also focuses on the structural modeling of inflation dynamics and argues that the output gap obtained using a smooth deterministic trend for potential output is not appropriate, because potential output should be stochastic and correspond to the output level that would prevail if there were no nominal rigidities in the economy (i.e., if prices and wages were flexible). In other words, potential output should be affected by real shocks over the business cycle and should not follow a smooth path, as typically assumed. However, rather than replacing the output gap with a marginal cost measure based on labor costs (as in the Sbordone paper), Neiss and Nelson advocate a new output gap that is constructed to be consistent in theory with a dynamic stochastic GE model.

Neiss and Nelson start by formulating a GE model characterized by habit formation and capital investment adjustment costs. They calibrate this model and discuss procedures for constructing an empirical potential output gap series that is consistent with the model. Using post-war data for the U.S., the U.K., and Australia, they find that output gaps defined in a manner consistent with their model perform as well as unit labor costs in predicting inflation. Therefore, they conclude that there is little evidence to support the recent emphasis on the role of labor market rigidities for modeling inflation.

Empirical analysis of policy interventions

Leeper and Zha attempt to provide a methodology for analyzing the response of the economy to changes in monetary policy. Such analyses are hindered by the Lucas critique, which states that changes in policy also affect the behavior of rational agents, and such behavioral changes can invalidate the model relationships estimated under the previous policy regime. As also described by Rudebusch (2002), the Lucas critique complicates the assessment of proposed policy actions.

Leeper and Zha first formulate a six-variable monthly structural VAR model and show that the monetary policy shocks identified have a fairly stable impact on the economy from 1959 to 1998, which suggests that there have been no substantive changes in agents' beliefs about the policy regime. Therefore, this estimated structural VAR model can be used to analyze the effects of hypothetical changes in policy as long as those changes are not too different from historical actions (and thus avoid the Lucas critique). Leeper and Zha propose a statistical metric for judging whether the hypothetical policy interventions are large enough to be considered changes in the policy regime. They apply this metric to judge whether hypothetical policies represent a recognizable break from past policy in two different contexts: first, in assessing the usual central bank forecasting assumption of constant nominal interest rates and, second, in examining various policy actions that the Federal Reserve could have taken in the 1990s.

Macroeconomic switching

Sims and Zha formulate a six-variable structural VAR in which they allow for certain types of parameter variation over time. In estimating the VAR, they first allow both the policy rule and the variances of the structural shocks to change over time, and then they compare the fit of this model to one in which only the shock variances are allowed to change. From their estimates, Sims and Zha conclude that allowing for changing shock variances over time is more important for improving model fit than allowing for a changing policy rule. Furthermore, counterfactural exercises suggest that, even without the presence of a "Volcker regime," inflation in the U.S. after 1979 would have declined and the recession in the early 1980s would have been smaller, although inflation would have fallen less rapidly in this alternative and output growth would have been much slower after 1984. In contrast, the conventional wisdom on this subject (described in Rudebusch 2002) is that the systematic component of Federal Reserve monetary policy has changed dramatically over time and has at least partly accounted for the rise and fall of the historical U.S. inflation rate.

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Conference Papers

Papers are available in pdf format at http://www.frbsf.org/economics/conferences/0203/index.html

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Financial Issues in the Pacific Basin Region

Federal Reserve Bank of San Francisco
September 26–27, 2002

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This *Economic Letter* summarizes the papers presented at the conference "Financial Issues in the Pacific Basin Region" held at the Federal Reserve Bank of San Francisco on September 26–27, 2002, under the joint sponsorship of the Bank's Center for Pacific Basin Monetary and Economic Studies and the *Journal of the Japanese and International Economies.*

The six conference papers examine important financial issues of relevance to the Pacific Basin. Four papers focus on Japan's banking sector problems. Two others focus on exchange rate polices in the Pacific Basin region.

Japanese banking reform

The persistent weakness of the Japanese banking system has been confounding that country's policymakers since the early 1990s, despite their efforts to improve the situation by passing several programs. Among the most notable programs are two that were enacted in 1998. One is the Financial Reconstruction Act (FRA), which established a framework for dealing with failed Japanese banks; the other is the Rapid Revitalization Act (RRA), which allowed for the injection of public funds to solvent Japanese banks needing assistance to deal with their bad loans and clean up their balance sheets.

Mark Spiegel and Nobuyoshi Yamori conducted an event study, analyzing how the news about the passage of these programs affected the equity values of Japanese banks. Their conjecture is the following: If market participants expected the passage of these laws to improve bank regulatory control in Japan, then equity values should fall for banks that are financially weak or poorly regulated.

Their results suggest that, while there was some perception that the FRA would lead to adverse treatment of weaker regional banks, the market expressed a healthy skepticism that the overall regulatory changes of 1998 would lead to serious reform. This implies that the actual closures resulting from the FRA were expected to be limited largely to regional banks. In addition, they find that news concerning the passage of the RRA was treated as disproportionately beneficial to the weaker regional and large city banks in the Japanese financial system; that is, the market anticipated that the government's capital injections would simply allow these banks to postpone or avoid financial reforms rather than induce them to clean up their balance sheets. The performance of Japan's banking system since the passage of the FRA and the RRA lends some credence to the notion that the markets were skeptical about the pace of reform afforded by these regulatory changes.

Loans to Japanese borrowers

David Smith conducts an empirical analysis of the Japanese banking system by assembling and analyzing data on loans to large Japanese firms. He tests the hypothesis that Japanese banks have been unprofitable over the past decade because they have been pricing their loans below profitable levels.

Smith's data show that the interest rate premiums on loans to Japanese firms were lower on average than those to borrowers from other developed countries. The lower premiums could reflect the underpricing of risks by Japanese banks due to one or more factors, including implicit government guarantees, strong relationship commitments to the borrower, and a desire to keep loans "performing" so as not to have to hold reserves against loan losses. However, the Japanese loans also were characterized by higher credit ratings, larger loan amounts, and—at least until 1997—longer maturities, all suggesting that they were less risky. This implies that they may have been priced appropriately. Indeed, after controlling for the characteristics related to loan riskiness in a regression analysis, the interest rate premium differences on loans from Japanese and non-Japanese banks disappears. Nevertheless, some questions remain about how well these findings reflect typical loans to Japanese businesses.

Bank regulation and financial crises in Japan

Robert Dekle and Kenneth Kletzer develop a formal banking sector model as a framework for understanding Japan's recent experience. In their model, government deposit in-

surance guarantees create moral hazard that encourages banks to underprice the true riskiness of their loans and to make riskier loans. Consequently, if adverse shocks hit the economy, depressing the value of the collateral underlying loans and leading some borrowers to fail, banks still will make more loans, even as the share of nonperforming loans in their portfolios rises. Eventually, the health of the banking sector deteriorates to the point that banks themselves become insolvent, bank loans dry up, and aggregate output declines.

The authors note that the dynamics of their model fit Japanese experience. As Japan was hit by a succession of adverse aggregate shocks in the 1990s, bank portfolios continued to deteriorate, and the market value of collateral (in particular, land) collapsed. The decline in collateral values in turn led to a fall in bank lending, a decline in physical investment, and finally, a fall in output.

Bank failures and banking relationships in Japan

A question of great interest to policymakers is how bank failures affect banking relationships, as reflected by the impact on the failing bank's customers. A bank failure interrupts the flow of credit to its customers, forcing them to find alternative financing. The extent to which these customers will be affected depends on such characteristics as their dependency on bank financing, their financial condition, and the industry to which they belong. If an individual bank failure is significant enough and signals the poor state of the financial sector or of the economy, it may adversely affect firms that are not only its own customers but also customers of other banks.

To shed light on these effects, Elijah Brewer III, Hesna Genay, William Curt Hunter, and George G. Kaufman examine the stock prices of over 1,000 Japanese firms following the 1997 failure announcement of the Hokkaido Takushoku Bank and the 1998 failure announcements of the Long-Term Credit Bank of Japan and the Nippon Credit Bank. In line with previous research for the U.S., they find that the customers of a failed bank experience negative abnormal returns around the time of the failure announcement; the extent of this effect is related to the firm's financial characteristics. Firms with greater access to alternative sources of funding are less adversely affected by bank failure announcements. The authors also find that the adverse impact of a failure on the market value of firms that are its customers is not significantly different from the impact on firms that are not its customers. That is, bank failures are "bad news" for all firms in the economy, not just for the customers of the failed banks.

To the extent that these results for Japan are representative, they cast doubt on the importance of bank failures to bank customer relationships. They also raise questions about the meaningfulness of other studies' results finding significant adverse effects of a bank failure on its loan clients if those studies do not also test for the effect on firms other than the failing bank's clients.

High demand for international reserves in Asia

In the aftermath of the Asian financial crises of 1997–1998, many countries in the region purportedly moved to exchange rate regimes with greater flexibility. In theory, there should be less demand for foreign exchange reserves under flexibility. In fact, however, most Asian countries have accumulated substantial reserves in recent years.

Joshua Aizenman and Nancy Marion analyze developing countries' demand for foreign exchange reserves, with special emphasis on understanding the reasons for the big accumulation of foreign reserves by Asian countries. Using panel data for 125 developing countries over the period 1980–1996, they show that reserve holdings can be predicted well by several key variables, including country population, GDP per capita, the volatility of international transactions, and political factors. The estimating equation also does a good job of predicting reserve holdings of East Asia countries before the 1997 financial crisis but underpredicts their holdings after the crisis; that is, their reserve levels in recent years are higher than the estimated model can explain.

To explain this finding, they formulate several models that are consistent with this underprediction result. Specifically, one model shows that if raising taxes is costly and access to global credit is limited in times of crisis, then countries will choose to hold foreign reserves for precautionary reasons. This precautionary demand rises with higher perceived sovereign risk and higher fiscal liabilities (both explicit and implicit)—such as may occur in the aftermath of a crisis. This precautionary demand declines if policymakers are impatient (that is, if the discount rate is high) or political arrangements are unstable or corrupt. A second model shows that the demand for reserves is higher if policymakers are loss-averse, that is, if they attach more weight to bad outcomes than to good ones. Hence, if a crisis increases the loss-aversion or the volatility of shocks, it also will increase the demand for reserves. The implication is that an econometric specification incorporating some of these factors would do better in explaining the observed high reserve holdings of Asia countries since 1997.

Post-crisis exchange rate policy in Asia

Leonardo Hernández and Peter Montiel ask three questions about the exchange rate policies of Asian countries: (1) Are

Asian countries managing their exchange rates more or less now than before the 1997–1998 crisis? (2) If they're managing their exchange rate, why are they doing it? (3) Does the specific experience of these Asian countries provide general lessons for other emerging markets?

The paper answers the first question by inspecting some simple statistical measures of the relative variability of exchange rates, foreign reserves, and domestic interest rates for the five Asian countries most affected by the crisis of 1997–1998—Korea, Thailand, Indonesia, the Philippines, and Malaysia. They conclude that these countries manage their exchange rates less in the post-crisis period than before, but do so more than "purer" floaters, such as Germany/Euroland and Japan. (Malaysia, because of its capital controls, has been able to maintain a fixed exchange rate and is the outlier in the sample.) These results are consistent with those who argue that developing countries have a "fear of floating."

The authors attribute the continued intervention activity by Asian policymakers to a desire to limit the adverse competitive effects of appreciations as well as to a desire to accumulate reserves. Lastly, on the basis of the Asian experience, they argue that active management of the exchange rate is still feasible, even when countries maintain open capital markets. Thus, developing countries need not choose solely between adopting a hard peg or allowing full exchange rate flexibility.

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Conference papers

Papers are available in pdf format at http://www.frbsf.org/economics/conferences/0209/index.html

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Technological Change

Federal Reserve Bank of San Francisco
November 14–15, 2002.

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This *Economic Letter* summarizes the papers presented at the conference "Technological Change," held at the Federal Reserve Bank of San Francisco on November 14–15, 2002, under the joint sponsorship of the Bank and the Stanford Institute for Economic Policy Research.

In the latter part of the twentieth century, information technology (IT) came to be used everywhere—in offices, factories, and homes—and transformed the way things are done in activities as diverse as jet aircraft design, document production, and home entertainment. This technology also has improved tremendously, as evidenced, for instance, by the quick succession of more powerful computers with faster processors, greater storage capacity, and so forth.

Two of the conference papers noted that the use of computers in diverse applications was similar to the use of earlier technologies, such as steam and electricity, and looked at the evolution of those older technologies to understand both how computers diffused through the economy and the effects they were likely to have on it. Another theme at the conference was "technological embodiment," which refers to technological change that is embedded in the machine and is the reason one must buy a new computer every few years in order to use the latest technology. Among other things, embodiment can explain why it took a long time for the effects of technological change in the computer industry to show up in higher productivity in the economy. Other papers at the conference were concerned with the spread of technology across countries, asking, for instance, whether the process of technological diffusion ensured that all countries grew at the same rate.

Industrial revolutions and the diffusion of technology

Nick Crafts (2002) uses two recent developments in economic analysis to study his well-known finding that the pace of productivity growth and technological innovation during the industrial revolution was not as rapid as had been believed. The first is work on general purpose technologies (GPTs), which Lipsey, et al. (1998) define as "a technology that initially has much scope for improvement and eventually comes to be widely used, to have many uses, and to have many…technological complementarities." The most cited examples of GPTs include electricity, steam, and IT. Second, because conventional methods of growth accounting do not account for the improvement in the quality of capital over time (and so tend to understate the contribution of technological change to growth), Crafts uses some recent techniques that explicitly account for embodiment.

An analysis of data incorporating these new developments leads him to confirm his earlier conclusion, which is that it takes a long time for GPTs to have a significant impact on productivity. In fact, he finds not only that steam power had a relatively small impact on productivity growth initially, but also that this impact was smaller than that of comparable GPTs, like electricity and IT, at a similar point in their development. An important reason was that the real price of steam power stayed high for many decades. And while he does find that using the new method of growth accounting rather than the traditional method raises the estimated effect of technological change on British output growth between 1780 and 1860, the difference is not very large.

Atkeson and Kehoe (2001) study technology diffusion during the "second industrial revolution" (1860–1900), when a host of new technologies were invented, including those based on the use of electricity. Economic historians have argued that the full effects of these technologies were not felt until many decades after their introduction. It is not hard to see why; for instance, in order to reap the benefits of electrification, manufacturing firms had to replace old machinery (which relied principally on steam power) and reorganize their production processes.

The authors' model reproducing this slow diffusion contains two key assumptions. First, new technologies are embodied in capital goods. Second, a plant's productivity rises with its age, reflecting a process of learning-by-doing. The authors then consider what happens when there is a sustained acceleration in the productivity of capital goods. While the standard model for studying this phenomenon predicts a rapid transition to a higher long-run growth rate

that is at odds with the historical experience, the authors' model yields a pattern of slow diffusion of new technologies through the economy, which is similar to the pace of electrification of the manufacturing sector in the first part of the last century.

Interestingly, their model does not imply slow diffusion during the "information technology revolution." Recent high rates of embodied technological progress imply that, compared to the past, capital goods now get obsolete much more quickly and firms have less time to accumulate experience with their capital (the learning-by-doing effect). As a result, firms scrap their old capital much more rapidly than before. This prediction of rapid diffusion counters the arguments of some economic historians, who use the slow diffusion of technology in the early twentieth century to explain why the introduction of IT late in the twentieth century did not have a more immediate impact on productivity growth.

International diffusion of technology

In a world with embodied technology, trade in capital goods provides a means for the international diffusion of technology. Caselli and Wilson (2002) look at what determines the kinds of capital goods countries import and the effects of these decisions on a country's level of income. They begin by specifying a production function where output depends upon labor and different kinds of capital and show that this can be rewritten as the product of two terms: a conventional production function where output depends upon the quantity of labor and of capital plus a term that contains information about the different kinds of capital in use. They hypothesize that the amount a country invests in a particular kind of capital depends upon the relative efficiency of that capital and upon its complementarity with various characteristics of the country in question (such as the skill level of its labor force). The relative efficiency of capital depends upon the amount of research and development embedded in it.

Since most countries acquire embodied technologies by importing capital from a relatively small number of technological "leaders," they argue that capital imports provide a measure of technology adoption by "follower" countries. Data on capital imports then can be used to draw inferences about the kinds of capital investments different countries make. They find a wide variation in the kinds of capital imported by different countries, with the mix depending upon country-specific factors such as human capital (or the skill level of the countries' workers), institutions (such as property rights), and the level of financial development. They also show that taking the quality of capital into account provides a significantly better explanation of income differences across countries than a specification where only the quantity of capital is accounted for.

Benhabib and Spiegel (2002) examine the role of human capital in the process of technology diffusion across countries and show that the way this diffusion takes place matters for the long-run distribution of per capita income across countries. They point out that several previous studies (including one of their own) adopted a specification for the technology diffusion process that ensures that (a measure of) productivity in all follower countries will grow at a pace determined by technological innovation in the leader country. However, it is possible to specify the diffusion process in other ways, including those in which diffusion gets weaker as the geographical distance between the follower and the leader increases. Indeed, if the human capital stock of a follower is sufficiently low, this kind of process implies that productivity growth in the follower country may never catch up with the leader.

Using data on productivity growth rates for a sample of 84 countries over the 1960–1985 period, they find that human capital (schooling) facilitates catch-up in productivity across countries. However, their results also favor the specification of the diffusion process which implies that productivity growth in some follower countries may never catch up with the leader. They estimate that an average of 1.78 years of schooling was required in 1960 to ensure that productivity growth in a given country caught up (eventually) with productivity growth in the U.S. Under this criterion, they identify 27 countries that were predicted to exhibit slower productivity growth than the U.S. Over the next 35 years, 22 of these countries did fall farther behind the U.S. in productivity growth, while the bulk of the nations in their sample tended to catch up with the U.S. in productivity growth

Some other implications of technological change

Hornstein, Krusell, and Violante (2002) present a model in which the interaction of embodied technological change with labor market institutions helps to determine key labor market characteristics, such as the unemployment rate and the distribution of wages across different kinds of workers. The model also provides an explanation for the differences in the behavior of U.S. and European labor markets in recent years. For example, in 1965 the unemployment rate was lower in virtually every European country than in the U.S. However, while the U.S. unemployment rate rose by only 1.7% over the next 30 years, the average increase for European countries was 8.4%.

To understand how their model works, note first that capital must be used for a minimal period in order to recover investment costs. Labor costs matter as well. The

U.S. economy has relatively low unemployment benefits, which implies low labor costs, so that capital can remain in use for a relatively long time. In contrast, Europe has high benefits and high labor costs, which forces firms to scrap capital earlier. Now consider what happens when there is an increase in the pace of technological change. The assumption of embodied technology means that the benefits of faster technological change can be obtained only by faster replacement of machines. This is relatively easy to do for U.S. firms, but it is hard for European firms because the life of capital in Europe is already very short. European firms must be compensated along some other margin; in their model this occurs through an increase in the probability that a firm's search for a worker will be successful. An increase in this probability, in turn, requires a larger pool of available workers, which is accomplished through longer spells of unemployment. In a quantitative exercise with their model, they show that a 2 percentage point increase in the rate of embodied technological progress raises the unemployment rate by less than 1 percentage point in a U.S.-type economy but by more than 8 percentage points in a European-type economy.

Greenwood, Seshadri, and Vandenbroucke (2002) use technological change to explain variations in fertility rates over time. According to the authors, two features stand out in the data on the fertility of U.S. women over the last 200 years. The first is a drastic decline: the average white woman had seven children in 1800 but only two in 1990. The second is a surprising recovery in fertility between the mid-1940s and the mid-1960s—the "baby boom."

Their model explains both features of the data by technological progress, although of different kinds. The long-run decline in fertility is explained by technological progress in the market sector. Ongoing technological progress over this period has raised individuals' wage rates. The implicit cost of having children has risen as a consequence, because individuals now must give up a greater amount of consumption goods for every hour spent on raising children; this tends to lower fertility. By contrast, technological progress in the household sector tends to raise fertility, because it frees up the time women used to spend on household tasks. Of course, having more children is not the only possible response to more free time; women could decide to spend some of this time in market activities as well, i.e., their labor force participation rates could increase as well. The authors argue that a burst of technological progress occurred in the household sector around the 1940s, arising from the second industrial revolution. For instance, refrigerators entered household service in the 1920s and the first fully automatic washing machine appeared in the 1930s. Consistent with their model, these innovations were followed by a period of rising fertility and rising female labor force participation rates. In fact, the biggest percentage increase in fertility during the baby boom was among working women.

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