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Robust Estimation and Monetary Policy with Unobserved Structural Change*

John C. Williams

Senior Vice President and Advisor

This paper considers the joint problem of model estimation and implementation of monetary policy in the face of uncertainty regarding the process of structural change in the economy. I model unobserved structural change through time variation in the natural rates of interest and unemployment. I show that certainty equivalent optimal policies perform poorly when there is model uncertainty about the natural rate processes. I then examine the properties of combined estimation methods and policy rules that are robust to this type of model uncertainty. I find that weighted averages of sample means perform well as estimators of natural rates. The optimal policy under uncertainty responds more aggressively to inflation and less so to the perceived unemployment gap than the certainty equivalent policy. This robust estimation/policy combination is highly effective at mitigating the effects of natural rate mismeasurement.

1. Introduction

The U.S. economy has changed substantially over the past two decades. The information technology revolution alone has transformed inventory management, fostered increased globalization of trade in goods and services, and improved the efficiency of labor and goods markets. These and other changes have had wide-ranging effects on the economy: The magnitude of macroeconomic fluctuations has declined dramatically, estimates of the long-run growth rate of productivity have risen more than 1 percentage point, and estimates of the natural rate of unemployment have declined about 1 percentage point.[1] The implications of structural change for the conduct of monetary policy have attracted increased attention from researchers and policymakers, as evidenced by the 2003 Jackson Hole conference, "Monetary Policy and Uncertainty: Adapting to a Changing Economy."[2] The goal of this paper is to examine issues related to the design of monetary policy when structural change is a regular feature of the economy and when there is considerable uncertainty about the precise nature of the underlying process of change.

I represent structural change by medium- and low-frequency variation in the natural rates of unemployment and interest. For the purpose of this paper, I define the natural rate of unemployment to be the unemployment rate consistent with a stable rate of inflation in the absence of transitory supply shocks; correspondingly, I define the natural rate of interest to be the real short-term interest rate consistent with the convergence of the unemployment rate to its natural rate in the absence of transitory demand shocks. I focus on shifts in natural rates because of the relatively strong evidence that they vary over time; I leave the analysis of the monetary policy implications of changes in other aspects in the economy to future research.[3]

*I thank Richard Dennis, Francis Diebold, Athanasios Orphanides, and Glenn Rudebusch for comments on earlier drafts. I also thank Kirk Moore and Judith Goff for outstanding research and editorial assistance respectively. This article was originally published in the conference volume *Models and Monetary Policy: Research in the Tradition of Dale Henderson, Richard Porter, and Peter Tinsley,* eds. J. Faust, A. Orphanides, and D. Reifschneider (Washington, DC: Federal Reserve Board of Governors, 2005).

1. Kim and Nelson (1999) and McConnell and Quiros (2000) analyze the decline in variability in output in the United States. Orphanides and Williams (2002) and Edge, Laubach, and Williams (2004) document the evolution of estimates of the natural rate of unemployment and the long-run rate of productivity growth respectively.

2. Symposium sponsored by the Federal Reserve Bank of Kansas City, Jackson Hole, Wyoming, August 28–30, 2003.

3. For example, Rudebusch and Svensson (1999) find no evidence of a break in slope coefficients in their model, while Estrella and Fuhrer (2003) find strong evidence of a break when testing jointly for intercepts—which are related to natural rates—and slope parameters. See also Kozicki and Tinsley (2001), who emphasize lower-frequency variation in intercepts in estimated models. The evidence for change in other macroeconomic relationships, such as the autocorrelation of inflation, is the subject of ongoing research; see Bernanke and Mihov (1998), Cogley and Sargent (2002a, 2002b), Sims (2002), Boivin and Giannoni (2003), and Stock and Watson (2003).

If there is uncertainty about the true levels of the natural rates, but their true data-generating processes (DGPs) are known, then, in a standard linear-quadratic framework, certainty equivalence obtains, and the form and parameters of the optimal monetary policy would be the same as if there were no natural rate uncertainty.[4] Similarly, Giannoni and Woodford (2005) emphasize that in a linear-quadratic framework the Euler equation describing the optimal monetary policy is invariant to the natural rate process. Nonetheless, implementation of the optimal policy requires that the policymaker form correct forecasts of endogenous variables, for which they need to know the true DGPs of the natural rates. However, the assumption that policymakers know the processes generating natural rates is highly unrealistic, as emphasized by Orphanides and Williams (2002).[5] In addition, the processes underlying movements in natural rates themselves may change over time, as evidenced by shifts in innovation variances noted in Cogley and Sargent (2002b) and others, further impairing policymakers' ability to infer the true model from the data. Thus, a key assumption of this approach is that uncertainty regarding the process of structural change is pervasive and that it is unlikely to vanish in the foreseeable future.

I assume that the policymaker must choose once and for all, without knowing the true DGPs for natural rates, both a method to estimate the natural rates in real time and a monetary policy rule. I consider two approaches to model uncertainty. In one, the policymaker has well-formed prior beliefs, stated as probabilities (priors) over the set of potential natural rate DGPs and chooses an estimation and policy rule combination that minimizes the expected loss—in terms of unconditional squared deviations of inflation, the unemployment rate, and the interest rate from target levels—when integrating over the set of natural rate DGPs. The second approach corresponds to Knightian uncertainty, in which the policymaker does not have well-formed priors over the natural rate models. In this case, I follow the robust-control literature and analyze the estimation and policy-rule combinations that minimize the maximum loss over the set of potential natural rate DGPs. This method of examining robust monetary policy under model uncertainty follows the approach advocated by McCallum (1988) and implemented by Taylor (1999), Levin, Wieland, and Williams (1999, 2003), and others.[6]

I implement this approach by specifying three representative natural rate processes that make up the set of possible natural rate processes: a highly persistent first-order autoregressive process, a fractionally integrated ("long-memory") process, and a two-state Markov-switching process. I choose these processes because they are all consistent with the data, but they differ in their implications for the specification of the optimal natural rate estimator. For each process, I also allow for uncertainty regarding the parameterization of the process, as evidenced by the wide range of estimates of natural rate innovation variances reported by Laubach and Williams (2003) and others in the case of the Kalman filter. To capture this form of parameter uncertainty, I include three different calibrations of the DGP for each natural rate.

A key contribution of this paper is its analysis of the joint problem of estimation and policy feedback when there is uncertainty about the processes underlying structural change. A number of researchers have examined the effects of natural rate mismeasurement on the performance and optimal specification of monetary policy rules, but most have treated natural rate mismeasurement as exogenous noise.[7] In this paper, I directly examine the performance of real-time estimation strategies and policy rules in which the true natural rates vary over time.[8] Thus, the occurrence of natural rate misperceptions and their correlation with other variables arise endogenously and depend on both the estimation method and the policy rule.

I conduct the analysis using a variant of the backward-looking model of Rudebusch and Svensson (1999) estimated on 50 years of postwar U.S. data. I focus on this model because Orphanides and Williams (2002) have shown that natural rate mismeasurement is relatively easy to overcome in forward-looking and hybrid models by specifying the policy rule in terms of changes of the interest rate as it reacts to inflation and the change in the unemployment rate. But such a strategy is far less effective in models of the Rudebusch-Svensson type, which have em-

4. See Simon (1956), Theil (1958), Chow (1975) and Kalchbrenner and Tinsley (1976) for early analysis of certainty equivalence, and Swanson (2004), Svensson and Woodford (2003), and Woodford (2003) for more recent treatments. Stochastic natural rates are a form of additive uncertainty, and therefore certainty equivalence applies for optimal policies and optimal filters. Certainty equivalence does not apply to uncertainty about slope parameters, as analyzed by Brainard (1967).

5. See also Stock and Watson (1998), Lansing (2000) and Orphanides and van Norden (2002).

6. See, for example, Orphanides and Williams (2002), Laxton and Pesenti (2003), Levin and Williams (2003), Brock, Durlauf, and West (2003), and Onatski and Williams (2003). Cogley and Sargent (2003) extend this type of analysis to the case in which the policymaker continuously updates his or her priors over models.

7. See, for example, Orphanides et al. (2000), Smets (2002), Orphanides (2002), Rudebusch (2001, 2002), and Orphanides and Williams (2002).

8. The use of the term "real time" for problems of this sort is due to Diebold and Rudebusch (1991).

pirical support (Estrella and Fuhrer, 2003).[9] In addition, the model has been extensively studied in the monetary policy literature, facilitating the comparison of results from studies by Rudebusch (2001, 2002), Onatski and Williams (2003), Brock, Durlauf, and West (2003), and Levin and Williams (2003).

I find that there can be very large costs, especially in terms of inflation variability, to ignoring natural rate uncertainty. However, I also show that it is possible to design estimation and monetary policy rules that are robust to a variety of models of natural rate evolution. In the terminology of Levin and Williams (2003), such estimation-and-policy combinations display a high degree of fault tolerance in the face of model uncertainty about natural rates. I find that weighted sample means of the real interest rate and the unemployment rate, in which the weights on past data decline gradually, yield very good estimates of the natural rates for use in the conduct of monetary policy. I also find that in the face of uncertainty about natural rates, the robust policy incorporates more policy inertia and a more muted response to a perceived unemployment gap than would be the case if the natural rates were known. By focusing primarily on the "inflation ball," such a policy reduces the unavoidable policy "mistakes" resulting from natural rate mismeasurement.

The remainder of the paper is organized as follows. The model is described in Section 2. In Section 3, the model estimation methodology and results are reported. Section 4 describes the method used by policymakers to estimate natural rates in real time. Section 5 analyzes optimal monetary policies assuming that the natural rate processes are known. Section 6 examines the characteristics of policies that are robust to misspecification of the natural rate processes. Section 7 concludes.

2. The Model

I use a modified version of the Rudebusch-Svensson model for the analysis (Rudebusch and Svensson 1999). Following Orphanides and Williams (2002), the model is specified in terms of the unemployment rate gap as opposed to the output gap specification of Rudebusch-Svensson, and allowance is made for time variation in the natural rates of interest and unemployment. Each unit of time corresponds to one quarter of a year.

9. The assumption of adaptive expectations is not without cost, as this framework ignores the endogenous response of expectations, which can exacerbate the problems associated with policy errors induced by faulty estimates of model parameters, as discussed by Orphanides and Williams (2002, 2005a) and others. The extension of the analysis of this paper to other models of expectations formation is left for future work.

2.1. Unemployment and Inflation Dynamics

The IS curve equation relates the unemployment rate, u_t, to its lags, its natural rate, u_t^*, and the lagged difference between the two-quarter average of the real federal funds rate, r_t, and its natural rate, r_t^*,

$$(1) \quad u_t = (1-\beta_1-\beta_2)u_{t-1}^* + \beta_1 u_{t-1} + \beta_2 u_{t-2} + \beta_3\left((r_{t-1}+r_{t-2})/2 - r_{t-1}^*\right) + \epsilon_t,$$

where $\epsilon_t \sim N(0, \sigma_\epsilon^2)$ is a serially uncorrelated innovation. The real federal funds rate is defined to be the difference between the nominal federal funds rate and a measure of expected inflation assumed to equal the inflation rate over the past four quarters:

$$r_t \equiv i_t - \bar{\pi}_t,$$

where $\bar{\pi}_t$ denotes the four-quarter moving average of the inflation rate.

The Phillips curve equation relates the GDP price deflator inflation rate, π_t, to its own lags (with a unity sum imposed on the coefficients) and the lagged difference between the unemployment rate and its natural rate:

$$(2) \quad \pi_t = \gamma_1\pi_{t-1} + (1-\gamma_1)\frac{1}{3}\sum_{j=2}^{4}\pi_{t-j} + \gamma_2(u_{t-1}-u_{t-1}^*) + \eta_t,$$

where $\eta_t \sim N(0, \sigma_\eta^2)$ is a serially uncorrelated innovation. As noted above, the natural rates of interest and unemployment are time-varying and are therefore identified with time subscripts.

2.2. Modeling Natural Rates

I consider three types of time-series models for time-varying natural rates: a first-order autoregressive process, a fractionally integrated ("long memory") process, and a two-state Markov-switching process. I focus on stationary processes for the natural rates.[10] For each model, I consider three parameterizations of the variance of the process, as described below.

The first type of model is the standard first-order autoregressive process, or AR(1), according to which the natural rate, z, follows the law of motion:

$$(3) \quad z_t = (1-\rho)\bar{z} + \rho z_{t-1} + \tau_t,$$

10. On the basis of the ADF test, one can reject the null of nonstationarity of both the unemployment and real federal funds rate over 1950–2003 at the 5 percent level.

where $\overline{z}$ is the unconditional mean of z, $|\rho| < 1$, and τ_t is assumed to be a white noise innovation.

The second type of model is a fractionally integrated, or "long memory," model studied by Granger (1980) and Diebold and Rudebusch (1989). The corresponding law of motion is given by

$$(1 - L)^d (z_t - \overline{z}) = \nu_t , \tag{4}$$

where $|d| < 1/2$ and ν_t is a white noise innovation. I approximate this process by its binomial expansion, truncated after 5,000 terms,

$$z_t = \overline{z} + \sum_{j=1}^{5000} (-1)^{j-1} \frac{\prod_{i=1}^{j} (d - i + 1)}{j!} (z_{t-j} - \overline{z}) . \tag{5}$$

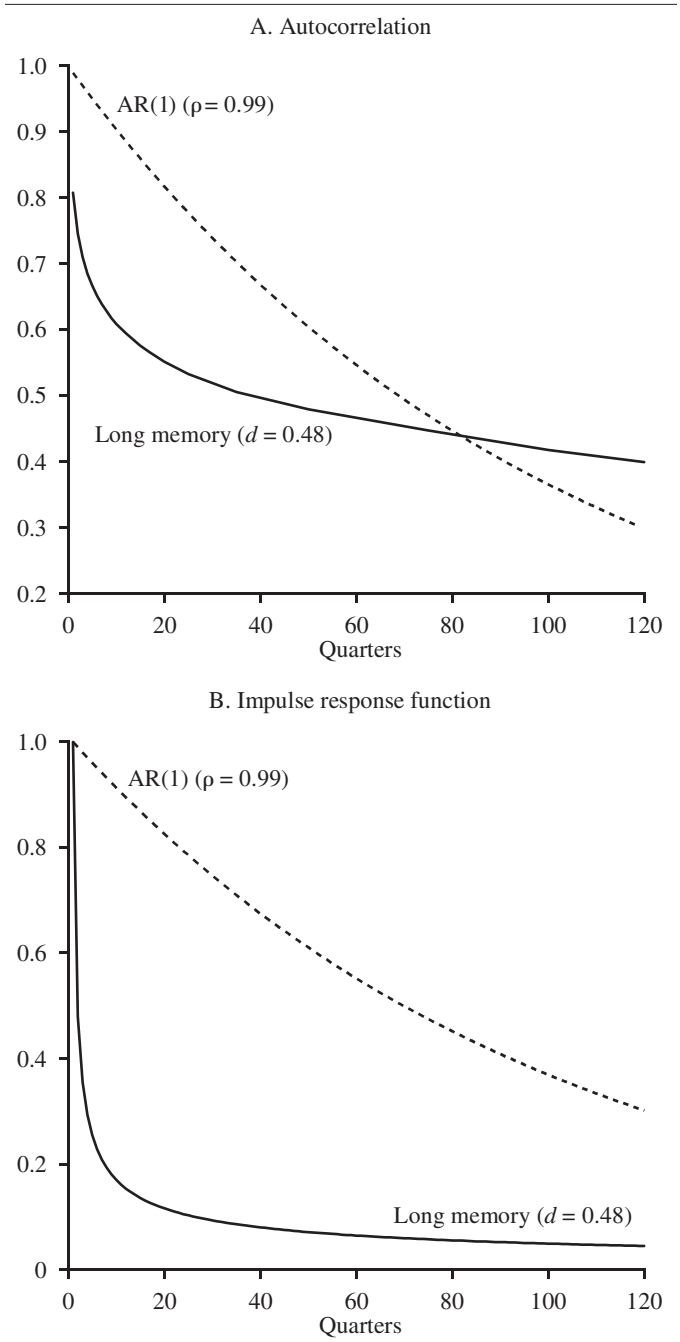
An interesting facet of, and possible justification for, the long-memory model highlighted by Granger (1980) is that it approximates the outcome from aggregating idiosyncratic AR(1) stochastic processes generated by differing values of the autocorrelation coefficient.

The fractionally integrated model differs from the AR(1) model in two important respects. First, the autocorrelation of an AR(1) decays geometrically, as shown by the dashed line in Figure 1, while that of the long-memory process displays approximately hyperbolic decay, as shown by the solid line. Thus, the long-memory process is able to generate significant lower-frequency variability without imposing a very high degree of high-frequency serial correlation. Second, the two processes differ markedly in their impulse responses. The impulse response function for an AR(1) declines geometrically, while that of the long-memory process falls rapidly for the first several periods but then declines very gradually. Evidently, the long-memory process behaves like a combination of a weighted sum of two AR(1) processes, one with a relatively low root and the other with a root near unity.

The third type of model is a two-state Markov-switching process as described by Hamilton (1989), in which with some probability, *p,* the natural rate shifts from the first state to the second state. I assume that the probability of switching states is the same for each state, so that the mean time spent in each state is the same and the unconditional mean of the natural rate is the average of the values in the "low" and "high" states.

Each of these three natural rate DGPs are characterized by two parameters, one describing the persistence of the natural rate and the other describing the variance of the innovations to the natural rate. Because I am interested in medium- and low-frequency variation in the natural rates, I assume values of $\rho = 0.99$, $d = 0.48$, and $p = 0.99$, which yield a high degree of lower-frequency persistence, as illustrated in Figure 1. I allow for uncertainty regarding the behavior of these processes by including three sets of values for the innovation variances, as discussed in the next section.

FIGURE 1
CHARACTERISTICS OF LONG-MEMORY AND AR(1) PROCESSES



Notes: For these calculations, $\rho = 0.99$ for the AR(1) processes (see equation (3)), and $d = 0.48$ for the long-memory process (see equation (4)).

2.3. Monetary Policy

I assume that the monetary policymaker's objective is to minimize the expected unconditional squared deviations of the four-quarter inflation rate from its target rate, π^*, of the unemployment rate from its natural rate, and of the deviation of the nominal interest rate from the long-run target nominal interest rate, $i_t^* = r_t^* + \pi^*$. Specifically, the loss, $\mathcal{L}$, is given by

$$(6)\quad \mathcal{L} = E\left\{(\pi - \pi^*)^2 + \lambda_u (u - u^*)^2 + \lambda_i (i - i^*)^2\right\},$$

where expectations are taken with respect to the innovations to the unemployment rate and inflation, $\{\epsilon_t\}_{t=0}^{\infty}$ and $\{\eta_t\}_{t=0}^{\infty}$, respectively, as well as to the natural rates of unemployment and interest, $\{u_t^*, r_t^*\}_{t=0}^{\infty}$. Throughout the remainder of the paper, I assume the following weights in the policymaker loss function: $\lambda_u = 1, \lambda_i = 0.5$; qualitatively, the results are not sensitive to moderate variations in these parameters.

Furthermore, I assume that the inflation target is zero. The expectation in the loss function takes into account both uncertainty about the realization of future innovations and uncertainty about the DGPs for the natural rates. Let S denote the set of the possible natural rate DGPs (which may differ across variables). Assume for the present purpose that the policymaker has well-defined prior beliefs regarding the distribution of $s \in S$, denoted by $F(s)$. Let $\mathcal{L}(s)$ denote the expected policymaker loss for the data-generating process s. Then, for a given specification of monetary policy, the expected unconditional loss is given by

$$(7)\quad \mathcal{L} = \int_S \mathcal{L}(s)\, dF(s).$$

In practice, I represent this expectation with a finite set of discrete elements, $\{s_i\}_{i=1}^{N_s}$ of S, weighted by ω_i:

$$(8)\quad \mathcal{L} = \sum_{i=t}^{N_s} \mathcal{L}(s_i)\ \omega_i\ ,$$

where $\sum \omega_i = 1$. In the example studied in this paper, $N_s = 9$.

I assume that monetary policy is implemented by setting the federal funds rate according to a monetary policy rule taking the form of an augmented Taylor (1993) rule similar to that found to perform well under natural rate uncertainty in Orphanides and Williams (2002). In the absence of natural rate uncertainty, policy rules of this type yield macroeconomic performance very nearly equal to the fully optimal policy. In particular, the federal funds rate is set according to the following:

$$(9)\quad i_t = \theta_i i_{t-1} + (1 - \theta_i)\{\hat{r}_{t-1}^* + (1 + \theta_{\bar{\pi}})\bar{\pi}_{t-1} + \theta_\pi \pi_{t-1} - \theta_u (u_{t-1} - \hat{u}_{t-1}^*) - \theta_{\Delta u} \Delta u_{t-1}\},$$

where $\hat{r}_t^*$ and $\hat{u}_t^*$ are the policymaker's real-time estimates of the natural rates of interest and unemployment, respectively, and Δu_t is the first difference in the unemployment rate. I abstract from the zero lower bound on interest rates.

3. Model Estimation

In this section, I estimate the basic model and calibrate the set of DGPs for the natural rates of interest and unemployment.

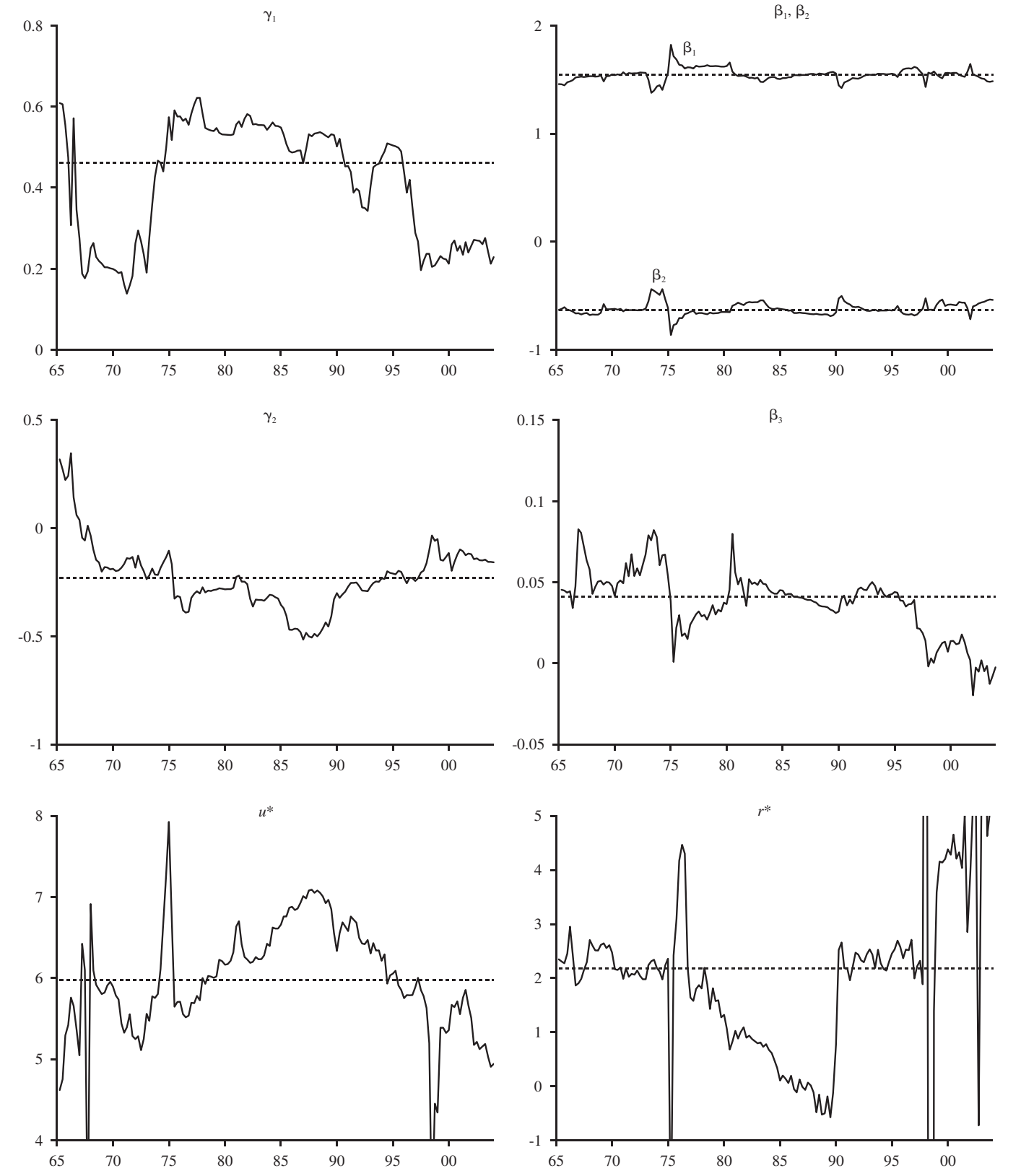
3.1. Unemployment and Inflation Dynamics

If the natural rates of interest and unemployment were constant, ordinary least squares (OLS) estimation of the parameters of the IS and Phillips curve equations would yield consistent estimates of these equations. However, if the natural rates change over time and are unobserved by the econometrician, the assumption of constant natural rates introduces mismeasurement in the right-hand-side variables, thereby potentially biasing all parameter estimates. To mitigate these effects, I estimate the IS curve and Phillips curve equations using rolling regressions in which each sample contains only 15 years of data. In addition, I proxy the true time-varying natural rate of unemployment with the estimates made by the Congressional Budget Office (CBO). Given the sample of data for the 1950–2003 period, I can thus run 156 regressions. I take as the model parameter estimate the median estimates from this set of 156 estimates.

Figure 2 plots the rolling regression estimates of the model parameters. The three panels on the left report the estimates pertaining to the Phillips curve equation, and the three on the right report those for the IS curve equation. For the Phillips curve equation, I plot estimates based on a specification that includes a constant but excludes the CBO estimate of the natural rate of unemployment; the bottom left panel shows the resulting rolling regression estimate of the natural rate of unemployment, given by the ratio of the estimated intercept divided by the estimate of γ_2. For the IS curve equation, I use the CBO estimate of the natural rate of unemployment; the bottom right panel reports the resulting estimates of the natural rate of interest, given by the ratio of the estimated intercept divided by the negative of the estimate of β_3.

The rolling regression estimates of the natural rates of unemployment and interest vary considerably over time and thus lend support for time variation in the true values of the natural rates, or for the difficulty in their real-time

FIGURE 2
CHARACTERISTICS OF LONG-MEMORY AND AR(1) PROCESSES



Notes: Sample length is 15 years. Dashed lines indicate the median estimates.

estimation, or both. An interesting feature, not investigated in this paper, is that some of the other parameters exhibit some signs of time variation. The estimate of γ_1, the coefficient on the first lag of inflation in the Phillips curve equation, also displays considerable time variation. This variation in estimates of γ_1 also obtains when the sum restriction on lagged inflation is not imposed.[11] The slope of the IS curve displays a downward trend over the sample. In contrast, the estimates of the slope of the Phillips curve and the lags of the unemployment rate in the IS curve are relatively stable over the sample.

The median estimates from the rolling regressions yield the following two equations, which I use in the analysis that follows:

$$u_t = 0.09u_{t-1}^{*CBO} + 1.54u_{t-1} - 0.63u_{t-2} + 0.04\left(\frac{r_{t-1} + r_{t-2}}{2} - 2.18\right) + \epsilon_t, \tag{10}$$

$$\pi_t = 0.46\pi_{t-1} + 0.54\frac{1}{3}\sum_{j=2}^{4}\pi_{t-j} - 0.23(u_{t-1} - 5.96) + \eta_t. \tag{11}$$

These estimates are similar to those from full-sample estimation and conform to estimates from similar models, such as Rudebusch and Svensson (1999) and Orphanides and Williams (2002). A key difference is that full-sample estimation through 2003 yields a much lower value for β_3, the slope of the IS curve, and thus suggests the possibility of bias owing to time variation of the natural rate of interest. The "sacrifice ratio" implied by the estimated Phillips curve is 2¼; that is, if the unemployment rate is 2¼ percentage points above its natural rate for one year, the inflation rate will eventually decline 1 percentage point.

3.2. Natural Rates of Interest and Unemployment

I now describe the calibration of the three natural rate DGP models and the various parameterizations of each. As noted above, there exists a great deal of uncertainty regarding the parameters of any specific model for the natural rates. For example, the Kalman filter has been extensively used to estimate time-varying natural rates of interest and unemployment.[12] A key finding in this literature is that the parameters describing the law of motion of natural rates are very imprecisely estimated (Laubach and Williams 2003), especially the innovation variance for the highly persistent component of natural rates. Thus, the data provide frustratingly little guidance on this key parameter.

I represent this uncertainty regarding the parameters describing natural rate processes by allowing for three parameterizations that span the set of values that are broadly consistent with the data. In one, the innovation variance for the natural rates is set to zero, a level corresponding to constant natural rates. In the second, the innovation variance is set to the baseline value computed as described below. In the third, the innovation variance is set to a larger value that lies within the range of other published estimates. Note that in the high-variance case, I am arguably being conservative in my approach in that even higher estimates of natural rate variability cannot be rejected by the data, according to some estimates. In the cases of a zero natural rate variance, the three DGPs collapse into one, so in the end there are seven unique alternative specifications of natural rate DGPs in all.

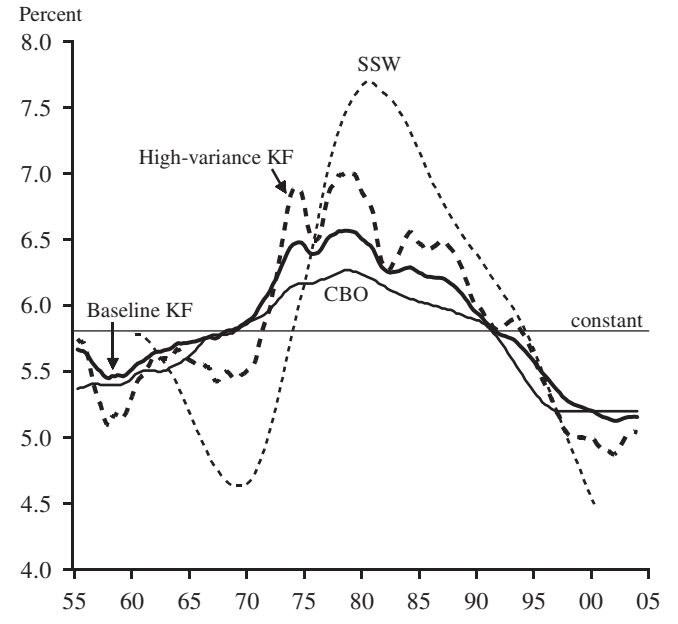
I follow the same basic procedure for calibrating the DGPs for both the natural rate of unemployment and the natural rate of interest. Starting with unemployment, I first estimate the natural rate using the Kalman filter applied to the Phillips curve equation, assuming that the natural rate follows a random walk. For this purpose, I use the Stock and Watson (1998) median-unbiased estimator. The sample period is 1970–2003. The estimate of the standard deviation of the natural rate innovation, σ_τ, is 0.22. The resulting "smoothed" or "two-sided" estimates of the natural rate of unemployment are shown in Figure 3 and are comparable to, albeit slightly more variable than, the CBO estimates shown in the figure for comparison.

To capture the uncertainty regarding the innovation standard deviation, I consider two representative alternative values for σ_τ, 0 and 0.44. The value of zero corresponds to a constant natural rate, and 0.44 yields estimates of the natural rate that are in fact less variable than the baseline estimates reported in Staiger, Stock, and Watson (2002), as seen in the figure. In terms of in-sample fit of the inflation equation, the data cannot clearly distinguish between the baseline values and the two alternatives.

11. In fact, the sum restriction cannot be rejected for the sample from 1970 to 2003. Only during the 1960s is the sum of coefficients on lagged inflation well below unity; see Orphanides and Williams (2005a) for a discussion of this issue.

12. See, for example, Staiger, Stock, and Watson (1997, 2002), Gordon (1998), Brainard and Perry (2000), and Laubach (2001), for Kalman filter estimates of the natural rate of unemployment. See Laubach and Williams (2003) and Orphanides and Williams (2002) for Kalman filter estimates of the natural rate of interest.

FIGURE 3
ESTIMATES OF THE NATURAL RATE OF UNEMPLOYMENT



Notes: All estimates are smoothed, or "two-sided" estimates.
KF Variations of the Kalman filter estimates computed for this paper.
CBO Current estimates from the Congressional Budget Office.
SSW Estimates reported in Staiger, Stock, and Watson (2002).

I use the values of the innovation standard deviations from the Kalman filter estimates to calibrate the three DGPs for the natural rate of unemployment. For the AR(1) model, I assume that $\rho = 0.99$ and set the standard deviation of the innovation to 0.22 for the baseline calibration (Table 1). The resulting process for the natural rate of unemployment has an unconditional standard deviation of 1.56 percentage points. For the high-variance version of the AR(1) model, I set the innovation standard deviation to 0.44; this yields an unconditional standard deviation of 3.12 percentage points. I do not formally estimate the long-memory process and the Markov-switching models for the natural rate of unemployment but instead calibrate them to have the same unconditional variances as those of the AR(1) process. For the long-memory process model, I set d to 0.48. For the Markov-switching model, I set the common switching probability, p, to 0.99 and set the difference in the natural rate of unemployment between the states at 3.12 percentage points; for the high-variance calibration, I set the difference between the states to 6.24 percentage points. Given this calibration, the unconditional variances are identical across the three processes for the baseline case and for the low- and high-variance cases.

The strategy for calibrating the DGPs for the natural rate of interest is the same as for the natural rate of unemployment. I use the same values of ρ, d, and p as before.

TABLE 1
CALIBRATION OF NATURAL RATE DGP MODELS

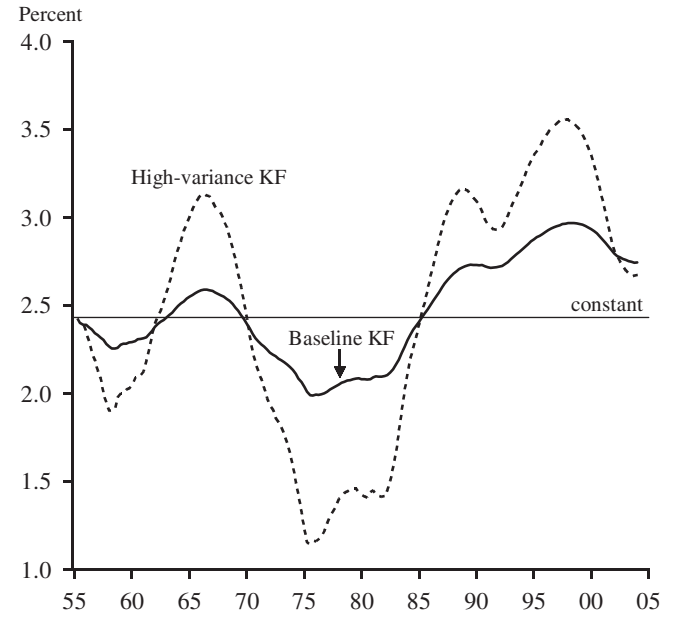
	Innovation standard dev.				Unconditional standard dev.	
Model	ϵ	η	r^*	u^*	r^*	u^*
Zero variance (constant)	.280	1.13	0	0	0	0
Baseline variance						
AR(1)	.276	1.12	0.11	0.22	0.78	1.56
Long-memory	.265	0.11	0.43	0.87	0.78	1.56
Markov-switching	.271	1.12	—	—	0.78	1.56
High variance						
AR(1)	.257	1.10	0.22	0.44	1.56	3.12
Long-memory	.210	1.03	0.84	1.75	1.56	3.12
Markov-switching	.253	1.07	—	—	1.56	3.12

DGP Data-generating process.
— Not applicable.

Kalman filter estimation of the IS curve yields an innovation standard deviation of 0.11 percentage point, which I use for the baseline AR(1) process (Table 1). This implies an unconditional standard deviation for the natural rate of interest of 0.78 percentage point. For the high-variance alternative, I set the innovation standard deviation to 0.22 percentage point, which is in the range of estimates reported by Laubach and Williams (2003). The resulting smoothed estimates are shown in Figure 4. For the two variants of the long-memory process, I set the innovation standard deviations so that they match those from the AR(1) model. For the baseline Markov-switching model, I set the difference between the two states at 1.56 percentage points, and for the high-variance alternative, I set the difference at 3.12 percentage points.

Finally, in order to make the seven DGPs equivalent in the sense of the implied overall variability of inflation and the unemployment rate gap, I adjust the standard deviations of the innovations to the IS curve and Phillips curve equations, as indicated in Table 1. In the case of constant natural rates, I use the median estimate of the standard error of the regression for the 15-year rolling regressions used to estimate the parameters of the model, as described above. This procedure yields an IS curve innovation standard deviation of 0.28 percentage point and a Phillips curve innovation standard deviation of 1.13 percentage points. For the other natural rate DGPs, I set the IS curve and Phillips curve innovation standard deviations so that the median estimate of the standard errors of the regression of the two curves for rolling 15-year-sample regressions on simulated data yield the same estimated standard deviations. The resulting calibration of the innovation standard deviations are reported in Table 1.

FIGURE 4
ESTIMATES OF THE NATURAL RATE OF INTEREST



Notes: All estimates are smoothed, or "two-sided" estimates.
KF Variations of the Kalman filter estimates computed for this paper.

4. Real-Time Estimation of Natural Rates

I assume that the policymaker makes an ex ante commitment to one method of estimating the natural rates of both interest and unemployment. I additionally assume that the degree of uncertainty regarding the nature of time-variation in the natural rates variables is fixed. Thus, the policymaker can neither modify the method of natural rate estimation based on incoming data nor deduce the true DGPs.

I analyze two commonly used methods for estimating natural rates. The first method is the weighted sample mean, in which the estimate of the natural rate of interest (unemployment) equals a weighted sample mean of the real interest (unemployment) rate over the past n periods. In the case of constant weights, this method corresponds to the simple sample mean. Examples of weighted sample mean estimators of the current natural rate include the Hodrick-Prescott and band-pass filters.[13]

The second method estimates the natural rates implied by the IS curve and Phillips curve equations. In each case, the dynamic equation is estimated with the natural rate term replaced by an intercept. In implementing this approach, I assume that the slope parameters are being estimated jointly with the intercept. In estimating the natural rate of interest, estimates of the natural rate of unemployment are needed because the natural rate of unemployment appears in the IS curve. For this purpose, I use the policymaker's estimates of the natural rate of unemployment derived from the estimated Phillips curve equation. Note that inaccuracy in estimates of the natural rate of unemployment spills over to estimates of the natural rate of interest.

As in the case of the sample mean estimator, two variants of this second estimator method are common. In the first, used for example by Rudebusch (2001) in estimating the natural rate of interest, the natural rate is assumed to be constant over the sample period, and the natural rate estimate equals the estimated constant divided by the negative of the estimated coefficient on the unemployment rate gap (in the case of the Phillips curve) or the natural rate gap (in the case of the IS curve). In the second variant, OLS is replaced by weighted least squares, where the weights decline with the difference between the date of the past observation and that of the current quarter; Ball and Mankiw (2002) use a method in this class to estimate the natural rate of unemployment. In the case of geometrically declining weights, the latter method is identical to the constant-gain least squares commonly used in the learning literature (see, for example, Sargent 1999, Evans and Honkapohja 2001, and Orphanides and Williams 2005b).

In the following section, I will analyze the optimal choice of the single free parameter for each estimation method. Throughout, I assume that the maximum feasible choice of n is 200, a limit consistent with the current availability of about 50 years of U.S. quarterly data on the unemployment rate and the inflation rate. For the methods that use weighted data, I assume that the weights decline geometrically, with the choice parameter being the decay factor, δ. For either method, increasing the decay factor provides better protection against time variation in the natural rate but at the cost of increased sampling variation and resulting loss in precision if the natural rates are in fact constant.

5. Optimized Policy

In this section, I compute optimized policies assuming the policymaker knows the true DGPs for the natural rates. I start with the textbook case that the natural rates are constant and known. I then analyze the optimal estimators and policy rules for the seven DGPs assuming the policymaker has only 200 observations on hand. To compute the policymaker loss under different policies, I perform model stochastic simulations that last 110,000 periods. I drop the first 10,000 periods to eliminate the effects of initial condi-

13. See Hodrick and Prescott (1997), Baxter and King (1999), and Christiano and Fitzgerald (2003) for descriptions of these univariate filters. See Orphanides and Williams (2002) for a discussion of their real-time properties as estimators of natural rates.

tions and compute moments from the remaining 100,000 (25,000 years of) simulated observations.

5.1. Optimal Policies for Known Natural Rates

As a benchmark for comparison, I consider the performance of rules that are based on the belief that the natural rates are constant and known with certainty, as is common in much of the literature on monetary policy rules. The coefficients of the resulting optimized policy rule are given at the top of Table 2. Such a rule incorporates very little policy inertia ($\theta_i = 0.10$) and a large response to the unemployment gap ($\theta_u = 1.05$): these characteristics are consistent with the findings of Rudebusch and Svensson (1999) and Orphanides and Williams (2002) for backward-looking models with no natural rate uncertainty. The resulting unconditional standard deviations of inflation, of the unemployment gap, and of the interest rate gap and the policymaker loss are given in the first row of the table. In this "ideal" world, in which natural rates are constant and known, the policymaker loss under the optimized rule is 17.1 (Table 2).

I now evaluate the performance of the optimized policy rule—that is, a rule designed under the assumption of no natural rate uncertainty despite the use of real-time, time-varying estimates of natural rates in monetary policymaking. I assume that the policymaker constructs real-time estimates of the natural rates of unemployment and interest using one of the two estimators described above. For the present purpose, I assume that in each period the policymaker estimates the natural rates of unemployment and interest using the most recent 50 years of simulated, equally weighted data. The interest rate is then set according to the policy rule using the estimated natural rates as inputs.

Increasing the variance of the natural rate innovations reduces the accuracy of the natural rate estimates. The first two columns of Table 2 show the unconditional standard deviations of the difference between the real-time values and true values of the natural rates. For this policy rule, the estimator based on the IS and Phillips curve equations does a slightly better job of real-time estimation of both natural rates than does the sample mean (first two columns of Table 2).

Under the policy rule optimized on the assumption of known natural rates, macroeconomic performance deteriorates modestly under the baseline calibrations of the natural rate DGPs but declines much more significantly under the high-variance alternatives. The policymaker loss in the case of the Markov-switching model is up to 60 percent higher than that implied by constant and known natural rates. With the greater variability in natural rates, the policymaker's estimates of natural rates become less accurate and thereby add persistent errors to the setting of policy. Experiments that separately consider the two sources of natural rate mismeasurement show that mismeasurement of the natural rate of unemployment, rather than of interest, is the predominant source of the reduction in macroeconomic performance. In the cases of the AR(1) and Markov-switching processes, the rise in inflation variability accounts for much of the increase in the loss. In contrast, for the long-memory process, the variabilities of both the inflation rate and the unemployment rate gap contribute to the higher value of the loss. The result for the long-memory process is due to its high-frequency component, which causes fluctuations in the natural rate of unemployment that, because they are short-lived, have little direct effect on inflation. Stabilization performance is modestly better when the policymaker derives estimates of the natural rates from estimated model equations rather than sample means.

TABLE 2
POLICY RULE OPTIMIZED FOR KNOWN NATURAL RATES, BY ESTIMATOR AND NATURAL RATE DGP MODEL
$\lambda_u = 1$, $\lambda_i = 0.5$

Optimized policy:
$\theta_i = 0.10$, $\theta_{\bar{\pi}} + \theta_{\pi} = 1.37$, $\theta_u = 1.05$, $\theta_{\Delta u} = 2.22$

Estimator and model	Unconditional standard deviation					Loss
	$\hat{u} - u^*$	$\hat{r} - r^*$	$\bar{\pi} - \pi^*$	$u - u^*$	$i - i^*$	$\mathcal{L}^*$
No misperceptions (constant)	—	—	2.2	1.3	4.6	17.1
Estimator: Sample mean						
Zero variance (constant)	0.4	1.0	2.3	1.3	4.8	18.7
Baseline variance						
AR(1)	1.5	1.2	2.6	1.4	4.9	20.9
Long-memory	1.3	1.1	2.4	1.6	4.8	19.7
Markov-switching	1.6	1.3	2.6	1.4	4.9	20.9
High variance						
AR(1)	2.8	1.7	3.3	1.5	5.3	26.9
Long-memory	2.6	1.5	2.6	2.3	4.6	22.1
Markov-switching	3.1	1.9	3.3	1.7	5.2	27.3
Estimator: Model equations						
Zero variance (constant)	0.4	0.9	2.2	1.4	4.8	18.5
Baseline variance						
AR(1)	1.3	1.1	2.4	1.4	5.0	20.1
Long-memory	1.3	1.1	2.2	1.7	4.8	19.3
Markov-switching	1.5	1.2	2.4	1.5	5.0	20.3
High variance						
AR(1)	2.4	1.6	2.8	1.6	5.2	23.8
Long-memory	2.5	1.5	2.3	2.3	4.6	21.3
Markov-switching	2.7	1.8	2.8	1.8	5.2	24.5

— not applicable.

5.2. Optimal Policies with Known Natural Rate DGPs

The preceding analysis illustrates the fact that policies designed to be optimal when natural rates are known can perform poorly if natural rates vary over time and must be estimated in real time. Some of the decline in macroeconomic performance associated with natural rate misperceptions is unavoidable: Even with optimal estimates, natural rate mismeasurement will occur and add noise to the setting of policy. And, as shown above, the greater the variability in natural rates, the greater the natural rate mismeasurement, on average, and the worse the macroeconomic performance. But, as I show in this section, appropriately designed estimation and monetary policy combinations can significantly reduce the stabilization costs associated with time varying natural rates.

I start by computing the optimized policies for each natural rate process, assuming that the true processes are known and that the realized values of the natural rates are not known. These policies provide benchmarks for the analysis in the next section, in which I seek a single estimation-and-policy-rule combination that is robust across the set of natural rate processes. Table 3 shows the optimized policies for each natural rate process and the resulting loss. The first and second columns report the optimal choices for the decay factors used in estimating the natural rates of unemployment and interest, respectively. The next four columns report the coefficients of the optimized policy rule. The final column reports the policymaker loss, denoted by $\mathcal{L}^*$.

The performance of optimized policies is nearly the same for the two types of natural rate estimators.[14] For both the sample mean and model-based estimators, the optimal choice of the decay factors is very small for all of the natural rate processes. For any given natural rate process, the coefficients of the policy rule are similar across the two natural rate estimators. The small differences in the performance of optimized policies between the types of estimators is striking given that the model-based estimators incorporate more information regarding the structure of the economy. In practice, such model-based methods are likely to be subject to misspecification, potentially causing them to perform worse than the sample mean estimator.

If the true natural rates are constant but unobserved, the optimized policy is nearly identical to the certainty-equivalent optimized policy; but, with time-varying natural rates, the optimized policies exhibit greater policy inertia and a more muted response to the unemployment rate gap. Note that certainty equivalence does not apply to this analysis owing to the violation of two necessary assumptions: First, the class of policy rules that I consider are not fully optimal, and second, the estimators are not optimal in that they do not yield conditional mathematical expectations of the natural rates. In response to measurement error in the natural rate of interest, optimized policies reduce the direct response to the natural rate of interest through a larger degree of interest rate smoothing, or policy inertia, represented by θ_i. To compensate for the lack of accurate estimates of the natural rates, optimized policies respond less aggressively to the perceived unemployment rate gap but respond more strongly to the change in the unemployment rate. In so doing, these policies dramatically reduce the "cost" associated with natural rate mismeasurement. Interestingly, for a given natural rate estimator, the optimized policy responses to inflation differ relatively little across the natural rate processes. Thus, relative to the optimal policy in the case of no uncertainty, the optimal policies with uncertainty are biased toward combating inflation

TABLE 3
OPTIMIZED POLICIES, BY ESTIMATOR AND NATURAL RATE DGP MODEL
$\lambda_u = 1$, $\lambda_i = 0.5$

Estimator and model	Policy coefficients						Loss
	δ_u	δ_i	θ_i	$\theta_{\bar{\pi}} + \theta_\pi$	θ_u	$\theta_{\Delta u}$	$\mathcal{L}^*$
Estimator: Sample mean							
Zero variance (constant)	0	0	0.1	1.5	1.1	2.3	18.6
Baseline variance							
AR(1)	0.011	0	0.4	1.5	0.7	2.9	19.8
Long-memory	0.002	0	0.2	1.5	0.9	2.5	19.4
Markov-switching	0.002	0.001	0.5	1.5	0.6	3.1	19.9
High variance							
AR(1)	0	0.005	0.7	1.5	0.3	4.0	21.5
Long-memory	0.006	0	0.4	1.5	0.7	2.7	21.0
Markov-switching	0	0.004	0.6	1.6	0.5	3.3	22.5
Estimator: Model equations							
Zero variance (constant)	0	0.002	0.1	1.3	1.0	2.2	18.5
Baseline variance							
AR(1)	0.001	0	0.5	1.2	0.6	3.0	19.6
Long-memory	0.001	0	0.2	1.3	0.9	2.2	19.3
Markov-switching	0.001	0	0.4	1.3	0.6	2.8	19.8
High variance							
AR(1)	0.001	0.002	0.7	1.3	0.3	3.8	21.3
Long-memory	0.001	0	0.4	1.2	0.7	2.6	20.9
Markov-switching	0.002	0.003	0.6	1.3	0.4	2.8	22.3

14. I also tried rolling-regression versions of these estimators with the sample length chosen as a free parameter and the decay parameters set to zero. These policies performed slightly worse in general than those that used the assumed "full" sample of 200 observations.

and away from controlling variability in the unemployment gap, and this bias is stronger under the high-variance natural rate processes.

6. Robust Policies

I now analyze the choice of estimation and policy rule parameters that minimize the loss taking into account uncertainty regarding the natural rate processes. I first consider the case in which the policymaker has priors across the natural rate processes; I then turn to the case of a min-max approach to model uncertainty.

6.1. Robust Policy with Priors across Natural Rate DGPs

I initially assume that the policymaker has well-formed priors over the seven natural rate processes. As noted above, I assume that the policymaker does not update these priors based on incoming data. I assume a weight of 1/4 for the case of constant natural rates; 1/6 on each of the baseline calibrations of the three natural rate processes, so that the sum of the weights on the baseline calibrations equals 1/2; and 1/12 on each of the three high-variance natural rate processes so that the sum of the weights on the high-variance processes equals 1/4 (Table 4).

For a given combination of a parameterized natural rate estimator and policy rule coefficients, I compute the loss in each model and sum the weighted losses to obtain the expected loss. I then numerically find the estimation and policy coefficients that minimize the expected loss (Table 4). The second through fourth columns report the resulting unconditional standard deviations of the inflation rate, unemployment rate gap, and the nominal interest rate gap, respectively. The fifth column reports the resulting loss. The final column—the policymaker loss shown in Table 3—reports the minimum attainable loss within the class of estimators and policy rule considered here assuming the natural rate process is known.

The single optimized combination of estimators and policy rule coefficients does very well across all natural rate processes; indeed, the robust policy delivers performance nearly on par with the first-best policy for each natural rate process. By incorporating a significant degree of policy inertia and a muted response to the unemployment gap, this policy combination is very effective at protecting against the high-variance natural rate processes and accomplishes this at negligible cost in terms of performance in the case in which the natural rates are constant. As before, the optimized rates of decay used in weighting past data in the natural rate estimators are very small. Finally, the optimized policy using the weighted sample mean estimators performs nearly as well as that using the model-based estimator. Although not reported here, this finding that a single combination of estimation method and policy is robust to natural rate model uncertainty generalizes to other parameterizations of the loss function.

Table 4
Robust Policy with Priors, by Estimator and Natural Rate DGP Model
$\lambda_u = 1$, $\lambda_i = 0.5$

Estimator and model	Weight ω	Standard deviation $\bar{\pi}$	$u - u^*$	$i - r^*$	Loss $\mathcal{L}$	$\mathcal{L}^*$
	Optimized policy: $\delta_u = 0.005$, $\delta_i = 0$					
Estimator: Sample mean	$\theta_i = 0.47$, $\theta_{\bar{\pi}} + \theta_\pi = 1.49$, $\theta_u = 0.60$, $\theta_{\Delta u} = 3.10$					
Zero variance (constant)	.250	2.2	1.4	4.9	18.9	18.6
Baseline variance						
AR(1)	.167	2.3	1.5	5.0	19.8	19.8
Long-memory	.167	2.2	1.7	4.9	19.5	19.4
Markov-switching	.167	2.3	1.5	5.0	19.9	19.9
High variance						
AR(1)	.083	2.6	1.6	5.1	22.0	21.5
Long-memory	.083	2.2	2.3	4.6	21.0	21.0
Markov-switching	.083	2.6	1.8	5.1	22.9	22.5
Expected loss	—	—	—	—	20.1	19.9
	Optimized policy: $\delta_u = 0.001$, $\delta_i = 0$					
Estimator: Model equations	$\theta_i = 0.43$, $\theta_{\bar{\pi}} + \theta_\pi = 1.26$, $\theta_u = 0.59$, $\theta_{\Delta u} = 2.75$					
Zero variance (constant)	.250	2.2	1.4	4.9	18.8	18.5
Baseline variance						
AR(1)	.167	2.3	1.5	5.0	19.7	19.6
Long-memory	.167	2.2	1.7	4.8	19.4	19.3
Markov-switching	.167	2.3	1.5	5.0	19.8	19.8
High variance						
AR(1)	.083	2.5	1.6	5.1	21.7	21.3
Long-memory	.083	2.2	2.3	4.6	20.9	20.9
Markov-switching	.083	2.6	1.8	5.1	22.6	22.3
Expected loss	—	—	—	—	19.9	19.8

— not applicable.

6.2. Robust Policy with a Min-Max Objective

I now consider the case in which the policymaker does not have well-formed priors over the different natural rate processes but instead follows a min-max approach, that is, choosing the estimation method and policy-rule coefficients that minimize the maximum loss in any of the seven states of the world corresponding to different processes.

TABLE 5
ROBUST POLICY WITH MIN-MAX LOSS, BY ESTIMATOR AND NATURAL RATE DGP MODEL
$\lambda_u = 1, \lambda_i = 0.5$

Estimator and model	Unconditional standard dev. $\bar{\pi}$	$u - u^*$	$i - r^*$	Loss $\mathcal{L}$	$\mathcal{L}^*$
Estimator: Weighted sample mean	*Optimized policy:* $\delta_u = 0$, $\delta_i = 0.004$ $\theta_i = 0.60$, $\theta_{\bar{\pi}} + \theta_\pi = 1.60$, $\theta_u = 0.48$, $\theta_{\Delta u} = 3.28$				
Zero variance (constant)	2.1	1.5	5.1	19.5	18.6
Baseline variance					
AR(1)	2.1	1.6	5.1	20.1	19.8
Long-memory	2.1	1.8	5.0	20.1	19.4
Markov-switching	2.1	1.6	5.1	20.2	19.9
High variance					
AR(1)	2.4	1.7	5.2	21.6	21.5
Long-memory	2.1	2.4	4.8	21.4	21.0
Markov-switching	2.4	1.8	5.2	22.5	22.5
Estimator: Model equations	*Optimized policy:* $\delta_u = 0.002$, $\delta_i = 0.003$ $\theta_i = 0.59$, $\theta_{\bar{\pi}} + \theta_\pi = 1.26$, $\theta_u = 0.41$, $\theta_{\Delta u} = 2.85$				
Zero variance (constant)	2.1	1.5	5.0	19.1	18.5
Baseline variance					
AR(1)	2.2	1.5	5.0	19.9	19.6
Long-memory	2.1	1.8	4.9	19.7	19.3
Markov-switching	2.2	1.6	5.0	20.0	19.8
High variance					
AR(1)	2.4	1.7	5.1	21.5	21.3
Long-memory	2.1	2.4	4.7	21.3	20.9
Markov-switching	2.4	1.8	5.1	22.3	22.3

This is the approach taken in the robust-control literature (see Sargent 1999 and Hansen and Sargent, forthcoming).

The min-max policy minimizes the "worst" state, that is, the high-variance version of the Markov-switching process (Table 5; as before, the values of $\mathcal{L}^*$ correspond to those from the weighted sample mean estimator reported in Table 3). The min-max policy incorporates greater policy inertia, a larger response to inflation, and a smaller response to the perceived unemployment gap relative to the optimized policy, which assumes priors over the seven processes examined above. The decay parameter used in constructing the sample mean is nearly the same as before. The min-max policy does a better job of protecting against the high-variance natural rate processes at the cost of slightly worse performance in the zero and baseline variance processes.

TABLE 6
POLICY EVALUATION SUMMARY: SAMPLE MEAN ESTIMATOR
$\lambda_u = 1$, $\lambda_i = 0.5$

Assumption	Optimal policy coefficients δ_u	δ_i	θ_i	$\theta_{\bar{\pi}} + \theta_\pi$	θ_u	$\theta_{\Delta u}$	Loss Mean	Max
Optimized Taylor-style rule								
No uncertainty	0	0	—	1.34	1.28	—	23.3	31.6
Bayesian	0.021	0	—	1.56	1.07	—	21.5	25.1
Min-max	0.012	0	—	1.79	0.81	—	21.9	24.4
Optimized generalized Taylor rule								
No uncertainty	0	0	0.10	1.37	1.05	2.22	21.3	27.3
Expected loss	0.005	0	0.47	1.49	0.60	3.10	20.1	22.9
Min-max	0	0.004	0.60	1.60	0.48	3.28	20.4	22.5

— not applicable.

6.3. Simple Rules

The preceding analysis shows that accounting for uncertainty about the natural rates of unemployment and interest changes the optimal degree of policy inertia and the responsiveness to inflation and the unemployment gap. For purposes of comparison with the literature, it is of interest to conduct the same analysis assuming that the policymaker is constrained to follow a version of the Taylor rule (Taylor 1993) in which the interest rate is determined by the perceived natural rate of interest, the inflation rate, and the perceived unemployment gap. In particular, I conduct the analysis exactly as before but constrain θ_I, θ_π, and $\theta_{\Delta u}$ to equal zero (Table 6). The upper part of Table 6 (optimized Taylor-style rule) summarizes the results from this experiment; the lower part of the table (optimized generalized Taylor rule) summarizes the results from more complicated policy rules discussed in the earlier part of the paper. For this purpose, I focus on the case of the sample mean estimator. The two loss columns report the expected (mean) loss assuming the priors over the natural rate DGPs described above and the maximum loss across the DGPs.

As before, the policy optimized under the assumption of no natural rate uncertainty performs relatively poorly when natural rates in fact vary over time. In contrast, the policy optimized with priors over the various natural rate DGPs responds more aggressively to inflation and less so to the unemployment gap. These differences are even more pronounced for the policy chosen to minimize the maximum loss. In both cases, the optimized decay factor in estimating the natural rate of unemployment is significantly higher than for the complicated rules, while that for the natural rate of interest is zero. The Taylor-style rules perform nearly as well as the more complicated rules, consistent with the findings of Williams (2003).

7. Conclusion

This paper studies the policymaker's joint problem of model estimation and robust monetary policy in an environment in which there is uncertainty regarding the true process underlying movements in the natural rates of interest and unemployment. I show that the costs of ignoring natural rate uncertainty can be very large. Thus, there is a danger that policymakers could again fall into a pattern of mistakes such as that of the late 1960s and 1970s, when, as argued by Orphanides and Williams (2005a), natural rate misperceptions contributed to the stagflation of that period.

On the positive side, it is possible to design estimation and monetary policy rules that are remarkably robust to a variety of models of natural rate evolution. Weighted sample means perform well for the conduct of monetary policy in an environment in which there is uncertainty regarding the data-generating processes for natural rates. The robust policy incorporates a significant degree of policy inertia and muted response to the perceived unemployment gap. In contrast, in the model studied here, the certainty-equivalent policy is characterized by virtually no policy inertia and a relatively strong response to the unemployment gap. In addition, the robust policy's response to inflation is somewhat greater than that of the certainty-equivalent policy. As a result, the robust policy is tilted more strongly toward the control of inflation relative to the unemployment gap than would be optimal if natural rates were known. This finding complements that of Orphanides and Williams (2005b), who show that learning on the part of private agents calls for policies that react more strongly to deviations of the inflation rate from its target.

The analysis can be extended in a number of fruitful ways, including the incorporation of private expectations and time variation in other model parameters. In addition, I have assumed that the policymaker does not update priors over the various natural rate data-generating processes as new data arrive. A natural extension would allow for the updating of beliefs about the various DGPs in the context of time variation in the innovation variances.

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Financial Market Signals and Banking Supervision: Are Current Practices Consistent with Research Findings?*

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The trend toward incorporating information derived from financial markets into the bank supervision process has gained momentum over the past several years. This in part reflects an evolution in the thinking about how private market information can contribute to the process. In light of the evolving view of the potential contributions of market information, this paper reviews the empirical evidence relevant to the usefulness of financial market information in the bank supervision process. This paper reviews the research on what information can be gleaned from the pricing of equity and debt securities issued by banking organizations. The weight of the research leaves little room for doubt that financial market signals reflect underlying bank risk and that market evaluations of the risk of individual banking organizations are strongly correlated with supervisory findings. The evidence on the extent to which market signals can augment the information set of bank supervisors is more subtle, but overall it demonstrates that financial market signals should play a role in the bank supervision process.

1. Introduction

Over the past several years, financial market information has been incorporated more frequently into the bank supervision process. Burton and Seale (2005), for example, discuss the use of market information in bank supervision by the Federal Deposit Insurance Corporation (FDIC). Feldman and Schmidt (2003) document the incidence of references to financial market information in Federal Reserve supervisory reports and identify the types of market information considered. A follow-up review of supervisory practices by Federal Reserve staff found that, while resources directed at the use of market information in the supervisory process remain modest, they are increasing.

As Burton and Seale (2005) point out, part of the appeal of incorporating financial market information such as that imbedded in the prices of equity and debt securities in the bank supervision process is that the information can provide an objective assessment of the financial condition of banking organizations. At the same time, there are reasons for skepticism about the market's ability to uncover with any regularity problems among traditional banking organizations ahead of bank supervisors, who have access to confidential information and, in the case of the very largest banking organizations, are on-site full-time.

Nevertheless, the trend in the use of market information in bank supervision indicates that the banking agencies see net benefits. Part of the reason is that the assessment of the contribution of market information has moved beyond the very narrow consideration of how likely it is that the market would catch problems before they are uncovered by the supervision process. The evolution in thinking points to three roles for market information in the bank supervision process. First, the information helps to reinforce other sources of supervisory information. Second, market sentiment can

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affect a banking organization's operations, especially its access to funding; thus, using market information along with other sources of information may be especially helpful in gauging the effects of adverse events on conditions in the banking industry or within a given banking organization. Third, financial market information can be useful when the informational advantage of bank supervisors might be more limited. In particular, under the supervisory responsibilities laid out in the Gramm-Leach-Bliley Act, bank supervisors may have less of a comparative advantage over the market when it comes to assessing activities related to securities and insurance services in nonbank subsidiaries of financial holding companies.[1]

In addition, the assessment of when to use market information has moved from the narrow consideration of the direct impact on supervisory findings to the broader concept of using the information in the various stages of the supervision process. Not surprisingly, market information is most commonly used in monitoring—by both surveillance staff and exam team members. However, market information also comes into play in other stages of bank and bank holding company (BHC) supervision, such as strategic planning, scoping for exams, and even in interactions with bank management.[2]

In light of the broadening channels of contribution for market information, this paper reviews the empirical evidence relevant to the usefulness of financial market information from banking-related securities in the bank supervision process.[3] This paper focuses on research on the information that can be gleaned from the pricing of equity and debt securities issued by banking organizations. The bulk of the research on these market signals in banking deals with interest rate spreads on bank debt, the issuance of banking-related debt, stock returns, and expected default frequencies (EDFs), which refers to the probability of default (see Box 1).[4] A more expansive set of sources of market information is presented in Table 1 in Box 1.

The studies reviewed in this paper examine the reliability of market signals for banking organizations relative to those for other types of firms, the relation of market signals to other measures of bank risk, and the informational advantage of bank supervisors over market participants, as well as evidence relating to direct market discipline from banking organizations' responses to market signals.

The remainder of this paper, then, reviews the evidence regarding the potential usefulness of market signals for bank supervision. Section 2 examines whether the incentives of market participants need to coincide with those of bank supervisors in order for market signals to be useful in the supervision process. Section 3 discusses the findings related to the degree of transparency of banking organizations. Section 4 then turns to the rich array of studies on the information content of market signals. That is followed in Section 5 with a discussion of the findings related to the informational advantages of bank supervisors and the evidence regarding the effects of market signals on the operations of banking organizations. Section 6 briefly reviews recent proposals for improving the reliability of market signals based on subordinated debt issued by banking organizations. Section 7 presents our conclusions about the consistency of bank supervision practices with the evidence on market information in banking.

2. Are Debt Signals Preferable to Equity Signals?

Before discussing the research findings regarding market signals in banking, it is useful to review what to expect from debt and equity market signals. Understandably, from a bank supervision perspective, debt signals might be preferable to equity signals since the interests of debt holders are more aligned with those of bank supervisors. In particular, compared to equity holders, debt holders and bank supervisors are concerned more about the downside risks affecting a bank's performance than the upside potential. Indeed, market discipline is often equated with oversight by debt holders because their motives and actions are expected to limit risk-taking. The ex ante (before debt issuance) actions that debt holders can take, such as demanding higher interest rates on riskier debt and with-

1. Flannery and Nikolova (2004) suggest other roles for market information. In particular, they note the work of Evanoff and Wall (2001) in connection with the use of market signals as trip wires to force regulatory action and, thus, forestall supervisory forbearance. Also see Evanoff and Wall (2002, 2003).

2. Another reason to focus on the use of market information in the supervision process is the provisions of Pillar 3 of the Basel II Accord that refer to the contribution of market discipline. See Lopez (2003).

3. Flannery and Nikolova (2004) review the research findings regarding market discipline in banking. Gropp (2004) reviews the related findings for banking organizations in Europe.

4. Other statistics reflecting equity market signals include dividend yields, book equity to market equity ratios, and price-to-earnings ratios. Empirical research on these statistics deals mainly with the power of the ratios to predict stock returns generally and, therefore, provide only indirect evidence for banking. Within the Federal Reserve System, a number of reports include data on these financial ratios, though there appears to be limited use of these ratios in the various stages of the supervisory process, and more research would be helpful to provide a coherent framework for using such market signals in monitoring banking organizations. In the Federal Reserve System, recent efforts also have focused on the use of information from credit default swaps.

Box 1
Financial Market Information Used in Bank Supervision

The term "financial market information" covers a wide range of items for bank supervision staff. Broadly defined, it is information derived from the private sector that relates to the financial condition of firms and sectors or broad financial markets. For example, in the interviews with Federal Reserve supervisory staff, they mentioned using information on broad financial markets such as the slope of the Treasury yield curve, measures of interest rate and stock market volatility, trading volumes in stock and debt markets, the performance of asset-backed securities markets, and even private sector sources of information on operational risk.

Supervision staff also consider market information relating directly to the financial condition of individual organizations, including quantitative market signals and sources of qualitative information. The quantitative signals are listed in the top part of Table 1. Most of the signals are derived from the prices of securities issued by individual firms. Market signals used most widely are stock returns, interest rate spreads on bonds, and EDFs. Another set of prominent quantitative indicators is the debt ratings issued by private rating agencies such as Moody's Investor Services, Standard & Poor's, and Fitch.

Qualitative private sector financial information also is incorporated into the supervisory process. As indicated in the bottom part of the table, the sources of qualitative information are analysis and reports from the rating agencies as well as stock and bond analysts' reports and firms' reports for investors and analysts.

The market signals and other financial information most commonly used are those for individual banking organizations or the banking sector generally. However, the scope is broader and includes information on nonbank financial sectors such as investment banking, insurance, and mutual funds—both for individual firms and for the respective sectors. Nonbank financial firms are used in peer-group analysis for nontraditional banking organizations. Financial information on the performance of these nonbank financial firms also is used in assessing risk associated with the related activities conducted by banking organizations more generally. Finally, financial market information on individual nonfinancial firms or sectors is used in assessing the credit risk of banking organizations with exposure to the firms or relevant sectors.

Table 1
Sources of Market Signals Used by Supervisors

Quantitative Signals
Debt
Subordinated debt (bond) interest rate spreads
Debt ratings by private agencies
Volumes of debt issuance
Uninsured CD interest rate spreads
Derivatives
Credit default swap premiums
Stock options (implied volatility of return)
Equity
Stock returns (stock price changes)
EDFs[a]
Market value of equity
Asset return volatility
Market betas (measure of systemic risk)[b]
Sharpe ratios[c]
Stock price-to-earnings ratios
Market-to-book equity ratios
Bid–ask spreads for stock prices
Trading volumes
Qualitative Signals
Private rating agency reports
Stock and bond analysis
Corporate briefings/reports
Financial statements required by the Securities and Exchange Commission
Media/Internet

a. Expected default frequencies (EDFs) are probabilities of default (usually over a one-year horizon). This market signal is produced by Moody's KMV. Key inputs are the market value of equity and the estimated volatility of the return on assets derived by applying an options model to stock prices of individual firms.

b. Market beta is a measure of the degree of exposure to systematic risk of a stock (or portfolio). If the systematic risk exposure of a stock is equal to that of the overall market, the stock's beta will equal 1. For stocks with betas greater (less) than one, their returns will be more (less) volatile than the return for the overall market. In a simple capital asset pricing model the expected return on an investment is related to the risk-free rate and the expected market return: $E(r_i) = R + \beta(E(r_m) - R)$, where i is a stock, $E(r_i)$ is expected rate of return of i, R is the rate of return of a riskless security, $E(r_m)$ is the expected return on the market portfolio, and β is the measure of the degree of systematic risk

c. Developed by William Sharpe, the Sharpe ratio is a measure of reward-to-risk. The idea is that investors require a higher return for holding assets with higher risk. Therefore, a higher Sharpe ratio for a portfolio would indicate a better risk–return tradeoff. The Sharpe ratio is calculated as $SR(i) = (r_i - R)/s(i)$, where i is an investment, r_i is the annual rate of return of i, R is the rate of return of a riskless security, and $s(i)$ is the standard deviation of r_i.

holding funding, would be expected to provide checks on risk-taking.[5] In addition, the ex post value of debt holders' claims declines as default risk increases. Therefore, if a firm's risk increases, the secondary market yield on its outstanding debt would be expected to rise relative to that benchmark security with little or no credit risks, typically a Treasury security of comparable maturity. Such a rise in the interest rate spread would provide a signal to other potential debt holders.[6]

For publicly held firms, equity holders also are a source of market oversight. Greater shareholder monitoring, for example, can result in better risk management procedures and controls at a banking organization. While it is the case that equity holders want a firm to attain an appropriate risk–return tradeoff, not to limit risk per se, equity signals still can be expected to reflect the risk posed by a banking organization. To put it another way, even though equity holders do not necessarily want to limit risk-taking as much as bank supervisors, they do have an interest in identifying and measuring risk accurately.[7]

There are circumstances that might affect the reliability of equity signals as indicators of risk. For banking organizations, in particular, the presence of a government safety net, owing to underpriced deposit insurance or the market's perception that some large banks may be "too big to fail," can affect the signals from changes in stock prices.[8] The explanation starts with noting that, with a safety net, the cost of funding for a banking organization will not be fully responsive to its risk-taking (though it could still be partially responsive). This means that a banking organization would benefit from the upside of taking risk without paying for the full cost of the downside.[9] In that case, the stock price (and the market value) of a banking organization could rise with an increase in its risk-taking, sending a "perverse" signal to bank supervisors.[10]

These considerations do not preclude the use of equity signals or mean that debt-based market signals are necessarily superior. First, as discussed in the research findings below, observed changes in stock prices tend to send appropriate signals about overall risk. Second, equity-based measures such as EDFs provide information on movements in market value and portfolio risk.[11] Third, on the choice of debt versus equity signals, interpreting debt spreads can also be problematic. If the market's perception is that uninsured debt holders might be protected, the signal from banking-related debt spreads also would be damped. Also, as discussed below, interest rate spreads on debt are affected by factors other than just default risk. Fourth, in terms of the depth and breadth of the market, the equity market is a much richer source of information on banking organizations than the long-term debt market. The dominant position of equity issuance for banking organizations is discussed in Board of Governors (2000), which examines public disclosures in banking. The study points out that the market value of common equity for banking organizations with data available on the Compustat database totaled $907 billion (as of the end of 1998). Moreover, the potential for equity market monitoring extends to medium-sized organizations, though large banking organizations account for the lion's share of the value of market equity. By comparison, the volume of subordinated debt (on a consolidated basis) at all BHCs was around $103 billion, or around 2 percent of assets.

In considering the potential contribution of market information, then, the differences in incentives between debt holders and equity holders in theory should not be a significant factor in differentiating between the use of debt and equity instruments issued by banking organizations.

5. As discussed in Furlong and Keeley (1987), in the presence of a federal subsidy to banks owing to, say, mispriced deposit insurance, debt holders' demanding higher interest rates on riskier bank debt is not sufficient to limit even ex ante risk-taking. The problem is that, with a subsidy associated with insured deposits, a bank may be willing to pay a higher rate to uninsured debt holders and still take the higher risk. In that case, bank supervision is still needed to limit risk-taking. On the other hand, the return to the bank from risk-taking would be reduced by the higher cost of uninsured funds, so it may be easier for bank supervisors to detect and control risk.

6. Note that for a banking organization approaching insolvency, the interests of subordinated debt holders regarding risk-taking can become aligned with those of equity holders.

7. The information content of equity markets for bank supervision is discussed in Board of Governors (2000). Also see Saunders (2001).

8. The provisions of the Federal Deposit Insurance Corporation Improvement Act (FDICIA) make it less likely that debt holders would be protected in the case of failure (insolvency) of a large banking organization. As discussed below, recent studies find that interest rate spreads on banking-related (bank and BHC) debt are sensitive to the risks of issuing organizations.

9. Deposit insurance, in effect, represents a put option on the value of a bank's assets at a strike price equal to the value of deposits. The effects of leverage and portfolio risk on the value of deposit insurance are described in Furlong and Keeley (1989). There are statistical techniques for controlling for the value of such federal guarantees for banking organizations (see Furlong 1988). However, equity market signals typically used in bank supervision do not include such an adjustment.

10. More generally, a firm can gain at the expense of existing debt holders by increasing risk. To guard against this, debt contracts often include covenants limiting a firm's ability to increase its risk ex post—that is, after it has issued the debt.

11. While the commercially available EDFs do not control for the value of the federal safety net for individual banking organizations, they should tend to rise with increases in both portfolio risk and leverage (see Gropp 2003).

Moreover, the greater depth and breadth of the market for BHC equity give a distinct advantage of equity-based signals compared to those from subordinated debt. A development that has cut somewhat into the advantage of equity-based signals is the growing prevalence of credit default swaps (CDSs). In CDS arrangements, one party agrees to provide protection to a second party upon a credit event of a reference entity, such as a BHC. Similar to the spread between the interest rate on subordinated debt and the yield on a comparable Treasury security, the premium (or spread) paid on a CDS should reflect the riskiness of the reference entity. However, the CDS market is more active than that for subordinated debt, so the signals about the risk from premiums on CDSs for which a BHC is the reference entity generally should be more reliable than those based directly on subordinated debt.[12]

3. Transparency in Banking

For market signals from either debt or equity instruments to be useful in bank supervision, it is necessary to have sufficient transparency in banking so that market signals have an acceptable degree of reliability. The observations that many assets, such as loans, held by banks tend to be opaque raises the concern that the makeup of bank portfolios presents a significant hurdle for the market's ability to evaluate the financial condition, performance, and risk of banking organizations.[13]

To investigate this exact issue, a study by Flannery, Kwan, and Nimalendran (2004) focuses on the adverse selection component of the bid-ask spreads on stocks; this component is the portion of the spread that compensates market makers for the risk of trading with informed parties. A wider spread can be interpreted as indicating more uncertainty or opacity. The study's results are consistent with the hypothesis that investors are able to value large banking firms about as well as they can value large nonbanking firms with matching characteristics. Moreover, the findings show that market investors have good information about smaller banking firms (listed on Nasdaq) compared with size-matched nonfinancial firms.

Another study, Morgan (2002), uses differences in ratings by Moody's and Standard & Poor's as proxies for the difficulty in assessing risk. Since the focus is on the rating agencies, the results do not provide direct evidence on the market's relative ability to assess banks. In any case, the study finds that the ratings of the two agencies tend to differ more for BHCs and insurance companies than for other firms of comparable size and risk. The study also finds that the likelihood of a split rating increases with a higher proportion of loans (as opposed to securities) in a bank's asset portfolio and decreases with higher capital ratios. These findings suggest that the riskiness of bank debt, particularly among less financially sound banks, may be more difficult for the rating agencies—and perhaps the market—to assess.

Overall, analysis using stock market data indicates that transparency among larger banking organizations is at least on a par with that for other types of firms. On the other hand, patterns of debt ratings suggest that the private rating agencies have more difficulty assessing banking organizations than they do assessing nonfinancial firms.

4. Market Signals and Bank Risk

Research findings on market signals and risk in banking relate to three basic questions. First, are market signals sensitive to differences in risk among banking organizations? Second, are the assessments of banking organizations reflected in market signals consistent with supervisory assessments? Third, if the market's assessment is consistent with the views of bank supervisors, does the information conveyed by market signals add to the "intelligence" amassed through other means in the supervision process?

4.1. Do Market Signals Reflect Bank Risk?

The short answer is yes, market signals reflect bank risk. Considerable research has been dedicated to determining the extent to which prices (interest rates) for the uninsured debt of banking organizations are related to various measures of risk. Most studies focus on longer-term subordinated debt. A core set of studies examines whether risk measures such as interest rate spreads on banking-related subordinated debt are sensitive to various accounting risk indicators, including problem loan ratios and charge-offs. Among these studies, most of the ones relying on data for periods prior to the 1990s tend to find little evidence that

12. In a CDS contract, one party pays a premium to a second party for protection against a credit event for a reference entity's security. A credit event could be a default on a bond (or loan) of the reference entity declaring bankruptcy or restructuring its debt obligations. The payment by the first party for the protection usually is expressed in terms of basis points of the value of the reference bond (loan). The premium in effect is the compensation to the second party for bearing risk, and, therefore, should reflect the credit risk of the reference entity. If a credit event occurs, the second party makes a payment to the first party, and the swap terminates. Also, note that some banking organizations use CDSs in managing their own risk (Minton, Stulz, and Williamson 2005 and Lopez 2005).

13. The transparency of banking organizations also can be limited by holdings of asset-backed securities and other derivatives and off-balance-sheet activities more generally.

yields on long-term debt consistently reflect traditional measures of risk in banking.[14]

More recent research, however, finds that yields on banking-related subordinated debt are sensitive to the risk of the issuing organizations. An especially pertinent study by Flannery and Sorescu (1996) concludes that interest rates on long-term bank debt tend to vary with the riskiness of the institution issuing the debt in the period 1989 to 1991, but not earlier in the 1980s. A subsequent study, Covitz, Hancock, and Kwast (2002), indicates that these results for the earlier 1980s may be related to measurement issues. The study finds that, after accounting for liquidity premiums in yields on subordinated debt, banking-related subordinated debt spreads were sensitive to organization-specific risks in the mid-1980s, and that the risk sensitivity of such spreads was about the same in the pre- and post-FDICIA periods.[15]

Even with the latter evidence, it is important to reiterate the point that only a limited number of banking organizations have tradable subordinated debt outstanding. Moreover, only the very largest BHCs have meaningful amounts of regularly traded subordinated debt. Again, this limits the scope for applying subordinated debt spreads in the supervision process. Hancock and Kwast (2001) also point out that the movements in debt spreads on subordinated debt at individual BHCs are sensitive to the data source for the bond prices, thus further complicating the interpretation of movements in yield spreads on long-term debt.[16]

Short-term banking-related debt instruments, such as large denomination certificates of deposit (CDs), commercial paper, and federal funds, are potential sources of market signals related to bank risk. As discussed in Board of Governors (2000), banks issue large volumes of short-term uninsured debt compared to subordinated debt. While yields on short-term instruments might not be sufficiently sensitive to an organization's risk, the volume of short-term debt issued by a banking organization might be an added source of information since potential holders of such instruments might withhold funding from an institution facing financial problems.

Most studies assessing the information content of market signals from short-term bank debt focus on large CDs. Studies of yields on large CDs have used quoted interest rates (marginal yields) and average interest rates paid based on bank Call Report data. Using quoted rates for a sample of large banks, Ellis and Flannery (1992) find that measured bank risk affects large CD rates in a plausible fashion. However, the Board of Governors (2000) indicates that quoted rates on large CDs have been less sensitive to bank-specific risk in recent years. This lower sensitivity may be in response to the substantial increase in bank capital during the 1990s. In addition, the depositor preference rule, instituted in 1993, may have had an effect. The intent of the rule was to provide more protection for the FDIC by placing it ahead of other general creditors. However, it also gives holders of large-denomination domestic CDs priority over other general creditors. The latter would be expected to be more responsive to changes in risk-taking by a bank.

The most comprehensive studies (in terms of the number of banks covered) have relied on average interest rates on large CDs based on bank Call Report information. This approach is appealing since it raises the possibility that market signals would be available at the individual bank level (rather than at the holding company level) and for small and medium-sized institutions. The drawback is that the studies use average, rather than marginal, interest rates; a recent example is Gilbert, Meyer, and Vaughan (2003), which compiles the results from a number of earlier studies along with new evidence on the risk premiums in large CD rates. The findings from these studies are somewhat mixed. While the studies tend to find links between large CD yields and traditional measures of bank risk, the relation appears to have weakened in recent years.

One study also tests for evidence that bank credit risk affects interest rates on federal funds. Furfine (2001) assembled a database of transactions on overnight federal funds for the period from January 2 to March 31, 1998. In the empirical analysis, the borrowing bank's leverage ratio was used to control for credit risk. The study finds that lower leverage did result in lower borrowing rates on federal

14. See, for example, Gorton and Santomero (1990) and Avery, Belton, and Goldberg (1988).

15. Also see Jagtiani and Lemieux (2001) and Morgan and Stiroh (2001). Jagtiani, Kaufman, and Lemieux (2002) find evidence of risk premiums for subordinated debt issued by BHCs and by banks. While these studies indicate that interest rate spreads on longer-term bank debt will respond to changes in risk, the spreads do not necessarily fully reflect the underlying risk of the issuer. For some very large organizations, for example, the debt holders might assume that under certain circumstances they would be protected, perhaps to stave off systemic risk. As pointed out earlier in the text, to the extent that this is the case, the interest rate spreads on a banking organization's debt would be smaller than they would be in the absence of the assumed protection of debt holders.

16. As indicated earlier, premiums on CDSs that are tied to debt issued by a BHC also provide market signals regarding the default risk of the banking organization. Studies examining broad samples of firms find consistent relationships between interest rate spreads on bonds and CDS premiums, suggesting they have similar information about a firm's risk (see, for example, Hull, Predescu, and White 2004). A recent study also finds a close relationship between estimates of default probabilities from EDFs and CDS premiums (Berndt et al. 2004). A few studies have examined the relation of CDS premiums and bank risk. Düllmann and Sosinka (2005), for example, examine a sample of German banking organizations and conclude that signals from CDSs are useful in gauging risk but should be used in conjunction with other market signals such as EDFs. Ito and Harada (2004) argue that CDS premiums (spreads) are good measures of the soundness of Japanese banking organizations.

funds. This study also reports that leverage has a statistically significant effect on the borrowing costs for smaller banks. The study, however, does not provide separate results for large banks.

4.2. Are Market Signals Consistent with Supervisory Assessments?

Empirical research does show that subordinated debt spreads and equity market signals are consistent with supervisory assessments of the financial condition of individual banking organizations. Key findings in this regard are that market participants' views about the financial condition of banking organizations, as reflected in individual financial market signals, tend to be consistent with the views of bank supervisors as reflected in their ratings of institutions. For example, the studies by Krainer and Lopez (2002, 2003, 2004) find that signals from banking-related debt and equity tend to anticipate changes in supervisory ratings. In particular, they find that interest rate spreads on banking-related subordinated debt show statistically significant increases (decreases) up to 12 months prior to downgrades (upgrades) in bank holding companies' BOPEC ratings.[17] Similarly, they find that abnormally low (high) BHC stock returns tend to precede downgrades (upgrades) in supervisory ratings.

In the univariate results of Curry, Fissel, and Hanweck (2003), the individual mean values of several variables derived from equity prices for BHCs grouped by supervisory ratings also suggest that market variables are consistent with the ratings. The equity market-based data for BHCs considered in Curry et al. (2003) are coefficients of variation of the stock prices, market abnormal returns (the difference between the actual cumulative quarterly return on a BHC's equity and the comparable return computed from an index of market performance), the standard deviation of the return for BHCs, the market-to-book equity ratio for BHCs, and the relative trading volume of a BHC's equity.

4.3. Is There an Informational Advantage? Market Signals versus Supervisory Information

The weight of the research leaves little room for doubt that financial market signals reflect underlying bank risk and that market evaluations of the risk of individual banking organizations are strongly correlated with supervisory findings. The evidence on the extent to which market signals can augment the information set of bank supervisors is somewhat more subtle. Several recent studies have assessed the contribution of market information by using empirical models that include various market signals with lagged supervisory ratings and information from financial statements of banking organizations.[18] Lagged supervisory ratings are assumed to capture the whole of supervisory information as of the most recent full-scope examinations and the data from financial statements are assumed to represent the information available between examinations.[19]

Using this approach in a multivariate regression analysis, Curry et al. (2003) find that various equity market based signals for BHCs were significant in explaining holding company ratings.[20] Those findings are consistent with the work by Krainer and Lopez, which is representative of the wider research findings. Their work shows that, for within-sample estimates, signals from debt and equity markets tend to be statistically significant in explaining supervisory ratings when controlling for past supervisory ratings and information from publicly available financial statements. Also of note, their research does not find that debt market signals perform better than equity market signals. Moreover, for equity market signals, Krainer and Lopez (2004) indicate that stock market return measures perform somewhat better than EDF measures.

The results from the in-sample tests showing the sensitivity of various market signals when controlling for certain supervisory information suggests that market data have the potential to provide useful information to supervisors in assessing banking organizations. A more stringent test of the information content of market signals is the per-

17. The term BOPEC 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 range from one (best) to five (worst). A rating of one or two indicates that the BHC is not considered to be of supervisory concern. BOPEC ratings are highly confidential and are not publicly available.

18. A noteworthy study that does not take this approach but finds a contribution from market information is Evanoff and Wall (2001). They find that using subordinated debt spreads results in more accurate predictions of supervisory ratings than using regulatory capital ratios.

19. Note, however, that these sources do not actually capture the full content of supervisory information between exams. As indicated earlier, bank supervisors have access to confidential information, and on-site examinations staff gain information between formal exams. In particular, the empirical research focuses on full-scope exams and cannot assess the "value" of information from targeted exams. This means that supervisors' full information set is not observable by researchers. If we assume that the bank examiners are correct in their assessments, the share of the supervisory ratings not explained by the off-site monitoring models that use the most current data is an indication of the contribution of the "insider" informational advantage of bank supervisors. In Krainer and Lopez (2004), the proportion of the variation in ratings (adjusted R^2) accounted for by the models that include lagged BHC supervisory ratings, financial statement data, and market signals is about 0.5 (out of a maximum of 1).

20. Also see Gunther, Levonian, and Moore (2001).

formance in out-of-sample predictions of supervisory ratings.[21] When this higher hurdle is used, the performance of market signals is less impressive, though financial market signals still appear to have scope for contribution in the bank supervision process.

Curry et al. (2003), for example, consider the contribution of equity market variables in out-of-sample forecasts of supervisory ratings for BHCs. In the study, the out-of-sample contribution of equity market variables is assessed in terms of the percent of actual ratings categories—that is, downgrades, no changes, and upgrades—that were predicted correctly. Based on this metric, the findings regarding the contribution of adding equity market information to a model with lagged supervisory ratings and financial statement variables are mixed. The inclusion of equity market information increases the percent of correctly predicted supervisory actions for some categories for certain time periods and reduces it for others.

An alternative metric for assessing the accuracy of model forecasts of supervisory ratings is the percent of, say, downgrades predicted by the models that were actually downgrades. This second criterion is critical since the share of false positives is important to supervisors. Consider downgrades, for example. From Curry et al. (2003) in the 1993 to 1995 period, about 6 percent of full-scope exams resulted in downgrades in their sample. For that period, a model that predicted that, say, all BHCs would be downgraded would have 100 percent accuracy for downgrades based on the first criterion. On the second criterion, however, the accuracy rate would be only 6 percent.[22] The practical problem posed by a false positive (prediction of a downgrade for a financially sound organization) is that following up on the false signal absorbs scarce supervisory resources.

The second criterion for assessing the accuracy of supervisory rating forecasts is reported on in the work by Krainer and Lopez. They estimate models for predicting BOPEC ratings for bank holding companies. The explanatory variables in the most complete models include the lagged BOPEC ratings and information from financial statements along with selected market signals.[23] The basic finding is that, when the models' forecast accuracy is calibrated in terms of the percent of predictions that were correct, the models' out-of-sample forecasting power is not appreciably increased by including market signals compared with forecasts of supervisory ratings based on information available to bank supervisors.

However, as pointed out by Krainer and Lopez (2004), the contribution of monitoring models that incorporate market signals can be increased if separate monitoring models are used for holding companies with publicly traded equity and for other holding companies.[24] They find that, while the overall out-of-sample accuracy of models with and without market information is about the same, the individual BHCs identified as potential problems are not exactly the same. In particular, models that included market data correctly flagged publicly traded banking organizations as potential downgrades that were not flagged by models with only lagged supervisory ratings and data from financial statements. As noted by Krainer and Lopez, the usefulness of models with and models without market signals depends on the acceptable trade-off between the costs of missed signals (that is, failures to predict rating downgrades for BHCs) and false positives (that is, incorrect predictions of downgrades for BHCs).

Another important study examines the contribution of risk premiums on the large CDs of small commercial banks in predicting supervisory ratings. Gilbert et al. (2003) find that, when combined with other accounting information relating to the condition of banks, the risk premiums on large CDs do not add to the predictive power of an off-site monitoring model.

The other side of the question is whether the bank supervisory process uncovers information ahead of financial markets; a number of studies take on this issue of informational advantage. Flannery and Houston (1999), for example, show that financial markets evaluate information from a bank's financial statements differently when an exam of the banks has occurred recently. For a sample of banks examined in the fourth quarter of 1988, they find that accounting statements of recently examined banks are more informative than those of "non-examined" banks; they also find that examined banks' market values are slightly higher. These effects are stronger for smaller banks, banks with higher stock return variance, banks with harder-to-value assets, and banks not rated by bond rating agencies.

21. Out-of-sample here means that the changes in supervisory ratings being predicted were not used in estimating the models relating supervisory ratings to the other explanatory variables.

22. This is pertinent to the findings reported in Curry et al. (2003) that models in the out-of-sample forecasts with only equity market information tend to be much more accurate at predicting downgrades because they overpredict by large margins, and tend to be less accurate for the other two categories because they underpredict no changes and upgrades. That is, these models had a large share of false positives for downgrades.

23. The model is roughly based on the System for Estimating Examiner Ratings (SEER) off-site monitoring model for banks (Krainer and Lopez 2002).

24. Curry et al. (2003) also argue for using a multiple models approach.

The authors argue that these findings provide evidence that bank examiners play a valuable role in the certification of banks' accounting data and that bank shareholders benefit from this activity.

Berger, Davies, and Flannery (2000) employ Granger causality tests to compare the relative timeliness of government supervisors' and market participants' assessments of banks to see if one or more of the groups use some relevant information before the others. They find that both bond rating agencies and supervisors regularly discover relevant information that is only subsequently incorporated into the other group's assessments. The evidence pointing to the discovery of information by stock market participants ahead of bank supervisors is not as strong. However, in terms of predicting future performance, the authors find that supervisory assessments contribute substantially to forecasting future bank performance and often exceed the contribution of the market's assessment for short periods following supervisory exams, but not for longer horizons.

Curry et al. (2003) also look at whether supervisors acquire information in exams that was not previously revealed to the market. The study finds that, even controlling for the information of financial statement variables, lagged information on supervisory ratings had predictive power for several of the equity-based, market variables. This suggests that some information acquired in on-site supervisory exams is not initially known by the market but apparently is disseminated to the equity market over time. These results are consistent with bank supervisors acquiring some information ahead of the equity market.

DeYoung, Flannery, Lang, and Sorescu (2001) examine whether private information uncovered in bank exams is incorporated into the pricing of banking-related subordinated debt. They find that examiner assessments contain relevant information about bank conditions that is not fully incorporated into the pricing of subordinated debt at the time of the exam but that is incorporated in subsequent quarters. They also find that when examiners uncover "bad" information in an exam, the information generally does not become public until subsequent quarters, but "good" information generally finds its way to the market quickly. This finding suggests that bank managers tend to disclose good news more readily than bad news.

The findings in Berger and Davies (1998) are also indicative of an informational advantage for bank supervisors. The authors examine the relationship between stock returns and the examination process. Analyzing abnormal stock returns of BHCs in the period after the lead bank had been examined, they find that exams discovering unfavorable information about bank conditions result in abnormal negative returns. The finding suggests that bank managers may reveal favorable information in advance, while the supervision process, in effect, forces the dissemination of unfavorable information.

Jordan, Peek, and Rosengren (2000) examine the effects of disclosing formal enforcement actions. The U.S. Congress adopted legislation in 1989 and 1990 requiring bank regulatory agencies to make public all formal enforcement actions imposed on banks. By making the formal actions public, bank supervisors were, in effect, disclosing that certain institutions were believed to have a high probability of failure in the absence of substantial remedial action.

The authors show that announcements of formal supervisory actions provide useful information to the market. They find that investors and depositors reacted to the news in a manner that was consistent with enhanced market discipline, and the reaction was far from catastrophic. On average, an announcement of a formal action caused the announcing bank's stock price to decline only 5 percent. The declines tended to be smaller for banks for which the market had already anticipated the problems and larger for those banks for which little news of impending problems had been revealed. Thus, the market's ability to uncover problems is at least in part a function of bank disclosure. There were some spillover effects, including rival banks experiencing moderate stock price declines. However, these spillover effects were limited to banks in the same region with portfolio positions similar to that of the announcing bank.

Market signals regarding risk from banking-related, longer-term debt and equity generally are consistent with supervisory assessments and tend to predict changes in supervisory ratings. Also, the results from the in-sample tests show that market data have the potential to provide useful information to supervisors in assessing banking organizations. However, a more stringent test of the information content of market signals is the performance in out-of-sample predictions of supervisory ratings. When this higher hurdle is used, the performance of market signals is less impressive, though financial market signals still have scope for contribution in the bank supervision process. Moreover, a number of studies find that market signals for banking organizations tend to respond as if adverse supervisory information is revealed to the market. This is consistent with the supervision process uncovering negative information ahead of the market.

5. Response of Banking Organizations to Signals: Direct Market Discipline

While the weight of the research suggests that bank supervisors typically have some informational advantage, the fact that market signals generally are consistent with supervisory assessments indicates that they can help reinforce

these assessments. Moreover, monitoring market signals also would be useful in the supervision process to the extent that the markets' assessment of a BHC affects the environment in which the banking organization operates or affects management decisions. For example, a banking organization might respond to changes in market signals indicating increased concern about risk by adjusting its portfolio or sources of funding, increasing its capital, or perhaps changing its risk management practices. Market participants might also affect a bank's operations through its access to funding or through debt covenants tied to the performance of an issuing banking organization.

The research on the issue of whether the operations of a banking organization are affected by market signals is limited. Bliss and Flannery (2002) find no evidence that market assessments of risk lead to changes in bank risk-taking. However, Goyal (2003) finds that covenants in debt contracts are a source of discipline on banking organizations. In particular, the author finds that the charter value of a banking organization can affect the degree of restrictive covenants in its bond agreements. The idea is that a higher charter value provides a check on a banking organization's risk-taking—the charter value often is gauged by comparing a banking organization's market value to its book value.[25]

Other research indicating that market assessments affect the operating environment of banking organizations focuses on funding. One compelling study, Covitz et al. (2002), shows that adverse market conditions appear to affect the timing of debt issuance by banking organizations. Other studies such as Billet, Garfinkel, and O'Neal (1998) find that risk premiums on banking debt can affect the mix of funding, with higher risk leading to less reliance on uninsured liabilities compared to insured deposits. Hall, King, Meyer, and Vaughan (2002) find that yields and runoffs of large CDs are risk-sensitive, though they argue the effects are economically small and are not likely to put much pressure on banks to constrain risk. Jordan et al. (2000) also find that disclosure of supervisory actions tends to affect a bank's funding. Following formal enforcement actions, total deposits of affected banks declined modestly, an average of 2 percent, with the largest declines occurring in deposit categories that were not fully insured.

In an attempt to reconcile the findings regarding the market influence on banking organizations, it appears that feedback from the market through, say, bond covenants and risk premiums can affect banking organizations' choices of business strategies, with the choices varying among banking organizations. At the same time, an individual banking organization may not abruptly change its underlying business strategy in the wake of, say, a decline in asset quality. An important function of banking is taking risk. Even with sound risk management and ex ante underwriting practices, a banking organization can experience a "bad draw." That is, the realization of a low probability event might not lead to an overhaul of a banking organization's business plan. However, market assessments appear to have some impact on funding choices for banking organizations.

6. Improving the Quality of Market Signals

A recent line of research has examined whether supervisory or regulatory measures could improve the reliability of market signals. One area is improving public disclosure among banking organizations. While there is little empirical work on the effectiveness of increased public disclosures, several studies have identified areas for improvements.[26] The Basel Committee on Banking Supervision published several studies and the Federal Reserve Board of Governors Staff Study (2000) deals specifically with improving public disclosure among banking organizations. Improved disclosure also is part of Pillar 3 of the Basel II Accord.

Most of the empirical analysis relating to improving the reliability of market signals in banking has focused on the issuance of subordinated debt. The findings are relevant for addressing several of the shortcomings of market signals from banking-related subordinated debt from the perspective of bank supervision—limited issuance, infrequent issuance, and thin secondary market trading, especially for debt issued directly by commercial banks.

Research findings suggest some policy prescriptions. Summaries of various subordinated debt proposals are provided in Kwast et al. (1999). The main thrust of proposals for improving the quality and usefulness of market signals derived from banking-related subordinated debt is for policies to require regularly scheduled and relatively frequent issuance of banking-related debt. Other research mentioned earlier, for example, finds that market conditions can affect the timing of debt issuance by banking organizations. This supports requiring banking organizations to issue subordinated debt regularly so as to limit strategic issuance. Regarding the frequency of issuance, recent work by Evanoff and Jagtiani (2004) finds that market signals are most reliable when debt is issued. One reason may be

25. See Keeley (1990).

26. Spiegel and Yamori (2003) find that voluntary disclosures regarding market values of assets by Japanese banking organizations do improve transparency.

that public issuance involves publishing a prospectus with enhanced disclosures. Also, purchasing volumes are higher, which is likely associated with greater market research and analysis.

7. Conclusion

The use of market data in the Federal Reserve System is roughly consistent with the research findings to date. In general, market signals (debt and equity) tend to provide information that is consistent with supervisory assessments. Traditional measures of bank risk are found to be reflected in market measures of risk. Also, signals from banking-related debt and equity tend to predict changes in supervisory ratings. Furthermore, for within-sample estimates, signals from debt and equity markets tend to be statistically significant in explaining supervisory ratings. On the choice of equity versus debt, the greater depth and breadth of the market for BHC-issued equity compared to that for BHC-issued subordinated debt supports the growing use of equity signals in the bank supervision process.

On the other hand, when used in conjunction with other information available to bank supervisors, the out-of-sample predictive power of market signals, either equity or debt, is less robust. The usefulness depends to some extent on the trade-off one is willing to accept between missed signals of potential banking failures and false positives. These findings support the use of market information to help reinforce supervisory assessments of traditional banking organizations where supervisors would be expected to have an informational advantage, though it does not necessarily add significant information in terms of earlier warning signals for such institutions.

With financial deregulation, the informational advantage of bank supervisors is less clear for nontraditional banking organizations with activities dominated by securities underwriting, brokerage services, or insurance. Under the Gramm-Leach-Bliley Act, the federal banking agencies do not have direct oversight authority for securities and insurance affiliates of financial holding companies. While more research is needed on the transparency and reliability of market signals for securities and insurance firms, the current research suggests that market signals likely provide useful information to bank supervisors.

The research on the feedback of market signals on the behavior of banking organizations is somewhat limited. However, the evidence does suggest that market sentiment can affect the funding decisions of banking organizations, even if the impact on risk-taking is less evident. On balance, the research supports the monitoring and analysis of market information by bank supervisors to understand the environment in which a banking organization operates.

Finally, research suggests that the quality and usefulness of market signals for individual banking organizations might be improved. More complete disclosures by banking organizations could improve transparency. Others have proposed regulatory changes that would lead to more frequent issuance of and deeper markets for subordinated debt issued by banking organizations.

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Current Account Adjustment with High Financial Integration: A Scenario Analysis*

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A narrowing of the U.S. current account deficit through exchange rate movements is likely to entail a substantial depreciation of the dollar. We assess how the adjustment is affected by the high degree of international financial integration, with exchange rate movements having a direct valuation impact on international assets and liabilities. In particular, a dollar depreciation generates a capital gain for the United States by boosting the value of its assets that are denominated in foreign currencies. We consider an adjustment scenario in which the U.S. net external debt is held constant. One key finding is that while the current account moves into balance, the pace of adjustment is smooth. Intuitively, the valuation gains stemming from the depreciation of the dollar allow the United States to finance ongoing, albeit shrinking, current account deficits. We find that the smooth pattern of adjustment is robust to alternative scenarios, although the ultimate movements in exchange rates are affected.

1. Introduction

A central feature of the global economy is the extent of international imbalances, mainly the large and growing current account deficit of the United States. The sustainability of this situation as well as the pattern of an eventual adjustment are the subjects of substantial analysis and debate. Overall, however, a consensus has emerged that the international imbalances are likely to unwind eventually, requiring a substantial adjustment in the exchange rate of the dollar. In a widely cited contribution, Obstfeld and Rogoff (2005, 2006) estimate that the dollar would have to depreciate by 30 to 38 percent against the world's currencies to erase the U.S. current account deficit.

In this paper, we assess how the adjustment of the U.S. current account deficit interacts with the high degree of financial integration in the world economy. In addition to making U.S. goods more competitive in world markets, hence helping U.S. exports, a depreciation of the dollar leads to a capital gain for the United States by boosting the dollar value of a given amount of its foreign-currency assets. This valuation channel is playing an increasingly large role in driving the U.S. net investment position and, therefore, in affecting the dynamics of international adjustment.

The magnitude of exchange rate movements, however, is only one dimension of the adjustment. Whether the adjustment is likely to take place gradually or suddenly remains an object of debate. Our analysis focuses on this dimension by considering an alternative experiment. Rather than immediately bringing the current account to zero, as Obstfeld and Rogoff do, we consider a scenario where U.S. net external debt is kept constant. We regard such a scenario as realistic, since the current level of U.S. net external debt has so far proved manageable. We find that the presence of valuation effects allows for a "smooth landing," with the U.S. current account imbalance gradu-

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ally disappearing. Specifically, it takes three years for the current account deficit to halve under our scenario.

Intuitively, the smooth pattern of the adjustment in our scenario reflects the fact that the capital gains stemming from the depreciation of the dollar are used to finance ongoing, albeit shrinking, current account deficits during the adjustment. In the first year of the adjustment, the dollar depreciates, generating a capital gain through the valuation effect. This gain is used to finance net imports, so the current account does not have to fall to zero immediately. This reduces the pressure on the exchange rate in the first year, with the dollar depreciating by only 9 percent. In the second year of the adjustment, this pattern is repeated, with a further narrowing of the current account deficit, and a dollar depreciation reaching 15 percent from the initial situation. Our adjustment scenario does ultimately bring the current account into balance, as this is the only way to stabilize the U.S. net debt.

An important feature of our scenario is the leverage in international balance sheets. While net international asset positions are constant, the values of gross assets and liabilities increase substantially. To assess the sensitivity of our results to this aspect, we complement our baseline scenario by considering two alternatives. In the first one, we set financial flows to zero so leverage is kept constant. In the second one, we increase the rate of return on U.S. liabilities to match the rate on U.S. assets. The magnitude of exchange rate movements is larger under both alternative scenarios, and especially under the second alternative of interest rate convergence, where the dollar depreciation is boosted by one-third. Interestingly, the gradual nature of adjustment remains robust, with the U.S. current account deficit only halving in three to four years. The composition of adjustment is different from the baseline scenario, however. In particular the U.S. trade balance adjusts faster under the alternative scenarios, as the United States is no longer shielded from the interest burden on its liabilities.

The remainder of the paper is organized as follows. Section 2 provides background information and refers to the literature on the topic. Section 3 presents the key elements of our model. Section 4 describes our adjustment scenario, as well as a sensitivity analysis to alternative scenarios. Section 5 concludes.

2. Background and Literature Review

The large and growing current account deficit of the United States has become a central feature of the global economy, particularly in recent years. The U.S. external deficit increased gradually in the early 1990s, reaching a moderate level of 1.7 percent of GDP in 1997, and subsequently widened at a fast pace, hitting 5.7 percent of GDP in 2004. This substantial borrowing from the rest of the world has pushed the United States into a substantial net debt vis-à-vis foreign investors, with net liabilities amounting to 21.7 percent of GDP at the end of 2004.[1]

A volume by Clarida (2006) provides an overview of the substantial analysis and debate surrounding the sustainability of the U.S. external deficit and the path—whether smooth or sudden—an eventual adjustment might take. Several economists argue that the current situation is driven by policy choices that are likely to persist over several years, and that the United States is not condemned to face a disruptive adjustment in order to stabilize its borrowing.[2] The United States may also have better growth prospects than the rest of the world, leading it to account for a permanently higher share of world GDP. In this situation foreign investors could increase the share of U.S. assets in their portfolio, leading to sustained U.S. deficits, with a gradual adjustment once the portfolio reallocation has run its course.[3] Or, the U.S. financial sector may have an advantage in intermediating world savings. In this scenario, the transit of world savings through the United States to be converted into investment would lead to sustained current account imbalances.[4]

On the other side of the debate, many argue that the current situation is not sustainable and will lead to a substantial depreciation of the dollar vis-à-vis other currencies. This adjustment can be gradual and relatively benign.[5] Several contributions, however, point to the risk of a rapid adjustment, with disruptive consequences for the world economy.[6] A representative, and widely cited contribution of the latter view is the work by Obstfeld and Rogoff (2005, 2006). They show that the return of the U.S. current account deficit to balance entails a depreciation of the U.S. dollar of 30 to 35 percent against the main world currencies. In addition, they argue that such an adjustment could take place in a disruptive manner if it stemmed from foreign investors losing confidence in the U.S. economy.

Exchange rate movements play a central role in most scenarios of international adjustment. These movements

1. See Cavallo and Tille (2006) for data from the Bureau of Economic Analysis, International Economic Accounts.

2. See Dooley, Folkerts-Landau, and Garber (2005, 2006).

3. See Backus, Henriksen, Lambert, and Telmer (2005), and Engel and Rogers (2006).

4. See Caballero, Farhi, and Gourinchas (2006).

5. See Blanchard, Giavazzi, and Sa (2005), Helbling, Batini, and Cardarelli (2005), and Faruqee, Lexton, Muir, and Pesenti (2006).

6. See Roubini and Setser (2005).

affect the relative prices of various goods traded on the world market; for example a weaker dollar would make U.S. goods cheaper, hence boost U.S. exports. More importantly, exchange rate movements affect the price of nontraded goods (such as services) relative to traded goods (such as manufactured goods), inducing a reallocation of consumption between traded and nontraded goods. Obstfeld and Rogoff (2005, 2006) point out that this second channel plays a key role in the adjustment.

A growing body of research suggests that the degree of financial integration has dramatically increased since the early 1990s.[7] The world has moved from a situation where net positions were dominant, with some countries being creditors and others being debtors, to a situation where holdings of financial assets across countries have surged, with the values of gross assets and liabilities positions dwarfing the values of net positions. This development has opened a new channel through which exchange rate movements affect the world economies, the so-called valuation effect. If countries are leveraged in terms of currencies, with the currency composition of their assets differing from that of their liabilities, exchange rate fluctuations have a different effect on the two sides of the balance sheet, leading to sizable capital gains and losses in net terms.

This mechanism is illustrated by the case of the United States: while U.S. liabilities are nearly exclusively denominated in dollars, about two-thirds of U.S. assets are denominated in foreign currencies (Tille 2005). A depreciation of the dollar then improves the U.S. net investment position by increasing the dollar value of U.S. assets denominated in foreign currencies, while leaving the dollar value of U.S. liabilities essentially unchanged. This valuation channel has become an increasingly important factor in shaping the evolution of the U.S. net investment position. Indeed, over the last three years there developed an apparently puzzling pattern: the U.S. net international indebtedness remained steady at 20 to 25 percent of GDP despite a current account deficit in the order of 5 percent of GDP. This unusual pattern is a consequence of the valuation effect of exchange rate movements. While net financial inflows required to fund the increasingly large current account deficit consistently pushed the United States into debt, the valuation effects of exchange rate movements also substantially affected the U.S. position. In particular, the depreciation of the dollar since 2002 generated capital gains that amounted to about two-thirds of the current account deficit, thereby significantly cushioning the deterioration in the U.S. net investment position that arose from the need to finance the deficit.[8]

While some analyses of a narrowing of the U.S. current account deficit take financial integration into account, they do so in a way that limits its role.[9] In particular, Obstfeld and Rogoff (2005, 2006) argue that taking the valuation effect of exchange rate movements into account reduces the required depreciation of the dollar only modestly. This modest effect reflects the exact nature of their experiment. Abstracting from valuation effects, the stabilization of U.S. net external debt at its current level requires the current account to move into balance. When taking valuation effects into account, Obstfeld and Rogoff still require the current account to move immediately into balance. This generates a valuation effect that substantially improves the U.S. position, reducing the U.S. net external debt by a factor of three, but has a limited impact on the magnitude of the exchange rate movement.

Another dimension of adjustment that is an important focus of our study is the pace of these movements. The adjustment requires an eventual large depreciation of the dollar, and a contraction in U.S. consumption, as outlined by Obstfeld and Rogoff (2005, 2006). If the adjustment were gradual, the reduction of consumption would not have to occur immediately. In addition, a gradual adjustment would be less likely to be disruptive to financial markets. For instance, a 30 percent depreciation of the dollar would entail more adverse effects if concentrated over a year than if smoothed over a decade.

3. A Three-Country Model of Interdependence

The main elements of our analysis are based on the work by Obstfeld and Rogoff (2005). In this section, we summarize these elements informally, and then focus on how our setup departs from theirs. A more detailed presentation of the model is available in Cavallo and Tille (2006).

3.1. Consumption Allocation and Relative Prices

The model economy consists of three regions: the United States, Europe, and Asia, which are indexed by *U, E,* and *A,* respectively. The regions are linked by trade flows and by cross-holdings of financial instruments. Each region produces a traded good and a nontraded good, with the three traded goods being imperfect substitutes. Aggregate

7. See Gourinchas and Rey (2005, 2006), Lane and Milesi-Ferretti (2003, 2005, 2006), Obstfeld (2004), and Tille (2003, 2005).

8. See Cavallo and Tille (2006) for details.

9. The valuation effects are incorporated into the analyses of Blanchard et al. (2005) and Obstfeld and Rogoff (2005, 2006).

consumption is first allocated between domestically produced nontraded goods, C_N^i, and an index of the traded goods produced in all regions, C_T^i. The consumption index of traded goods, C_T^i, includes the consumption of goods produced in the United States, Europe, and Asia, denoted by C_U^i, C_E^i, and C_A^i, respectively. The consumption indexes of traded goods in all regions include a home bias, with consumers' preferences being tilted towards domestically produced goods

The costs of the various consumption baskets are captured by corresponding price indexes. These price indexes indicate the smallest amount of income required to purchase a unit quantity of the corresponding basket. P_C^i denotes the consumer price index in country *i*, while P_N^i is the price of nontraded goods and P_T^i is the price index of traded goods in region *i*. For simplicity we use the U.S. currency as a numeraire in which prices are expressed. P_T^U, P_T^E, and P_T^A are the price indexes of traded consumption in the three regions expressed in dollars. Throughout this article we assume that all prices are fully flexible and there are no impediments to trade, so that the price of a given traded good is the same across the world.

Demand for the various goods in a given region is driven by the aggregate consumption in the region, as well as the various relative prices. The bilateral terms-of-trade $\tau_{i,j}$, is the price of the traded good produced in region *j*, relative to the price of the traded good produced in region *i*. The three bilateral terms-of-trade in our setup are $\tau_{U,A}$, $\tau_{U,E}$, and $\tau_{E,A}$. An increase in $\tau_{U,E}$ indicates a deterioration of the U.S. terms-of-trade vis-à-vis Europe, because European-made goods are now more expensive in terms of U.S.-produced goods. It can also be interpreted as a competitiveness gain for the United States vis-à-vis Europe.

A key relative price in region *i* is the price of the domestic nontraded goods relative to the price of the traded basket in the region, x^i. An increase in x^i indicates that, in region *i*, nontraded goods are more expensive in terms of the composite traded consumption basket.

The bilateral nominal exchange rates represent the value of a currency in terms of another, with $E_{i,j}$ being the amount of region *i*'s currency that is required to purchase one unit of region *j*'s currency. We refer to the currencies of the United States, Europe, and Asia as the dollar, the euro, and the yen, respectively. The three bilateral nominal exchange rates in our setup are $E_{U,E}$, $E_{U,A}$, and $E_{E,A}$, with an increase in $E_{U,E}$ reflecting a nominal depreciation of the dollar against the euro. The nominal exchange rates are completed by the real exchange rates, which represent the ratios of consumer prices across countries. The three bilateral real exchange rates in our setup are $q_{U,E}$, $q_{U,A}$, and $q_{E,A}$. An increase in $q_{U,E}$ is an increase in the European consumer price index, relative to the United States. Such an increase represents a *real depreciation* of the dollar against the euro, that is a depreciation of the U.S. currency that is not offset by movements in the local currency price index. Bilateral real exchange rates are driven by both the terms-of-trade and the relative prices of nontraded goods.

An effective measure of the external value of a currency is obtained by taking weighted averages of the various bilateral exchange rates. The three effective real exchange rates in our setup are q^U, q^E, and q^A. An increase in q^U indicates that the dollar depreciates in real effective terms, reflecting a depreciation against the euro (an increase in $q_{U,E}$) or the yen (an increase in $q_{U,A}$).

While real exchange rates are driven entirely by *relative* prices, namely the terms-of-trade and the relative prices of nontraded goods, the nominal exchange rates are also affected by the *level* of prices in particular regions. Solving for nominal exchange rates then requires a specification of monetary policy to determine the price levels. We follow Obstfeld and Rogoff (2005) and assume that central banks keep the price of a basket of domestically produced goods constant in local currency. We focus our discussion on real exchange rates, as the movements in nominal exchange rates are very similar.

3.2. International Financial Positions

A central feature of our analysis is the integration of financial markets, with each region holding substantial asset positions in the other two regions.

3.2.1. Initial Asset and Liability Positions

Assets and liabilities on each region's balance sheet consists of assets denominated in different currencies. Exchange rate movements, then, affect asset values and lead to capital gains and losses across the three regions. Following Obstfeld and Rogoff (2005), we consider that positions are in a high-return bond paying an interest rate r^W, except for the liabilities of the United States, which are in a low-return dollar-denominated bond paying an interest rate $r^U < r^W$. This feature captures the "exorbitant privilege" the United States enjoys in its ability to borrow from the rest of the world at lower rates than it faces when lending (see Gourinchas and Rey 2006, and Lane and Milesi-Ferretti 2006).

Table 1 summarizes the initial currency composition of *international* balance sheets in the three regions derived from those used by Obstfeld and Rogoff (2005).[10] For the

10. For a more detailed illustration of the initial composition of assets and liabilities, see Cavallo and Tille (2006).

Table 1
Initial Structure of Assets and Liabilities
($ trillions)

	Assets (a)	Liabilities (b)	Net (c)
United States			
Total	8.3	11.0	–2.8
dollar	3.3	11.0	–7.7
euro and yen	4.9	—	4.9
Europe			
Total	11.0	11.0	0
dollar	3.5	2.2	1.3
euro and yen	7.5	8.8	–1.3
Asia			
Total	11.0	8.3	2.8
dollar	8.8	2.4	6.4
euro and yen	2.2	5.8	–3.6

United States, assets include positions in all currencies, and liabilities are in low-return dollar-denominated bonds. The United States is a net debtor, and a sizable share of U.S. assets (60 percent) is denominated in foreign currencies, while all U.S. liabilities are in dollars, in the low-return bond. This pattern is consistent with the U.S. numbers detailed in Tille (2005). The U.S. net position is then highly leveraged, with substantial asset positions in foreign currencies and large liabilities in dollars.

The European balance sheet includes assets and liabilities in all currencies. The position of Europe is balanced with equal amounts of assets and liabilities. European assets are mostly denominated in euros and dollars (57 and 37 percent of the total, respectively), with the latter consisting mostly of low-return bonds invested in the United States. Similarly, European liabilities are predominantly denominated in euros (80 percent), with the remainder in dollars.

The Asian balance sheet indicates that the region is a net creditor to the rest of the world, with the bulk (80 percent) of its assets consisting of dollar-denominated assets, essentially in low-return bonds invested in the United States. The liability side is relatively evenly split across the three currencies. In net terms, Asia is substantially leveraged, with large assets in dollars and substantial liabilities in yen and, to a lesser extent, in euros.

3.2.2. Dynamics of Balance Sheets

Tracking the dynamics of assets and liabilities is a central dimension of our model, with these values fluctuating for three reasons. First, gross trade flows lead to the accumulation of additional assets and liabilities. Second, the existing positions generate a stream of interest payments. Third, exchange rate fluctuations affect the value of positions in different currencies.

Trade flows. The first factor reflects gross trade flows. The mapping of trade flows into the dynamics of the balance sheet requires us to address two issues that are not present in simpler models, namely the relative magnitude of financial and trade flows and currency compositions.

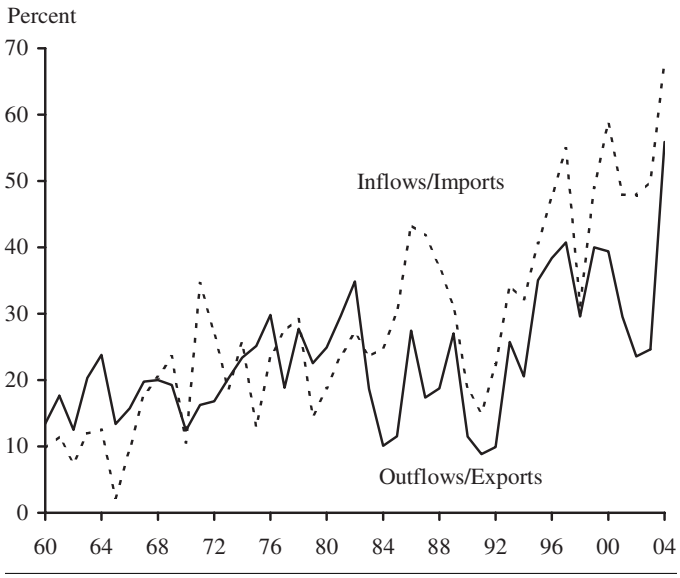
In net terms, the trade balance maps into an equal change in the net foreign asset position, ceteris paribus. The linkage is looser when we consider gross flows, however. Consider an example where a country *(A)* exports $100 worth of goods to another country *(B)* and imports $120 worth of goods. Country *A* clearly runs a trade deficit of $20, with a corresponding deterioration in its net foreign asset position. The picture in terms of gross flows is not as straightforward. A first possibility is that all gross exports lead to an accumulation of gross foreign assets, whereas all gross imports lead to an accumulation of foreign liabilities. The gross assets and liabilities of country *A* then increase by $100 and $120, respectively. Another possibility is that the entire proceeds of exports are used to pay for imports, with an accumulation of liabilities amounting only to the trade deficit. The gross assets and liabilities of country *A* then increase by $0 and $20, respectively. This simple example shows how a given situation in net terms can correspond to vastly different situations in gross terms.

We rely on the empirical evidence for the relative magnitude of gross trade and financial flows, as economic theory does not provide us with an a priori guess. Data for the United States are presented in Figure 1, where the solid line is the ratio between gross financial outflows and gross exports, and the dotted line is the ratio between gross financial inflows and gross imports. Both lines show similar positive trends, with gross financial flows increasing from 10 to 15 percent of trade flows in the early 1960s to 40 to 50 percent in recent years, a pattern that reflects the increase in financial integration. Based on this evidence, we assume that a fraction $\pi = 0.5$ of trade flows maps into corresponding financial flows.

In addition to the magnitude of gross financial flows, their currency composition affects the dynamics of our model. If, for instance, the United States accumulates assets in foreign currencies, future exchange rate movements will lead to a larger valuation effect than if the additional U.S. assets are in dollars.

While we lack evidence on the currency composition of gross financial flows, we take an educated guess relying on the available evidence on the invoicing of international

Figure 1
Ratio of Gross Financial Flows to Gross Trade Flows



Source: Bureau of Economic Analysis, International Economic Accounts.

trade flows, as reported by Goldberg and Tille (2005).[11] We assume that trade flows to and from the United States lead predominantly to an accumulation of dollar assets and liabilities.[12] Trade flows between Europe and Asia lead primarily to an accumulation of positions in euros, with a sizable secondary role for dollar positions.

Interest payments and valuation gains. The second driver of changes in assets and liabilities is the flow of interest income. For simplicity, we assume that a share π of the proceeds from interest payments are simply added to the principal of the corresponding position, with π being the same as the share of gross trade flows that map into financial flows. The *net* interest income for each region is the difference between the interest earned on its assets and that paid on its liabilities. See Box 1 for details.

The final driver of balance sheet dynamics is the valuation effect stemming from exchange rate movements. As we express all positions in dollars, there is no such effect for the positions in dollar-denominated assets. However, the dollar value of positions in euro- or yen-denominated assets is affected. We again assume that a share π of these valuation effects is added to the principal of the corresponding positions.

11. While a flow can be invoiced in one currency and transacted in another, we posit that the invoicing currency is a good indicator of the transaction currency.

12. Details are given in Cavallo and Tille (2006). The accumulation of U.S. liabilities takes place in the low-return dollar bond.

Overall dynamics and consistency. The dynamics of the various exchange rates are given by combining the three channels, as shown in Box 1.

While the assumption that trade flows, interest income, and valuation gains all map into gross positions up to a scaling π simplifies our model, one may worry that it could lead to inconsistencies across the various assets and liabilities. In Box 2 we show that this is not the case in the particular scenario we consider. As our scenario analysis focuses on constant net asset positions, our scaling of gross flows and valuations by π across the board is fine, though it would be problematic for other scenarios.

Aggregating the various components of balance sheet dynamics, the changes in the net foreign asset positions of the various countries are the sums of the current accounts and the valuation effects on assets and liabilities, as shown in Box 2.

3.3. Market-Clearing Conditions

In each region, the current account, in dollars, is the sum of net interest income and the trade balance, the latter being the difference between the value of tradable output and the value of consumption of tradable goods. For simplicity, the supply side of the world economy is modeled as an endowment economy.

We denote the endowments of tradable and nontraded goods in region *i* by Y_T^i and Y_N^i, respectively. Note that the valuation effects of exchange rate movements, *VH* and *VL,* do not enter the current account as they do not entail any financial flows across countries. Region *i*'s current account is then $CA^i = NI^i + P_i Y_T^i - P_T^i C_T^i$.

The clearing of goods markets requires that the endowments of the various goods are equal to the sum of domestic and foreign consumptions which depend on aggregate consumptions in the various regions and on relative prices. We define the following ratios between the various endowments of tradable and nontraded goods: $\sigma_{U/E} = Y_T^U / Y_T^E$, $\sigma_{U/A} = Y_T^U / Y_T^A$, and $\sigma_{N/i} = Y_N^i / Y_T^i$. We use lowercase variables to denote the ratio between a dollar value and the value of the endowment of U.S. tradable good, $P_U Y_T^U$. We scale the various trade flows in this way: $gh_j^i = GH_j^i / (P_U Y_T^U)$. Net interest incomes and current accounts are similarly scaled, with $ni^i = NI^i / P_U Y_T^U$ and $ca^i = CA^i / P_U Y_T^U$.

Using the allocation of consumption across the various goods, we write the various trade flows in terms of relative prices (the terms-of-trade and price between traded and nontraded goods) and the trade balance (current account net of interest income). The market-clearing condition for a particular traded good states that the endowment of the good is equal to the sum of domestic and foreign demands.

Box 1
What Drives Changes in Asset and Liability Positions?

We denote region i's foreign assets by H^i, and its liabilities by L^i. The difference represents the net international position of the region, which we denote by $F^i = H^i - L^i$. H^i_j denotes region i's assets that are denominated in region j's currency. For instance, H^E_U is the value of dollar-denominated assets held by European investors. Similarly, L^i_j denotes region i's liabilities that are denominated in region j's currency. Positions are in a high-return bond paying an interest rate r^W, except for the liabilities of the United States which are in a low-return dollar-denominated bond paying an interest rate $r^U < r^W$. Positions in the low-return bond are denoted by a tilde.

The three factors we consider that drive changes in a region's assets and liabilities are trade flows, interest payments, and exchange rate changes.

Trade flows: We denote the value of trade flows, in dollars, of region i's exports to region j by GH^i_j. For instance, GH^E_A is the value of European exports to Asia. In terms of region i's exports to region j, GH^i_j, we assume that a share $\mu^i_{j,U}$ of these flows leads to the accumulation of assets denominated in dollars. Similarly, a share $\mu^i_{j,E}$ leads to the accumulation of assets denominated in euros, and a share $\mu^i_{j,A} = 1 - \mu^i_{j,U} - \mu^i_{j,E}$ leads to the accumulation of assets denominated in yen.

Interest payments: Based on the structure of the balance sheets, we write net interest income for the three regions as:

$$NI^U = r^W H^U - r^U L^U, \tag{1}$$

$$NI^E = r^U \tilde{H}^E_U + r^W \left(H^E_U + H^E_E + H^E_A\right) - r^W L^E, \tag{2}$$

$$NI^A = r^U \tilde{H}^A_U + r^W \left(H^A_U + H^A_E + H^A_A\right) - r^W L^A. \tag{3}$$

Exchange rate changes: We denote by VH^i_j the change in the value of region i's gross assets denominated in region j's currency due to exchange rate movements. VL^i_j is defined similarly for liabilities.

Valuation effects are driven by nominal exchange rates. Consider a period when the dollar-euro exchange rate changes from $E_{U,E0}$ to $E_{U,E}$, while the dollar-yen exchange rate changes from $E_{U,A0}$ to $E_{U,A}$. The valuation changes for U.S. assets denominated in euros and yen are:

$$VH^U_E = \left(\frac{E_{U,E}}{E_{U,E0}} - 1\right) H^U_E \qquad \text{and} \qquad VH^U_A = \left(\frac{E_{U,A}}{E_{U,A0}} - 1\right) H^U_A. \tag{4}$$

The valuation effects for Europe and Asia are computed along similar lines.

Overall adjustments: U.S. assets and liabilities at the end of a period are given as follows, with a prime indicating values at the end of the period:

$$H^{U\prime}_U = H^U_U + \pi \left[r^W H^U_U + \mu^U_{E,U} GH^U_E + \mu^U_{A,U} GH^U_A\right]$$

$$H^{U\prime}_E = H^U_E + \pi \left[r^W H^U_E + \mu^U_{E,E} GH^U_E + \mu^U_{A,E} GH^U_A + VH^U_E\right]$$

$$H^{U\prime}_A = H^U_A + \pi \left[r^W H^U_A + \left(1 - \mu^U_{E,U} - \mu^U_{E,E}\right) GH^U_E + \left(1 - \mu^U_{A,U} - \mu^U_{A,E}\right) GH^U_A + VH^U_A\right]$$

$$\tilde{L}^{U\prime} = \tilde{L}^U + \pi \left[r^U \tilde{L}^U + \left(GH^E_U + GH^A_U\right)\right].$$

The dynamics of the European and Asian balance sheets are computed along similar lines.

Similarly the market clearing for a nontraded good is an equality between the endowment and the domestic demand.

A noteworthy feature of the various market-clearing conditions is that they do not involve the share π linking trade flows and financial flows. Given the current accounts and net interest incomes (ca^U, ca^E, ni^U, ni^E) we can compute the various terms-of-trade and traded-nontraded prices. Aggregate consumption in each region i can be computed from its endogenous endowment of the nontraded good, and the various relative prices, using the

Box 2
NET FINANCIAL FLOWS

Focusing on the United States for brevity, net financial flows consist of two main components. The first is the proceeds of trade flows and net interest payments that are added to net assets (which are a share π of these flows). The second is the share $(1-\pi)$ of valuation gains that is not added to the principal of the corresponding positions, bearing in mind that a valuation gain that is brought back into the United States is a financial inflow, that is, a negative financial flow. Net financial flows are then:

$$\begin{aligned} FF^U &= \pi\left[\left(GH_E^U + GH_A^U\right) - \left(GH_U^E + GH_U^A\right) + NI^U\right] - (1-\pi)\left(VH_E^U + VH_A^U\right) \\ &= \pi CA^U - (1-\pi)\left(VH_E^U + VH_A^U\right), \end{aligned}$$

where CA^U is the U.S. current account, that is the overall net trade and interest payments flow. Net financial flows and current accounts are equal, as they should be, only when:

$$FF^U = CA^U = \pi CA^U - (1-\pi)\left(VH_E^U + VH_A^U\right) \Rightarrow CA^U = -\left(VH_E^U + VH_A^U\right).$$

Therefore, our assumption that π is the same across the board is valid only when the current account is the inverse of the capital gains, that is when capital gains are associated with a current account deficit. A complementary way to establish this point is to look at the dynamics of the net foreign asset position. In our setup, the change in the net foreign asset position is the sum of the proceeds from trade flows and from net interest payments that are added to net assets, and the valuation gains that are added to the corresponding positions:

$$F^{U\prime} - F^U = \pi CA^U + \pi\left(VH_E^U + VH_A^U\right). \tag{5}$$

The changes in the net positions in the data, such as those published by the Bureau of Economic Analysis, combine the current account and the valuation effects:

$$\left(F^{U\prime} - F^U\right)_{\text{BEA}} = CA^U + \left(VH_E^U + VH_A^U\right). \tag{6}$$

Comparing (5) and (6) clearly shows that the dynamics of net foreign assets are inconsistent in general. The notable exception is the case where net foreign assets are constant: $\left(F^{U\prime} - F^U\right)_{\text{BEA}} = \left(F^{U\prime} - F^U\right) = 0$. In this case, the trade flows, interest income, and valuation effects sum to zero, whether or not they are all multiplied by π.

The changes in the net foreign asset positions for each region are

$$0 = CA^U + \left(VH_E^U + VH_A^U\right), \tag{7}$$

$$0 = CA^E + \left(VH_E^E + VH_A^E\right) - \left(VL_E^E + VL_A^E\right), \tag{8}$$

$$0 = CA^A + \left(VH_E^A + VH_A^A\right) - \left(VL_E^A + VL_A^A\right). \tag{9}$$

demand for nontraded goods. The share π matters only in mapping the ensuing results into the dynamics of the various components of the international balance sheets.

3.4. Solution Method

Our solution method computes the various prices in a period based on the initial international balance sheets and structural parameters. The results are then mapped into the dynamics of the balance sheet to compute a new set of international assets and liabilities that underpin the solution for the following period.

Given an initial structure of assets and liabilities and initial nominal exchange rates, we can easily compute the net interest incomes in Box 1, equations (1) to (3). We then pick values for the U.S. and European current accounts in dollars, CA^U and CA^E, and the endowment of U.S. tradable goods, Y_T^U. The values of the various current account balances are not freely picked. As we aim for constant net asset positions, we iterate our procedure so the current accounts lead to constant positions. Similarly, the endowment of U.S. tradable goods is computed based on the current allocation (as in Obstfeld and Rogoff 2005) and then held constant.

Armed with the values for the U.S. and European current accounts, the net interest income, and the endowment of U.S. tradable goods, we compute the terms-of-trade $\tau_{U,A}$ and $\tau_{U,E}$, the relative prices of nontraded goods, x^U, x^E, and x^A, and the price of the U.S. tradable good, P_U. This is done by numerically solving a system including the market-clearing conditions, and the expression for the price of the U.S. tradable good. Having solved the various relative prices, the real and nominal exchange rates easily follow. Combining the nominal exchange rates with the ones taken from the previous period, we compute the valuation effects on assets and liabilities. Combining the trade flows, interest income, and valuation effects, we compute the dynamics of the balance sheets, using the scaling factor π. These new asset and liability positions serve as the basis for the solution in the following period.

Note that the dynamic dimension of our analysis comes solely through the dynamics of the international balance sheets. For instance, consumption is not computed from an intertemporal optimization but is given by the exogenous endowments and the current account, the latter being set by our assumption of the dynamics of net foreign assets.

4. Global Adjustment under Various Scenarios

Our parameter values are as in Cavallo and Tille (2006), and we follow Obstfeld and Rogoff (2005) as much as possible. We assume that half the gross trade flows map into financial flows ($\pi = 0.5$) as is the case in the United States currently (Figure 1). We consider two extensions: one with no accumulation of assets and liabilities beyond the current positions ($\pi = 0$), and one where the interest rate on U.S. liabilities, r^U, increases from 3.75 percent to 5 percent to match the world interest rate, r^W.

4.1. Static Scenarios

We start by briefly reviewing the results of Obstfeld and Rogoff (2005). They consider static scenarios in the sense that the current accounts in all countries return to zero immediately.[13] The first column of Table 2 shows the main results for their analysis. The top section indicates the real depreciation of the dollar against the other currencies, while the bottom section shows the effective real depreciations of the various currencies (the movements in nominal exchange rates are very similar).[14]

Column (a) in Table 2 shows a scenario that entirely abstracts from any valuation effect, that is, a scenario where all assets and liabilities are denominated in dollars. The global rebalancing of the world economy requires a sharp depreciation of the dollar of 38 percent in effective terms, mirrored mainly by a substantial yen appreciation. Obstfeld and Rogoff (2005) also consider valuation effects, a case presented in column (b) of Table 2. Their exact scenario still requires all current accounts to move to zero. The adjustment entails a substantial depreciation of the dollar. This, in turn, generates a substantial capital gain for the United States, with its net debt falling by 70 percent, mostly at the expense of Asia. This improves the net interest income of the United States, and the trade balance does not have to narrow as much in order to bring the current account into balance. This, in turn, reduces the required movement in the exchange rate. Obstfeld and Rogoff (2005) argue that the benefits from the valuation effect are secondary, as the dollar still has to depreciate by 33 percent.

4.2. A Dynamic Scenario

The limited impact of the valuation effect on the exchange rate in Obstfeld and Rogoff (2005) is a consequence of using the valuation gain to reduce the U.S. net debt while still requiring an immediate adjustment in the current account. This is only one of several possible uses of the valuation gains, and our analysis focuses on an alternative scenario where net international investment positions are held constant in all three regions. We regard this scenario as a reasonable alternative, as the U.S. net external debt has remained essentially unchanged in the last three years at a level that has so far proved manageable. In our scenario, the valuation effects stemming from exchange rate movements allow the various regions to run current account surpluses and deficits. These imbalances are financed by valuation gains and losses, keeping international investment positions constant, as shown by equations (7) to (9) in Box 2.

Our scenario highlights two dimensions of adjustment, namely the pace of adjustment and the ultimate movements in the various variables. Equation (4) in Box 1 shows that valuation effects require movements in nominal exchange rates. In the long run, once adjustment has run its course, the economy reaches a new steady state where all vari-

13. Obstfeld and Rogoff (2005) do not present their scenario as the adjustment taking place in one period, but rather in terms of comparing the current situation with a steady state where net positions are constant. However, as they abstract from any dynamics, their scenarios implicitly assume an immediate adjustment.

14. The numbers in Table 2 differ slightly from the ones presented in Obstfeld and Rogoff (2005), because we consider a structure of assets and liabilities in Table 2 that is slightly different from the one they use.

Table 2
Long-run Adjustment
(Percent, after Ten Periods)

	O&R global rebalancing		Dynamic adjustment	No gross financial flows	Convergence of interest rates
	without valuation (a)	with valuation (b)	(c)	(d)	(e)
Real depreciation of the dollar					
Against the euro	33.5	28.7	27.0	31.6	36.3
Against the yen	40.8	34.8	33.6	38.5	44.0
Effective real depreciations					
Dollar	38.4	32.7	31.4	36.2	41.4
Euro	–6.3	–5.5	–4.6	–6.0	–7.0
Yen	–24.1	–20.4	–20.1	–22.7	–25.8

Notes: O&R refers to Obstfeld and Rogoff (2005). O&R global rebalancing without valuation: all current accounts go to 0 in one period; initial positions are all in dollars. O&R global rebalancing with valuation: all current accounts go to 0 in one period; initial positions are listed in Table 1, Cavallo and Tille (2006). Dynamic adjustment: current accounts gradually go to zero, leaving the dollar value of net positions unchanged; initial positions are as in Table 1, Cavallo and Tille (2006). No gross financial flows: gross financial flows amount to 0, interest rate on U.S. liabilities remains at 3.75 percent. Convergence of interest rates: gross financial flows amount to 50 percent of corresponding gross trade flows, interest rate on U.S. liabilities increases to 5 percent from the first period.

ables, including nominal ones, are constant, since we assume that the central banks stabilize prices. Therefore there is no ongoing valuation in the long run, and equations (7) to (9) show that the current accounts are in balance. While our scenario still requires an ultimate balancing of current accounts, it can accommodate a gradual adjustment. This dimension is relevant in assessing whether the rebalancing of current account imbalances can be disruptive, as a sizable depreciation of the dollar is likely to be more benign if it is spread across several years than if it is concentrated in a short span.

4.2.1. Pace of Adjustment

The key feature of our alternative scenario is that the adjustment takes place at a much smoother pace than under the static scenarios. Figure 2 shows the paths of the various current accounts, expressed as percentages of the value of U.S. traded output. All current accounts eventually go to zero, as the economy reverts to a new steady state. The adjustment is quite gradual and spread over several periods (years). For instance, the U.S. current account deficit is only halved in the first three years.

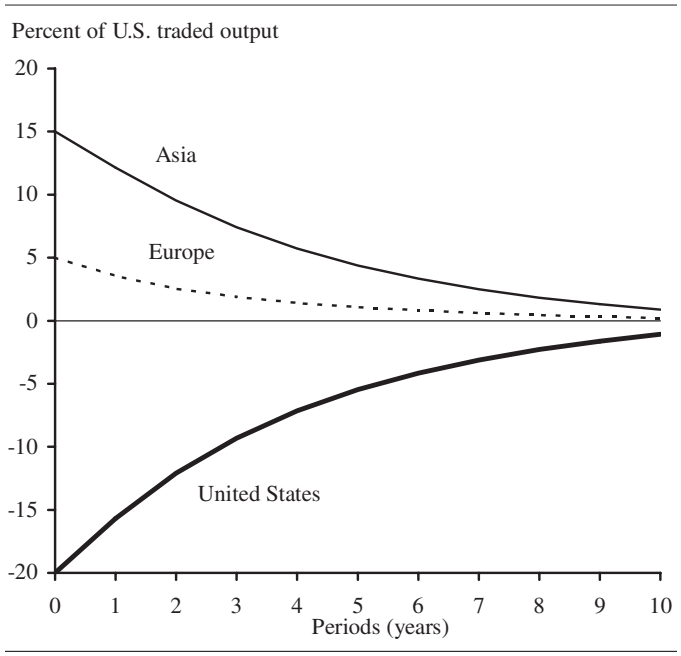
The smooth pattern of adjustment is also observed for exchange rates. Figure 3 shows the paths of bilateral and effective real exchange rates, expressed in percentage changes from initial levels. The dashed lines indicate the adjustment in the static scenario with valuation effect (column b of Table 2), while the solid lines show the adjustments under the dynamic scenario. The dynamic scenario's depreciation of the dollar clearly takes place at a gradual pace, against both the euro (panel A) and the yen (panel B) and in trade-weighted terms (panel D). For instance, the dollar depreciates by 8.6 percent in the first year (in trade-weighted terms), and 15 percent by the second year. A similar pattern of gradual adjustment is observed for the (moderate) appreciation of the euro (in trade-weighted terms, panel E) and the (substantial) appreciation of the yen (in trade-weighted terms, panel F).

Intuitively, the gradual nature of the adjustment reflects the use of valuation gains to finance international imbalances. The depreciation of the dollar leads to a sizable capital gain for the United States, which uses the proceeds to finance a trade deficit. While this mechanism can operate only temporarily because valuation gains eventually return to zero, it allows for a gradual decline in trade gaps. In the first year, the 8.6 percent depreciation of the dollar allows the United States to finance a current account deficit of 15.7 percent of its tradable output, which represents a narrowing by only 4.3 percentage points from the initial deficit. The 6.4 percent depreciation in the second year generates a smaller capital gain, with the current account deficit narrowing an additional 3.6 percentage points to 12.1 percent of U.S. tradable output. This pattern is repeated period after period, with the exchange rate ultimately stabilizing and the current account returning to balance.

4.2.2. Magnitude of Adjustment

In addition to the gradual nature of the adjustment, our dynamic scenario allows for a moderate reduction in its ulti-

FIGURE 2
CURRENT ACCOUNTS, BASELINE SCENARIO



mate magnitude. Column (c) of Table 2 shows the magnitude of depreciation in our dynamic scenario after ten periods. While the dollar still substantially depreciates, the magnitude is reduced to 31 percent. The depreciation of the dollar is therefore reduced by nearly one-fifth compared to the static scenario that ignores valuation effects (where the dollar depreciates by 38 percent). This magnitude is broadly consistent with the results in Gourinchas and Rey (2005), who find that valuation effects stemming from exchange rate movements account for one-third of the historical adjustment of U.S. external imbalances. Using a richer multi-country model, Helbling, Batini, and Cardarelli (2005) argue that higher financial integration facilitates the process of current account adjustment. Compared to the static case including valuation effects, our dynamic scenario shows a moderate dampening, with the depreciation of the dollar being reduced by 4 percent in effective terms.

4.2.3. The Impact on International Balance Sheets

Our adjustment scenario implies substantial valuation effects for international assets and liabilities. The substantial depreciation of the dollar results in a large capital gain for the United States, amounting to $1.8 trillion for the first ten years after the adjustment started. This comes essentially at the expense of Asia, which suffers a loss of $1.4 trillion, while Europe faces a moderate capital loss. The high exposure of Asia to capital loss is consistent with the findings of Higgins and Klitgaard (2004).

The combination of trade flows, interest income, and valuation effects leads to substantial movements in international balance sheets. While the net positions are unchanged by assumptions, the gross asset and liability positions essentially double over ten years.[15] This represents a sizable increase in leverage but is consistent with empirical evidence. Between 1994 and 2004, U.S. gross assets nearly doubled from 47 percent to 85 percent of GDP, while liabilities increased even more from 49 percent to 107 percent.

4.3. Sensitivity Analysis: Alternative Scenarios

We complete our baseline scenario by considering two extensions. In the first we assume that all gross financial flows are netted out ($\pi = 0$), so that gross assets and liabilities are held constant at their initial levels. This alternative with no gross financial flows illustrates the influence of the increase of gross positions on our results. In the second extension we assume that the U.S. exorbitant privilege disappears, with the interest rate on the low-return dollar bonds, r^U, immediately increasing to the world interest rate, r^W (this scenario holds π at 0.5). This second alternative with convergence of interest rates allows us to weight the gains from valuation effects against the interest burden of the U.S. net debt.

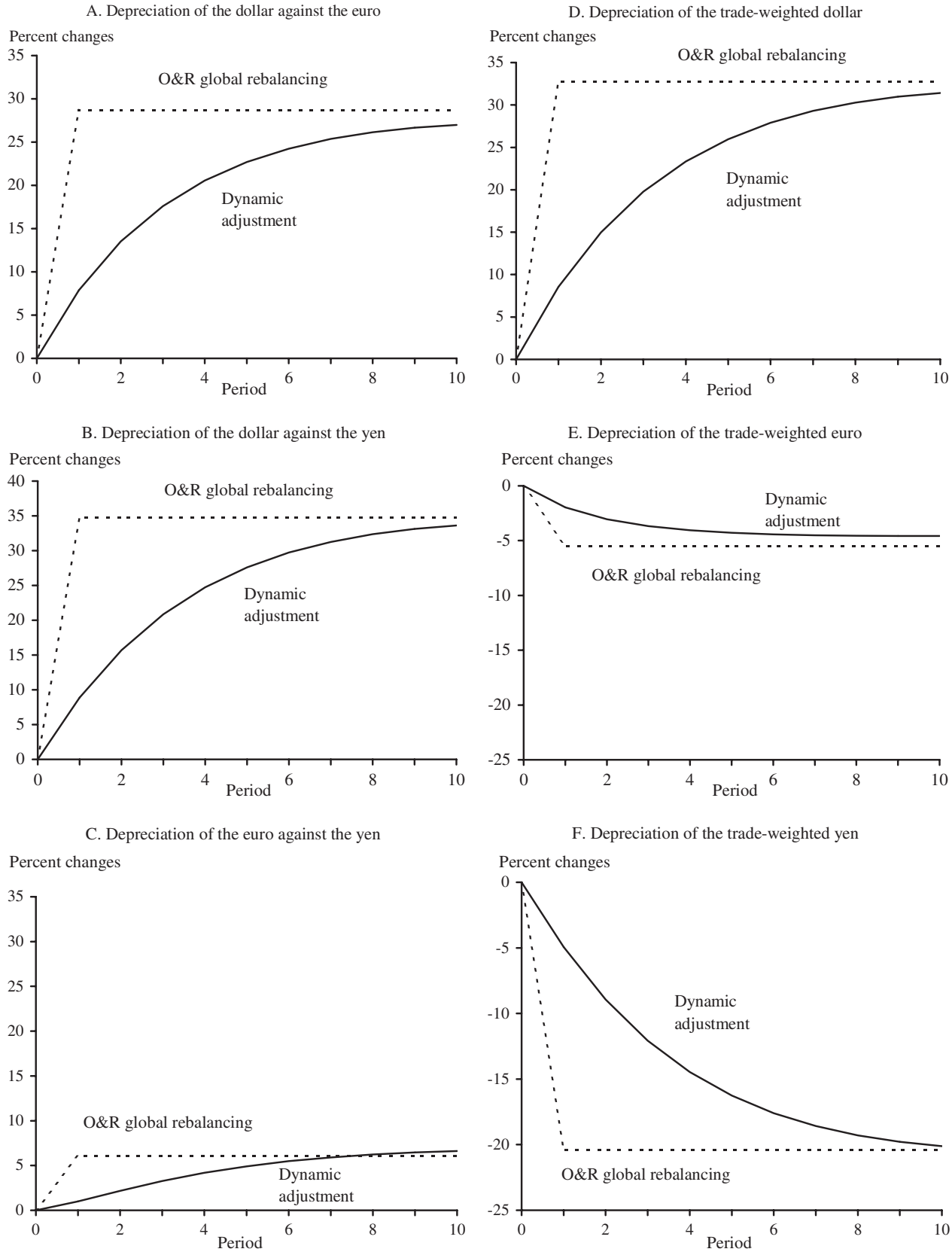
4.3.1. Pace and Magnitude of Adjustment

The gradual nature of the adjustment is observed across all scenarios, and, therefore, is robust to the alternatives. Adjustment is slower under interest rate convergence, but the gap is small and entirely reflects the jump in interest rate in the first period. The pace of exchange rate adjustment also remains gradual, although the ultimate magnitude of adjustment (after ten years) is sensitive to our alternatives. Column (d) of Table 2 shows the exchange rate movements under the alternative with no gross financial flows. The magnitude of adjustment is substantially increased, with the dollar depreciating by 36 percent in effective terms, an increase by one-sixth compared to the baseline scenario.

The magnitude of the ultimate adjustment is also sensitive to the path of interest rates, with exchange rate movements being larger under the alternative of convergence (column e). The dollar now depreciates by 41 percent in effective terms, a one-third increase compared to the baseline scenario. The sensitivity to interest rates goes beyond the

15. See Cavallo and Tille (2006) for details.

FIGURE 3
REAL EXCHANGE RATE MOVEMENTS



Note: Percent change refers to percent change from current situation. Periods are in years. O&R refers to Obstfeld and Rogoff (2005).

impact computed by Obstfeld and Rogoff (2005), who find that a convergence moderately increases the depreciation of the dollar vis-à-vis the euro (from 28.6 to 30.1 percent). This difference in our results reflects two aspects. First, Obstfeld and Rogoff (2005) assume that the convergence applies only to U.S. debt in short-duration bonds, which represents only 30 percent of U.S. liabilities. Second, our assumption that gross positions increase ($\pi > 0$) implies an increasing and costly leverage for the United States. This dimension is substantial, as the gross positions double under the alternative scenario.

4.3.2. The Composition of Adjustment

While the adjustment of the current account shows little difference across our baseline scenario and the two alternatives we consider, the components of the current account are more contrasted. Table 3 summarizes the overall adjustment over the ten periods we consider. The top section indicates the cumulative valuation gains for the three regions. Under the baseline adjustment (column a), the depreciation of the dollar leads to a $1.8 trillion capital gain for the United States, allowing it to finance a gradual rebalancing of the current account. The U.S. gain is mirrored primarily by a loss in Asia. The valuation effect is essentially unchanged in the absence of gross flows (column b). In the alternative with a convergence of interest rates, the valuation effects are magnified, amounting to $2.5 trillion, i.e., $0.7 trillion more than in the baseline scenario.

The valuation gains and losses exactly correspond to the cumulative current account under our assumption that net asset positions are constant. The cumulative current accounts are in turn the sum of net interest income and the trade balance, which are presented in the middle and bottom sections of Table 3. Under the baseline scenario, the United States benefits from net interest income, despite being a net debtor, because it earns a larger return on its assets than it pays on its liabilities. This interest transfer comes essentially at the expense of Europe, while the net assets of Asia are large enough to offset its earning a lower rate on its assets than it pays on its liabilities. As a result of this "exorbitant privilege," the United States can run a cumulative trade deficit ($2.2 trillion) that exceeds its cumulative current account deficit ($1.8 trillion). This limits the pressure on the exchange rate, which is driven primarily by the required adjustment in the trade balance.

The cumulative current accounts are essentially the same in the alternative with no financial flows: they are driven more by trade balances. The United States earns no net interest income, so the rebalancing requires a smaller trade deficit ($1.8 trillion) than under the baseline scenario ($2.2 trillion). In the absence of gross flows, the United States cannot increase its leverage between high-return assets and low-return liabilities, which limits its interest income. As more of the adjustment comes through the trade balance, the dollar depreciates more under this alternative.

While the United States runs a larger cumulative current account deficit in the alternative with interest rate convergence ($2.5 trillion) than in the baseline ($1.8 trillion), this is merely a reflection of the large movement of the exchange rate due to the interest burden of U.S. liabilities. The increase in the interest rate that the United States pays on these liabilities removes its "exorbitant privilege," and the net debt translates into substantial net interest payments. Compared to the baseline scenario, the United States pays $1.4 trillion in net interest. This represents a $1.8 trillion shift from the baseline scenario, where the United States was receiving a net interest income of $0.4 trillion. While the country benefits from a larger valuation gain ($2.5 trillion, compared to $1.8 trillion in the baseline), the extra gain is too small to offset the surge in the interest burden. The burden then requires a faster narrowing of the trade deficit, with the cumulative trade deficit amounting to $1.2 trillion, i.e., half of its value under the baseline case. The faster narrowing in the trade deficit requires a larger depreciation of the dollar. Note that the presence of valuation effects still smooths the adjustment. With the valuation effect, the difference in the trade balance from the baseline scenario ($1.0 trillion) amounts to 60

Table 3
Cumulative Flows and Valuation Gains
($ trillions)

	Baseline dynamic adjustment (a)	No gross financial flows (b)	Convergence of interest rates (c)
Cumulative valuation gain			
U.S.	1.82	1.80	2.52
Europe	–0.38	–0.36	–0.56
Asia	–1.44	–1.44	–1.96
Cumulative net interest income			
U.S.	0.41	0.00	–1.38
Europe	–0.52	–0.38	0
Asia	0.11	0.38	1.38
Cumulative trade balance			
U.S.	–2.23	–1.80	–1.15
Europe	0.89	0.74	0.56
Asia	1.33	1.06	0.59

Notes: All amounts represent total amounts between the initial period and period ten. Valuation gain: total amounts transferred through the valuation effect of exchange rate movements. Net interest income: total amounts transferred through interest receipts net of payments. Trade balance: total amounts transferred through exports net of imports.

percent of the additional interest payments ($1.8 trillion), while in the absence of these effects the trade balance would have to match the additional interest payments exactly. The sensitivity of U.S. external accounts to alternative scenarios for the returns on assets and liabilities is in line with the results of Higgins, Klitgaard, and Tille (2005).

5. Concluding Remarks

The rapidly widening U.S. current account deficit has received a lot of attention, with several economists pointing out that bringing the current account down to a more sustainable level could require a substantial, and possibly disruptive, depreciation of the dollar. This paper assesses how such an adjustment would be affected by the high degree of financial integration across countries. The main consequence of financial integration is the growing relevance of valuation effects, where exchange rate movements lead to sizable changes in the value of a country's assets and liabilities. We consider an adjustment scenario where current account imbalances are resorbed, and the net asset positions of the various countries are kept constant.

Our main finding is that high financial integration can potentially generate a "smooth landing" pattern, with a very gradual movement of the current accounts into balance. Focusing on the United States in our model, the depreciation of the dollar generates capital gains, which can be used to finance a narrowing current account deficit while keeping the net debt vis-à-vis the rest of the world unchanged. The pace of adjustment is an important feature of the rebalancing scenario. One of the main concerns in unwinding the current account imbalance is that the adjustment may prove sudden and disorderly, with foreign investors losing confidence in the United States, for instance. Obstfeld and Rogoff (2005) focus on the risk of a "hard landing," where the depreciation of the dollar that they calculate would take place in a fast and disruptive manner. While a 30 percent depreciation of the dollar in a single year could be disruptive for world markets, a similar movement spread over several years would be more manageable. Our scenario explores a situation in which the largest one-year depreciation of the dollar is less than 10 percent, a magnitude that can be absorbed by markets: in 2003 and 2004 the dollar depreciated by 12.2 and 8.2 percent (as measured by the major currency index published by the Federal Reserve Board of Governors),[16] a movement that proved manageable.

A sensitivity analysis shows that the gradual pace of adjustment, which is the central result of our analysis, remains robust to alternative scenarios. However, the magnitude of the exchange rate movements is larger if we limit gross financial flows, thereby limiting the leverage between assets and liabilities with different rates of return. The United States also benefits from earning a larger return on its assets than it pays on its liabilities, and removing this spread leads to a larger adjustment in the exchange rate.

A caveat to our setup is that the dynamic linkages remain quite simple, as we do not consider any intertemporal optimization by agents. Nevertheless, several studies, such as Blanchard et al. (2005), Helbling et al. (2005), and Faruqee et al. (2006), use richer models of the world economy and find a gradual adjustment to be a manageable alternative.

16. The values of the index are 105.98 (2002), 93.04 (2003), and 85.42 (2004). See http://www.federalreserve.gov/releases/g5a/current/.

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The Welfare Consequences of ATM Surcharges: Evidence from a Structural Entry Model

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John Krainer, *FRB San Francisco*

We estimate a structural model of the market for automatic teller machines (ATMs) in order to evaluate the implications of regulating ATM surcharges on ATM entry and consumer and producer surplus. We estimate the model using data on firm and consumer locations, and identify the parameters of the model by exploiting a source of local quasi-experimental variation, that the state of Iowa banned ATM surcharges during our sample period while the state of Minnesota did not. We develop new econometric methods that allow us to estimate the parameters of equilibrium models without computing equilibria. Monte Carlo evidence shows that the estimator performs well. We find that a ban on ATM surcharges reduces ATM entry by about 12 percent, increases consumer welfare by about 10 percent and lowers producer profits by about 10 percent. Total welfare remains about the same under regimes that permit or prohibit ATM surcharges and is about 17 percent lower than the surplus-maximizing level. This paper can help shed light on the theoretically ambiguous implications of free entry on consumer and producer welfare for differentiated products industries in general and ATMs in particular.

WP 2005-02

On Using Relative Prices to Measure Capital-Specific Technological Progress

Milton Marquis, *Florida State University*
Bharat Trehan, *FRB San Francisco*

Recently, Greenwood, Hercowitz and Krusell (GHK) have identified the relative price of (new) capital with capital-specific technological progress. In a two-sector growth model, however, the relative price of capital equals the ratio of the productivity processes in the two sectors. Restrictions from this model are used with data on wages and prices to construct measures of productivity growth and test the GHK identification, which is easily rejected by the data. This raises questions about various measures of the contribution that capital-specific technological progress might make to the economy. This identification also induces a negative correlation between the resulting measures of capital-specific and economy-wide technological change, which potentially explains why papers employing this identification find that capital-specific technological change accelerated in the mid-1970s. We impose structure on the productivity measures based on their long-run behavior and find evidence of a slowdown in productivity in the 1970s that is common to both sectors and an acceleration in the mid-1990s that is exclusive to the capital sector.

WP 2005-03

Government Consumption Expenditures and the Current Account

Michele Cavallo, *FRB San Francisco*

This paper distinguishes between two components of government consumption, expenditure on final goods and expenditure on hours, and compares the effects of changes in these two on the current account. I find that changes in government expenditure on hours do not directly affect the current account and that their impact is considerably smaller than the impact produced by changes in government expenditure on final goods. These findings indicate that considering government consumption as entirely expenditure on final goods leads to overestimating its role in accounting for movements in the current account balance.

WP 2005-04
Modeling Bond Yields in Finance and Macroeconomics

Francis X. Diebold, *University of Pennsylvania*
Monika Piazzesi, *University of Chicago*
Glenn D. Rudebusch, *FRB San Francisco*

Published in *American Economic Review Papers and Proceedings* 95(2) (May 2005), pp. 415–420.
See p. 60 for the abstract of this paper.

WP 2005-05
Offshore Financial Centers: Parasites or Symbionts?

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

This paper analyzes the causes and consequences of offshore financial centers (OFCs). Since OFCs are likely to be tax havens and money launderers, they encourage bad behavior in source countries. Nevertheless, OFCs may also have unintended positive consequences for their neighbors, since they act as a competitive fringe for the domestic banking sector. We derive and simulate a model of a home country monopoly bank facing a representative competitive OFC which offers tax advantages attained by moving assets offshore at a cost that is increasing in distance between the OFC and the source. Our model predicts that proximity to an OFC is likely to have pro-competitive implications for the domestic banking sector, although the overall effect on welfare is ambiguous. We test and confirm the predictions empirically. Proximity to an OFC is associated with a more competitive domestic banking system and greater overall financial depth.

WP 2005-06
Alternative Measures of the Federal Reserve Banks' Cost of Equity Capital

Michelle L. Barnes, *FRB Boston*
Jose A. Lopez, *FRB San Francisco*

Forthcoming in *Journal of Banking and Finance.*
See p. 59 for the abstract of this paper.

WP 2005-07
Exchange Rate Overshooting and the Costs of Floating

Michele Cavallo, *FRB San Francisco*
Kate Kisselev, *Citigroup*
Fabrizio Perri, *New York University*
Nouriel Roubini, *New York University*

Currency crises are usually associated with large nominal and real depreciations. In some countries depreciations are perceived to be very costly ("fear of floating"). In this paper we try to understand the reasons behind this fear. We first look at episodes of currency crises in the 1990s and establish that countries entering a crisis with high levels of foreign debt tend to experience large real exchange rate overshooting (devaluation in excess of the long-run equilibrium level) and large output contractions. We then develop a model of a small open economy that helps to explain this evidence. The key element of the model is the presence of a margin constraint on the domestic country. Real devaluations, by reducing the value of domestic assets relative to international liabilities, make countries with high foreign debt more likely to hit the constraint. When countries hit the constraint they are forced to sell domestic assets, and this causes a further devaluation of the currency (overshooting) and a reduction of their stock prices (overreaction). This fire sale can have a significant negative wealth effect. The model highlights a key tradeoff when considering fixed versus flexible exchange rate regimes; a fixed exchange regime can, by avoiding exchange rate overshooting, mitigate the negative wealth effect but at the cost of additional distortions and output drops in the short run. There are plausible parameter values under which fixed exchange rates dominate flexible exchange rates from a welfare perspective.

WP 2005-08
Beggar Thy Neighbor? The In-State vs. Out-of-State Impact of State R&D Tax Credits

Daniel Wilson, *FRB San Francisco*

In this paper, I exploit the cross-sectional and time-series variation in research and development (R&D) tax credits, and in turn the user cost of R&D, available from U.S. states between 1981 and 2002 to estimate the elasticity of private R&D with respect to both the within-state (internal) user cost and the out-of-state (external) user cost. To facilitate

comparisons to previous studies of the R&D cost elasticity, I first estimate an R&D cost elasticity omitting external R&D costs; the estimated elasticity is negative, above unity (in absolute value), and statistically significant—similar to previous findings based on alternative data. In contrast to previous studies, however, I then add the external R&D user cost to the regressions. I find the external-cost elasticity is positive and significant, raising concerns as to whether having state-level R&D tax credits on top of federal credits is socially desirable. Moreover, I find the aggregate R&D price elasticity—the difference between the internal- and external-cost elasticities—is far smaller than previously estimated. In fact, the preferred specification yields a zero aggregate elasticity, suggesting a zero-sum game among states and raising questions about the efficacy of R&D tax credits more broadly.

WP 2005-09

How Have Borrowers Fared in Banking Megamergers?

Kenneth A. Carow, *Indiana University*
Edward J. Kane, *Boston College*
Rajesh P. Narayanan, *Ohio University*

Previous studies of event returns surrounding bank mergers show that banks gain value in megamergers and additional value when they absorb in-market competitors. A portion of these gains has been traced to the increased bargaining power of banks vis-à-vis regulators and other competitors. We demonstrate that increased bargaining power of megabanks adversely affects loan customers of the acquired institution. Wealth losses are greater when loan customers are credit-constrained, the loan customer is smaller, or the acquisition is an in-market deal. These findings reinforce complaints that the ongoing consolidation in banking has unfavorably affected the availability of credit for smaller firms and especially capital-constrained firms.

WP 2005-10

Maintenance Expenditures and Indeterminacy under Increasing Returns to Scale

Jang-Ting Guo, *University of California, Riverside*
Kevin J. Lansing, *FRB San Francisco*

This paper develops a one-sector real business cycle model in which competitive firms allocate resources for the production of goods, investment in new capital, and maintenance of existing capital. Firms also choose the utilization rate of existing capital. A higher utilization rate leads to faster capital depreciation, while an increase in maintenance activity has the opposite effect. We show that, as the equilibrium ratio of maintenance expenditures to GDP rises, the required degree of increasing returns for local indeterminacy declines over a wide range of parameter combinations. When the model is calibrated to match empirical evidence on the relative size of maintenance and repair activity, we find that local indeterminacy (and belief-driven fluctuations) can occur with a mild and empirically plausible degree of increasing returns—around 1.08.

WP 2005-11

Collateral Damage: Trade Disruption and the Economic Impact of War

Reuven Glick, *FRB San Francisco*
Alan M. Taylor, *University of California, Davis*

Conventional wisdom in economic history suggests that conflict between countries can be enormously disruptive of economic activity, especially international trade. Yet nothing is known empirically about these effects in large samples. We study the effects of war on bilateral trade for almost all countries with available data extending back to 1870. Using the gravity model, we estimate the contemporaneous and lagged effects of wars on the trade of belligerent nations and neutrals, controlling for other determinants of trade. We find large and persistent impacts of wars on trade, and hence on national and global economic welfare. A rough accounting indicates that such costs might be of the same order of magnitude as the "direct" costs of war, such as lost human capital, as illustrated by case studies of World War I and World War II.

WP 2005-12

The IMF in a World of Private Capital Markets

Barry Eichengreen, *University of California, Berkeley*
Kenneth Kletzer, *University of California, Santa Cruz*
Ashoka Mody, *International Monetary Fund*

The IMF attempts to stabilize private capital flows to emerging markets by providing public monitoring and emergency finance. In analyzing its role we contrast cases where banks and bondholders do the lending. Banks have a

natural advantage in monitoring and creditor coordination, while bonds have superior risk-sharing characteristics. Consistent with this assumption, banks reduce spreads as they obtain more information through repeat transactions with borrowers. By comparison, repeat borrowing has little influence in bond markets, where publicly available information dominates. But spreads on bonds are lower when they are issued in conjunction with IMF-supported programs, as if the existence of a program conveyed positive information to bondholders. The influence of IMF monitoring in bond markets is especially pronounced for countries vulnerable to liquidity crises.

WP 2005-13

Tradability, Productivity, and Understanding International Economic Integration

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

This paper develops a two-country macro model with endogenous tradability to study features of international economic integration. Recent episodes of integration in Europe and North America suggest some surprising observations: while quantities of trade have increased significantly, especially along the extensive margin of goods previously not traded, price dispersion has not decreased and may even have increased. These observations challenge the usual understanding of integration in the literature. We propose a way of reconciling these price and quantity observations in a macroeconomic model where the decision of heterogeneous firms to trade internationally is endogenous. Trade is shaped both by the nature of heterogeneity—trade costs versus productivity—and by the nature of trade policies—cuts in fixed costs versus cuts in per unit costs like tariffs. For example, in contrast to tariff cuts, trade policies that work mainly by lowering various fixed costs of trade may have large effects on entry decisions at the extensive margin without having direct effects on price-setting decisions. Whether this entry raises or lowers price dispersion depends on the type of heterogeneity that distinguishes the new entrants from incumbent traders.

WP 2005-14

The Value of Knowledge Spillovers

Yi Deng, *Southern Methodist University*

This paper aims at quantifying the economic value of knowledge spillovers by exploring information contained in patent citations. I estimate a market valuation equation for semiconductor firms during the 1980s and 1990s and find an average value in the amount of 0.6 to 1.2 million "R&D-equivalent" dollars for the knowledge spillovers, as embodied in one patent citation. For an average semiconductor firm, such an estimate implies that the total value of knowledge spillovers the firm received during the sample period could be as high as half of its actual total R&D expenditures in the same period. This provides a direct measure of the economic values of the social returns or externalities of relevant technological innovations. I also find that the value of knowledge spillovers declines as the size of the firm's patent portfolio increases, and that self citations are more valuable than external citations, indicating a significant amount of tacit knowledge or know-how spillovers that occur within the firm.

WP 2005-15

Monetary Policy under Uncertainty in Micro-Founded Macroeconometric Models

Andrew T. Levin, *Federal Reserve Board of Governors*
Alexei Onatski, *Columbia University*
John C. Williams, *FRB San Francisco*
Noah Williams, *Princeton University*

We use a micro-founded macroeconometric modeling framework to investigate the design of monetary policy when the central bank faces uncertainty about the true structure of the economy. We apply Bayesian methods to estimate the parameters of the baseline specification using postwar U.S. data and then determine the policy under commitment that maximizes household welfare. We find that the performance of the optimal policy is closely matched by a simple operational rule that focuses solely on stabilizing nominal wage inflation. Furthermore, this simple wage stabilization rule is remarkably robust to uncertainty about the model parameters and to various assumptions regarding the nature and incidence of the innovations. However, the characteristics of optimal policy are very sensitive to the specification of the wage contracting mechanism, thereby highlighting the importance of additional research regarding the structure of labor markets and wage determination.

WP 2005-16

Government Employment Expenditure and the Effects of Fiscal Policy Shocks

Michele Cavallo, *FRB San Francisco*

Since World War II, about 75 percent of consumption expenditure by the U.S. government has consisted of wages and salaries for government employees. I distinguish between the goods and the employment expenditure components of government consumption in assessing the effects of fiscal shocks on the macroeconomy. Identifying exogenous fiscal shocks with the onset of military buildups, I show that they lead to a substantial increase in both the number of hours worked and output for the government. I also show that allowing for the distinction between the two main components of government consumption improves the quantitative performance of the neoclassical growth model. In particular, a neoclassical model economy with government employment does a good job of accounting for the dynamic response of private consumption to a fiscal policy shock. Government employment expenditure acts as a transfer payment for households, thereby dampening substantially the wealth effect on consumption and labor supply associated with fiscal shocks.

WP 2005-17

Monetary Policy with Imperfect Knowledge

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

We examine the performance and robustness of monetary policy rules when the central bank and the public have imperfect knowledge of the economy and continuously update their estimates of model parameters. We find that versions of the Taylor rule calibrated to perform well under rational expectations with perfect knowledge perform very poorly when agents are learning and the central bank faces uncertainty regarding natural rates. In contrast, difference rules, in which the change in the interest rate is determined by the inflation rate and the change in the unemployment rate, perform well when knowledge is both perfect and imperfect.

WP 2005-18

Accounting for the Secular "Decline" of U.S. Manufacturing

Milton Marquis, *Florida State University*
Bharat Trehan, *FRB San Francisco*

The share of employment in manufacturing as well as the relative price of manufactures has declined sharply over the postwar period, while the share of manufacturing output relative to GDP has remained roughly constant. Household preferences turn out to play a key role in reconciling this behavior with a closed-economy, two-sector model with differential rates of productivity growth. We show that the data imply that households are not willing to substitute between the two goods at all and also that this inference is independent of whatever the income elasticity of demand for services might be. Because we are unable to account for the entire decline in employment over this period, we expand the model to allow for manufactured exports. While this does not change our estimate of the elasticity of substitution, it does improve the model's ability to explain the decline in relative employment in the 1990s. However, larger errors in the 1970s remain unexplained.

WP 2005-19

Monetary Policy Inertia: Fact or Fiction?

Glenn D. Rudebusch, *FRB San Francisco*

Estimated monetary policy rules often appear to indicate a sluggish partial adjustment of the policy interest rate by the central bank. In fact, such evidence does not appear to be persuasive, since the illusion of monetary policy inertia may reflect spuriously omitted persistent influences on the setting of policy. Similarly, theoretical arguments do not provide a compelling case for real-world policy inertia. However, empirical evidence on the policy rule obtained by examining expectations of future monetary policy embedded in the term structure of interest rates is very informative and indicates that the actual amount of policy inertia is quite low.

WP 2005-20

Robust Control with Commitment: A Modification to Hansen-Sargent

Richard Dennis, *FRB San Francisco*

This paper studies robust control problems when policy is set with commitment. One contribution of the paper is to articulate an approximating equilibrium that differs importantly from that developed in Hansen and Sargent (2003). The paper illustrates how the proposed approximating equilibrium differs from Hansen-Sargent in the context of two New Keynesian business cycle models. A further contribution of the paper is to show that once misspecification is acknowledged, commitment is no longer necessarily superior to discretion.

WP 2005-21

Trend Breaks, Long-Run Restrictions, and the Contractionary Effects of Technology Improvements

John Fernald, *FRB San Francisco*

Structural vector autoregressions (VARs) with long-run restrictions are extraordinarily sensitive to low-frequency correlations. This paper explores this sensitivity analytically and via simulations, focusing on the contentious issue of whether hours worked rise or fall when technology improves. Recent literature finds that when hours per person enter the VAR in levels, hours rise; when they enter in differences, hours fall. However, once one allows for (statistically and economically plausible) trend breaks in productivity, the treatment of hours is relatively unimportant: Hours fall sharply on impact following a technology improvement. The issue is the common high-low-high pattern of hours per capita and productivity growth since World War II. Such low-frequency correlation almost inevitably implies a positive estimated impulse response. The trend breaks control for this correlation. In addition, the specification with breaks can easily "explain" (or encompass) the positive estimated response when the breaks are omitted; in contrast, the no-breaks specification has more difficulty explaining the negative response when breaks are included. More generally, this example suggests a need for care in applying the long-run restrictions approach.

WP 2005-22

Empirical Analysis of the Average Asset Correlation for Real Estate Investment Trusts

Jose A. Lopez, *FRB San Francisco*

The credit risk capital requirements within the current Basel II Accord are based on the asymptotic single risk factor (ASRF) approach. The asset correlation parameter, defined as an obligor's sensitivity to the ASRF, is a key driver within this approach, and its average values for different types of obligors are to be set by regulators. Specifically, for commercial real estate (CRE) lending, the average asset correlations are to be determined using formulas for either income-producing real estate or high-volatility commercial real estate. In this paper the value of this parameter was empirically examined using portfolios of U.S. publicly traded real estate investment trusts (REITs) as a proxy for CRE lending more generally. CRE lending as a whole was found to have the same calibrated average asset correlation as corporate lending, providing support for the recent U.S. regulatory decision to treat these two lending categories similarly for regulatory capital purposes. However, the calibrated values for CRE categories, such as multifamily residential or office lending, varied in important ways. The comparison of calibrated and regulatory values of the average asset correlations for these categories suggests that the current regulatory formulas generate parameter values that may be too high in most cases.

WP 2005-23

Markov-Perfect Industry Dynamics with Many Firms

Gabriel Weintraub, *Stanford University*
C. Lanier Benkard, *Stanford University*
Benjamin Van Roy, *Stanford University*

We propose an approximation method for analyzing Ericson and Pakes (1995)-style dynamic models of imperfect competition. We develop a simple algorithm for computing an "oblivious equilibrium," in which each firm is assumed to make decisions based only on its own state and knowledge of the long-run average industry state, but where firms ignore current information about competitors' states. We prove that, as the market becomes large, if the equilibrium distribution of firm states obeys a certain "light-tail" condition, then oblivious equilibria closely approximate Markov-perfect equilibria. We develop bounds that can be computed to assess the accuracy of the approx-

imation for any given applied problem. Through computational experiments, we find that the method often generates useful approximations for industries with hundreds of firms and in some cases even tens of firms.

WP 2005-24

Optimal Nonlinear Policy: Signal Extraction with a Non-Normal Prior

Eric Swanson, *FRB San Francisco*

Forthcoming in *Journal of Economic Dynamics and Control.*
See p. 62 for the abstract of this paper.

WP 2005-25

Why Has the U.S. Beveridge Curve Shifted Back? New Evidence Using Regional Data

Robert G. Valletta, *FRB San Francisco*

The Beveridge curve depicts the empirical relationship between job vacancies and unemployment, which in turn reflects the underlying efficiency of the job matching process. Previous analyses of the Beveridge curve suggested deterioration in match efficiency during the 1970s and early 1980s, followed by improved match efficiency beginning in the late 1980s. This paper combines aggregate and regional data on job vacancies and unemployment to estimate the U.S. aggregate and regional Beveridge curves, focusing on the period 1976–2005. Using new data on job vacancies from the U.S. Bureau of Labor Statistics, the help-wanted advertising series that formed the basis of past work are modified to form synthetic job vacancy series at the national and regional levels. The results suggest that a decline in the dispersion of employment growth across geographic areas contributed to a pronounced inward shift in the Beveridge curve since the late 1980s, reversing the earlier pattern identified by Abraham (1987) and reinforcing findings of favorable labor market trends in the 1990s (e.g., Katz and Krueger 1999).

WP 2005-26

Macroeconomic Derivatives: An Initial Analysis of Market-Based Macro Forecasts, Uncertainty, and Risk

Refet Gürkaynak, *Bilkent University, Ankara, Turkey*
Justin Wolfers, *University of Pennsylvania*

In September 2002, a new market in "economic derivatives" was launched, allowing traders to take positions on future values of several macroeconomic data releases. We provide an initial analysis of the prices of these options. We find that market-based measures of expectations are similar to survey-based forecasts, although the market-based measures somewhat more accurately predict financial market responses to surprises in data. These markets also provide implied probabilities of the full range of specific outcomes, allowing us to measure uncertainty, assess its driving forces, and compare this measure of uncertainty with the dispersion of point-estimates among individual forecasters (a measure of disagreement). We also assess the accuracy of market-generated probability density forecasts. A consistent theme is that few of the behavioral anomalies present in surveys of professional forecasts survive in equilibrium, and that these markets are remarkably well calibrated. Finally we assess the role of risk, finding little evidence that risk-aversion drives a wedge between market prices and probabilities in this market.

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

Optimal Policy in Rational Expectations Models: New Solution Algorithms

Richard Dennis

Forthcoming in
Macroeconomic Dynamics.

This paper develops methods to solve for optimal discretionary policies and optimal commitment policies in rational expectations models. These algorithms, which allow the optimization constraints to be expressed conveniently in second-order structural form, are more general than existing methods and are simple to apply. I use several New Keynesian business cycle models to illustrate their application. Simulations show that the procedures developed in this paper can quickly solve small-scale models and that they can be usefully and effectively applied to medium- and large-scale models.

How Important Is Precommitment for Monetary Policy?

Richard Dennis, with
Ulf Söderström,
Università Bocconi, Milan

Forthcoming in
Journal of Money, Credit, and Banking.

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.

When Do Matched-Model and Hedonic Techniques Yield Similar Price Measures?

Mark Doms, with
Ana Aizcorbe,
Federal Reserve Board of Governors
Carol Corrado,
Federal Reserve Board of Governors

Forthcoming in conference volume,
SSHRC International Conference on Index Number Theory and the Measurement of Prices and Productivity.

Hedonic techniques were developed to control for quality differences across goods and over time in order to construct constant-quality aggregate price measures. When the available data are a panel of high-frequency data on models whose characteristics are constant over time, matched-model price indexes can also be used to obtain constant-quality price measures. We show this by demonstrating that, given data of this type, certain matched-model indexes yield price measures that are numerically close to those obtained using hedonic techniques.

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

Prices for Local Area Network Equipment

Mark Doms, with
Christopher Forman,
Carnegie Mellon University

Published in *Information Economics and Policy* 17(3) (July 2005), pp. 365–388.

In this paper we examine quality-adjusted prices for local area network (LAN) equipment. Hedonic regressions are used to estimate price changes for the two largest classes of LAN equipment, routers and switches. A matched model was used for LAN cards, and the prices for hubs were inferred by using an economic relationship to switches. Overall, we find that prices for the four groups of LAN equipment fell at a 17 percent annual rate between 1995 and 2000. These results stand in sharp contrast to the producer price index for communications equipment that is nearly flat over the 1990s.

Are Technology Improvements Contractionary?

John Fernald, with
Susanto Basu, *University of Michigan*
Miles Kimball, *University of Michigan*

Forthcoming in
American Economic Review.

Yes. We construct a measure of aggregate technology change, controlling for varying utilization of capital and labor, nonconstant returns and imperfect competition, and aggregation effects. On impact, when technology improves, input use and nonresidential investment fall sharply. Output changes little. With a lag of several years, inputs and investment return to normal and output rises strongly. We discuss what models could be consistent with this evidence. For example, standard one-sector real business cycle models are not, since they generally predict that technology improvements are expansionary, with inputs and (especially) output rising immediately. However, the evidence is consistent with simple sticky-price models, which predict the results we find: When technology improves, input use and investment demand generally fall in the short run, and output itself may also fall.

Military Expenditure, Threats, and Growth

Reuven Glick, with
Joshua Aizenman,
University of California, Santa Cruz

Forthcoming in *Journal of International Trade and Development.*

This paper clarifies one of the puzzling results of the economic growth literature: the impact of military expenditure is frequently found to be nonsignificant or negative, yet most countries spend a large fraction of their GDP on defense and the military. We start by empirical evaluation of the nonlinear interactions between military expenditure, external threats, corruption, and other relevant controls. While growth falls with higher levels of military spending, given the values of the other independent variables, we show that military expenditure in the presence of threats increases growth. We explain the presence of these nonlinearities in an extended version of Barro and Sala-i-Martin (1995), allowing the dependence of growth on the severity of external threats, and on the effective military expenditure associated with these threats.

Productivity, Tradability, and the Long-Run Price Puzzle

Reuven Glick, with
Paul Bergin,
University of California, Davis
Alan M. Taylor,
University of California, Davis

Forthcoming in
Journal of Monetary Economics.

Long-run cross-country price data exhibit a puzzle. Today, richer countries exhibit higher price levels than poorer countries, a stylized fact usually attributed to the "Balassa-Samuelson" effect. But looking back 50 years or more, this effect virtually disappears from the data. What is often assumed to be a universal property is actually quite specific to recent times. What might explain this historical pattern? We adopt a framework where goods are differentiated by tradability and productivity. A model with monopolistic competition, a continuum-of-goods, and endogenous tradability allows for theory and history to be consistent for a wide range of underlying productivity shocks.

Currency Crises, Capital Account Liberalization, and Selection Bias

Reuven Glick, with
Xueyan Guo,
University of California, Santa Cruz
Michael Hutchison,
University of California, Santa Cruz

Forthcoming in
Review of Economics and Statistics.

Are countries with unregulated capital flows more vulnerable to currency crises? Efforts to answer this question properly must control for "self selection" bias since countries with liberalized capital accounts may also have more sound economic policies and institutions that make them less likely to experience crises. We employ a matching and propensity score methodology to address this issue in a panel analysis of developing countries. Our results suggest that, after controlling for sample selection bias, countries with liberalized capital accounts experience a lower likelihood of currency crises. That is, when two countries have the same likelihood of allowing free movement of capital (based on historical evidence and a very similar set of economic and political characteristics)—and one country imposes controls and the other does not—the country without controls has a lower likelihood of experiencing a currency crisis.

Capital Controls and Exchange Rate Instability in Developing Countries

Reuven Glick, with
Michael Hutchison,
University of California, Santa Cruz

Published in *Journal of International Money and Finance* 24(3) (April 2005), pp. 387–412.

A large literature on the appropriate sequencing of financial liberalization suggests that removing capital controls prematurely may contribute to currency instability. This paper investigates whether legal restrictions on international capital flows are associated with greater currency stability. We employ a comprehensive panel data set of 69 developing economies over the 1975–1997 period, identifying 160 currency crises. We control for macroeconomic, political, and institutional characteristics that influence the probability of a currency crisis, employ alternative measures of restrictions on international payments, and account for possible joint causality between the likelihood of a currency attack and the imposition of capital controls. We find evidence that restrictions on capital flows do not effectively insulate economies from currency problems; rather, countries with less restrictive capital controls and more liberalized regimes appear to be less prone to speculative attacks.

House Prices and Consumer Welfare

John Krainer, with
Patrick Bajari, *University of Michigan*
C. Lanier Benkard, *Stanford University Graduate School of Business*

Published in *Journal of Urban Economics* 58(3) (November 2005) pp. 474–487.

We develop a new approach to measuring changes in consumer welfare due to changes in the price of owner-occupied housing. In our approach, an agent's welfare adjustment is defined as the transfer required to keep expected discounted utility constant given a change in current home prices. We demonstrate that, up to a first-order approximation, there is no aggregate change in welfare due to price increases in the existing housing stock. This follows from a simple market clearing condition where capital gains experienced by sellers are exactly offset by welfare losses to buyers. Welfare losses can occur, however, from price increases in new construction and renovations. We show that this result holds (approximately) even in a model that accounts for changes in consumption and investment plans prompted by current price changes. We estimate the welfare cost of house price appreciation to be an average of $127 per household per year over the 1984–1998 period.

Lock-in of Extrapolative Expectations in an Asset Pricing Model

Kevin J. Lansing

Forthcoming in *Macroeconomic Dynamics.*

This paper examines an agent's choice of forecast method within a standard asset pricing model. To make a conditional forecast, a representative agent may choose one of the following: (1) a rational (or fundamentals-based) forecast that employs knowledge of the stochastic process governing dividends, (2) a constant forecast based on a simple long-run average of the forecast variable, or (3) a time-varying forecast that extrapolates from the last observation of the forecast variable. I show that a representative agent who is concerned about minimizing forecast errors may inadvertently become "locked in" to an extrapolative forecast. In particular, the initial use of extrapolation alters the law of motion of the forecast variable so that the agent perceives no accuracy gain from switching to one of the alternative forecast methods. Under extrapolative expectations, the model can generate excess volatility of stock prices, time-varying volatility of returns, long-horizon predictability of returns, bubbles driven by optimism about the future, and sharp downward movements in stock prices that resemble market crashes. All of these features appear to be present in long-run U.S. stock market data.

Exchange Rate Cointegration across Central Bank Regime Shifts

Jose A. Lopez

Published in *Research in Finance,* ed. A.H. Chen, volume 22 (2005) pp. 327–356.

Foreign exchange rates are examined using cointegration tests over various time periods linked to regime shifts in central bank behavior. The number of cointegrating vectors varies across these regime changes within the foreign exchange market. For example, cointegration is generally not found prior to the Plaza Agreement of September 22, 1985, but it is present after that date. The significance of these changes is tested using a likelihood ratio procedure proposed by Quintos (1997). The changing nature of these cointegrating relationships indicate that certain types of central bank activity do have long-term effects on exchange rates.

Alternative Measures of the Federal Reserve Banks' Cost of Equity Capital

Jose A. Lopez, with
Michelle Barnes, *FRB Boston*

Forthcoming in
Journal of Banking and Finance.

The Monetary Control Act of 1980 requires the Federal Reserve System to provide payment services to depository institutions through the 12 Federal Reserve Banks at prices that fully reflect the costs a private-sector provider would incur, including a cost of equity capital (COE). Although Fama and French (1997) conclude that COE estimates are "woefully" and "unavoidably" imprecise, the Reserve Banks require such an estimate every year. We examine several COE estimates based on the capital asset pricing model (CAPM) and compare them using econometric and materiality criteria. Our results suggest that the benchmark CAPM applied to a large peer group of competing firms provides a COE estimate that is not clearly improved upon by using a narrow peer group, introducing additional factors into the model, or taking account of additional firm-level data, such as leverage and line-of-business concentration. Thus, a standard implementation of the benchmark CAPM provides a reasonable COE estimate, which is needed to impute costs and set prices for the Reserve Banks' payments business.

Evaluating Interest Rate Covariance Models within a Value-at-Risk Framework

Jose A. Lopez, with
Miguel Ferreira,
ISCTE Business School, Lisbon

Published in *Journal of Financial Econometrics* 2005 3(1) (Winter 2005) pp. 126–168.

A key component of managing international interest rate portfolios is forecasts of the covariances between national interest rates and accompanying exchange rates. How should portfolio managers choose among the large number of covariance forecasting models available? We find that covariance matrix forecasts generated by models incorporating interest-rate level volatility effects perform best with respect to statistical loss functions. However, within a value-at-risk (VaR) framework, the relative performance of the covariance matrix forecasts depends greatly on the VaR distributional assumption, and forecasts based just on weighted averages of past observations perform best. In addition, portfolio variance forecasts that ignore the covariance matrix generate the lowest regulatory capital charge, a key economic decision variable for commercial banks. Our results provide empirical support for the commonly used VaR models based on simple covariance matrix forecasts and distributional assumptions.

Assessing the Lucas Critique in Monetary Policy Models

Glenn D. Rudebusch

Published in *Journal of Money, Credit, and Banking* 37(2) (April 2005), pp. 245–272.

Empirical estimates of monetary policy rules suggest that the behavior of U.S. monetary policymakers changed during the past few decades. However, for that same time period, 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 reconciles these results with the Lucas critique 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.

Modeling Bond Yields in Finance and Macroeconomics

Glenn D. Rudebusch, with
Francis X. Diebold,
University of Pennsylvania
Monika Piazzesi, *University of Chicago*

Published in *American Economic Review Papers and Proceedings* 95(2) (May 2005), pp. 415–420.

From a macroeconomic perspective, the short-term interest rate is a policy instrument under the direct control of the central bank, which adjusts the rate to achieve its economic stabilization goals. From a finance perspective, the short rate is a fundamental building block for yields of other maturities, which are just risk-adjusted averages of expected future short rates. Thus, as illustrated by much recent research, a joint macro-finance modeling strategy will provide the most comprehensive understanding of the term structure of interest rates. In this paper, we discuss some salient questions that arise in this research, and we also present a new examination of the relationship between two prominent dynamic, latent factor models in this literature: the Nelson-Siegel and affine no-arbitrage term-structure models.

Using a Long-Term Interest Rate as the Monetary Policy Instrument

Glenn D. Rudebusch and
John C. Williams, with
Bruce McGough,
Oregon State University

Published in *Journal of Monetary Economics* 52(5) (July 2005), pp. 855–879.

Using a short-term interest rate as the monetary policy instrument can be problematic near its zero-bound constraint. An alternative strategy is to use a long-term interest rate as the policy instrument. We find when Taylor-type policy rules are used to set the long rate in a standard New Keynesian model, indeterminacy—that is, multiple rational expectations equilibria—may often result. However, a policy rule with a long rate policy instrument that responds in a "forward-looking" fashion to inflation expectations can avoid the problem of indeterminacy.

Accounting for a Shift in Term Structure Behavior with No-Arbitrage and Macro-Finance Models

Glenn D. Rudebusch and
Tao Wu

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

This paper examines a shift in the dynamics of the term structure of interest rates in the U.S. during the mid-1980s. We document this shift using standard interest rate regressions and using dynamic, affine, no-arbitrage models estimated for the pre- and post-shift subsamples. The term structure shift largely appears to be the result of changes in the pricing of risk associated with a "level" factor. Using a macro-finance model, we suggest a link between this shift in term structure behavior and changes in the dynamics and risk pricing of the Federal Reserve's inflation target as perceived by investors.

Solvency Runs, Sunspot Runs, and International Bailouts

Mark M. Spiegel

Published in *Journal of International Economics* 65(1) (January 2005), pp. 203–219.

This paper introduces a model of intervention by an international financial institution (IFI) under asymmetric information. The IFI is unable to distinguish between runs due to fundamentals and those which are the result of pure sunspots. However, it maximizes global welfare by offering a relending package consistent with generating a separating equilibrium, where voluntary creditor participation implies that underlying fundamentals are good. The need for direct IFI lending in the package is shown to depend on the commitment capacity of creditors. This adverse selection problem provides an alternative rationale for Bagehot's principle of last-resort lending at high rates of interest to the moral hazard motivation commonly found in the literature.

Institutional Efficiency, Monitoring Costs, and the Investment Share of FDI

Mark M. Spiegel, with Joshua Aizenman, *University of California, Santa Cruz*

Forthcoming in *Review of International Economics.*

This paper models and tests the implications of institutional efficiency on the pattern of foreign direct investment (FDI). We posit that domestic agents have a comparative advantage over foreign agents in overcoming some of the obstacles associated with corruption and weak institutions. We model these circumstances in a principal-agent framework with costly ex post monitoring and enforcement of an ex ante labor contract. Ex post monitoring and enforcement costs are assumed to be lower for domestic entrepreneurs than for foreign ones, but foreign producers enjoy a countervailing productivity advantage. Under these asymmetries, multinationals pay higher wages than domestic producers, in line with the insight of efficiency wages and with the evidence about the "multinationals wage premium." FDI is also more sensitive to increases in enforcement costs. We then test this prediction for a cross section of developing countries. We use Mauro's (1995) index of institutional efficiency as an indicator of the strength of property rights enforcement within a given country. We compare institutional efficiency levels for a large cross section of countries in 1989 to subsequent FDI flows from 1990 to 1999. We find that institutional efficiency is positively associated with the ratio of subsequent foreign direct investment flows to both gross fixed capital formation and to private investment. This finding is true for both simple cross sections and for cross sections weighted by country size.

Have Increases in Federal Reserve Transparency Improved Private Sector Forecasts of Short-Term Interest Rates?

Eric T. Swanson

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

Yes. This paper shows that, since the late 1980s, U.S. financial markets and private sector forecasters have become: (1) better able to forecast the federal funds rate at horizons out to several months, (2) less surprised by Federal Reserve announcements, (3) more certain of their interest rate forecasts ex ante, as measured by interest rate options, and (4) less diverse in the cross-sectional variety of their interest rate forecasts. I also present evidence that strongly suggests increases in Federal Reserve transparency played a role: for example, private sector forecasts of GDP and inflation have not experienced similar improvements over the same period, indicating that the improvement in interest rate forecasts has been special.

Optimal Nonlinear Policy: Signal Extraction with a Non-Normal Prior

Eric T. Swanson

Published in *Journal of Economic Dynamics and Control* 30(2) (February 2006), pp. 185–203.

The literature on optimal monetary policy typically makes three major assumptions: (1) policymakers' preferences are quadratic, (2) the economy is linear, and (3) stochastic shocks and policymakers' prior beliefs about unobserved variables are normally distributed. This paper relaxes the third assumption and explores its implications for optimal policy. The separation principle continues to hold in this framework, allowing for tractability and application to forward-looking models, but policymakers' beliefs are no longer updated in a linear fashion, allowing for plausible nonlinearities in optimal policy. I consider in particular a class of models in which policymakers' priors about the natural rate of unemployment are diffuse in a region around the mean. When this is the case, optimal policy responds cautiously to small surprises in the observed unemployment rate, but becomes increasingly aggressive at the margin. These features match statements by Federal Reserve officials and the behavior of the Fed in the 1990s.

Inflation Targeting and the Anchoring of Inflation Expectations in the Western Hemisphere

Eric T. Swanson, with
Refet Gürkaynak,
Bilkent University, Ankara, Turkey
Andrew Levin,
Federal Reserve Board of Governors
Andrew Marder,
Federal Reserve Board of Governors

Forthcoming in *Series on Central Banking, Analysis and Economic Policies X: Monetary Policy under Inflation Targeting,* eds. Frederic Mishkin and Klaus Schmidt-Hebbel. Santiago, Chile: Banco Central de Chile.

We investigate the extent to which long-run inflation expectations are well anchored in three Western Hemisphere countries—Canada, Chile, and the United States—using a high-frequency event-study analysis. Specifically, we use daily data on far-ahead forward inflation compensation—the difference between forward rates on nominal and inflation-indexed bonds—as an indicator of financial market perceptions of inflation risk and the expected level of inflation at long horizons. For the United States, we find that far-ahead forward inflation compensation reacts significantly to macroeconomic data releases, suggesting that long-run inflation expectations are not completely anchored. In contrast, the Canadian inflation compensation data do not exhibit significant sensitivity to either Canadian or U.S. macroeconomic news, suggesting that inflation targeting in Canada has been successful in anchoring long-run inflation expectations. Finally, while the requisite data for Chile is available for only a limited sample period (2002–2005), our results are consistent with the hypothesis that inflation targeting in Chile has also succeeded in anchoring long-run inflation expectations.

Do Actions Speak Louder Than Words? The Response of Asset Prices to Monetary Policy Actions and Statements

Eric T. Swanson, with
Refet Gürkaynak,
Bilkent University, Ankara, Turkey
Brian Sack,
Federal Reserve Board of Governors

Published in *International Journal of Central Banking* 1(1) (May 2005), pp. 55–93.

We investigate the effects of U.S. monetary policy on asset prices using a high-frequency event-study analysis. We test whether these effects are adequately captured by a single factor—changes in the federal funds rate target—and find that they are not. Instead, we find that two factors are required. These factors have a structural interpretation as a "current federal funds rate target" factor and a "future path of policy" factor, with the latter closely associated with Federal Open Market Committee statements.We measure the effects of these two factors on bond yields and stock prices using a new intraday data set going back to 1990. According to our estimates, both monetary policy actions and statements have important but differing effects on asset prices, with statements having a much greater impact on longer-term Treasury yields.

The Sensitivity of Long-Term Interest Rates: Evidence and Implications for Macroeconomic Models

Eric T. Swanson, with
Refet Gürkaynak,
Bilkent University, Ankara, Turkey
Brian Sack,
Federal Reserve Board of Governors

Published in *American Economic Review* 95(1) (March 2005), pp. 425–436.

This paper demonstrates that long-term forward interest rates in the United States often react considerably to surprises in macroeconomic data releases and monetary policy announcements. This behavior is in contrast to the prediction of many macroeconomic models, in which the long-run properties of the economy are assumed to be time-invariant and perfectly known by all economic agents: Under those assumptions, the shocks we consider would have only transitory effects on short-term interest rates, and hence would not generate large responses in forward rates. Our empirical findings suggest that private agents adjust their expectations of the long-run inflation rate in response to macroeconomic and monetary policy surprises. We present an alternative model that captures this behavior. Consistent with our hypothesis, forward rates derived from inflation-indexed Treasury debt show little sensitivity to these shocks, indicating that the response of nominal forward rates is mostly driven by inflation compensation.

Implications of Intellectual Property Rights for Dynamic Gains from Trade

Diego Valderrama, with
Michelle Connolly, *Duke University*

Published in *American Economic Review Papers and Proceedings* 95(2) (May 2005), pp. 318–322.

This article focuses on the implications of intellectual property rights (IPR) for dynamic gains from trade. IPR were introduced into a North-South model of technological diffusion through trade and imitation. The model explicitly considers positive spillovers from innovation in the North to imitative research in the South through exposure to trade. These spillovers, in combination with feedback effects between innovating Northern and imitating Southern firms, implies that welfare in both regions depends on how IPR affect world growth. Rather than finding that increasing IPR protection in the South always increases Northern welfare at the expense of the South, it was found out that properly designed Southern IPR are welfare-enhancing for both regions, especially during Southern trade liberalization. Similarly, poorly designed IPR are welfare-decreasing for both regions.

A Submerging Labor Market Institution? Unions and the Nonwage Aspects of Work

Robert G. Valletta, with
Thomas Buchmueller,
University of California, Irvine
John DiNardo, *University of Michigan*

Published in *Emerging Labor Market Institutions for the 21st Century,* eds. R. Freeman, J. Hersch, and L. Mishel, pp. 231–263. Chicago: NBER and University of Chicago Press, 2005.

Using data from a variety of different sources and straightforward econometric methods, we investigate the differences between union and nonunion jobs. Despite the substantial decline in union membership and collective bargaining over the last 20 years, union jobs continue to differ from comparable nonunion jobs in regard to readily observable nonwage characteristics. In general, union workers work fewer hours per week and fewer weeks per year, and they spend more time on vacation and more time away from work due to their own illness or the illness of a family member. They also are more likely to be offered and to be covered by employer-provided health insurance, more likely to receive retiree health benefits from their employer, more likely to be offered and to be covered by a pension plan, and more likely to receive dental insurance, long-term disability plans, paid sick leave, maternity leave, and paid vacation time. The size of some of these gaps, however, appears to have declined over time.

Robust Estimation and Monetary Policy with Unobserved Structural Change

John C. Williams

Published in *Models and Monetary Policy: Research in the Tradition of Dale Henderson, Richard Porter, and Peter Tinsley,* eds. J. Faust, A. Orphanides, and D. Reifschneider, pp. 53–81. Washington, DC: Board of Governors of the Federal Reserve System, 2005.

This paper considers the joint problem of model estimation and implementation of monetary policy in the face of uncertainty regarding the process of structural change in the economy. I model unobserved structural change through time variation in the natural rates of interest and unemployment. I show that certainty equivalent optimal policies perform poorly when there is model uncertainty about the natural rate processes. I then examine the properties of combined estimation methods and policy rules that are robust to this type of model uncertainty. I find that weighted averages of sample means perform well as estimators of natural rates. The optimal policy under uncertainty responds more aggressively to inflation and less so to the perceived unemployment gap than the certainty equivalent policy. This robust estimation/policy combination is highly effective at mitigating the effects of natural rate mismeasurement.
This article is published in this volume, pp. 1–16.

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

John C. Williams, with
Simon Gilchrist, *Boston University*

Published in *Review of Economic Dynamics* 8(1) (January 2005), pp. 1–27.

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. In the presence of irreversible factor proportions, a mean-preserving spread in the productivity of investment reduces investment at the project level, but raises aggregate investment, productivity, and output. Increases in uncertainty have important dynamic implications, causing sustained increases in investment and hours and a medium-term expansion in the growth rate of labor productivity.

Inflation Scares and Forecast-Based Monetary Policy

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

Published in *Review of Economic Dynamics* 8(2) (April 2005), pp. 498–527.

Central bankers frequently emphasize the critical importance of anchoring private inflation expectations for successful monetary policy and macroeconomic stabilization. In most monetary policy models, however, expectations are already anchored through the assumption of rational expectations and perfect knowledge of the economy. In this paper, we reexamine the role of inflation expectations by relaxing the assumption of rational expectations with perfect knowledge and positing, instead, that agents have imperfect knowledge of the precise structure of the economy and policymakers' preferences, and rely on a perpetual learning technology to form expectations. We find that with learning, disturbances can give rise to endogenous inflation scares, that is, significant and persistent deviations of inflation expectations from those implied by rational expectations, even at long horizons. The presence of learning increases the sensitivity of inflation expectations and the term structure of interest rates to economic shocks, in line with the empirical evidence. We also explore the role of private inflation expectations for the conduct of efficient monetary policy. Under rational expectations, inflation expectations equal a linear combination of macroeconomic variables and as such provide no additional information to the policymaker. In contrast, under learning, private inflation expectations follow a time-varying process and provide useful information for the conduct of monetary policy.

The Decline of Activist Stabilization Policy: Natural Rate Misperceptions, Learning, and Expectations

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

Published in *Journal of Economic Dynamics and Control* 29(11) (November 2005) pp. 1927–1950.

We develop an estimated model of the U.S. economy in which agents form expectations by continually updating their beliefs regarding the behavior of the economy and monetary policy. We explore the effects of policymakers' misperceptions of the natural rate of unemployment during the late 1960s and 1970s on the formation of expectations and macroeconomic outcomes. We find that the combination of monetary policy directed at tight stabilization of unemployment near its perceived natural rate and large real-time errors in estimates of the natural rate uprooted heretofore quiescent inflation expectations and contributed to poor macroeconomic performance. Had monetary policy reacted less aggressively to perceived unemployment gaps, inflation expectations would have remained anchored and the stagflation of the 1970s would have been avoided. Indeed, we find that less-activist policies would have been more effective at stabilizing both inflation and unemployment. We argue that policymakers, learning from the experience of the 1970s, eschewed activist policies in favor of policies that concentrated on the achievement of price stability, contributing to the subsequent improvements in macroeconomic performance of the U.S. economy.

Micro and Macro Data Integration: The Case of Capital

Daniel J. Wilson, with
Randy Becker, *U.S. Census Bureau*
John Haltiwanger,
University of Maryland
Ron Jarmin, *U.S. Census Bureau*
Shawn Klimek, *U.S. Census Bureau*

Forthcoming in *A New Architecture for the U.S. National Accounts,* NBER/CRIW Volume.

Micro and macro data integration should be an objective of economic measurement as it is clearly advantageous to have internally consistent measurement at all levels of aggregation—firm, industry, and aggregate. In spite of the apparently compelling arguments, there are few measures of business activity that achieve anything close to micro/macro data internal consistency. The measures of business activity that are arguably the worst on this dimension are capital stocks and flows. In this paper, we document, quantify, and analyze the widely different approaches to the measurement of capital from the aggregate (top down) and micro (bottom up) perspectives. We find that recent developments in data collection permit improved integration of the top down and bottom up approaches. We develop a prototype hybrid method that exploits these data to improve micro/macro data internal consistency in a manner that could potentially lead to substantially improved measures of capital stocks and flows at the industry level. We also explore the properties of the micro distribution of investment. In spite of substantial data and associated measurement limitations, we show that the micro distributions of investment exhibit properties that are of interest to both micro and macro analysts of investment behavior. These findings help highlight some of the potential benefits of micro/macro data integration.

What Do We Know about the Interstate Economic Effects of State Tax Incentives?

Daniel J. Wilson, with
Kirk Stark, *UCLA Law School*

Published in *Georgetown Journal of Law and Public Policy* 4(1) (Winter 2006) pp. 133–164

Over the last few decades, state and local governments increasingly have adopted tax and other policies to encourage economic development within their borders. These programs have recently come under attack as potentially inconsistent with the U.S. Supreme Court's dormant Commerce Clause jurisprudence. In an opinion issued in late 2004, the Sixth Circuit Court of Appeals invalidated Ohio's investment tax credit, contending that it discriminates against interstate commerce. The U.S. Supreme Court has granted certiorari in the case. In the meantime, similar litigation is under way in other states. In reaction to these developments, legislation has been introduced in Congress to protect the right of states to provide tax incentives. To shed light on the issues involved in these ongoing controversies, we offer an introduction to existing research concerning the economic effects of state tax incentives. There is a voluminous literature concerning the efficacy of state business subsidies. Surprisingly, however, very few econometric studies have examined the multistate impact of tax credits for physical investment (for example, the investment tax credit) or research and development (R&D tax credits). This focus may be due in part to the fact that, up until now, the issue was primarily one for state and local policymakers. Yet the interstate economic effects have significance for the Commerce Clause analysis of state tax incentives. Our goal is to provide a general introduction to these issues and to shed some light on the complexities involved in evaluating interstate economic effects.

Macro Factors and the Affine Term Structure of Interest Rates

Tao Wu

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

This paper formulates an affine term structure model of bond yields from a dynamic stochastic equilibrium model, with observable macro state variables as the term structure factors. Model implications for the joint macro-term structure dynamics are consistent with the empirical patterns from the VAR estimation. Model calibration and simulation exercises also provide clear macroeconomic interpretations of the latent term structure factors as found in the finance literature: most of the "slope" factor movement can be explained by exogenous monetary policy shocks, and the "level" factor movement is closely related to the technology shocks.

Conferences

Fiscal and Monetary Policy

The San Francisco Fed's Research Department organized three conferences and a symposium in 2005.

Revived Bretton Woods System: A New Paradigm for Asian Development?

The Department's annual macroeconomic conference explored the interaction between fiscal and monetary policy. Several of the papers examined the role of fiscal policy in macroeconomic stabilization, an area of renewed interest in both research and policy circles. Other papers studied the design of fiscal policy in a monetary union, the use of long-term bond rates to estimate monetary policy reaction functions, and how to conduct monetary policy when faced with uncertainty about the economy's structure.

External Imbalances and Adjustment in the Pacific Basin

In February, the Bank's Center for Pacific Basin Studies (CPBS) and U.C. Berkeley's Clausen Center for International Business and Policy cosponsored a symposium on the sustainability of the U.S. current account deficit entitled, "Revived Bretton Woods System: A New Paradigm for Asian Development?" The symposium provided an opportunity for debate among leading scholars on this important policy issue.

Productivity Growth: Causes and Consequences

The question of the U.S. current account deficit was revisited in the CPBS annual conference "External Imbalances and Adjustment in the Pacific Basin," held in September. The Center's annual conference presents leading current research that is relevant to the Pacific Basin. The conference included a panel discussion on the external imbalance issue, as well as a number of other papers on economic policy issues relevant to the Pacific Basin region.

The Bank's Center for the Study of Innovation and Productivity (CSIP) sponsored a conference in November on "Productivity Growth: Causes and Consequences." Conference papers covered the entire spectrum of the process of productivity growth, from its fundamental cause—invention—to the diffusion and adoption of invented technologies, to the consequences of technological change, such as longer life spans.

These conferences bring professional economists from the Federal Reserve System and from research institutions together with policymakers from the United States 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.*

Fiscal and Monetary Policy

Federal Reserve Bank of San Francisco
March 4–5, 2005

Sponsored by the Federal Reserve Bank of San Francisco

Papers presented at this conference can be found on the website
http://www.frbsf.org/economics/conferences/0503/index.html

Keynote Speaker

Douglas Holtz-Eakin, *Congressional Budget Office*

Monetary and Fiscal Policy in a Liquidity Trap: The Japanese Experience 1999–2004

Mitsuru Iwamura, *Waseda University*
Takeshi Kudo, *Hitotsubashi University*
Tsutomu Watanabe, *Hitotsubashi University*

Discussants: Laurence Ball, *Johns Hopkins University*
Marvin Goodfriend, *FRB Richmond*

Optimal Fiscal Policy in a Monetary Union

Jordi Galí, *Universitat Pompeu Fabra*
Tommaso Monacelli, *Università Bocconi*

Discussants: Maurice Obstfeld, *University of California, Berkeley*
Carl Walsh, *University of California, Santa Cruz*

Model Uncertainty and Policy Evaluation: Some Theory and Empirics

William Brock, *University of Wisconsin*
Steven Durlauf, *University of Wisconsin*
Kenneth West, *University of Wisconsin*

Discussants: Lars Hansen, *University of Chicago*
Christopher Sims, *Princeton University*

Estimating the Effects of Fiscal Policy in OECD Countries

Roberto Perotti, *Università Bocconi*

Discussants: Alan Auerbach, *University of California, Berkeley*
Valerie Ramey, *University of California, San Diego*

The Design of Monetary and Fiscal Policy: A Global Perspective

Jess Benhabib, *New York University*
Stefano Eusepi, *FRB New York*

Discussants: George Evans, *University of Oregon*
John Leahy, *New York University*

No-Arbitrage Taylor Rules

Andrew Ang, *Columbia University*
Sen Dong, *Columbia University*
Monika Piazzesi, *University of Chicago*

Discussants: Andrew Levin, *Federal Reserve Board of Governors*
Thomas Philippon, *New York University*

Symposium
Revived Bretton Woods System: A New Paradigm for Asian Development?

Federal Reserve Bank of San Francisco
February 4, 2005

Cosponsored by the Center for Pacific Basin Studies, Federal Reserve Bank of San Francisco, and Clausen Center for International Business and Policy, University of California, Berkeley

Papers presented at this symposium can be found on the website http://www.frbsf.org/economics/conferences/0502/index.html

Introduction: An Essay on the Revived Bretton Woods System	Michael Dooley, *University of California, Santa Cruz* Peter Garber, *Deutsche Bank*
Global Imbalances and the Lessons of Bretton Woods	Barry Eichengreen, *University of California, Berkeley*
The Unsustainable U.S. Current Account Position Revisited	Maurice Obstfeld, *University of California, Berkeley*
Will the Bretton Woods 2 Regime Unravel Soon? The Risk of a Hard Landing in 2005–2006	Nouriel Roubini, *New York University*
China's Role in the Revived Bretton Woods System: A Case of Mistaken Identity	Nicholas Lardy, *Institute for International Economics* Morris Goldstein, *Institute for International Economics*
The Revived Bretton Woods System: Does It Explain Developments in Non-China Developing Asia?	Steven Kamin, *Federal Reserve Board of Governors*
Exchange Rates, Wages, and International Adjustment: Japan and China versus the United States	Ronald McKinnon, *Stanford University*
Budget and External Deficits: Not Twins but the Same Family	Edwin Truman, *Institute for International Economics*

External Imbalances and Adjustment in the Pacific Basin

Federal Reserve Bank of San Francisco
September 22–23, 2005

Sponsored by the Center for Pacific Basin Studies, Federal Reserve Bank of San Francisco

Papers presented at this conference can be found on the website http://www.frbsf.org/economics/conferences/0509/agenda.pdf

Keynote Speech: International Finance in the Post 9/11 Era

John Taylor, *Stanford University*

International Financial Adjustment

Hélène Rey, *Princeton University*
Pierre-Olivier Gourinchas, *University of California, Berkeley*

Discussants: Dale Henderson, *Federal Reserve Board of Governors*
Cédric Tille, *FRB New York*

Why the Renminbi Might Be Overvalued (But Probably Isn't)

Menzie Chinn, *University of Wisconsin*
Yin-Wong Cheung, *University of California, Santa Cruz*
Eiji Fujii, *University of Tsukuba*

Discussants: Henning Bohn, *University of California, Santa Barbara*
Andrew Rose, *University of California, Berkeley*

The Domestic and Global Impact of Japan's Policies for Growth

Alessandro Rebucci, *International Monetary Fund*
Nicoletta Batini, *International Monetary Fund*
Papa N'Diaye, *International Monetary Fund*

Discussants: Paul Bergin, *University of California, Davis*
Takeo Hoshi, *University of California, San Diego*

The Unsustainable U.S. Current Account Position Revisited

Maurice Obstfeld, *University of California, Berkeley*
Kenneth Rogoff, *Harvard University*

Discussants: Michael Devereux, *University of British Columbia*
Catherine Mann, *Institute for International Economics*

Panel Discussion: External Imbalances in the Pacific Basin Region

Reuven Glick, *FRB San Francisco*
Brad DeLong, *University of California, Berkeley*
Ronald McKinnon, *Stanford University*
Richard Meese, *Barclays Global Investors*
Robert McCauley, *Bank for International Settlements*

International Reserves: Precautionary versus Mercantilist Views, Theory and Evidence

Joshua Aizenman, *University of California, Santa Cruz*
Jaewoo Lee, *International Monetary Fund*

Discussants: Linda Goldberg, *FRB New York*
Tom Willett, *Claremont McKenna College*

Maturity Mismatch and Financial Crises: Evidence from Emerging Market Corporations

Hoyt Bleakley, *University of Chicago*
Kevin Cowan, *Central Bank of Chile*

Discussants: Rob Dekle, *University of Southern California*
Jaewoo Lee, *International Monetary Fund*

Unilateral and Regional Trade Liberalization: China's WTO Accession and FTA with ASEAN

Kar-Yiu Wong, *University of Washington*
Mesut Saygili, *University of Washington*

Discussants: Bruce Blonigen, *University of Oregon*
Wing Woo, *University of California, Davis*

Productivity Growth: Causes and Consequences

Federal Reserve Bank of San Francisco
November 18–19, 2005

Sponsored by the Center for the Study of Innovation and Productivity, Federal Reserve Bank of San Francisco

Papers presented at this conference can be found on the website http://www.frbsf.org/economics/conferences/0511/

Keynote Speech: Information Technology and the World Economy

Dale W. Jorgenson, *Harvard University*

Why Did Europe's Productivity Catch-up Sputter Out? A Tale of Tigers and Tortoises

Robert J. Gordon, *Northwestern University*
Ian Dew-Becker, *Northwestern University*

Discussants: Bart Van Ark, *University of Gronigen and Conference Board*
Susanto Basu, *Boston College*

The Burden of Knowledge and the Death of the Renaissance Man: Is Innovation Getting Harder?

Benjamin F. Jones, *Northwestern University*

Discussants: Sam Kortum, *University of Minnesota*
Joel Mokyr, *Northwestern University*

The Value of Life and the Rise in Health Spending

Robert E. Hall, *Stanford University*
Charles I. Jones, *University of California, Berkeley*

Discussants: Robert Topel, *University of Chicago*
Joseph Paul Newhouse, *Harvard University*

Increasing Global Competition and Labor Productivity: Lessons from the U.S. Automotive Industry

Martin Neil Baily, *Institute for International Economics*
Diana Farrell, *McKinsey Global Institute*
Ezra Greenberg, *McKinsey Global Institute*
Jan-Dirk Henrich, *McKinsey Global Institute*
Naoko Jinjo, *McKinsey Global Institute*
Maya Jolles, *McKinsey Global Institute*
Jaana Remes, *McKinsey Global Institute*

Discussants: Timothy Bresnahan, *Stanford University*
George Hall, *Yale University*

Identifying Technology Spillovers and Product Market Rivalry

Nick Bloom, *Stanford University*
Mark Schankerman, *London School of Economics*
John Van Reenen, *London School of Economics*

Discussants: C. Lanier Benkard, *Stanford University*
Scott Stern, *Northwestern University*

Learning about a New Technology: Pineapple in Ghana

Timothy G. Conley, *Chicago Graduate School of Business*
Christopher R. Udry, *Yale University*

Discussants: Yaw Nyarko, *New York University*
Giorgio Topa, *FRB New York*

Technology Adoption from Hybrid Corn to Beta Blockers

Jonathan Skinner, *Dartmouth College*
Douglas Staiger, *Dartmouth College*

Discussants: Bart Hobijn, *FRB New York*
Pete Klenow, *Stanford University*

Fiscal and Monetary Policy: Conference Summary

Reprinted from FRBSF Economic Letter *2005-12, June 10, 2005*

This *Economic Letter* summarizes the papers presented at a conference on "Fiscal and Monetary Policy" held at the Federal Reserve Bank of San Francisco on March 4 and 5, 2005.

This year's conference brought together six research papers that explore issues related to fiscal and monetary policy and their interaction. The papers ranged from a theoretical analysis of the design of fiscal policy in a monetary union to the use of long-term bond rates to estimate monetary policy reaction functions.

Several of the papers examine the role of fiscal policy in macroeconomic stabilization, an area of renewed interest in both research and policy circles. Over the past few decades, many economists had come to the conclusion that activist fiscal policy, outside of so-called "automatic stabilizers," such as unemployment insurance, was in general poorly suited as a tool for macroeconomic stabilization. According to this view, fiscal policy should instead primarily focus on longer-run issues, including the provision of public goods, correction of market failures, and the achievement of equity and efficiency goals.

Recent developments, including the active use of countercyclical fiscal policy in Japan and the United States and the formation of a monetary union in Europe, have provided an impetus for a wide range of research on fiscal policy and its interaction with monetary policy, as represented by four of the conference papers. Iwamura, Kudo, and Watanabe study the use of monetary and fiscal policy in Japan during its prolonged downturn. Galí and Monacelli argue that national fiscal policy in a monetary union should take over some of the short-run stabilization duties normally performed by monetary policy. Benhabib and Eusepi look at the interaction between fiscal and monetary policy and show that the design of monetary policy should be sensitive to how fiscal policy is conducted. And Perotti examines the empirical evidence regarding the effects of changes in government spending and taxes on the economy.

The remaining two papers focus on issues related to monetary policy. Brock, Durlauf, and West analyze the design of monetary policy rules in an environment where the policymaker is uncertain about the true structure of the economy. Ang, Dong, and Piazzesi develop a new method of estimating monetary policy reaction functions using information in the entire interest rate term structure.

Fiscal and monetary policy in Japan

For many years now, Japan has been suffering from slow or at times contracting economic activity and deflation. In response, policymakers in Japan have taken a number of steps to stimulate the economy through monetary and fiscal policies. Notably, in February 1999 the Bank of Japan lowered the overnight nominal interest rate to zero, as low as it can go. After a small policy tightening, in March 2001 the overnight cash rate was again lowered to zero and it has remained at zero since then. To understand why the Japanese economy has been slow to recover, Iwamura, Kudo, and Watanabe develop a model of the economy and use it to study the interaction between fiscal and monetary policy and the characteristics of optimal monetary policies. They find that the policy pursued by the Bank of Japan between 1999 and 2004 lacked important characteristics of optimal monetary policy, and, in particular, they suggest that the Bank of Japan may not have been fully committed to its zero-interest rate policy. They also show that the term structure of interest rates was not downward sloping after 1998, indicating that the Bank of Japan's policy failed to have sufficient influence on market expectations about the future course of monetary policy. Finally, the authors argue that Japan should have run larger government deficits and that the combination of this fiscal policy and the Bank of Japan's apparent lack of commitment to low interest rates has delayed economic recovery in Japan.

Optimal fiscal policy in a monetary union

The creation of a monetary union in Europe, which is set to expand to include several more countries in coming years, offers new challenges for fiscal and monetary policymakers. Part and parcel of joining a monetary union is the loss of independent monetary policies in each of the member countries, which limits the ability to use monetary policy to stabilize economic disturbances that affect only a subset of the countries in the union. Nonetheless, member countries are still at liberty to formulate independent fiscal policies, and Galí and Monacelli tackle the question of how to design jointly optimal national fiscal policies and the collective monetary policy to maximize the welfare of the entire

union. A key finding is that when prices are sticky, members of a monetary union will have a motive for fiscal stabilization that extends beyond the simple optimal provision of public goods. This motive for fiscal stabilization emerges because monetary policy, which would normally be used to stabilize the economy in response to country-specific shocks, can instead be used only to address union-wide disturbances. To stabilize a member economy, national fiscal policy should "lean against the wind," with policy expansionary when output and inflation are below their equilibrium levels and contractionary when they are above their equilibrium levels.

The interaction of monetary and fiscal policy

Monetary policy rules are often expressed such that the choice variable for the central bank, usually a short-term nominal interest rate, is determined by a number of economic variables according to a mathematical equation. However, a well-known problem with such rules is that certain specifications of the rule can lead to indeterminacy, that is, an economy for which many different outcomes are possible given the same fundamental economic situation. Clearly, a good monetary policy should avoid such non-uniqueness. One widely discussed solution that works in many models is to have the interest rate rule be "active," in the sense that the nominal interest rate responds more than one-for-one to movements in the inflation rate. But, this solution may not be sufficient to avoid indeterminacy in all models. Benhabib and Eusepi examine the interaction of monetary and fiscal policy and the conditions for indeterminacy. They show that when households are able to save by buying bonds, then the conduct of fiscal policy and the resulting interaction between fiscal and monetary policy can be critical to whether indeterminacy occurs. Interestingly, they also show that active monetary policy rules that also respond to an output gap, as in the well-known Taylor rule, facilitate the avoidance of indeterminacy.

The effects of fiscal policy

While many economists agree that expansionary monetary policy eventually manifests itself in higher output and prices, they generally do not agree about the effects of expansionary fiscal policy. Some theories suggest that a fiscal expansion will cause private consumption to decline through "crowding out," while others predict that private consumption will rise. Weighing in on this issue, Perotti studies the effects of government spending shocks and tax shocks in Australia, Canada, West Germany, the United Kingdom, and the United States, employing the same statistical methods that are commonly used to identify and quantify the effects of monetary policy shocks to separate innovations to government spending and taxes from the systematic responses of these variables to the state of the economy. Some key results from this study are that the effects of fiscal policy shocks on GDP tend to be small overall but that the effects of shocks prior to 1980 tend to be much larger than those after 1980. He also finds no evidence that tax cut shocks work any faster or have larger effects than government spending shocks and that, for the post-1980 period, positive shocks to government spending and negative shocks to taxes tend to elicit negative responses in GDP, private consumption, and private investment.

Model uncertainty and policy evaluation

Monetary policymakers recognize that they face a great deal of uncertainty about the outlook for the economy and the effects of policy on that outlook. Brock, Durlauf, and West develop a general framework for how policymakers should formulate, assess, and evaluate different policy options in an uncertain world. Their approach incorporates model uncertainty into standard statistical calculations, thereby integrating model uncertainty into policy evaluation. They illustrate their methods using two classes of macroeconomic models that differ in the treatment of expectations. In the "backward" class of models, expected inflation is treated as a distributed lag over past inflation; in their "hybrid" class, expected inflation is partly forward-looking and partly backward-looking. When model uncertainty is present, they show that a Taylor rule, in which the nominal interest rate responds to current inflation and the current output gap, is very robust in the sense that risk estimates show relatively little variation across models. However, they also show that a three-parameter rule that responds to the lagged interest rate in addition to current inflation and the contemporaneous output gap, where the parameters in the rule are optimized for model uncertainty, generally does better than the Taylor rule in the backward-looking model and uniformly does better than the Taylor rule in the hybrid model.

No-arbitrage Taylor rules

According to standard asset pricing theory, long-term interest rates should reflect risk-adjusted future short-term interest rates, and, as a result, the entire term structure can in principle be very informative about market participants' views of the conduct of monetary policy today and in the future. Ang, Dong, and Piazzesi exploit the relationship between long-term bond rates and expected short-term interest rates to estimate monetary policy reaction function

rules for the United States. They embed various specifications of Taylor monetary policy rules in a model of the Treasury security term structure that assumes that investors have fully exploited all arbitrage opportunities. They allow for time-varying bond risk premiums that may depend on the state of the economy. In principle, employing information from the entire term structure for estimation can produce more efficient estimates of how monetary policy shocks affect the economy. The authors find that over 60 percent of the time variation in yields can be attributed to shocks to either GDP growth or inflation and that movements in yield spreads are largely due to shocks to inflation. Furthermore, they find that monetary policy shocks estimated under the no-arbitrage assumption are much less volatile than those found by standard methods.

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Conference papers

Papers are available in pdf format at
http://www.frbsf.org/economics/conferences/0503/index.html

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Revived Bretton Woods System: A New Paradigm for Asian Development? Symposium Summary

Reprinted from "The Bretton Woods System: Are We Experiencing a Revival?"
FRBSF Economic Letter *2005-32, November 25, 2005*

This *Economic Letter* summarizes the papers presented at the symposium "Revived Bretton Woods System: A New Paradigm for Asian Development?" held at the Federal Reserve Bank of San Francisco on February 4, 2005, under the joint sponsorship of the Bank's Center for Pacific Basin Studies and the University of California at Berkeley's Clausen Center for International Business and Policy.

At the center of this symposium was a presentation by Michael Dooley (University of California at Santa Cruz and Deutsche Bank) and Peter Garber (Deutsche Bank) based on their papers with David Folkerts-Landau (2003a, b, 2004). Dooley and Garber presented their views on the current international exchange rate system, the sustainability of global trade imbalances, and the implications for development by emerging markets, such as China. Other participants presented papers that questioned the bases of their arguments and the extent to which those arguments account for current developments.

A revival of Bretton Woods?

Dooley, Folkerts-Landau, and Garber (DFG 2003b) argue that the current international exchange rate system operates much like the Bretton Woods system of fixed exchange rates that prevailed for nearly a quarter of a century, from the end of World War II until the early 1970s. Under Bretton Woods, foreign currencies were pegged to the dollar at fixed parities, and the dollar was pegged to gold at $35 an ounce. The system was abandoned when foreign governments perceived that guarantees of currency conversion at fixed rates were no longer credible.

Although the current international exchange rate regime carries no guarantees of fixed parities in terms of gold or the dollar, DFG argue that many countries, particularly those in Asia, do limit exchange rate fluctuations against the dollar to varying degrees. For example, Japan often has conducted foreign exchange intervention—selling yen for dollars, which pushes the yen down against the dollar—in order to maintain its export competitiveness. As a result, Japan has been a net accumulator of dollar-denominated assets; indeed, it ranks first among official reserve holders of U.S. Treasury securities.

China's policy of keeping exchange rates low relative to the dollar is also related to a desire to boost exports. In addition, according to DFG, China has also been motivated by a desire to attract foreign direct investment by multinational firms as well as the technical expertise that usually comes with it. As a result, China also has been a net accumulator of dollar-denominated assets and is second only to Japan among official reserve holders of U.S. Treasury securities.

This result is surprising, however. Given that China is a rapidly growing developing country, one might expect it to be a net international borrower, as capital presumably enjoys a higher rate of return there than in the United States. Naturally, this question also arises with other developing economies that may peg their exchange rates to varying degrees to the dollar. Whether this issue is a valid point or not, DFG (2004) have an answer. They argue that developing nations like China need to accumulate U.S. Treasury securities because they provide a form of "collateral" against concerns about possible future expropriation of the assets of U.S. foreign direct investors.

This argument has implications for the U.S. trade deficit. The exchange rate policies discussed have been accompanied by large trade surpluses in most Asian countries vis-à-vis the U.S., as well as by a corresponding need by the United States to borrow to finance its purchases of net imports. This implies that, insofar as developing countries like China continue to accumulate these U.S. assets, the United States will see ongoing trade deficits.

Perhaps the biggest question facing DFG's world view is whether the current system is sustainable as the U.S. current account deficit continues to grow. DFG (2003a) argue that the system is sustainable in the near term (though their estimates of what the "near term" is varies from three to ten years or more) as long as Asian countries are willing to finance the growing U.S. current account deficit by purchasing additional U.S. securities.

Does China fit the story?

Several symposium participants questioned the merits and viability of a strategy of deliberate currency undervaluation by developing countries, particularly in the case of China.

For example, Nicholas Lardy (Institute of International Economics), in his paper with Morris Goldstein, pointed out that more than half of China's exports go to markets other than the United States or to countries with currencies not pegged to the dollar. Thus, a strategy of undervaluation by China to boost its exports should depend not just on the renminbi's exchange rate against the dollar but also on its effective rate against the currencies of all of its trading partners. In fact, between 1994 and 2001 the renminbi's real trade-weighted exchange rate (adjusted for inflation differences across countries) appreciated by 30 percent before falling by 13 percent since 2001. Lardy also disagreed with DFG's argument that the undervaluation contributed significantly to increasing foreign direct investment in China and the growth of China's capital stock. In his view, this argument ignores the fact that foreign direct investment in China has financed less than 5 percent of fixed asset investment over the past few years.

Barry Eichengreen (University of California, Berkeley) dismissed the purported role of U.S. assets as collateral that justify U.S. multinational firms' decisions to invest in China. For one thing, he argues that the timing is wrong: rising U.S. foreign direct investment in China began around 1992, whereas China's massive reserve accumulation came a decade later. In addition, he doubts that political conditions would support U.S. expropriation of Chinese claims, invalidating the collateral role these claims are purported to play. Finally, he points out that in recent years the United States has accounted for less than 10 percent of China's inward foreign direct investment.

Steven Kamin (Board of Governors) agreed with DFG that the authorities in developing economies other than China have been acting to maintain the competitiveness of their exports by limiting currency appreciation. However, he argues that the recent large current account surpluses in the region mainly reflect the special, ongoing effects of a decline in investment and domestic demand following the Asian financial crisis of 1997–1998. He attributes this fall in investment to factors such as the presence of considerable excess capacity after the crisis and the near collapse of domestic banking systems in the region. To be sure, immediately after the Asian financial crisis, the desire to rebuild foreign exchange reserves was another reason that authorities in the region intervened in foreign exchange markets to acquire dollar assets, but this motive has diminished in importance as reserves have grown. He believes that, over time, Asian investment spending will revive, that the authorities will be more comfortable in allowing their currencies to strengthen, and that their trade surpluses will narrow.

Will the system last?

Barry Eichengreen and Ted Truman (Institute of International Economics) argue that DFG make a false analogy between the current international foreign exchange system and Bretton Woods. In particular, they argue that the United States is now no longer a net saver with current account surpluses, as it was in the years immediately after World War II. In addition, domestic financial systems are more liberalized, capital accounts are more open, and exchange rates are more flexible, for both industrial and emerging market economies. These differences make it harder to sustain undervalued exchange rates indefinitely.

Nouriel Roubini (New York University) and Brad Setser (Roubini Global Economics) also questioned the sustainability of efforts to limit dollar appreciation, arguing that the scale of the financing required is increasing faster than the willingness of the world's central banks to build up their dollar reserves. In addition, the enormous reserve growth in these countries has become increasingly harder to sterilize fully, particularly in China, where the resulting increase in the money supply is fueling a lending boom and an asset-price bubble. Lardy and Roubini both suggest an earlier rather than a later end of China's peg to the dollar. Eichengreen argues that China has good reason to abandon its peg soon, while confidence is strong, capital is still flowing in, and reserves are still being accumulated.

DFG suggest that because the euro area has borne a large and disproportionate share of the adjustment of the U.S. trade imbalance, the European Central Bank will be compelled to engage in large-scale currency intervention to resist further euro appreciation. However, Roubini and Setser and Truman all argue that the European Central Bank is unlikely to do so, in part because of its conviction that the recent massive Japanese intervention had limited effectiveness. The implication is that there will be continuing downward pressure on the dollar against floating currencies until the overall adjustment is consistent with a lower U.S. current account deficit.

Might global imbalances spark a sharp decline in the dollar? Maurice Obstfeld (University of California at Berkeley) discusses the likelihood that the U.S. might face an emerging markets-style "sudden stop" crisis. In his work with Kenneth Rogoff, he questions the sustainability of U.S. current account imbalances, and suggests that a large depreciation of the dollar is indeed very likely.

Ron McKinnon (Stanford University) agrees with DFG that it is in China's interest to maintain a dollar peg, but his

argument is different. He argues that a stable exchange rate is an important way for China to anchor low inflation expectations. Accordingly, he provides three arguments for why it is not a good idea for China to allow the renminbi to appreciate. First, an appreciation of the renminbi would not necessarily improve the U.S. trade balance; for example, it could lead to reduced world demand for China's exports, thus slowing China's economic growth, which, in turn, could lead to significant declines in Chinese demand for U.S. products. Second, it may create deflationary pressure in China. Third, it would encourage more speculative capital inflows.

Conclusion

One way to assess the arguments of DFG and their critics may be to examine the implications of the revaluation of the Chinese renminbi in July 2005, five months after the symposium took place. On one hand, it is clear that the Chinese have adjusted their currency by revaluing against the dollar and announced that they would move towards more flexibility in the future. These developments would seem to portend changes that conflict with the DFG vision of Asian countries' ongoing willingness to finance ever-increasing U.S. deficits in the interest of maintaining their trade balance surpluses.

On the other hand, it must be acknowledged that DFG's first works on this subject were published in 2003, and the imminent sharp adjustment in the dollar that was predicted by many has yet to take place. Indeed, so far, the renminbi has adjusted by less than 3 percent. As such, the DFG framework has already lasted for a notably long duration in today's volatile international financial markets.

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Symposium papers

Papers are available in pdf format at
http://www.frbsf.org/economics/conferences/0502/

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McKinnon, Ronald. "Exchange Rates, Wages, and International Adjustment: Japan and China versus the United States."

Obstfeld, Maurice, and Kenneth Rogoff. "The Unsustainable U.S. Current Account Position Revisited."

Roubini, Nouriel, and Brad Setser. "Will the Bretton Woods 2 Regime Unravel Soon? The Risk of a Hard Landing in 2005–2006."

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External Imbalances and Adjustment in the Pacific Basin: Conference Summary

Reprinted from FRBSF Economic Letter *2006-04, March 10, 2006*

This *Economic Letter* summarizes the papers presented at the conference on "External Imbalances and Adjustment in the Pacific Basin" held at the Federal Reserve Bank of San Francisco on September 22–23, 2005, under the sponsorship of the Bank's Center for Pacific Basin Studies.

The U.S. current account balance on international transactions in goods and services has deteriorated significantly over the last 15 years. Since recording a small surplus in 1991, it has swelled to a deficit in 2005 of more than 6 percent of GDP, the highest such ratio in over 40 years. In the past, other countries with a current account deficit above 5 percent of GDP have typically faced worsening borrowing terms, either in the form of reduced borrowing opportunities or increased interest charges. By that standard, some would argue that the U.S. is overdue for such adjustments, including a significant fall in the value of the dollar.

This year's Pacific Basin Conference brought together seven papers examining the U.S. current account deficit and its implications, with special emphasis on the prominent role of Asian countries, which accounted for over 40 percent of the overall U.S. trade deficit in 2004.

The U.S. current account and net international investment position

Maurice Obstfeld of U.C. Berkeley and Kenneth Rogoff of Harvard University use a small general equilibrium model of the United States and the rest of the world to estimate the magnitude of dollar depreciation necessary to eliminate the U.S. current account deficit. Focusing only on the relative price effects of currency change, they calculate that a devaluation of as much as 30 percent is necessary to achieve this goal. These estimates are sensitive to assumptions about key parameters, particularly the degree of substitutability of traded and nontraded goods. For example, a lower substitutability implies that a greater depreciation is required to induce a shift of resources out of nontradables and into tradables production. Obstfeld and Rogoff note that currency and price changes are only part of the adjustment mechanism through which the U.S. trade imbalance will be reduced; other factors, such as the relative growth of foreign output, matter as well. They also point out that it is difficult to determine when the adjustment to the U.S. current account will begin and whether it will be rapid or slow.

The ongoing U.S. trade deficits have contributed to the buildup of U.S. net international liabilities. Since the early 1980s, the U.S. net international investment position has swung from a creditor position of more than 5 percent of GDP to a debtor position amounting to 22 percent of GDP. This situation has raised concerns about the extent to which the U.S. can continue to accumulate foreign liabilities. Pierre-Olivier Gourinchas of U.C. Berkeley and Hélène Rey of Princeton University analyze how a depreciation of the dollar affects the U.S. net international investment position through two channels, trade and finance. Through the "trade channel," a depreciation makes U.S. goods more competitive than foreign goods, encouraging a switch of world consumption towards U.S. goods, improvement of the trade balance, and lessening of the accumulation of foreign liabilities. Second, through the "financial channel" dollar depreciation affects the dollar value of U.S. financial assets and liabilities denominated in foreign currencies.

Gourinchas and Rey argue that recent dollar depreciations have generated sizable capital gains and reduced the U.S. net debt position. In particular, because approximately 70 percent of U.S. foreign assets are in foreign currencies, while almost all of U.S. foreign liabilities are in dollars, a dollar depreciation on balance reduces the net U.S. international debt position in dollars. In fact, because of substantial valuation effects associated with the dollar depreciations since the end of 2001, the net U.S. debt position has remained roughly constant, despite current account deficits in excess of 5 percent of GDP.

Imbalances in the Pacific Basin region are not limited to international trade. For example, Japan has been running large fiscal deficits during its recent era of sluggish growth. Given the demographic complications associated with the aging of the Japanese population, Japan is expected to address these fiscal imbalances once its economic growth has proven to be sustainable. This raises the question of what a change in Japan's fiscal policy is likely to mean for the Japanese economy and the pattern of world trade.

Nicoletta Batini, Papa N'Diaye, and Alessandro Rebucci from the International Monetary Fund (IMF) address this question using the IMF's global economy model. This model divides the world into five blocks—the U.S., Japan, emerging Asia, Europe, and the rest of the world. Batini

et al. explore the implications of bringing Japan's fiscal policy back into balance, both with and without accompanying structural reforms to the Japanese economy. The authors compare the results of three scenarios. In the first scenario, Japan slowly brings its government into fiscal balance but makes no other changes. In the second, Japan achieves modest productivity growth to accompany its fiscal adjustment. In the third, Japan achieves more rapid productivity growth but makes no explicit policy effort to reduce its fiscal budget deficits. The results for the first scenario show that the U.S. current account falls further into deficit; specifically, the demand for U.S. goods declines as Japan reduces its degree of fiscal stimulus. The other two scenarios, however, demonstrate that enhanced productivity growth can accelerate the pace of fiscal adjustment without exacerbating Japan's current account imbalance. The policy conclusion, therefore, is that Japan can regain fiscal balance without disrupting the world economy, provided it simultaneously pursues reforms that achieve productivity growth.

China's trade

The U.S. bilateral trade deficit with China reached over $200 billion in 2005. Some have attributed this development to an undervalued currency that makes Chinese goods unduly cheap in world markets, such as the United States. Indeed, since 1994, China has maintained a fixed exchange rate with respect to the U.S. dollar (although a small degree of flexibility was introduced in July 2005).

Yin-Wong Cheung from U.C. Santa Cruz, Menzie Chinn from the University of Wisconsin at Madison, and Eiji Fujii of the University of Tsukuba evaluate the extent to which the renminbi might be undervalued using a variety of criteria, such as purchasing power parity calculations. Because of the vast structural changes in China over time, the calculations depend on the base period used. Cheung et al. find that some approaches imply substantial undervaluation of the renminbi, while others imply little or no undervaluation. China's undervaluation appears to be driven not by competitive reductions in the nominal value of its currency, but rather by greater inflation in the mid-1990s that was not accompanied by an appreciation of the renminbi. Since the late 1990s inflation in China has been comparable to that in the U.S.

China's accession to the World Trade Organization (WTO) in 2001 entailed several liberalization requirements, including reductions in its tariffs and capital inflow restrictions as well as harmonization of its corporate tax policy on foreign and domestic firms. A year later, China took major steps toward liberalization by agreeing to form a free trade area with the ASEAN nations by 2012.

Mesut Saygili and Kar-yiu Wong of the University of Washington evaluate the impact of China's accession to the WTO and its formation of a free trade area with the ASEAN nations. They develop a model of trade among China, ASEAN, and the rest of the world. They then consider the impact of China's accession to the WTO, both in isolation and accompanied by the formation of a free trade area with the ASEAN nations. They find that accession to the WTO alone would greatly increase China's openness, as its imports increase and resources previously employed in import-competing industries are transferred to the production of exports. They then examine the combination of China's accession to the WTO and its formation of a free trade area with the ASEAN nations. They again find that China's trade increases overall, but the pattern of trade is quite different. China's trade with the rest of the world declines, in favor of increased trade with ASEAN. Overall, both China and the rest of the world are shown to experience modest declines in welfare as a result of the pursuit of both policies, while the ASEAN nations emerge as large winners.

Foreign reserve accumulation

The recent increase in the U.S. trade deficit has been accompanied by large buildups of holdings of U.S. securities by Asian governments. Some have suggested that these buildups are motivated by mercantilist desires to maintain export competitiveness by keeping exchange rates low; others have argued that they represent a precautionary response to the 1997 Asian financial crisis experience. Joshua Aizenman from U.C. Santa Cruz and Jaewoo Lee from the IMF use a theoretical model to identify testable differences between these two explanations. They find that the empirical patterns followed by foreign reserve buildups have been more consistent with the precautionary motive hypothesis. In particular, countries with more liberal capital regimes, which would expose them to greater risk of capital outflows, holding all else equal, are shown to hold greater stocks of international reserves.

Maturity mismatches

"Maturity mismatch," whereby a country borrows abroad short-term, but invests the borrowed capital in long-term assets, exposes borrowing countries to significant risk. In the event of a "sudden stop," where foreign creditors refuse to roll over these short-term obligations, a borrowing country could find itself illiquid, compelling it to curtail investment plans and perhaps even liquidate assets prematurely. The contention that the potential for disruptive sudden stops exists has largely been based on the observation that

countries that issue short-term debt obligations often experience poorer economic performance. However, this observed correlation may simply reflect the fact that poorly performing economies are limited to short-term borrowing by creditors because they are expected to exhibit inferior performance.

To assess the role of maturity mismatches in sudden stop crises, Hoyt Bleakley of U.C. San Diego and Kevin Cowan of the Inter-American Development Bank use micro data for 3,000 publicly traded firms from a cross section of 16 emerging market nations, including five in East Asia. Their sample includes firms in countries that experienced high capital account volatility as well as countries that issued large volumes of short-term debt liabilities. Surprisingly, they find no statistically significant difference in the investment response of firms with high and low short-term debt obligations to changes in aggregate short-term capital flows. They do determine that firms with more short-term debt find capital outflows more costly and are sometimes forced to liquidate in the wake of capital outflows, but these outflows do not disproportionately affect their investment behavior relative to firms with fewer short-term debt obligations.

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Conference papers

Papers are available in pdf format at
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Aizenman, Joshua, and Jaewoo Lee. "International Reserves: Precautionary versus Mercantilist Views, Theory and Evidence."

Batini, Nicoletta, Papa N'Diaye, and Alessandro Rebucci. "The Domestic and Global Impact of Japan's Policies for Growth."

Bleakley, Hoyt, and Kevin Cowan. "Maturity Mismatch and Financial Crises: Evidence from Emerging Market Corporations."

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Obstfeld, Maurice, and Kenneth Rogoff. "The Unsustainable U.S. Current Account Position Revisited."

Saygili, Mesut, and Kar-Yiu Wong. "Unilateral and Regional Trade Liberalization: China's WTO Accession and FTA with ASEAN."

Productivity Growth: Causes and Consequences, Conference Summary

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This *Economic Letter* summarizes the papers presented at the conference "Productivity Growth: Causes and Consequences" held at the Federal Reserve Bank of San Francisco on November 18–19, 2005, under the sponsorship of the Bank's Center for the Study of Innovation and Productivity.

The study of productivity growth is among the most important pursuits of economic science. Assessments of it influence macroeconomic policy and in the long run productivity growth drives improvements in the standard of living, the mix of goods and services available, as well as the mix of jobs in an economy. The seven papers presented and discussed at the conference covered the entire spectrum of the process of productivity growth, from its fundamental cause—invention—to the diffusion and adoption of invented technologies, to the consequences of technological change, such as longer life spans.

Causes of productivity growth

A paper by Jones explored the genesis of technology and productivity growth—that is, the process of invention. In particular, he examined how this process, which typically builds on prior knowledge, is affected by the growing volume of knowledge. In Jones's model, inventors decide on the balance between acquiring knowledge that is narrow but deep and knowledge that is broad but shallow. The model predicts that, as the volume of knowledge grows deeper and broader over time, invention requires levels of depth and breadth that are increasingly difficult, in general, for a single individual to attain. As a result, inventors (researchers) would likely deepen their knowledge and become more specialized by spending more time learning rather than inventing, and they would likely gain more breadth of knowledge by engaging in more teamwork. Jones tested this hypothesis using U.S. data from 1975–2000 and found favorable results: the average time students spent in doctoral programs increased, the average age of inventors at the time of their first invention increased, and the number of inventors per patent increased. Another testable implication of Jones's model is that, looking across technological fields, inventions in deeper, more mature fields should be generated by larger teams with more specialized team members. As Jones demonstrated, this prediction is supported by data on U.S. patents.

Two closely related papers explored how new technologies diffuse or spread across parts of an economy. Conley and Udry considered the role of social networks in this diffusion process. Identifying such networks has been an elusive goal in the field of productivity research. Conley and Udry found a unique setting ideal for achieving this identification: pineapple farming in Ghana. In recent years, Ghanaian farmers have increasingly switched from traditional crops, such as maize and cassava, to the more profitable crop of pineapples, which has involved learning new technologies, such as the use of modern fertilizers. A basic part of the learning is discovering the best trade-off between the cost of the fertilizer and the value of the crop per acre. Conley and Udry use surveys to identify the social networks for a sample of farmers, some of whom adopted pineapple farming and some of whom did not. They find that communication with farmers who have *successfully* adopted pineapple farming is a strong predictor of whether a given farmer subsequently adopts the same technology (that is, the same use of fertilizer) for growing pineapples. In contrast, and consistent with their model, such networking is found to play no role in cultivation decisions for other crops whose technologies are widely known. These findings point to the potential importance of networking as a channel for the diffusion of technology. They also suggest, though, that factors that limit social networks, such as barriers to communication, may slow technology adoption in developing countries.

Skinner and Staiger explored technology diffusion by investigating the empirical patterns of technology adoption among the U.S. states. It is widely recognized that the pace and extent of adopting new technologies—from telephones to color television to computers—starts out slowly and picks up speed over time. This pattern generally reflects the fact that newly rolled out technologies tend to be costly, which limits the number of purchasers or users; then, over time, as quality improves and costs decline, these technologies are diffused more quickly and more widely. Cross-country, or regional, differences in the timing and pace of technology adoption generally are attributed in part to differences in income levels, with lower-income regions typically the slower to adopt.

However, such economic differences may not account for all regional differences in the pace of adopting technology. For example, Skinner and Staiger found that some

states were much slower to adopt the use of beta blockers—that is, they found that doctors as a group in those states were much slower to prescribe beta blockers to patients in the hospital recovering from heart attacks. Skinner and Staiger argue that, because the drug's cost is low and its benefits are clear, economic factors, such as differences across states in income or prices, are unlikely to explain the wide cross-state differences in the rate at which this medical practice is adopted. In developing an alternative explanation, the authors point out that states that were slow to adopt hybrid corn during the first half of the twentieth century generally are the same states that recently have been slow to adopt beta blockers as a treatment for heart attacks. In fact, they find this pattern for the adoption of other technologies, as well. The authors posit that states with faster adoption rates may have characteristics that facilitate technology diffusion more generally. One characteristic correlated with faster adoption rates appears to be education, and communications networks may also play a role.

Baily et al. investigate whether competitive pressures influence technology adoption decisions. Specifically, their paper looks at the timing and extent of process innovations adopted by U.S. automakers from 1987 to 2002, a period in which foreign automakers increasingly penetrated the U.S. market and were themselves adopting these innovations. The authors argue that nearly half of the productivity increase over this period in the U.S. domestic auto industry was driven by the adoption of improved process technologies, such as "lean manufacturing" techniques. Another quarter of the measured increase in productivity is argued to have come from the product innovation of introducing new vehicle lines, especially SUVs, for which there was apparently unmet demand and on which U.S. manufacturers could realize larger markups.

Gordon and Dew-Becker sought to determine the cause of the rather stark divergence in productivity growth in the European Union (EU) relative to the strong performance in the U.S. since 1995. The authors pointed out that about half of the comparative slowdown in EU productivity growth was due to the acceleration in growth in the U.S., while the other half was due to a deceleration in Europe. Previous research had shown that information technology (IT) played a big role in the U.S. acceleration in the second half of the 1990s, so one might think the slowing in EU productivity might be due to developments affecting the IT sector in Europe. On the contrary, Gordon and Dew-Becker show that the slowdown in Europe was quite broad-based and not due just to weakness in IT-related industries. A common explanation for the EU slowdown is that institutional and legal barriers limit flexibility, and it is frequently illustrated by a story about zoning laws in Europe that prevent big-box stores, like Wal-Mart and Target, from expanding and establishing the ultra-efficient distribution systems they have in the U.S., which some argue have contributed to higher U.S. labor productivity.

Gordon and Dew-Becker offered a different story: Somewhat ironically, the labor market reforms enacted in the mid-1990s in many EU countries actually had a negative effect on productivity growth—at least temporarily. The authors claimed that, by relaxing rigid work rules and high wage floors, EU employers could hire more low-wage, low-productivity workers and substitute away from high-skill workers and capital. Indeed, before the mid-1990s, productivity growth in the EU was above that for the U.S. By opening the door to these low-productivity workers, Gordon and Dew-Becker argue, average productivity is pulled down, at least until the economy adjusts to the new composition of the workforce.

Consequences of productivity growth

Two papers presented at the conference address some consequences of innovation and productivity growth. Bloom, Schankerman, and Van Reenen looked at the social returns to innovative activity, as measured by research and development (R&D) spending. The authors conceive of social returns to R&D as the technology spillovers flowing from R&D-performing firms to other firms, net of the social costs of having rival firms engage in parallel, duplicative research rather than working together. Using panel data on U.S. firms between 1981 and 2001, they find that both technology spillovers and market rivalry effects are quantitatively important, though the former dominate such that the net social returns to R&D are several times larger than the private returns. They argue that since large firms tend to produce greater technological spillovers and engender less rival R&D, their model implies that the current emphasis in U.S. R&D policy on small and medium-sized firms may not be the most effective use of government-provided incentives.

Hall and Jones consider the consequences of continued productivity improvements in the U.S. health-care industry. Much of the discussion over public policy in the U.S., according to these authors, assumes that the rapid growth in health spending in recent decades has been excessive. One argument, for example, is that the rise in health spending as a share of GDP is due to the lack of cost controls and misaligned incentives. Hall and Jones provide a plausible alternative, or at least an additional view, by developing an economic model of individual consumption behavior where life span is a function of health-care spending. Calibrating their model using standard parameters, they find that as income grows over time, the optimal share of spending on health also grows. Specifically, because indi-

viduals receive diminishing marginal utility from consumption in a given time period, they optimally respond to increases in income by putting a greater share of resources toward increasing the number of periods in which they can consume (longer life spans). That is, with rising incomes, individuals will choose to spend proportionately less on food, cars, housing, and so on, and more on health today so as to be able to consume in more tomorrows. Based on projections of aggregate income growth, their model suggests the optimal health share is likely to double over the next half century, exceeding 30 percent of GDP by 2050.

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Conference papers

Papers are available at in pdf format at
http://www.frbsf.org/economics/conferences/0511/index.html

Baily, Martin Neil, Diana Farrell, Ezra Greenberg, Jan-Dirk Henrich, Naoko Jinjo, Maya Jolles, and Jaana Remes. "Increasing Global Competition and Labor Productivity: Lessons from the U.S. Automotive Industry."

Bloom, Nick, Mark Schankerman, and John Van Reenen. "Identifying Technology Spillovers and Product Market Rivalry."

Conley, Timothy, and Christopher Udry. "Learning about a New Technology: Pineapple in Ghana."

Gordon, Robert, and Ian Dew-Becker. "Why Did Europe's Productivity Catch-up Sputter Out? A Tale of Tigers and Tortoises."

Hall, Robert, and Charles I. Jones. "The Value of Life and the Rise in Health Spending."

Jones, Benjamin. "The Burden of Knowledge and the Death of the Renaissance Man: Is Innovation Getting Harder?"

Skinner, Jonathan, and Douglas Staiger. "Technology Adoption from Hybrid Corn to Beta Blockers."

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05-21 Housing Markets and Demographics / *John Krainer*

05-22 Policymaking on the FOMC: Transparency and Continuity / *Janet L. Yellen*

05-23 A Look at China's New Exchange Rate Regime / *Mark Spiegel*

05-24 Why Has Output Become Less Volatile? / *Bharat Trehan*

05-25 Inflation Expectations: How the Market Speaks / *Simon Kwan*

05-26 The Rise and Spread of State R&D Tax Credits / *Daniel Wilson*

05-27 Estimating the "Neutral" Real Interest Rate in Real Time / *Tao Wu*

05-28 Oil Price Shocks and Inflation / *Bharat Trehan*

05-29 Economies of Scale and Continuing Consolidation of Credit Unions / *James A. Wilcox*

05-30 Spendthrift Nation / *Kevin J. Lansing*

05-31 Why Hasn't the Jump in Oil Prices Led to a Recession? / *John Fernald and Bharat Trehan*

05-32 The Bretton Woods System: Are We Experiencing a Revival? Symposium Summary / *Reuven Glick and Mark Spiegel*

05-33 Uncertainty and Monetary Policy / *Richard Dennis*

05-34 Recent Policy Issues Regarding Credit Risk Transfer / *Jose A. Lopez*

05-35 Shifting Data: A Challenge for Monetary Policymakers / *John Fernald and Stephanie Wang*

05-36 Bank ATMs and ATM Surcharges / *Gautam Gowrisankaran and John Krainer*

05-37 The Diffusion of Personal Computers across the U.S. / *Mark Doms*

05-38 Do Oil Futures Prices Help Predict Future Oil Prices? / *Tao Wu and Andrew McCallum*

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