Economic Review 2007

An annual publication of the Economic Research Department

Federal Reserve Bank of San Francisco

Table of Contents

The Federal Reserve Bank of San Francisco's *Economic Review* is published annually by the Research Department, under the supervision of

John Judd, Executive Vice President and Director of Research;
Glenn Rudebusch, Senior Vice President and Associate Director of Research;
John C. Williams, Senior Vice President and Advisor;
Frederick Furlong, Group Vice President, Financial and Applied Microeconomic Research, and Executive Director of the Center for the Study of Innovation and Productivity;
Reuven Glick, Group Vice President, International Research;
Mary Daly, Vice President, Applied Microeconomic Research and Regional Developments, and Director of the Center for the Study of Innovation and Productivity;
John Fernald, Vice President, Macroeconomic Research;
Simon Kwan, Vice President, Financial Research;
Mark Spiegel, Vice President, International Research, and Director of the Center for Pacific Basin Studies.

The publication is edited, compiled, and produced by Anita Todd, Research Editor.

Please send editorial comments and requests for subscriptions, back copies, address changes, and reprint permission to:

Public Information Department
Federal Reserve Bank of San Francisco
PO Box 7702
San Francisco, CA 94120

phone (415) 974-2163
fax (415) 974-3341
e-mail Pubs.sf@sf.frb.org

The *Economic Review* and other publications and information from this Bank are available on our website:

http://www.frbsf.org

See also *Fed in Print*, a searchable database of all research publications in the Federal Reserve System:

http://www.frbsf.org/publications/fedinprint/index.html

Printed on recycled paper with soybean inks

Inflation Targeting under Imperfect Knowledge*

Athanasios Orphanides

Senior Adviser
Board of Governors of the Federal Reserve System

John C. Williams

Senior Vice President and Advisor
Federal Reserve Bank of San Francisco

A central tenet of inflation targeting is that establishing and maintaining well-anchored inflation expectations are essential. In this paper, we reexamine the role of key elements of the inflation targeting framework towards this end, in the context of an economy where economic agents have an imperfect understanding of the macroeconomic landscape within which the public forms expectations and policymakers must formulate and implement monetary policy. Using an estimated model of the U.S. economy, we show that monetary policy rules that would perform well under the assumption of rational expectations can perform very poorly when we introduce imperfect knowledge. We then examine the performance of an easily implemented policy rule that incorporates three key characteristics of inflation targeting: transparency, commitment to maintaining price stability, and close monitoring of inflation expectations, and find that all three play an important role in assuring its success. Our analysis suggests that simple difference rules in the spirit of Knut Wicksell excel at tethering inflation expectations to the central bank's goal and in so doing achieve superior stabilization of inflation and economic activity in an environment of imperfect knowledge.

1. Introduction

A central tenet of inflation targeting is that establishing and maintaining well-anchored inflation expectations are essential. Well-anchored expectations enable inflation-targeting central banks to achieve greater stability of output and employment in the short run, while ensuring price stability in the long run. Three elements of inflation targeting have been critically important for the successful implementation of this framework.[1] First and foremost is the announcement of an explicit quantitative inflation target and the acknowledgment that low, stable inflation is the primary objective and responsibility of the central bank. Second is the clear communication of the central bank's policy strategy and the rationale for its decisions, which enhances the predictability of the central bank's actions and its accountability to the public. Third is a forward-looking policy orientation, characterized by the vigilant monitoring of inflation expectations at both short-term and longer-term horizons. Together, these elements provide a focal point for inflation, facilitate the formation of the public's inflation expectations, and provide guidance on actions that may be needed to foster price stability.

*We would like to thank Richard Dennis, Bill English, Ali Hakan Kara, Thomas Laubach, Nissan Liviatan, John Murray, Rodrigo Vergara, and participants of presentations at the Federal Reserve Board, the Bundesbank, the Federal Reserve Banks of Chicago and New York, the American University, the conference on "Monetary Policy under Inflation Targeting," Santiago, October 20–21, 2005, the conference in honor of Alex Cukierman on "New Developments in the Analysis of Monetary Policy and Institutions," Tel Aviv, December 15–16, 2005, and the British Columbia Macro/Bank of Canada conference, Vancouver, April 7–8, 2006, for useful comments. This article is reprinted from the conference volume *Series on Central Banking, Analysis, and Economic Policies X: Monetary Policy under Inflation Targeting,* eds. Frederic Mishkin and Klaus Schmidt-Hebbel. Santiago, Chile: Central Bank of Chile, 2007. Opinions expressed do not necessarily reflect the views of the management of the Federal Reserve Bank of San Francisco or the Board of Governors of the Federal Reserve System.

1. A number of studies have examined in detail the defining characteristics of inflation targeting. See Leiderman and Svensson (1995), Bernanke and Mishkin (1997), Bernanke et al. (1999), and Goodfriend (2004).

Although inflation-targeting central banks stress these key elements, the literature that studies inflation targeting in the context of formal models largely describes inflation targeting in terms of the solution to an optimization problem within the confines of a linear rational expectations model. This approach is limited in its appreciation of the special features of the inflation-targeting framework, as emphasized by Faust and Henderson (2004), and it strips inflation targeting of its raison d'être. In an environment of rational expectations with perfect knowledge, for instance, inflation expectations are anchored as long as policy satisfies a minimum test of stability. Furthermore, with the possible exception of a one-time statement of the central bank's objectives, central bank communication loses any independent role because the public already knows all it needs in order to form expectations relevant for its decisions. In such an environment, the public's expectations of inflation and other variables are characterized by a linear combination of lags of observed macroeconomic variables, and, as such, they do not merit special monitoring by the central bank or provide useful information to the policymaker for guiding policy decisions.

In this paper, we argue that in order to understand the attraction of inflation targeting to central bankers and its effectiveness relative to other monetary policy strategies, it is essential to recognize economic agents' imperfect understanding of the macroeconomic landscape within which the public forms expectations and policymakers formulate and implement monetary policy. To this end, we consider two modest deviations from the perfect-knowledge rational expectations benchmark, and we reexamine the role of the key elements of the inflation-targeting framework in the context of an economy with imperfect knowledge. We find that including these modifications provides a rich framework in which to analyze inflation-targeting strategies and their implementation.

The first relaxation of perfect knowledge that we incorporate is to recognize that policymakers face uncertainty regarding the evolution of key natural rates. In the United States, for example, estimates of the natural rates of interest and unemployment are remarkably imprecise.[2] This problem is arguably even more dramatic for small open economies and transitional economies that have tended to adopt inflation targeting. Policymakers' misperceptions regarding the evolution of natural rates can result in persistent policy errors, hindering successful stabilization policy.[3]

Our second modification is to allow for the presence of imperfections in expectations formation that arise when economic agents have incomplete knowledge of the economy's structure. We assume that agents rely on an adaptive learning technology to update their beliefs and form expectations based on incoming data. Recent research highlights the ways in which imperfect knowledge can act as a propagation mechanism for macroeconomic disturbances in terms of amplification and persistence that have first-order implications for monetary policy.[4] Agents may rely on a learning technology to guard against numerous potential sources of uncertainty. One source could be the evolution of natural rates in the economy, paralleling the uncertainty faced by policymakers. Another might involve the policymakers' understanding of the economy, their likely response to economic developments, and the precise quantification of policy objectives. Recognition of this latter element in the economy highlights a role for central bank communications, including that of an explicit quantitative inflation target, which would be absent in an environment of perfect knowledge.

We investigate the role of inflation targeting in an environment of imperfect knowledge using an estimated quarterly model of the U.S. economy. Specifically, we compare the performance of the economy subject to shocks with characteristics similar to those observed in the data over the past four decades under alternative informational assumptions and policy strategies. Following McCallum (1988) and Taylor (1993), we focus on implementable policy rules that capture the key characteristics of inflation targeting. Our analysis shows that some monetary policy rules that would perform well under the assumption of rational expectations with perfect knowledge perform very poorly when we introduce imperfect knowledge. In particular, rules that rely on estimates of natural rates for setting policy are susceptible to persistent errors. Under certain conditions, these errors can give rise to endogenous inflation scares, whereby inflation expectations become unmoored from the central bank's desired anchor. These results illustrate the potential shortcomings of such standard policy rules and the desirability of identifying an alternative monetary policy framework when knowledge is imperfect.

2. For discussion and documentation of this imprecision, see Orphanides and Williams (2002), Laubach and Williams (2003), and Clark and Kozicki (2005). See also Orphanides and van Norden (2002) for the related unreliability regarding the measurement of the natural rate of output and implied output gap.

3. For analyses of the implications of misperceptions for policy design, see Orphanides and Williams (2002), Orphanides (2003b), and Cukierman and Lippi (2005).

4. See Orphanides and Williams (2004, 2005a, b, c), Gaspar and Smets (2002), Gaspar, Smets and Vestin (2006), and Milani (2005).

We then examine the performance of an easily implemented policy rule that incorporates the three key characteristics of inflation targeting highlighted above in an economy with imperfect knowledge. The exercise reveals that all three play an important role in ensuring success. First, central bank transparency, including explicit communication of the inflation target, can lessen the burden placed on agents to infer central bank intentions and can thereby improve macroeconomic performance. Second, policies that do not rely on estimates of natural rates are easy to communicate and are well designed for ensuring medium-run inflation control when natural rates are highly uncertain. Finally, policies that respond to the public's near-term inflation expectations help the central bank avoid falling behind the curve in terms of controlling inflation, and they result in better stabilization outcomes than policies that rely only on past realizations of data and ignore information contained in private agents' expectations.

A reassuring aspect of our analysis is that despite the environment of imperfect knowledge and the associated complexity of the economic environment, successful policy can be remarkably simple to implement and communicate. We find that simple difference rules that do not require any knowledge of the economy's natural rates are particularly well suited to ensure medium-run inflation control when natural rates are highly uncertain. These rules share commonalities with the simple robust strategy first proposed by Wicksell (1936 [1898]), who, after defining the natural interest rate, pointed out that precise knowledge about it, though desirable, was neither feasible nor necessary for policy implementation aimed toward maintaining price stability.

> This does not mean that the bank ought actually to *ascertain* the natural rate before fixing their own rates of interest. That would, of course, be impracticable, and would also be quite unnecessary. For the current level of commodity prices provides a reliable test of the agreement or diversion of the two rates. The procedure should rather be simply as follows: *So long as prices remain unchanged, the bank's rate of interest is to remain unaltered. If prices rise, the rate of interest is to be raised; and if prices fall, the rate of interest is to be lowered; and the rate of interest is henceforth to be maintained at its new level until a further movement in prices calls for a further change in one direction or the other. . . .*
>
> In my opinion, the main cause of the instability of prices resides in the instability of the banks to follow this rule.[5]

5. Wicksell (1936 [1898] p. 189; emphasis in original).

Our analysis confirms that simple difference rules that implicitly target the price level in the spirit of Wicksell excel at tethering inflation expectations to the central bank's goal. In so doing, they achieve superior stabilization of inflation and economic activity.

The remainder of the paper is organized as follows. Section 2 describes the estimated model of the economy. Section 3 lays out the model of perpetual learning and its calibration. Section 4 analyzes key features of the model under rational expectations and imperfect knowledge. Section 5 examines the performance of alternative monetary policy strategies, including our implementation of inflation targeting. Section 6 concludes.

2. A Simple Estimated Model of the U.S. Economy

We use a simple estimated quarterly model of the U.S. economy from Orphanides and Williams (2002), the core of which consists of the following two equations:

$$(1)\quad \pi_t = \phi_\pi \pi^e_{t+1} + (1-\phi_\pi)\pi_{t-1} + \alpha_\pi (u^e_t - u^*_t) + e_{\pi,t},\;\; e_\pi \sim \text{i.i.d.}\,(0, \sigma^2_{e_\pi})\ ,$$

$$(2)\quad u_t = \phi_u u^e_{t+1} + \chi_1 u_{t-1} + \chi_2 u_{t-2} + \chi_3 u^*_t + \alpha_u\,(r^a_{t-1} - r^*_t) + e_{u,t}\,,\;\; e_u \sim \text{i.i.d.}\,(0, \sigma^2_{e_u})\ .$$

Here π denotes the annualized percent change in the aggregate output price deflator, u denotes the unemployment rate, u^* denotes the (true) natural rate of unemployment, r^a denotes the (ex ante) real interest rate with one-year maturity, and r^* the (true) natural real rate of interest. The superscript e denotes the public's expectations formed during $t-1$. This model combines forward-looking elements of the new synthesis model studied by Goodfriend and King (1997), Rotemberg and Woodford (1999), Clarida, Galí, and Gertler (1999), and McCallum and Nelson (1999), with intrinsic inflation and unemployment inertia as in Fuhrer and Moore (1995b), Batini and Haldane (1999), Smets (2003), and Woodford (2003).

The "Phillips curve" in this model (1) relates inflation in quarter t to lagged inflation, expected future inflation, and expectations of the unemployment gap during the quarter, using retrospective estimates of the natural rate discussed below. The estimated parameter ϕ_π measures the importance of expected inflation for the determination of inflation. The unemployment equation (2) relates unemployment in quarter t to the expected future unemployment rate, two lags of the unemployment rate, the natural rate of unemployment, and the lagged real interest rate gap. Here, two elements reflect forward-looking behavior: the estimated parameter ϕ_u which measures the importance of expected unemployment, and the duration of the real interest rate, which serves as a summary of the influence of interest rates of various maturities on economic activity. We restrict the coefficient χ_3 to equal $1-\phi_u-\chi_1-\chi_2$ so that the equation can be equivalently written in terms of the unemployment gap.

In estimating this model, we face the difficulty that expected inflation and unemployment are not directly observed. Instrumental variable and full-information maximum likelihood methods impose the restriction that the behavior of monetary policy and the formation of expectations be constant over time, neither of which appears tenable over the sample period that we consider (1969–2002). Instead, we follow the approach of Roberts (1997) and use survey data as proxies for expectations.[6] In particular, we use the median forecasts from the Survey of Professional Forecasters from the prior quarter as the relevant expectations for determining inflation and unemployment in period t; that is, we assume expectations are based on information available at time $t-1$. We also employ first-announced estimates of these series in our estimation, to match the inflation and unemployment data as well as possible with the forecasts. Our primary sources for these data are the Real-Time Dataset for Macroeconomists and the Survey of Professional Forecasters, both currently maintained by the Federal Reserve Bank of Philadelphia (Zarnowitz and Braun 1993, Croushore 1993, Croushore and Stark 2001). Using least squares over the sample 1969:Q1 to 2002:Q2, we obtain the following estimates:

$$
\begin{aligned}
(3)\quad \pi_t = {}& \underset{(0.086)}{0.540}\ \pi^e_{t+1} + \underset{(--)}{0.460}\ \pi_{t-1} \\
& - \underset{(0.099)}{0.341}\ (u^e_t - u^*_t) + e_{\pi,t}, \\
& \qquad SER = 1.38,\ DW = 2.09,
\end{aligned}
$$

$$
\begin{aligned}
(4)\quad u_t = {}& \underset{(0.084)}{0.257}\ u^e_{t+1} + \underset{(0.107)}{1.170}\ u_{t-1} - \underset{(0.071)}{0.459}\ u_{t-2} \\
& - \underset{(--)}{0.032}\ u^*_t + \underset{(0.013)}{0.043}\ (r^a_{t-1} - r^*_t) + e_{u,t}, \\
& \qquad SER = 0.30,\ DW = 2.08.
\end{aligned}
$$

The numbers in parentheses are the estimated standard errors of the corresponding regression coefficients; SER is the standard error of the regression and DW is the Durbin-Watson statistic. (Dashes are shown under the restricted parameters.) The estimated unemployment equation also includes a constant term (not shown) that captures the average premium of the one-year Treasury bill rate we use for estimation over the average of the federal funds rate, which corresponds to the natural interest rate estimates we employ in the model. For simplicity, we do not model the evolution of risk premiums. In the model simulations, we impose the expectations theory of the term structure, whereby the one-year rate equals the expected average of the federal funds rate over four quarters.

2.1. Natural Rates

We assume that the true processes governing natural rates in the economy follow highly persistent autoregressions. Specifically, we posit that the natural rates follow

$$
\begin{aligned}
u^*_t &= 0.01\bar{u}^* + 0.99\ u^*_{t-1} + e_{u^*,t}, \\
r^*_t &= 0.01\bar{r}^* + 0.99\ r^*_{t-1} + e_{r^*,t},
\end{aligned}
$$

where $\bar{u}^*$ and $\bar{r}^*$ denote the unconditional means of the natural rates of unemployment and interest, respectively. The assumption that these processes are stationary is justified by the finding, based on a standard augmented Dickey-Fuller (ADF) test, that one can reject the null hypothesis of nonstationarity of both the unemployment rate and the ex post real federal funds rate over 1950–2003 at the 5-percent level. To capture the assumed high persistence of these series, we set the first-order autoregressive, or AR(1), coefficient to 0.99 and then calibrate the innovation variances to be consistent with estimates of time variation in the natural rates in postwar U.S. data.

As discussed in Orphanides and Williams (2002), estimates of the variances of the innovations to the natural rates differ widely. Indeed, owing to the imprecision in estimates of these variances, the postwar U.S. data do not provide clear guidance regarding these parameters. We therefore consider three alternative calibrations of these variances, which we index by s. The case of $s=0$ corresponds to constant and known natural rates, where $\sigma_{e_{u^*}} = \sigma_{e_{r^*}} = 0$. For the case of $s=1$, we assume $\sigma_{e_{u^*}} = 0.070$ and $\sigma_{e_{r^*}} = 0.085$. These values imply an unconditional standard deviation of the natural rate of unemployment (interest) of 0.50 (0.60), which is in the low end of the range of standard deviations of smoothed estimates of these natural rates suggested by various estimation methods (see Orphanides and Williams 2002 for details). Finally, the case of $s=2$ corresponds to the high end of the range of estimates, for which case we assume $\sigma_{e_{u^*}} = 0.140$ and $\sigma_{e_{r^*}} = 0.170$. The relevant values of s for many small open economies and transitional economies may be even higher than estimates based on U.S. data, given the relative stability of the postwar U.S. economy.

6. See also Rudebusch (2002) and Orphanides and Williams (2005c).

2.2. Monetary Policy

We consider two classes of simple monetary policy rules. First, we analyze versions of the Taylor rule (Taylor 1993), where the *level* of the nominal interest rate is determined by the perceived natural rate of interest, $\hat{r}_t^*$, the inflation rate, and a measure of the *level* of the perceived unemployent gap (namely, the difference between the unemployment rate and the perceived natural rate of unemployment, $\hat{u}_t^*$):

$$(5)\quad i_t = \hat{r}_t^* + \bar{\pi}_{t+j}^e + \theta_\pi(\bar{\pi}_{t+j}^e - \pi^*) + \theta_u(u_{t+k}^e - \hat{u}_t^*),$$

where $\bar{\pi}$ denotes the four-quarter average of the inflation rate, π^* is the central bank's inflation objective, j is the forecast horizon of inflation, and k is the forecast horizon of the unemployment rate forecast. We consider a range of values for the forecast horizons from -1, in which case policy responds to the latest observed data (for quarter $t-1$), to a forecast horizon up to three years into the future. When policy is based on forecasts, we assume that the central bank uses the same forecasts of inflation and the unemployment rate that are available to private agents.

We refer to this class of rules as level rules because they relate the level of the interest rate to the level of the unemployment gap. Rules of this type have been found to perform quite well in terms of stabilizing economic fluctuations, at least when the natural rates of interest and unemployment are accurately measured. For our analysis, we consider a variant of the Taylor rule that responds to the unemployment gap instead of the output gap, recognizing that the two are related by Okun's (1962) law. In his 1993 exposition, Taylor examines response parameters equal to 0.5 for the inflation gap and the output gap, which, with an Okun's coefficient of 2.0, corresponds to setting $\theta_\pi = 0.5$ and $\theta_u = -1.0$.

If policy follows a level rule given by equation (5), then the policy error introduced in period t by natural rate misperceptions is given by

$$(\hat{r}_t^* - r_t^*) - \theta_u(\hat{u}_t^* - u_t^*).$$

Although unintentional, these errors could subsequently induce undesirable fluctuations in the economy, worsening stabilization performance. The extent to which misperceptions regarding the natural rates translate into policy-induced fluctuations depends on the parameters of the policy rule. As is evident from the above expression, policies that are relatively unresponsive to real-time assessments of the unemployment gap—that is, those with small θ_u—minimize the impact of misperceptions regarding the natural unemployment rate.

As discussed in Orphanides and Williams (2002), one policy rule that is immune to natural rate mismeasurement of the kind considered here is a difference rule, in which the change in the nominal interest rate is determined by the inflation rate and the change in the unemployment rate:

$$(6)\quad \Delta i_t = \theta_\pi(\bar{\pi}_{t+j}^e - \pi^*) + \theta_{\Delta u}\Delta u_{t+k}.$$

This rule is closely related to price-level targeting strategies. It corresponds to the first difference of the rule that would be obtained if the price level were substituted for inflation in the level rule (5).[7] This policy rule is as simple, in terms of the number of parameters, as the original formulation of the Taylor rule. However, the difference rule is simpler to communicate and implement in practice than the Taylor rule because it does not require knowledge of the natural rates of interest or unemployment. Policy guided by a difference rule can thus be more transparent than policy guided by a level rule.

3. Perpetual Learning

Expectations play a central role in determining inflation, the unemployment rate, and the interest rate in the model. We consider two alternative models of expectations formation. One model, used in most monetary policy research, is rational expectations, that is, expectations that are consistent with the model. The second model is one of perpetual learning, where agents continuously reestimate a forecasting model and form expectations using that model.

In the case of learning, we follow Orphanides and Williams (2005c) and posit that agents obtain forecasts for inflation, unemployment, and interest rates by estimating a restricted vector autoregression (VAR) corresponding to the reduced form of the rational expectations equilibrium with constant natural rates. We assume that this VAR is estimated recursively with constant-gain least squares.[8] Each period, agents use the resulting VAR to construct one-step-ahead and multi-step-ahead forecasts. This learning model can be justified in two ways. First, in practice agents are working with finite quantities of data, and the assumption of rational expectations only holds in the distant future when sufficient data have been collected. Alternatively, agents may allow for the possibility of structural change

7. For related policy rule specifications, see Judd and Motley (1992), Fuhrer and Moore (1995a), and Orphanides (2003a). See also Orphanides and Williams (2002, 2005b) for analyses of a generalization that nests the level rule (5) and difference rule (6).

8. Sargent (1993, 1999) and Evans and Honkapohja (2001) discuss properties of constant-gain learning.

and therefore place less weight on older data, in which case learning is a never-ending process.

Specifically, let Y_t denote the 1×3 vector consisting of the inflation rate, the unemployment rate, and the federal funds rate, each measured at time t: $Y_t = (\pi_t, u_t, i_t)$. Let X_t be the $j \times 1$ vector of a constant and lags of Y_t that serve as regressors in the forecast model. The precise number of lags of elements of Y_t that appear in X_t may depend on the policy rule. For example, consider the difference rule (6) when policy responds to the three-quarter-ahead forecast of inflation, $j = 3$, and the lagged change in the unemployment rate, $k = -1$. (This is one of the policies for which we present detailed simulation results later on). In this case, two lags of the unemployment rate and one lag each of inflation and the interest rate suffice to capture the reduced-form dynamics under rational expectations with constant natural rates, so $X_t = (1, \pi_{t-1}, u_{t-1}, u_{t-2}, i_{t-1})'$.

The recursive estimation can be described as follows: Let c_t be the $j \times 3$ vector of coefficients of the forecasting model. Then, using data through period t, the parameters for the constant-gain least squares forecasting model can be written as

$$c_t = c_{t-1} + \kappa R_t^{-1} X_t (Y_t - X_t' c_{t-1}), \tag{7}$$

$$R_t = R_{t-1} + \kappa (X_t X_t' - R_{t-1}), \tag{8}$$

where $\kappa > 0$ is a small constant gain.

This algorithm estimates all parameters of the agent's forecasting system and does not explicitly incorporate any information regarding the central bank's numerical inflation objective. Later, we introduce this element of inflation targeting by positing that the announcement and explicit commitment to a quantitative inflation target simplifies the agent's forecasting problem by reducing by one the number of parameters requiring estimation and updating.

A key parameter for the constant-gain learning algorithm is the updating rate κ. To calibrate the relevant range for this parameter, we examined how well different values of κ fit the expectations data from the Survey of Professional Forecasters (SPF), following Orphanides and Williams (2005c). To examine the fit of the SPF, we generated a time series of forecasts using a recursively estimated VAR for the inflation rate, the unemployment rate, and the federal funds rate. In each quarter we reestimated the model using all historical data available during that quarter (generally from 1948 through the most recent observation). We allowed for discounting of past observations by using geometrically declining weights. This procedure resulted in reasonably accurate forecasts of inflation and unemployment, with root mean squared errors (RMSE) comparable to the residual standard errors from the estimated structural equations (3) and (4). We found that discounting past data with values for κ in the range 0.01 to 0.04 yielded forecasts closer to the SPF, on average, than the forecasts obtained with lower or higher values of κ. Milani (2005) finds a similar range of values in an estimated dynamic stochastic general-equilibrium (DSGE) model with learning. In light of these results, we consider three alternative calibrations of the gain, $\kappa = \{0.01, 0.02, 0.03\}$, with $\kappa = 0.02$ serving as a "baseline" value.[9] As in the case of natural rate variation, the relevant values of κ may be higher for small open economies and transitional economies than for the U.S. data, owing to the relative stability of the postwar U.S. economy.

Given this calibration of the model, this learning mechanism represents a relatively modest deviation from rational expectations and yields reasonable forecasts. Indeed, agents' average forecasting performance in the model is close to the optimal forecast.

3.1. Central Bank Learning

In the case of level rules, policymakers need a procedure to compute real-time estimates of the natural rates. If policymakers knew the true data-generating processes governing the evolution of natural rates, they could use this knowledge to design the optimal estimator. In practice, however, considerable uncertainty surrounds these processes, and the optimal estimator for one process may perform poorly if the process is misspecified. Williams (2005) shows that a simple constant-gain method to update natural rate estimates based on the observed rates of unemployment and (ex post) real interest rates is reasonably robust to natural rate model misspecification. We follow this approach and assume that policymakers update their estimates of natural rates using simple constant-gain estimators given by the following equations:

$$\hat{r}_t^* = \hat{r}_{t-1}^* + 0.005(i_{t-1} - \pi_{t-1} - \hat{r}_{t-1}^*),$$

$$\hat{u}_t^* = \hat{u}_{t-1}^* + 0.005(u_{t-1} - \hat{u}_{t-1}^*).$$

4. Effects of Imperfect Knowledge on Economic Dynamics

We first present some simple comparisons of the economy's behavior under rational expectations with known natural rates and under learning with time-varying and

9. The value $\kappa = 0.02$ is also in line with the discounting that Sheridan (2003) finds to best explain the inflation expectations data reported in the Livingston Survey.

unobservable natural rates. Under learning, the economy is governed by nonlinear dynamics, so we use numerical simulations to illustrate the properties of the model economy, conditional on the policymaker following a specific policy rule.

4.1. Simulation Methodology

In the case of rational expectations with constant and known natural rates, we compute all model moments and impulse responses numerically as described in Levin, Wieland, and Williams (1999). In all other cases, we compute approximations of the unconditional moments and impulse responses using simulations of the model.

For model stochastic simulations used to compute estimates of unconditional moments, the initial conditions for each simulation are given by the rational expectations equilibrium with known and constant natural rates. Specifically, all model variables are initialized to their steady-state values, assumed without loss of generality to be zero. The central bank's initial perceived levels of the natural rates are set to their true values, likewise equal to zero. Finally, the initial values of the c and R matrices describing the private agents' forecasting model are initialized to their respective values, which correspond to the reduced form of the rational equilibrium solution to the structural model assuming constant and known natural rates.

Each period, innovations are generated from Gaussian distributions, with variances reported above. The innovations are serially and contemporaneously uncorrelated. For each period, the structural model is simulated, the private agent's forecasting model is updated (resulting in a new set of forecasts), and the central bank's natural rate estimate is updated. To estimate model moments, we simulate the model for 41,000 periods and discard the first 1,000 periods to mitigate the effects of initial conditions. We compute the unconditional moments from sample root mean squares from the remaining 40,000 periods (10,000 years) of simulation data.[10]

The private agents' learning process injects a nonlinear structure into the model, which may generate explosive behavior in a stochastic simulation of sufficient length for some policy rules that would have been stable under rational expectations. One source of instability stems from the possibility that the forecasting model itself may become unstable. We take the view that private forecasters reject unstable models in practice. Each period of the simulation, we compute the maximum modulus root of the forecasting VAR excluding the constants. If the modulus of this root falls below the critical value of one, the forecasting model is updated as described above; if not, we assume that the forecasting model is not updated and the c and R matrices are held at their respective previous-period values.[11]

Stability of the forecasting model is not sufficient to ensure stability in all simulations. We therefore impose a second condition that restrains explosive behavior. In particular, if the inflation rate or the unemployment gap exceeds, in absolute value, five times its respective unconditional standard deviation (computed under the assumption of rational expectations and known and constant natural rates), then the variable that exceeds this bound is constrained to equal the corresponding limit in that period. These constraints on the model are sufficient to avoid explosive behavior for the exercises that we consider in this paper; they are rarely invoked for most of the policy rules we study, particularly for optimized policy rules.

For impulse responses, we first compute an approximation of the steady-state distribution of the model state vector by running a stochastic simulation of 100,000 periods. We then draw 1,001 sample state vectors from this distribution and compute the impulse response function for each of these draws. From these 1,001 impulse response functions, we compute an estimate of the distribution of the model impulse response functions.

4.2. Impulse Responses

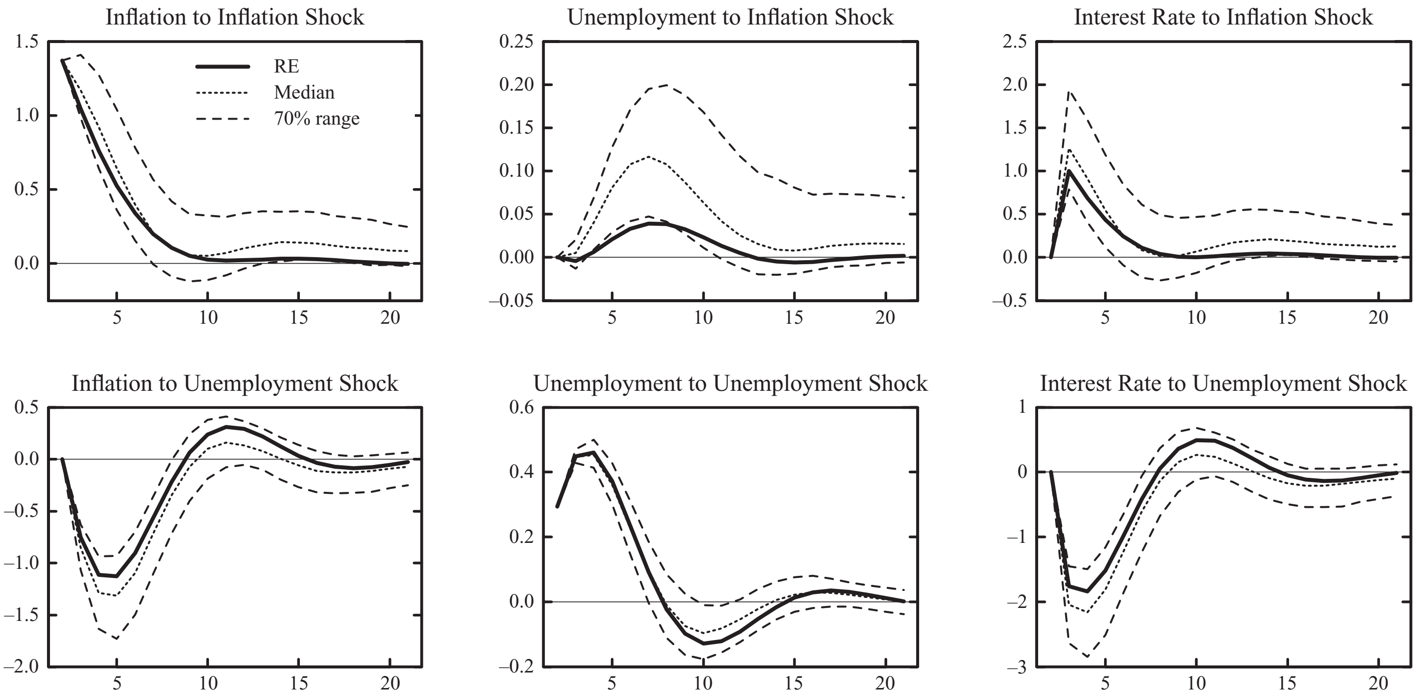
We use model impulse responses to illustrate the effects of learning on macroeconomic dynamics. For this purpose, let monetary policy follow a level policy rule similar to that proposed by Taylor (1993), with $\theta_\pi = 0.5$ and $\theta_u = -1$, where the inflation forecast horizon is three quarters ahead ($j = 3$) and that of the unemployment rate is the last observed quarter (that is, $k = -1$).

Figure 1 compares the impulse responses of inflation, the nominal interest rate, and the unemployment rate to one-standard-deviation shocks to inflation and unemployment under perfect knowledge (that is, rational expectations with known natural rates) with the corresponding impulse responses under imperfect knowledge with time variation in the natural rates, $s = 1$, and perpetual learning with gain $\kappa = 0.02$. Each period corresponds to one quarter. Under learning, the impulse responses to a spe-

10. Simulations under rational expectations, in which we can compute the moments directly, indicate that this sample size is sufficient to yield very accurate estimates of the unconditional variances. Testing further indicates that 1,000 periods are sufficient to remove the effects of initial conditions on simulated second moments.

11. We chose this critical value so that the test would have a small effect on model simulation behavior while eliminating explosive behavior in the forecasting model.

FIGURE 1
IMPULSE REPONSES UNDER THE TAYLOR RULE: $i_t = \hat{r}_t^* + \bar{\pi}_{t+3}^e + 0.5\left(\bar{\pi}_{t+3}^e - \pi^*\right) - \left(u_{t-1} - \hat{u}_t^*\right)$



Note: For all figures, unless otherwise specified, RE refers to rational expectations with perfect knowledge; under learning, median and 70-percent range of outcomes assume $s = 1$, $\kappa = 0.02$.

cific shock vary with the state of the economy and the state of beliefs governing the formation of expectations. In other words, the responses vary with the initial conditions, $\{X, c, R\}$, at the time the shock occurs. To summarize the range of possible outcomes in the figure, we plot the median and the 70-percent range of the distribution of impulse responses, corresponding to the stationary distribution of $\{X, c, R\}$. Under rational expectations, the responses are invariant to the state of the economy.

The dynamic impulse responses to a specific shock exhibit considerable variation under learning. Furthermore, the distribution of responses is not symmetric around the impulse response that obtains under rational expectations. For example, the impulse responses of inflation and unemployment to an inflation shock are noticeably skewed in a direction that yields greater persistence. This persistence may be quite extreme with some probability, indicating that transitory shocks can have very long-lasting effects under learning.

4.3. Macroeconomic Variability and Persistence

Perpetual learning provides a powerful propagation mechanism for economic shocks in the economy, resulting in greater volatility and persistence. We present a summary comparison of the asymptotic variances and persistence for this experiment in Table 1, which includes the full range of natural range variation and values of κ that we consider here. Learning on the part of the public increases the variability and persistence of key macroeconomic variables. Even in the absence of natural rate misperceptions (the case of $s = 0$), shocks to inflation and unemployment engender time variation in private agents' estimates of the VAR used for forecasting. This time variation in the VAR coefficients adds persistent noise to the economy relative to the perfect-knowledge benchmark. As a result, the unconditional variances and the serial correlations of inflation, unemployment, and the interest rate rise under learning. These effects are larger for higher values of κ, for which the sensitivity of the VAR coefficients to incoming data is greater.

The presence of natural rate variation amplifies the effects of private sector learning on macroeconomic variability and persistence. Under rational expectations and the Taylor rule, time-varying natural rates and the associated misperceptions increase the variability of inflation, but have relatively little effect on the variability of the unemployment gap and interest rates. Nevertheless, the combi-

TABLE 1
PERFORMANCE UNDER THE TAYLOR RULE

Expectations		Standard deviation			First-order autocorrelation		
	s	π	$u-u^*$	Δi	π	$u-u^*$	i
RE	0	2.93	0.87	2.33	0.81	0.88	0.78
	1	3.22	0.88	2.35	0.84	0.88	0.82
	2	3.94	0.89	2.39	0.89	0.88	0.89
$\kappa = 0.01$	0	3.29	0.93	2.57	0.84	0.89	0.81
	1	4.16	1.10	2.89	0.89	0.92	0.86
	2	5.00	1.22	3.10	0.93	0.93	0.89
$\kappa = 0.02$	0	3.66	0.99	2.80	0.86	0.90	0.83
	1	4.35	1.11	3.01	0.90	0.92	0.87
	2	5.21	1.24	3.29	0.93	0.93	0.89
$\kappa = 0.03$	0	3.95	1.04	3.00	0.87	0.91	0.84
	1	4.57	1.15	3.22	0.90	0.92	0.87
	2	5.37	1.29	3.48	0.92	0.93	0.89

nation of private sector learning and natural rate variation (and misperceptions) can dramatically increase macroeconomic variability and persistence. For example, under the Taylor rule, the standard deviation of the unemployment gap rises from 0.87 percent under rational expectations with constant natural rates to 1.11 percent under learning with $s = 1$ and $\kappa = 0.02$. For inflation, the increase in the standard deviation is even more dramatic, from 2.93 percent to 4.35 percent. The first-order autocorrelation of the unemployment gap rises from 0.88 to 0.92 and that of inflation rises from 0.81 to 0.90. The presence of natural rate variation and misperceptions interferes with the public's ability to forecast inflation, unemployment, and interest rates accurately. These forecasting errors contribute to a worsening of macroeconomic performance.

4.4. Excess Sensitivity of Long-Horizon Expectations

The adaptive learning algorithm that economic agents employ to form expectations under imperfect knowledge in our model also allows us to investigate the behavior of long-horizon expectations. This allows examination of the apparent excess sensitivity of yields on long-run government bonds to shocks—a phenomenon that appears puzzling in standard models when knowledge is perfect. Shiller (1979) and Mankiw and Summers (1984) point out that long-term interest rates appear to move in the same direction following changes in short-term interest rates and to overreact relative to what would be expected if the expectations hypothesis held and expectations were assumed to be rational. Changes in the federal funds rate generally cause long-term interest rates to move considerably and in the same direction (Cook and Hahn 1989, Roley and Sellon 1995, Kuttner 2001). Kozicki and Tinsley (2001a, b), Cogley (2005), and Gürkaynak, Sack, and Swanson (2005) suggest that this sensitivity could be attributed to movements in long-run inflation expectations that differ from those implied by standard linear rational expectations macroeconomic models with fixed and known parameters.

Learning-induced expectations dynamics provide a potential explanation for these phenomena.[12] Figure 2 shows the one-, two-, and ten-year-ahead forecasts of the inflation and nominal interest rates from the impulse response to a one-standard-deviation inflation shock, based on the same shocks used in computing Figure 1; Figure 3 shows the same for a one-standard-deviation shock to the unemployment rate. These measure the annualized quarterly inflation or interest rate expected to prevail n quarters in the future, not the average inflation or interest rate over the next n quarters. These forward rates are computed by projecting ahead using the agents' forecasting model. Under perfect knowledge, inflation is expected to be only a few basis points above baseline two years after the shock, and expectations of inflation ten years in the future are nearly unmoved. The same pattern is seen in forward interest rates.

In contrast to the stability of longer-run expectations found under perfect knowledge, the median response under imperfect knowledge shows inflation and interest rate expectations at the two- and ten-year horizons rising by nearly 10 basis points in response to a transitory inflation shock. Moreover, the excess sensitivity of longer-run inflation expectations to transitory shocks exhibited by the median response is on the lower end of the 70-percent range of impulse responses, indicating that the response of longer-run expectations is, on average, even larger and depends crucially on the conditions in which the shock occurs. Indeed, under unfavorable conditions, the inflation expectations process can become unmoored for an extended period. Such episodes correspond to endogenously generated "inflation scares" and are similar to historical episodes for the United States described in Goodfriend (1993). In these episodes, inflation expectations and long-term interest rates appear to react excessively and persistently to some event that would not warrant such a reaction if expectations were well anchored.

These results also serve to highlight one of the crucial concerns regarding the behavior of expectations that the practice of inflation targeting attempts to address and that cannot appear in an environment of rational expectations

12. Orphanides and Williams (2005a) and Beechey (2004) analyze the reaction of the term structure of expectations to news in the presence of perpetual learning.

Figure 2
Impulse Responses to Inflation Shock under the Taylor Rule: $i_t = \hat{r}_t^* + \bar{\pi}_{t+3}^e + 0.5\left(\bar{\pi}_{t+3}^e - \pi^*\right) - \left(u_{t-1} - \hat{u}_t^*\right)$

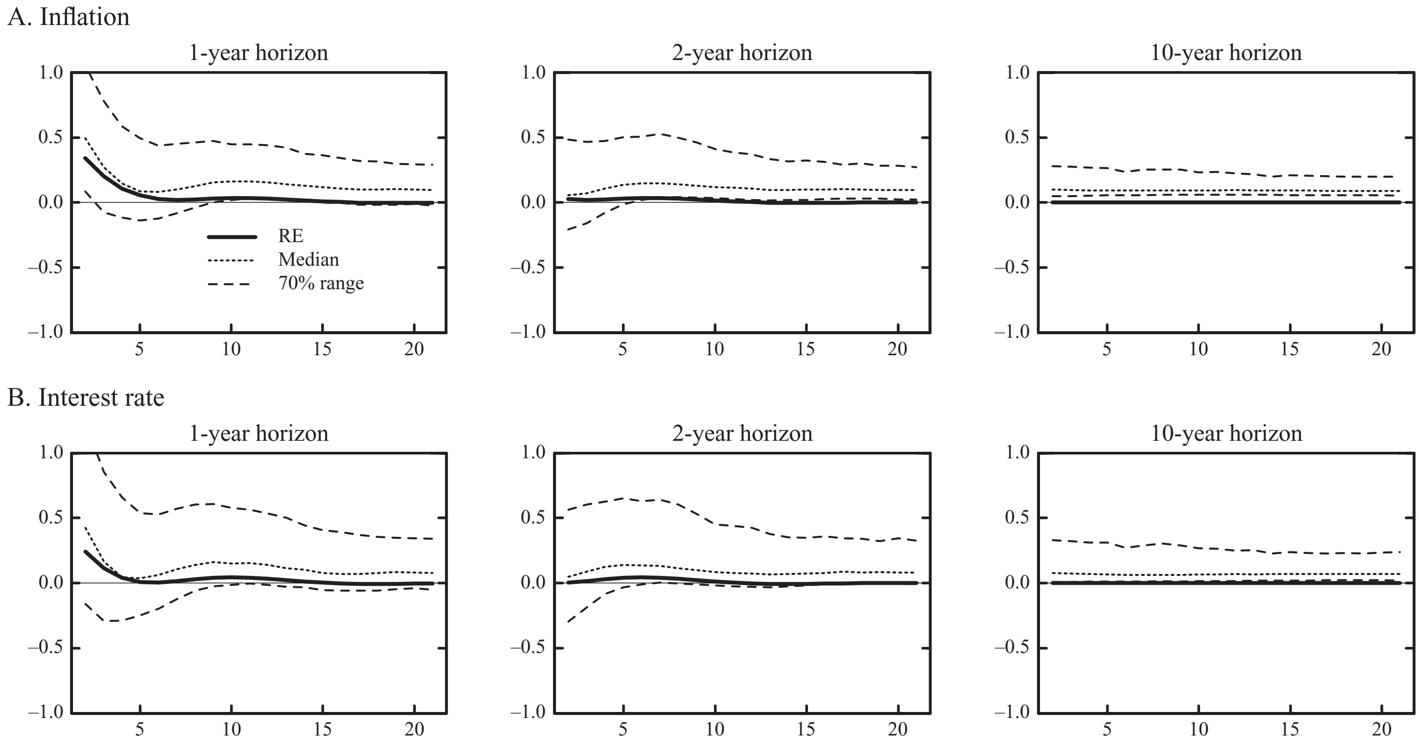
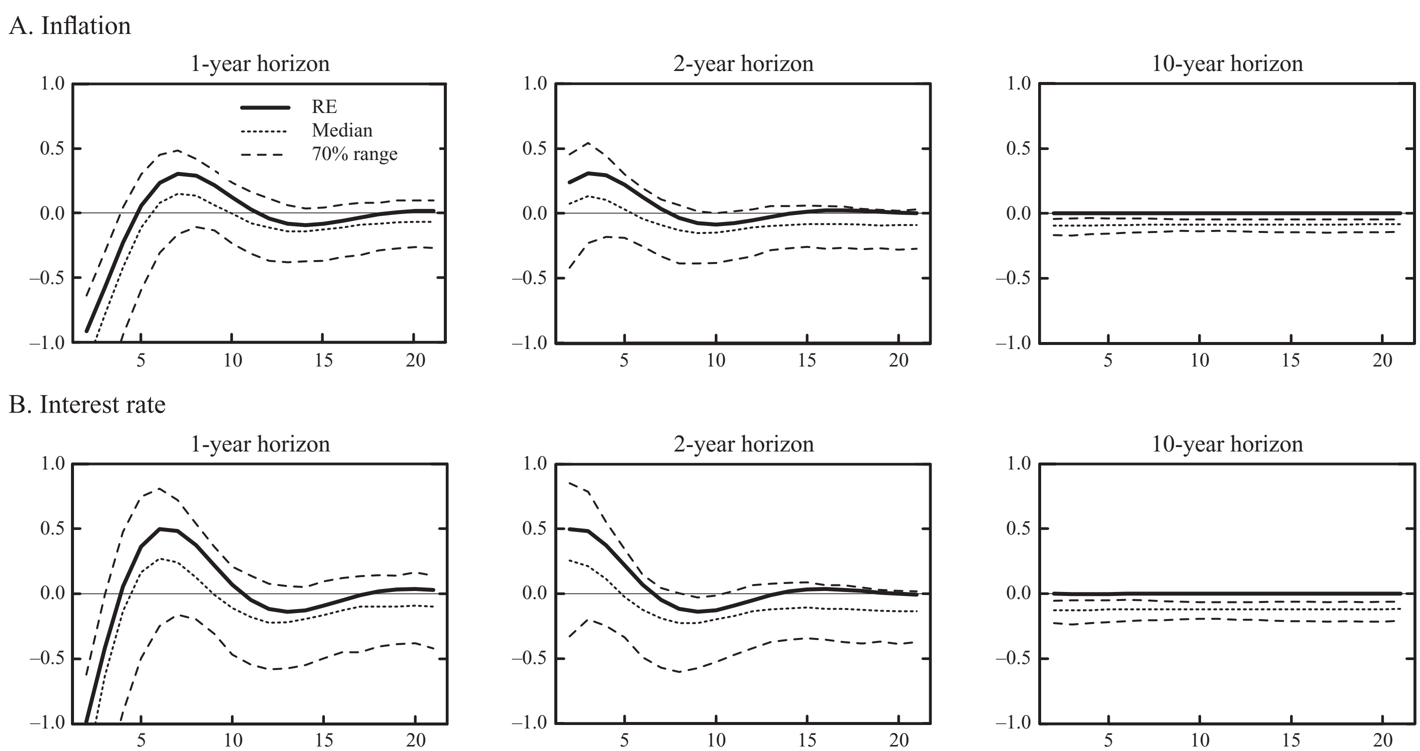


Figure 3
Impulse Responses to Unemployment Shock under the Taylor Rule: $i_t = \hat{r}_t^* + \bar{\pi}_{t+3}^e + 0.5\left(\bar{\pi}_{t+3}^e - \pi^*\right) - \left(u_{t-1} - \hat{u}_t^*\right)$



with perfect knowledge. Under perfect conditions, expectations always remain well anchored.

5. Implications for Monetary Policy Design

This section explores the ways in which monetary policy can be improved in an environment of imperfect knowledge. We consider three issues, all of which are closely related key characteristics of inflation targeting. First, we compare the performance of the economy under the level policy rule framework and under the easier to communicate and more transparent difference policy framework. As we discuss, the difference rule strategy appears superior for ensuring achievement of the policymakers' inflation objective, especially in an environment with uncertainty regarding natural rates—a situation in which level rules that rely on "gaps" from natural rate concepts for policy implementation run into substantial difficulties. Next, we consider the optimal horizon for expectations of inflation and unemployment rates to which policy reacts in the policy rule, as well as some robustness characteristics of policy under alternative preferences for inflation stabilization versus stabilization of real economic activity. Finally, we turn to the role of communicating an explicit numerical long-run inflation objective to the public for the performance of the economy under alternative policies.

To facilitate comparisons, we compare the performance of the economy using a loss function as a summary statistic. Specifically, we assume that the policymakers' objective is to minimize the weighted sum of the unconditional variances of inflation, the unemployment gap, and the change in the nominal federal funds rate:

$$(9)\quad \mathcal{L} = Var(\pi - \pi^*) + \lambda Var(u - u^*) + \nu Var(\Delta(i)),$$

where $Var(x)$ denotes the unconditional variance of variable x. As a benchmark, we consider $\lambda = 4$ and $\nu = 1$, but we also consider alternatives for the relative weight of real-activity stabilization, λ. (Note that $\lambda = 4 = 2^2$ corresponds to the case of equal weights on inflation and output gap variability—based on Okun's law with coefficient 2.)

5.1. Comparing the Level and Difference Rule Approaches

Up to this point, we have assumed that policy follows a specific formulation of the Taylor rule. As emphasized in Orphanides and Williams (2002), such policies are particularly prone to making errors when there is considerable uncertainty regarding natural rates. In particular, persistent misperceptions of the natural unemployment or interest rates translate into persistent deviations of inflation from its target value. Perpetual learning on the part of economic agents amplifies the effect of such errors and further complicates the design of policy. It is thus instructive to also study alternative monetary policy rules that are robust to natural rate misperceptions and are therefore better designed for achieving medium-run inflation stability as in an inflation-targeting framework.

We start by examining more closely the performance of alternative parameterizations of the Taylor rule. Figure 4 presents iso-loss contours of the economy with the above loss function for alternative parameterizations of the level rule with $j = 3$ and $k = -1$:

$$(10)\quad i_t = \hat{r}^*_t + \bar{\pi}^e_{t+3} + \theta_\pi(\bar{\pi}^e_{t+3} - \pi^*) + \theta_u(u^e_{t-1} - \hat{u}^*_t)\,.$$

Panel A shows the loss under rational expectations with constant natural rates, referred to in this discussion as perfect knowledge, while the other panels show the loss under learning with $\kappa = 0.02$ and time-varying natural rates for values of $s = \{0, 1, 2\}$. In each panel, the horizontal axis shows the value of the inflation response, θ_π, and the vertical axis shows the value of the unemployment response, θ_u. The contour charts are constructed by computing the loss for each pair of policy rule coefficients along a grid. The contour surface traces the losses corresponding to the values of these response coefficients. The coordinates corresponding to the minimum loss (marked with an X) identify the optimal parameters, among the set of values along the grid that we evaluated, for the underlying rule.[13] Thus, from panel A , the optimal level rule under perfect knowledge is given by:

$$i_t = \hat{r}^*_t + \bar{\pi}^e_{t+3} + 0.6(\bar{\pi}^e_{t+3} - \pi^*) - 3.2(u_{t-1} - \hat{u}^*_t)\,.$$

The level rule optimized under the assumption of perfect knowledge is not robust to uncertainty regarding the formation of expectations or natural rate variation. Comparison of panels B and D, for example, indicates that if the optimal level policy under perfect knowledge were implemented when the economy is governed by $s = 1$ and $\kappa = 0.02$, the loss would be very high relative to the loss associated with the best policy under learning. (The same is true for the classic Taylor rule, with $\theta_\pi = 0.5$ and $\theta_u = -1.0$.) One problem with the optimal level rule under perfect knowledge is that policymaker misperceptions of

13. In constructing the loss contour charts, we only evaluate the losses along the points of the grid. Thus, the minima reported in the charts are approximate and do not correspond precisely to the true minimum values. In cases where the true optimal policy rule coefficients lie near the midpoint between two grid points, the true optimal policy will yield a loss that may be slightly lower than that reported in the chart, even after rounding to one decimal place.

FIGURE 4
PERFORMANCE OF THE LEVEL RULE: $i_t = \hat{r}_t^* + \bar{\pi}_{t+3}^e + \theta_\pi(\bar{\pi}_{t+3}^e - \pi^*) + \theta_u(u_{t-1} - \hat{u}_t^*)$

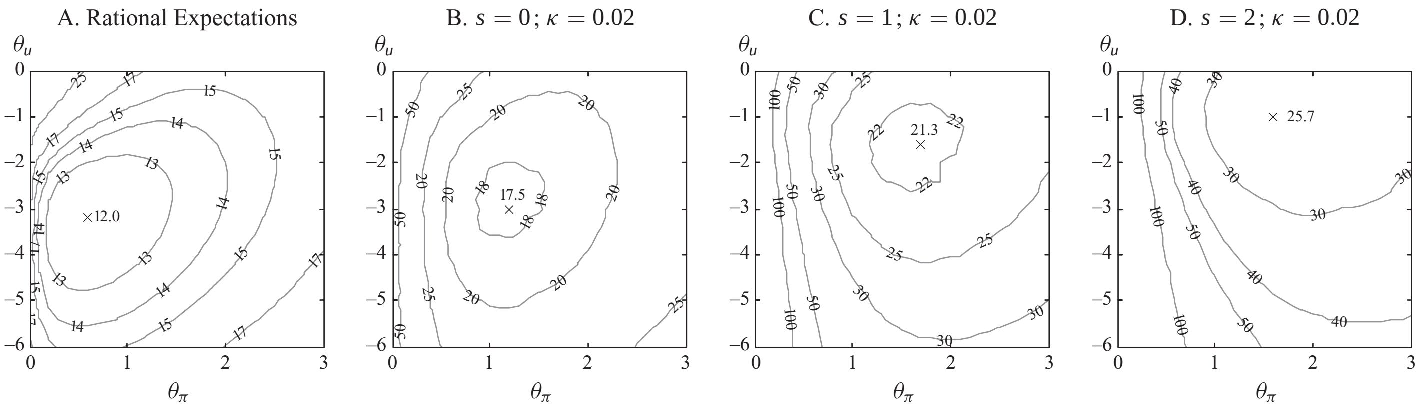


FIGURE 5
AUTOCORRELATION OF INFLATION UNDER THE LEVEL RULE: $i_t = \hat{r}_t^* + \bar{\pi}_{t+3}^e + \theta_\pi(\bar{\pi}_{t+3}^e - \pi^*) + \theta_u(u_{t-1} - \hat{u}_t^*)$

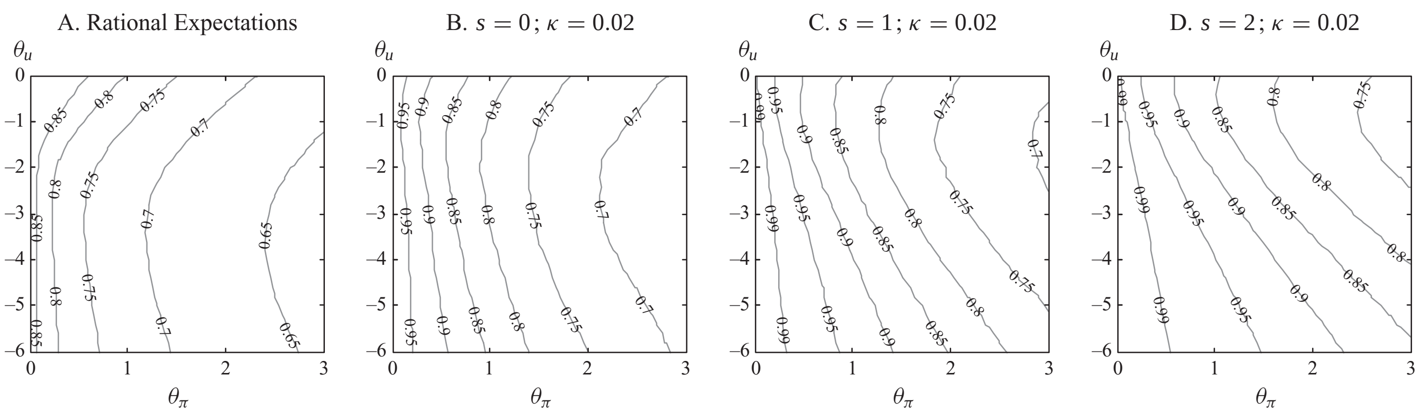
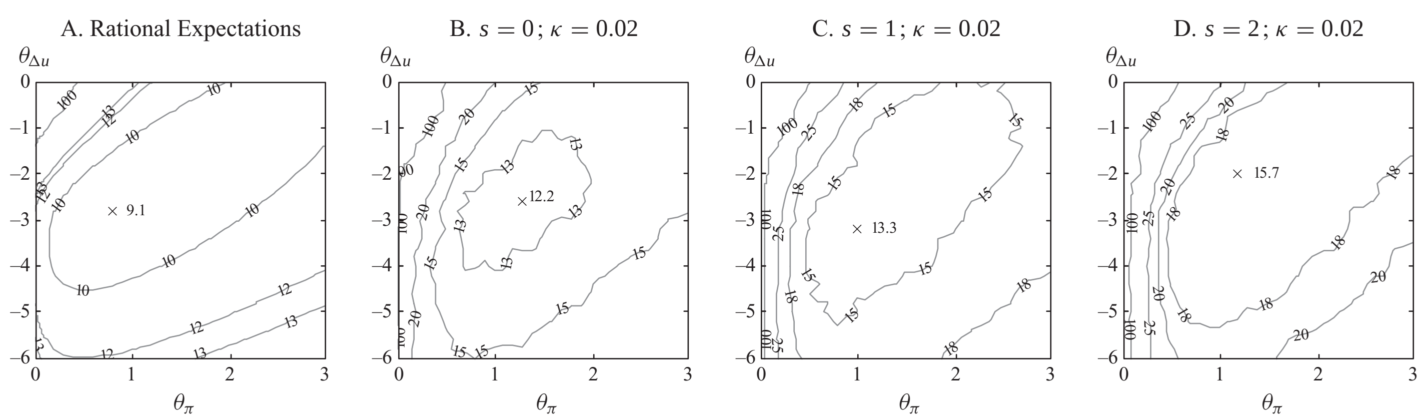


FIGURE 6
PERFORMANCE OF THE DIFFERENCE RULE: $i_t = i_{t-1} + \theta_\pi(\bar{\pi}_{t+3}^e - \pi^*) + \theta_{\Delta u}\Delta u_{t-1}$



the natural rates of interest and unemployment translate into persistent overly expansionary or contractionary policy mistakes. In such circumstances, the policy rule's rather timid response to inflation is insufficient to contain inflation expectations near the policymakers' target. This is seen in the autocorrelation of inflation, shown in contour plots in Figure 5. The combination of private sector learning and natural rate misperceptions yield an autocorrelation of inflation dangerously close to unity when the optimal policy under perfect knowledge is followed.

Level rules of this type entail a trade-off between achieving optimal performance in one model specification and being robust to model misspecification. We have shown that the optimal rule under perfect knowledge is not robust to the presence of imperfect knowledge. For our benchmark case with imperfect knowledge, $s = 1$ and $\kappa = 0.02$, a rule with response coefficients close to $\theta_\pi = 1.5, \theta_u = -1.5$ would be best in this family. The greater responsiveness to inflation in this parameterization proves particularly helpful for improving economic stability here, but this policy performs noticeably worse if knowledge is, in fact, perfect.

Next we turn to the alternative policy that avoids gaps from natural concepts altogether. Figure 6 presents comparable iso-loss contours for the difference rule (6) with $j = 3$ and $k = -1$:

$$i_t = i_{t-1} + \theta_\pi(\bar{\pi}^e_{t+3} - \pi^*) + \theta_{\Delta u}\Delta u_{t-1}\,. \tag{11}$$

The structure of this figure is comparable to Figure 4, except that here, the vertical axis in each panel reflects the responsiveness to the change in unemployment, $\theta_{\Delta u}$. Comparing Figure 6 with Figure 4 suggests that the difference rule generally yields superior performance, especially when knowledge is imperfect. Furthermore, in sharp contrast to the level rule optimized assuming perfect knowledge, the difference rule optimized assuming perfect knowledge appears to be robust to learning and natural rate variation. A difference rule with a response coefficient to inflation of about 1 and to the change in the unemployment rate of about -3 is nearly optimal under both perfect and imperfect knowledge. Indeed, the loss surface is relatively flat in the region of parameters close to this policy.[14] By avoiding policy mistakes related to natural rate misperceptions, this rule keeps inflation—and thereby inflation expectations—under tight control despite the presence of imperfect knowledge.

To demonstrate how the economy behaves under imperfect knowledge with a well-designed difference rule, Figures 7, 8, and 9 present impulse responses for the difference rule with $\theta_\pi = 1$, $\theta_{\Delta u} = -3$. The three figures are directly comparable to the impulse responses for the Taylor rule shown earlier in Figures 1, 2, and 3. These responses exhibit some overshooting and secondary cycling, as is typical of difference rules. The resulting loss, however, is significantly lower than that resulting under the level rules that may not exhibit such oscillations. In contrast to the impulse responses under the Taylor rule, the 70-percent range of impulse responses under the difference rule shown in these figures is much tighter and concentrated around the impulse response under perfect knowledge. This serves to demonstrate the relative usefulness of this strategy for mitigating the role of imperfect knowledge in the economy. In particular, Figures 8 and 9 show that even without incorporating explicit information about the policymakers' objective in the formation of expectations, this policy rule succeeds in anchoring long-horizon expectations, especially of inflation, under imperfect knowledge.

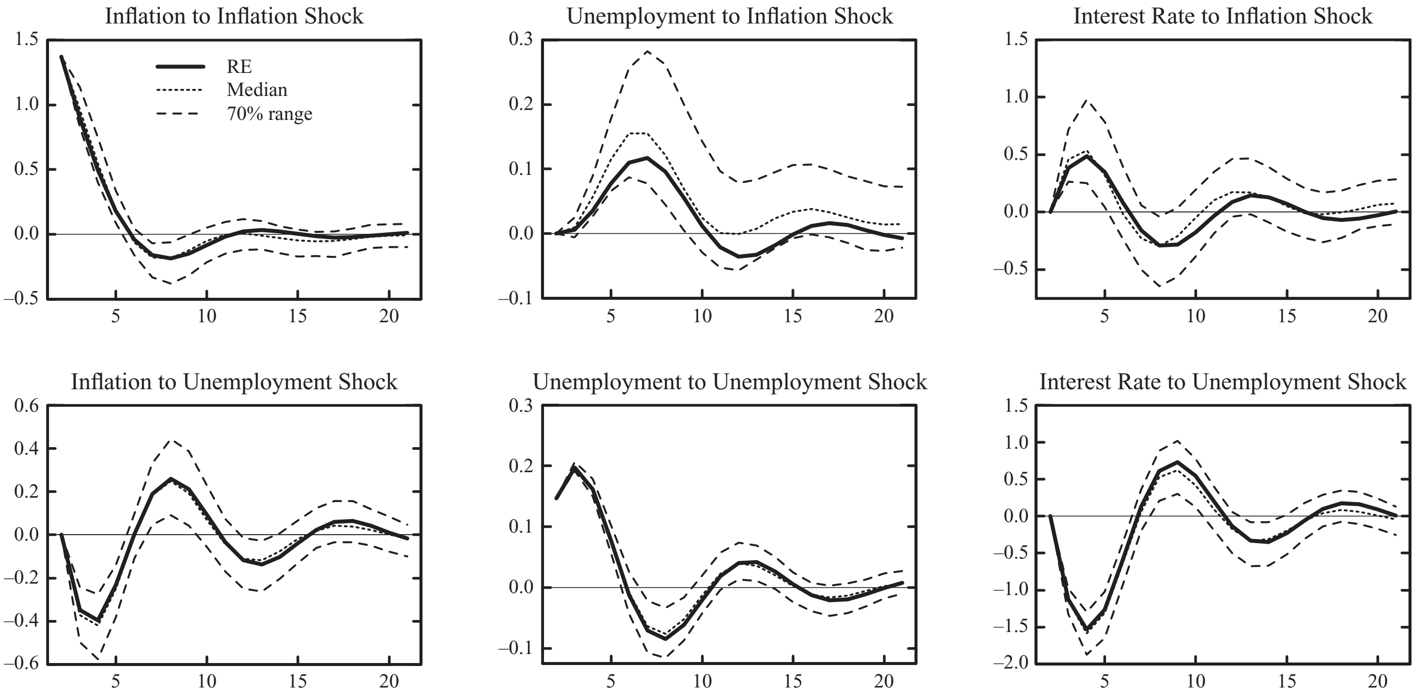
5.2. Forecast Horizons

Throughout the analysis so far, we have assumed that the policy rule responds to expected inflation at a three-quarter-ahead horizon and to the lagged unemployment rate or the lagged change in the unemployment rate. We also explicitly examine the choice of horizon for the class of difference rules. We find that under perfect knowledge, an outcome-based difference rule that responds to lagged inflation and unemployment performs about as well as forward-looking alternatives, consistent with the findings of Levin, Wieland, and Williams (2003). Under imperfect knowledge, however, an optimized difference rule that responds to the three-quarter horizon for expected inflation outperforms its outcome-based counterpart. As discussed in Orphanides and Williams (2005a), under learning, inflation expectations represent an important state variable for determining actual inflation that is not collinear with lagged inflation. Expected inflation can thus be a more useful summary statistic for inflation in terms of a policy rule.[15]

14. In Orphanides and Williams (2006), we compute the optimal Bayesian policy assuming equal weights across the specifications of learning and natural rate variability considered here. We find that a difference rule with $\theta_\pi = 1.1$ and $\theta_{\Delta u} = 2.6$ is remarkably robust to uncertainty regarding the degree of imperfect knowledge.

15. Using a simpler model, Orphanides and Williams (2005a) show that with certain parameterizations of the loss function, it is better to respond to actual inflation, while in others, it pays to respond to expected inflation. A hybrid rule that responds to both actual and expected inflation outperforms either type of simple rule that responds to one or the other.

FIGURE 7
IMPULSE RESPONSES UNDER THE DIFFERENCE RULE: $i_t = i_{t-1} + 1\,(\bar{\pi}^e_{t+3} - \pi^*) - 3\,\Delta u_{t-1}$



The inflation forecast horizon in the policy rule should not be too far in the future. Rules that respond to inflation expected two or more years ahead generally perform very poorly. Such rules are prone to generating indeterminacy, as discussed by Levin, Wieland, and Williams (2003). In contrast to inflation, the optimal horizon for the change in the unemployment rate is -1, meaning that policy should respond to the most recent observed change in unemployment (that is, for the previous quarter), as opposed to a forecast of the change in the unemployment rate in subsequent periods.

5.3. Alternative Preferences

Next, we explore the sensitivity of the simple policy rules we advocate as a benchmark for successful policy implementation to the assumed underlying policymaker preferences. In our benchmark parameterization, we examined preferences with a unit weight on inflation variability and a weight, $\lambda = 4$, on unemployment variability, noting that from Okun's law this implies equal weights on inflation and output gap variability. As with various other aspects of the policy problem we examine, however, it is unrealistic to assume that policymakers can have much confidence in the appropriate relative weights they should attach to inflation and employment stabilization in the economy from a public welfare perspective. It is therefore important to know whether a policy under consideration performs well across a range of reasonable alternative preferences. Indeed, robustness to such a range of preferences appears to be essential for successful implementation of inflation targeting in practice.

Figures 10 and 11 present the iso-loss contours of the benchmark difference rule with weights $\lambda = 1$ and $\lambda = 8$, respectively, comparable to that in Figure 6 with $\lambda = 4$. The iso-loss contours associated with placing greater emphasis on price stability (Figure 10) or employment stability (Figure 11) suggest that policies derived based on our benchmark loss function would do rather well under either alternative. This speaks well for the robustness of our benchmark difference rules as guides for policy, as a robust policy guide ought to perform well across a range of reasonable alternative preferences.

5.4. Explicit Numerical Inflation Objective

The policy features we have described so far may be important not only for characterizing policy under inflation targeting, but also for characterizing policy for non-inflation-targeting central banks that may not have an explicit quantitative inflation target but still recognize the value of price stability and well-anchored inflation expec-

FIGURE 8
IMPULSE RESPONSES TO INFLATION SHOCK UNDER THE DIFFERENCE RULE: $i_t = i_{t-1} + 1\,(\bar{\pi}^e_{t+3} - \pi^*) - 3\,\Delta u_{t-1}$

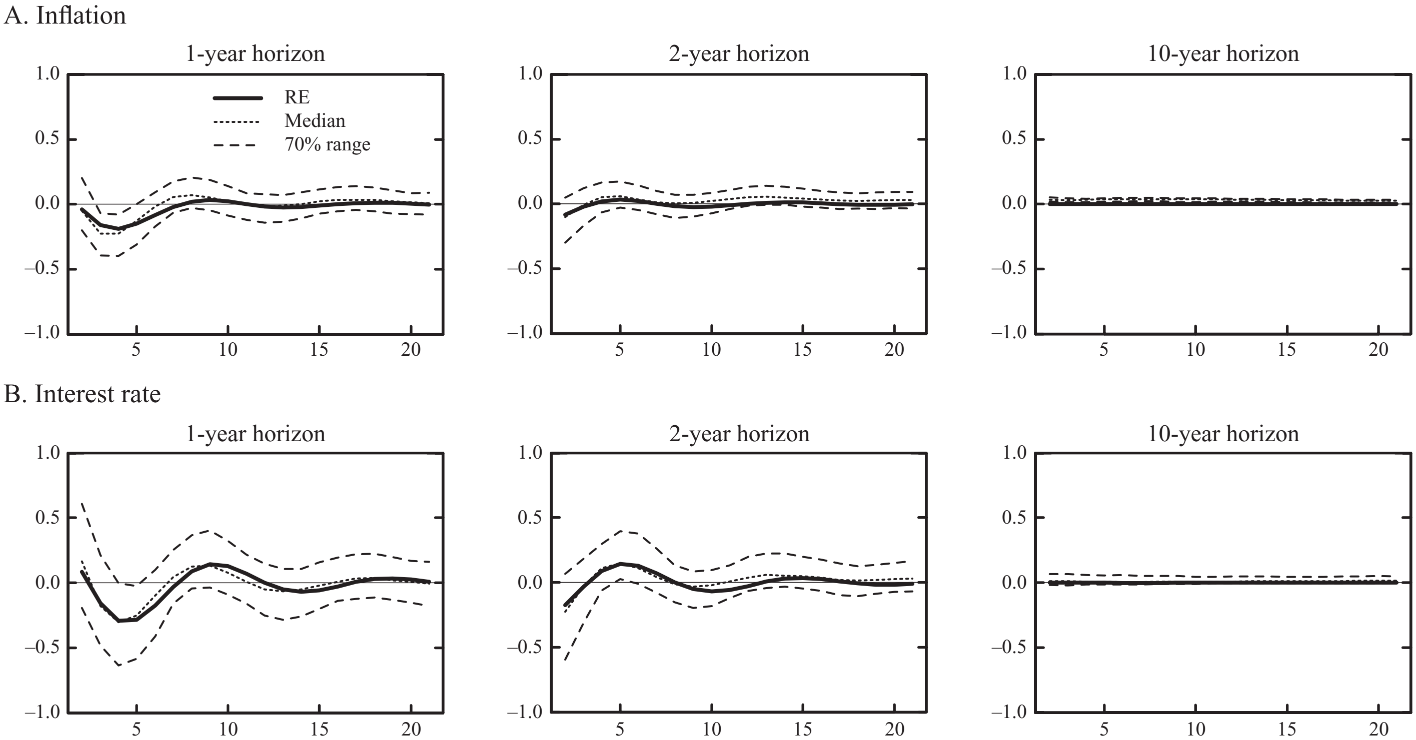


FIGURE 9
IMPULSE RESPONSES TO UNEMPLOYMENT SHOCK UNDER THE DIFFERENCE RULE: $i_t = i_{t-1} + 1\,(\bar{\pi}^e_{t+3} - \pi^*) - 3\,\Delta u_{t-1}$

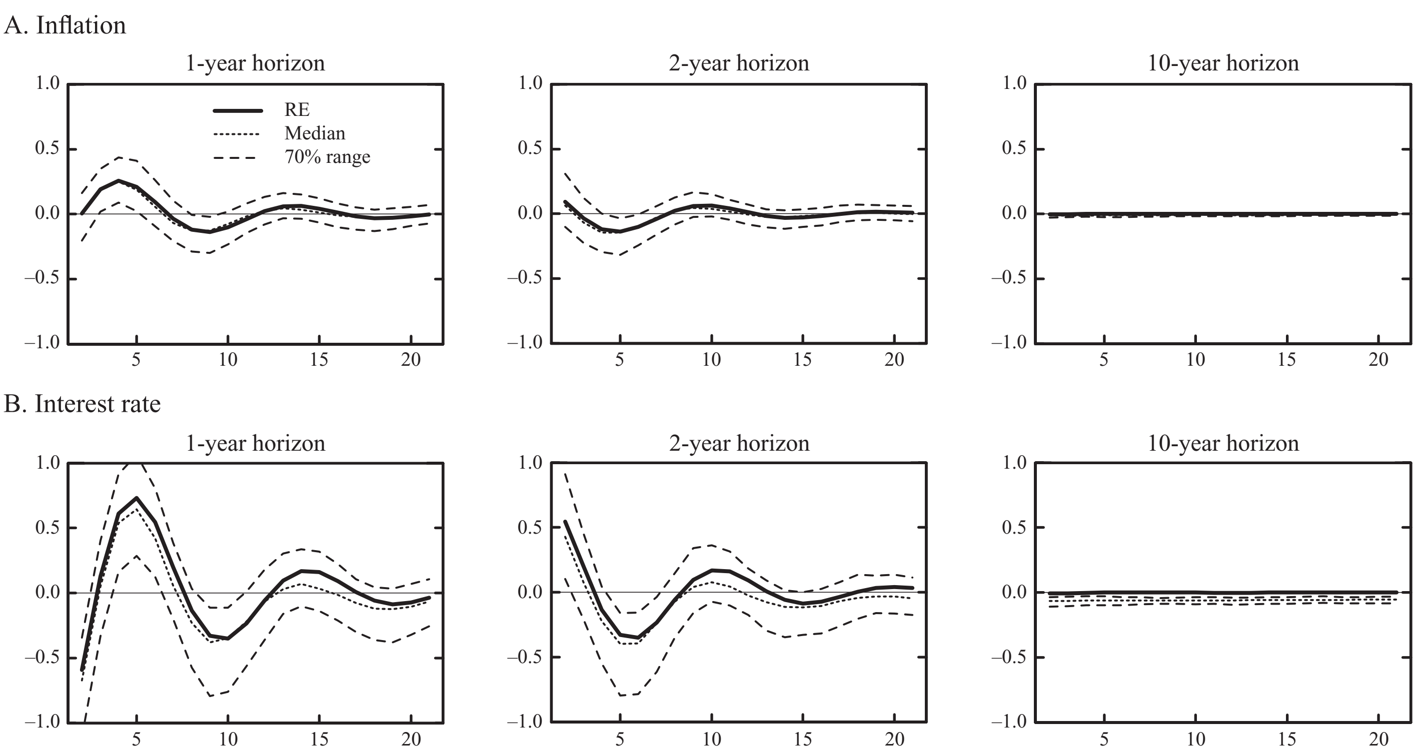


FIGURE 10
PERFORMANCE OF THE DIFFERENCE RULE WITH GREATER EMPHASIS ON INFLATION STABILITY ($\lambda = 1$):
$i_t = i_{t-1} + \theta_\pi (\bar{\pi}^e_{t+3} - \pi^*) + \theta_{\Delta u} \Delta u_{t-1}$

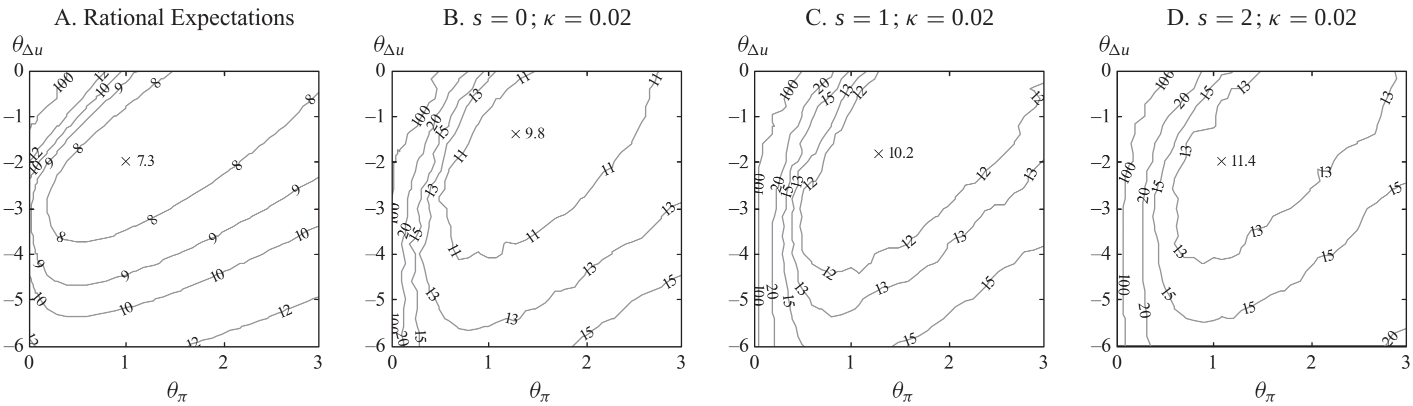
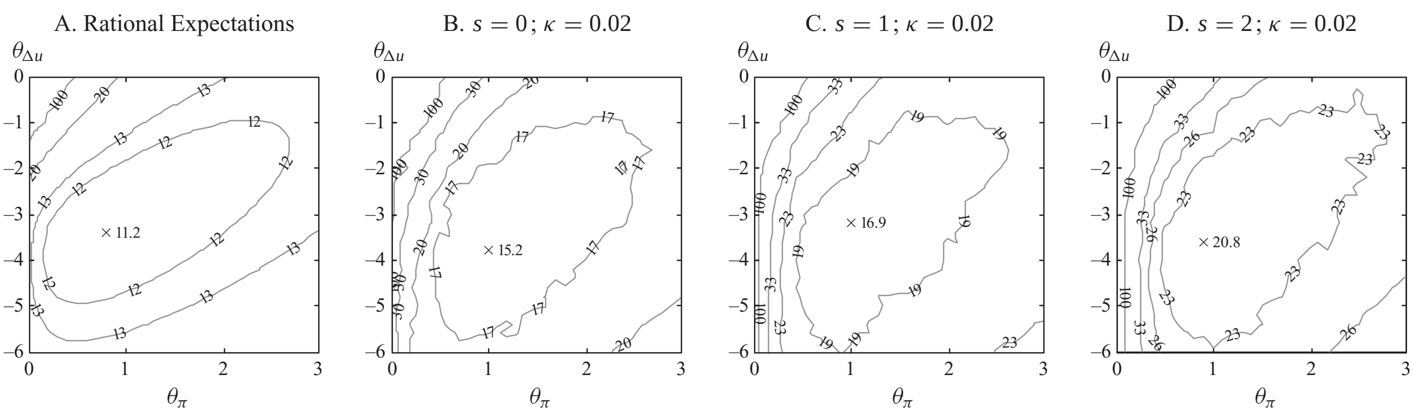


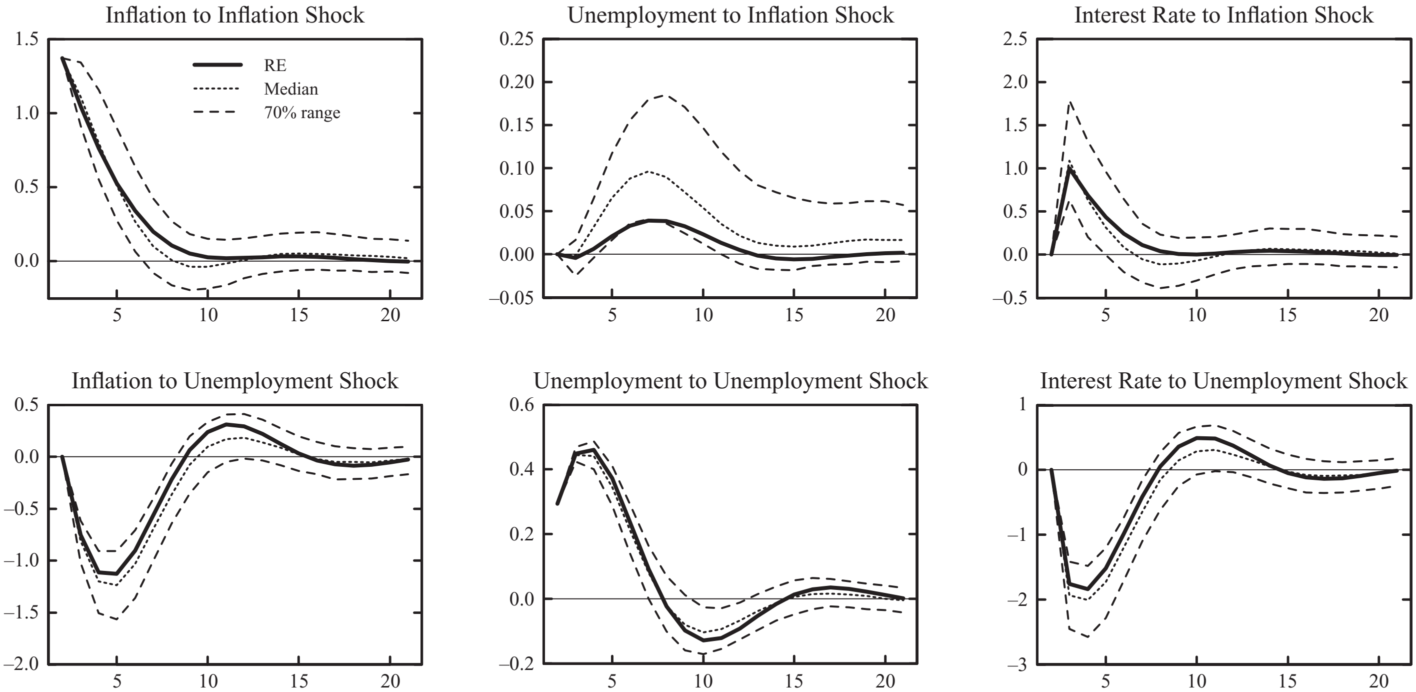
FIGURE 11
PERFORMANCE OF THE DIFFERENCE RULE WITH GREATER EMPHASIS ON EMPLOYMENT STABILITY ($\lambda = 8$):
$i_t = i_{t-1} + \theta_\pi (\bar{\pi}^e_{t+3} - \pi^*) + \theta_{\Delta u} \Delta u_{t-1}$



tations for fostering overall economic stability. This section examines what is arguably the most important distinguishing characteristic of inflation targeting, relative to alternative policy frameworks—namely, the specification of an explicit numerical inflation objective.

As in Orphanides and Williams (2004, 2005a), we formalize this element of transparency by positing that the announcement of an explicit target is taken at face value by economic agents, who incorporate this information directly into their recursive forecasting algorithm. We implement the idea of a known numerical inflation target by modifying the learning model that agents use in forecasting to have the property that inflation asymptotically returns to target. No other changes are made to the model or the learning algorithm. In essence, with a known inflation target, agents need to estimate one fewer parameter in their forecasting model for inflation than they would need to do if they did not know the precise numerical value of the central bank's inflation objective. More precisely, we assume that agents estimate reduced-form forecasting equations for the unemployment rate and the inflation rate, just as before. We then solve the resulting two-equation system for its steady-state values of the unemployment rate and the interest rate, assuming that the steady-state inflation rate equals its target value. We modify the forecasting equation for the interest rate by subtracting the steady-state values of each variable from the observed values on both sides of the equation and by eliminating the constant term. This equa-

FIGURE 12
IMPULSE RESPONSES WITH KNOWN π^* UNDER THE TAYLOR RULE: $i_t = \hat{r}_t^* + \bar{\pi}_{t+3}^e + 0.5(\bar{\pi}_{t+3}^e - \pi^*) - (u_{t-1} - \hat{u}_t^*)$



tion is estimated using the constant-gain algorithm. The resulting three-equation system has the property that inflation asymptotically goes to target. This system is used for forecasting as before.

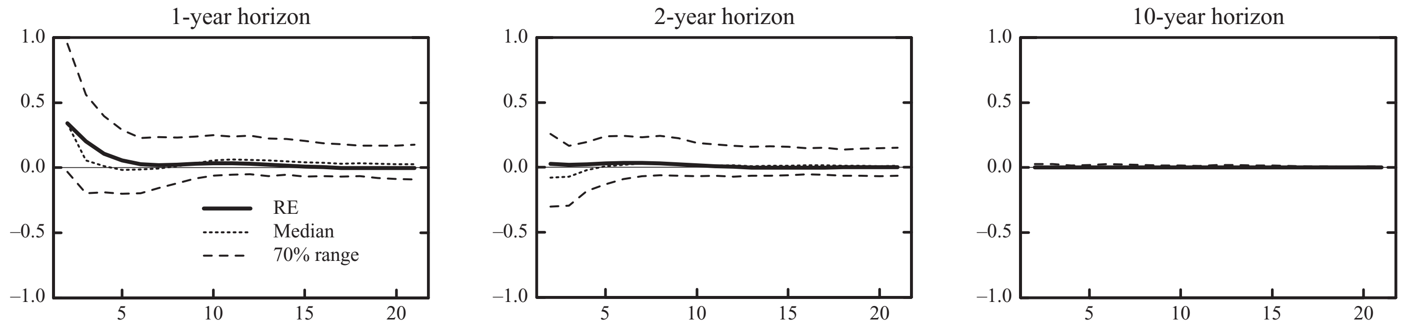
To trace the role of a known target in the economy under alternative policy rules, we compute impulse responses corresponding to the same policy rules examined earlier. Figure 12 shows the impulse responses to the inflation and unemployment shocks for the classic parameterization of the Taylor rule, assuming that the central bank has communicated its inflation objective to the public. Compared with Figure 1, the responses of inflation under imperfect knowledge are more tightly centered around the responses under perfect knowledge. The differences are more noticeable when we examine long-run inflation expectations. Figures 13 and 14 show the impulse responses of longer-run inflation and interest rate expectations, following the format of Figures 2 and 3. The communication of an explicit numerical inflation objective yields a much tighter range of responses of longer-run inflation expectations, centered around the actual target. Absent here is the upward bias in the response of inflation expectations evident when agents do not know the target. Interestingly, although knowledge of the long-term inflation objective anchors long-term inflation expectations much better, it is unclear whether this translates to a much reduced sensitivity of forward interest rates to economic shocks.[16]

Figures 15, 16, and 17 show the impulse responses corresponding to the difference rule specified as above and assuming the central bank has successfully communicated its objective to the public as described above. Short-run expectations tend to cluster around those that obtain under perfect knowledge. The median responses are remarkably close to those under rational expectations, and the 70 percent ranges tend to be quite narrow, especially for inflation. Long-horizon inflation expectations are extremely stable under the difference rule coupled with an explicit numerical inflation objective. For instance, the behavior of

16. These comparisons, however, are based on the assumption that forecasts of these rates are governed by the same learning process governing the expectations for inflation and economic activity at shorter horizons that matter for the determination of economic outcomes in the model. If, instead, the long-horizon interest rate expectations embedded in financial markets reflect additional knowledge, it could result in smaller deviations from the perfect-knowledge benchmark than those presented here.

FIGURE 13
IMPULSE RESPONSES TO INFLATION SHOCK WITH KNOWN π^* UNDER THE TAYLOR RULE:
$i_t = \hat{r}_t^* + \bar{\pi}_{t+3}^e + 0.5(\bar{\pi}_{t+3}^e - \pi^*) - (u_{t-1} - \hat{u}_t^*)$

A. Inflation



B. Interest rate

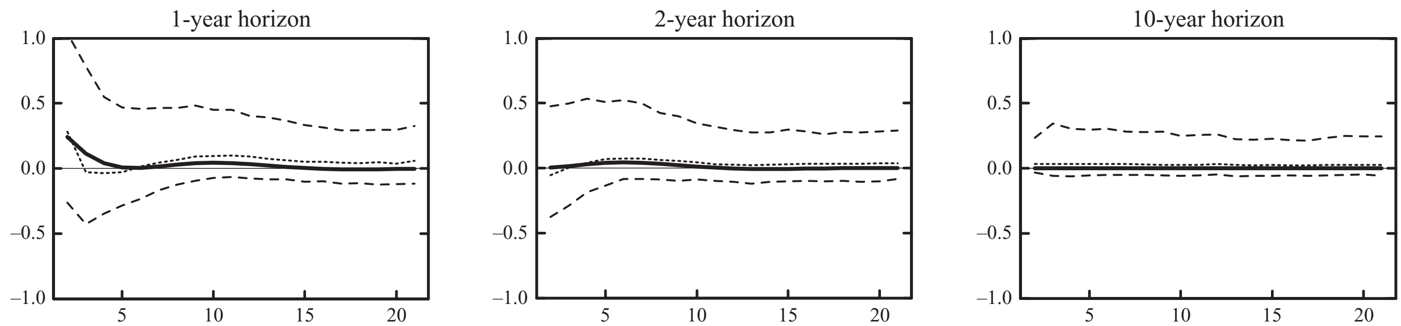
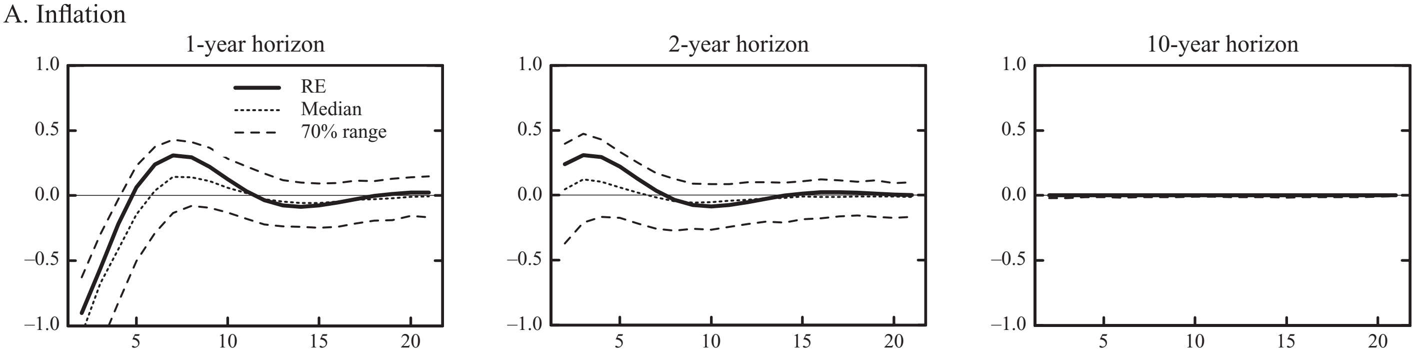


FIGURE 14
IMPULSE RESPONSES TO UNEMPLOYMENT SHOCK WITH KNOWN π^* UNDER THE TAYLOR RULE:
$i_t = \hat{r}_t^* + \bar{\pi}_{t+3}^e + 0.5(\bar{\pi}_{t+3}^e - \pi^*) - (u_{t-1} - \hat{u}_t^*)$

A. Inflation



B. Interest rate

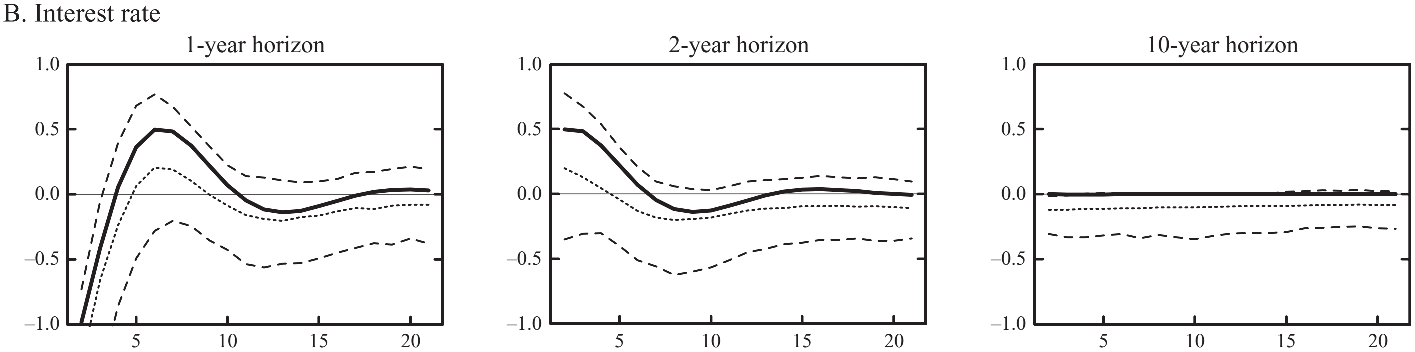
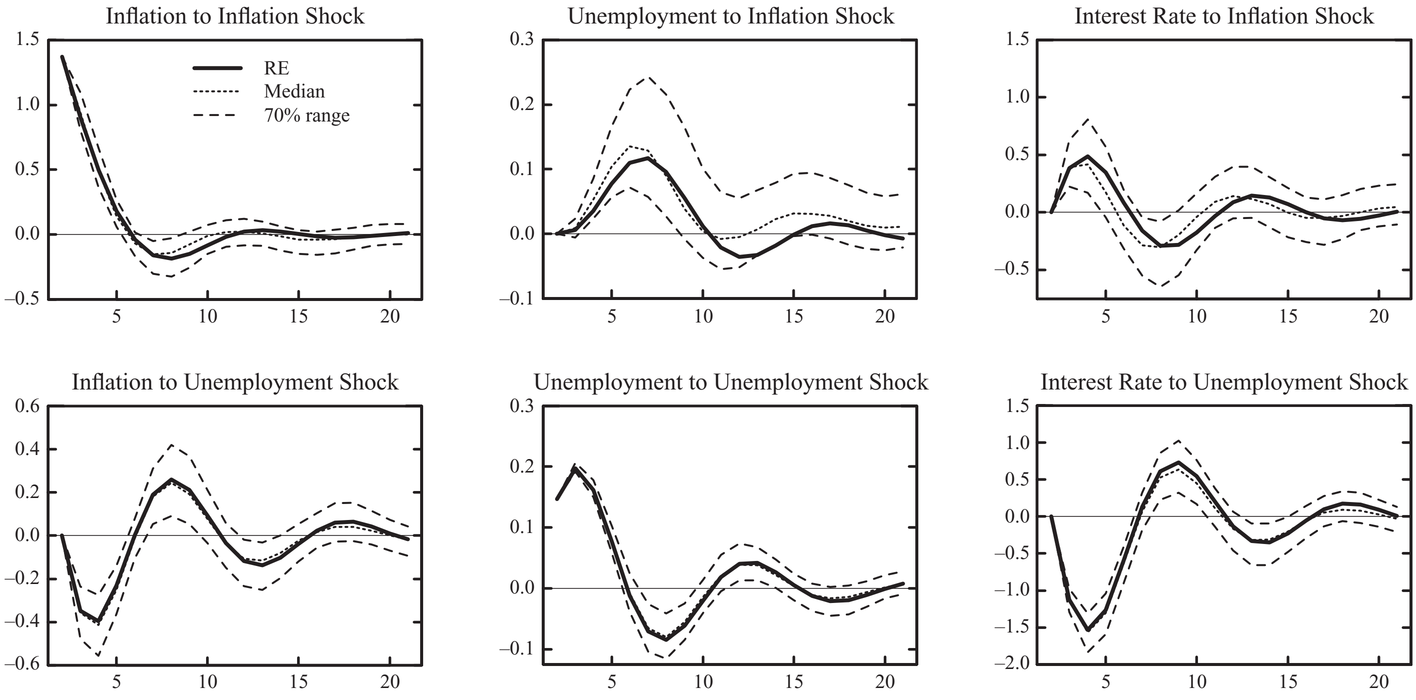


FIGURE 15
IMPULSE RESPONSES WITH KNOWN π^* UNDER THE DIFFERENCE RULE: $i_t = i_{t-1} + (\bar{\pi}^e_{t+3} - \pi^*) - 3\Delta u_{t-1}$



ten-year-ahead inflation expectations is virtually indistinguishable from what would be expected under perfect knowledge. Forward interest rates, however, continue to show some small movements.

These impulse responses suggest that the expected benefits of announcing an explicit inflation target may be quite different depending on the policy rule in place. In terms of anchoring long-horizon inflation expectations, for example, the benefits of a known target seem considerably larger if policy follows the classic parameterization of the Taylor rule than if policy is based on a well-designed difference rule. The extent of these benefits also depends on the precise degree of imperfections in the economy (that is, the learning rate, κ, and variation in natural rates, s, in our model). In the limiting case of rational expectations, for instance, the "announcement" of the policymaker's target in our model does not make any difference at all, since agents already know the policymaker's preferences and objectives, by assumption.

To provide a clearer picture of the stabilization benefits of a known inflation target in an environment of imperfect knowledge, we compare the performance of an economy with a known target to that with an unknown target for a given set of policies.

Table 2 presents this comparison when expectations are formed with our benchmark learning rate, $\kappa = 0.02$. In panel A , we present the results for the classic Taylor rule with $\theta_\pi = 0.5$ and $\theta_u = -1.0$, whose properties under learning without a known inflation target were examined in detail in Section 4. In panel B, we present the results for the level rule with $\theta_\pi = 1.5$ and $\theta_u = -1.5$, which performs best within this family of level rules when $\kappa = 0.02$ and $s = 1$. In panel C, we present comparable results for the difference rule with $\theta_\pi = 1$ and $\theta_{\Delta u} = -3$, which performs well even under learning with an unknown inflation target.

The economy's stabilization performance uniformly improves with a known inflation target under all three rules. Successful communication of an inflation target results in a modest reduction in the persistence of inflation. In addition, for each rule, the variability of inflation, real activity, and interest rates is smaller when the central bank successfully communicates its numerical inflation objective to the public. The extent of this improvement varies considerably, however. The gains of making the target known appear substantial under the classic Taylor rule. A more modest reduction in volatility is evident for the more aggressive level rule, while the gains associated with a known target are

FIGURE 16

IMPULSE RESPONSES TO INFLATION SHOCK WITH KNOWN π^* UNDER THE DIFFERENCE RULE: $i_t = i_{t-1} + (\bar{\pi}^e_{t+3} - \pi^*) - 3\Delta u_{t-1}$

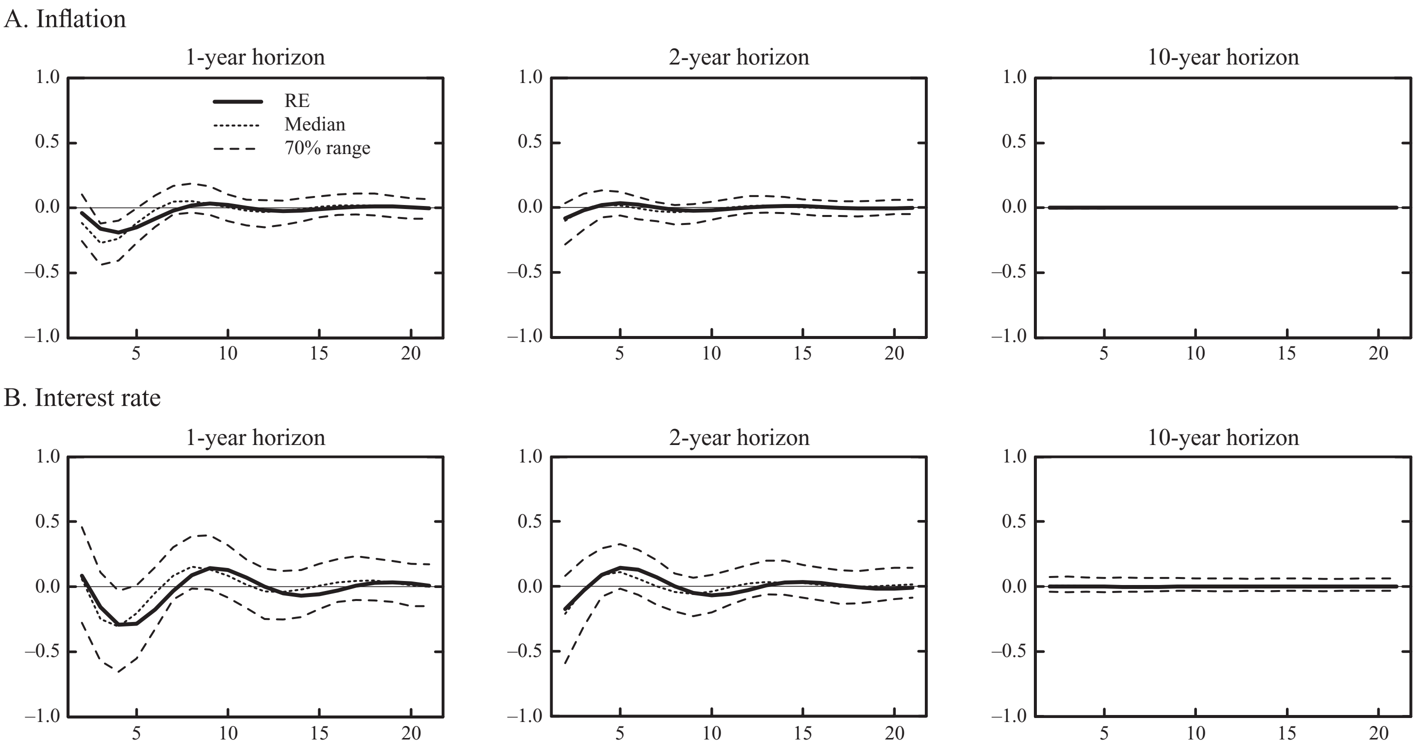


FIGURE 17

IMPULSE RESPONSES TO UNEMPLOYMENT SHOCK WITH KNOWN π^* UNDER THE DIFFERENCE RULE:
$i_t = i_{t-1} + (\bar{\pi}^e_{t+3} - \pi^*) - 3\Delta u_{t-1}$

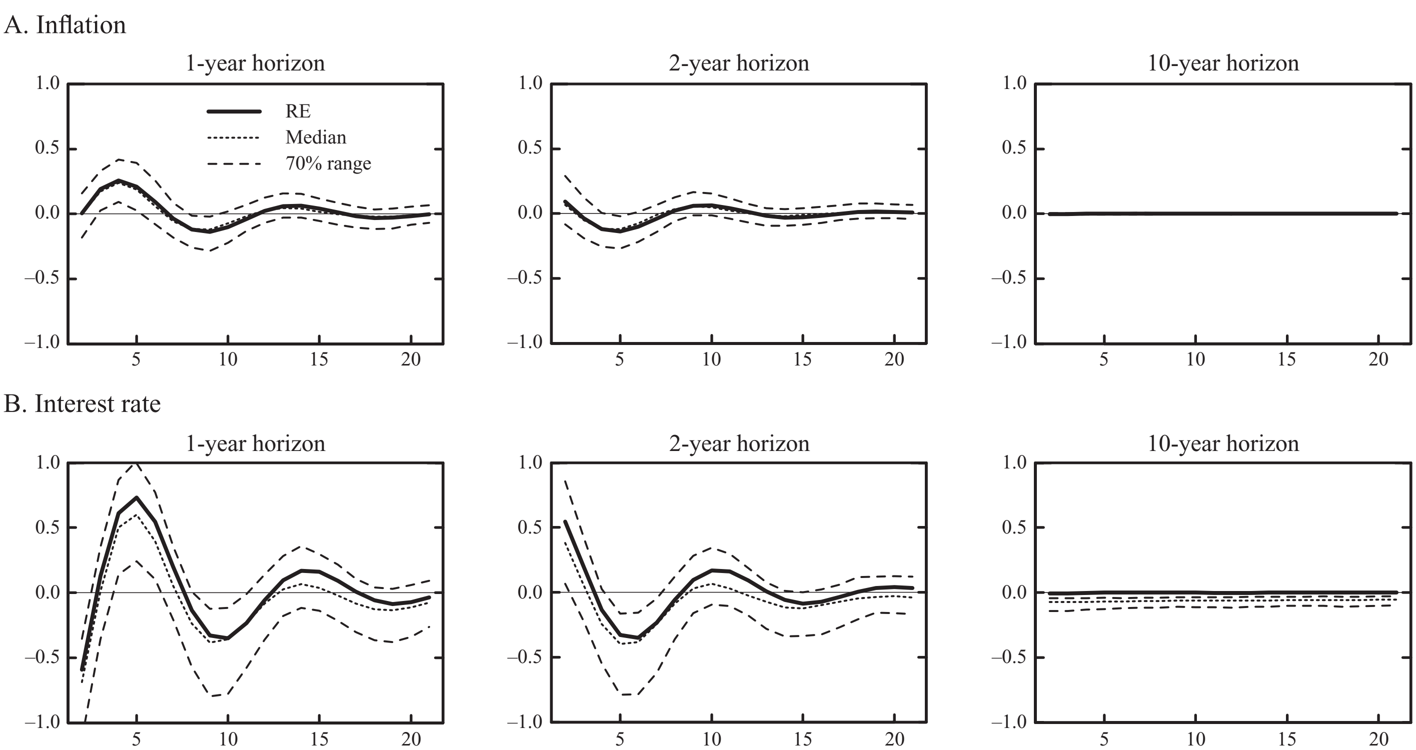


TABLE 2
THE ROLE OF AN EXPLICIT QUANTITATIVE INFLATION OBJECTIVE

	Unknown π^*					Known π^*				
	Standard deviation					Standard deviation				
s	π	u–u^*	Δi	Loss	AR(π)	π	u–u^*	Δi	Loss	AR(π)
A. Level rule ($\theta_\pi = 0.5$, $\theta_u = -1.0$)										
0	3.66	0.99	2.80	25.1	0.86	3.37	0.95	2.67	22.1	0.84
1	4.35	1.11	3.01	32.9	0.90	3.76	1.04	2.80	26.4	0.87
2	5.21	1.24	3.29	44.2	0.93	4.21	1.18	3.02	32.5	0.90
B. Level rule ($\theta_\pi = 1.5$, $\theta_u = -1.5$)										
0	2.43	0.84	3.15	18.6	0.75	2.34	0.82	3.02	17.2	0.72
1	2.62	0.96	3.31	21.5	0.78	2.37	0.89	3.05	18.1	0.74
2	2.93	1.13	3.58	26.5	0.82	2.65	1.08	3.29	22.5	0.79
C. Difference rule ($\theta_\pi = 1$, $\theta_{\Delta u} = -3.0$)										
0	2.15	0.89	2.20	12.6	0.67	2.03	0.80	2.08	11.0	0.64
1	2.20	0.98	2.26	13.7	0.68	2.08	0.90	2.11	12.0	0.65
2	2.35	1.18	2.36	16.6	0.72	2.26	1.13	2.23	15.2	0.70

All evaluations are for the case of learning with $\kappa = 0.02$. The loss function corresponds to (9) with $\lambda = 4$ and $\nu = 1$. AR(π) denotes the first-order serial correlation of inflation.

quite small when policy is based on the more robust difference rule. These results suggest that the improvement associated with successfully communicating a target can be rather small, compared with the improvement that could be expected from adopting the other elements of robust policies. For example, abandoning policy based on even the best parameterization of the level rule in favor of the robust difference rule yields a larger benefit than communicating a numerical inflation objective while continuing to follow a level rule.

6. Conclusion

Inflation targeting has been a very popular strategy among central banks, particularly in small open economies. Researchers have struggled, however, to pin down exactly what inflation targeting means in terms of an implementable policy rule. To some, the Taylor rule, or any monetary policy rule with a fixed long-run inflation target, is a form of inflation targeting; to others, inflation targeting is identified with solving a central bank optimization problem in a rational expectations model. One shortcoming of these approaches is that they abstract from the very cause that gave rise to inflation targeting in the first place: the loss of a nominal anchor that transpired under previous policy regimes in many countries.

This paper has attempted to put inflation-targeting strategy back into the context in which it was born—namely, one in which inflation expectations can endogenously drift away from the central bank's goal. We assume that private agents and the central bank have imperfect knowledge of the economy; in particular, private agents attempt to infer the central bank's goals and reactions through past actions. In such an environment, key characteristics of inflation targeting in practice—including transparency, a commitment to price stability, and close attention to inflation expectations—can influence the evolution of inflation expectations and the economy's behavior.

The problem of imperfect knowledge may be especially acute in small open economies and transition economies that have been drawn to inflation targeting. Many of these countries have undergone dramatic structural change over the past few decades. Consequently, conclusions regarding the characteristics of optimal monetary policy rules that are based on rational expectations models with perfect knowledge cannot provide trustworthy guidance. Our analysis suggests that policies formulated and communicated in terms of gaps from natural rate concepts that are fundamentally unknowable may be particularly problematic. A more reliable approach to successfully implementing inflation targeting is to search for monetary policy strategies that are robust to imperfect knowledge.

References

Batini, Nicoletta, and Andrew Haldane. 1999. "Forward-looking Rules for Monetary Policy." In *Monetary Policy Rules,* ed. John B. Taylor. Chicago: University of Chicago.

Beechey, Meredith. 2004. "Learning and the Term Structure of Interest Rates." Unpublished manuscript, University of California, Berkeley (April).

Bernanke, Ben S., Thomas Laubach, Frederic S. Mishkin, and Adam Posen. 1999. *Inflation Targeting: Lessons from the International Experience.* Princeton, NJ: Princeton University Press.

Bernanke, Ben S., and Frederic S. Mishkin. 1997. "Inflation Targeting: A New Framework for Monetary Policy?" *Journal of Economic Perspectives* 11(2) (Spring) pp. 97–116.

Clarida, Richard, Jordi Galí, and Mark Gertler. 1999. "The Science of Monetary Policy." *Journal of Economic Literature* 37(4) (December) pp. 1,661–1,707.

Clark, Todd, and Sharon Kozicki. 2005. "Estimating Equilibrium Interest Rates in Real Time." *The North American Journal of Economics and Finance* 16(3) pp. 395–413.

Cogley, Timothy. 2005. "Changing Beliefs and the Term Structure of Interest Rates: Cross-Equation Restrictions with Drifting Parameters." *Review of Economic Dynamics* 8(2) (April) pp. 420–451.

Cook, Timothy, and Thomas Hahn. 1989. "The Effect of Changes in the Federal Funds Rate Target on Market Interest Rates in the 1970s." *Journal of Monetary Economics* 24, pp. 331–351.

Croushore, Dean. 1993. "Introducing: The Survey of Professional Forecasters." FRB Philadelphia *Business Review* (November/December) pp. 3–13. http://www.phil.frb.org/files/spf/spfbr.pdf

Croushore, Dean, and Tom Stark. 2001. "A Real-Time Data Set for Macroeconomists." *Journal of Econometrics* 105 (November) pp. 111–130.

Cukierman, Alex, and Francesco Lippi. 2005. "Endogenous Monetary Policy with Unobserved Potential Output." *Journal of Economic Dynamics and Control* 29(11) (November) pp. 1,951–1,983.

Evans, George, and Seppo Honkapohja. 2001. *Learning and Expectations in Macroeconomics.* Princeton, NJ: Princeton University Press.

Faust, Jon, and Dale W. Henderson. 2004. "Is Inflation Targeting Best-Practice Monetary Policy?" FRB St. Louis *Review* 86(4) pp. 117–144. http://research.stlouisfed.org/publications/review/past/2004/

Fuhrer, Jeffrey C., and George R. Moore. 1995a. "Inflation Persistence." *Quarterly Journal of Economics* 110(1) pp. 127–159.

Fuhrer, Jeffrey C., and George R. Moore. 1995b. "Forward-Looking Behavior and the Stability of a Conventional Monetary Policy Rule." *Journal of Money, Credit, and Banking,* 27(4, Part 1) (November) pp. 1,060–1,070.

Gaspar, Vitor, and Frank Smets. 2002. "Monetary Policy, Price Stability, and Output Gap Stabilisation." *International Finance* 5(2) (Summer) pp. 193–211.

Gaspar, Vitor, Frank Smets, and David Vestin. 2006. "Adaptive Learning, Persistence, and Optimal Monetary Policy." European Central Bank working paper (June).

Goodfriend, Marvin. 1993. "Interest Rate Policy and the Inflation Scare Problem: 1979–1992." FRB Richmond *Economic Quarterly* 79(1) (Winter) pp. 1–23. http://www.richmondfed.org/publications/economic_research/economic_quarterly/years.cfm/1993

Goodfriend, Marvin. 2004. "Inflation Targeting in the United States?" In *The Inflation Targeting Debate,* eds. Ben Bernanke and Michael Woodford. Chicago: University of Chicago Press.

Goodfriend, Marvin, and Robert King. 1997. "The New Neoclassical Synthesis and the Role of Monetary Policy." *NBER Macroeconomics Annual* 12, pp. 231–283.

Gürkaynak, Refet, Brian Sack, and Eric Swanson. 2005. "The Sensitivity of Long-Term Interest Rates to Economic News: Evidence and Implications for Macroeconomic Models." *American Economic Review* 95(1) pp. 426–436.

Judd, John P., and Brian Motley. 1992. "Controlling Inflation with an Interest Rate Instrument," FRB San Francisco *Economic Review* 92(3) pp. 3–22. http://www.frbsf.org/publications/economics/review/1992/92-3_3-22.pdf

Kozicki, Sharon, and Peter A. Tinsley. 2001a. "Term Structure Views of Monetary Policy under Alternative Models of Agent Expectations." *Journal of Economic Dynamics and Control* 25(1–2) pp. 149–184.

Kozicki, Sharon, and Peter A. Tinsley. 2001b. "What Do You Expect? Imperfect Policy Credibility and Tests of the Expectations Hypothesis." FRB Kansas City working paper 01-02 (April). http://www.kansascityfed.org/publicat/reswkpap/rwp01-02.htm

Kuttner, Kenneth N. 2001. "Monetary Policy Surprises and Interest Rates: Evidence from the Fed Funds Futures Market." *Journal of Monetary Economics* 47(3) (June) pp. 523–544.

Laubach, Thomas, and John C. Williams. 2003. "Measuring the Natural Rate of Interest." *Review of Economics and Statistics* 85(4) pp. 1,063–1,070.

Leiderman, Leonardo, and Lars E.O. Svensson, eds. 1995. *Inflation Targets.* London: Centre for Economic Policy Research.

Levin, Andrew, Volker Wieland, and John Williams. 1999. "Robustness of Simple Monetary Policy Rules under Model Uncertainty." In *Monetary Policy Rules,* ed. John B. Taylor. Chicago: University of Chicago.

Levin, Andrew, Volker Wieland, and John Williams. 2003. "The Performance of Forecast-Based Policy Rules under Model Uncertainty." *American Economic Review* 93(3) (June) pp. 622–645.

Mankiw, N. Gregory, and Lawrence H. Summers. 1984. "Do Long-Term Interest Rates Overreact to Short-Term Interest Rates?" *Brookings Papers on Economic Activity* 1984(1) pp. 223–242.

McCallum, Bennett T. 1988. "Robustness Properties of a Rule for Monetary Policy." *Carnegie-Rochester Conference Series on Public Policy* 29 (Autumn) pp. 173–203.

McCallum, Bennett T., and Edward Nelson. 1999. "Performance of Operational Policy Rules in an Estimated Semi-classical Structural Model." In *Monetary Policy Rules,* ed. John B. Taylor. Chicago: University of Chicago.

Milani, Fabio. 2005. "Expectations, Learning, and Macroeconomic Persistence." Unpublished manuscript, University of California, Irvine.

Okun, Arthur. 1962. "Potential Output: Its Measurement and Significance." In *American Statistical Association 1962 Proceedings of the Business and Economic Section.* Washington, DC: American Statistical Association.

Orphanides, Athanasios. 2003a. "Monetary Policy Evaluation with Noisy Information." *Journal of Monetary Economics* 50(3) (April) pp. 605–631.

Orphanides, Athanasios. 2003b. "Historical Monetary Policy Analysis and the Taylor Rule." *Journal of Monetary Economics* 50(5) (July) pp. 983–1,022.

Orphanides, Athanasios, and Simon van Norden. 2002. "The Unreliability of Output Gap Estimates in Real Time." *Review of Economics and Statistics* 84(4) (November) pp. 569–583.

Orphanides, Athanasios, and John C. Williams. 2002. "Robust Monetary Policy Rules with Unknown Natural Rates." *Brookings Papers on Economic Activity* 2002(2) pp. 63–118.

Orphanides, Athanasios, and John C. Williams. 2004. "Imperfect Knowledge, Inflation Expectations and Monetary Policy." In *The Inflation Targeting Debate,* eds. Ben Bernanke and Michael Woodford. Chicago: University of Chicago Press.

Orphanides, Athanasios, and John C. Williams. 2005a. "Inflation Scares and Forecast-Based Monetary Policy." *Review of Economic Dynamics* 8(2) pp. 498–527.

Orphanides, Athanasios, and John C. Williams. 2005b. "Robust Monetary Policy with Imperfect Knowledge." Working paper.

Orphanides, Athanasios, and John C. Williams. 2005c. "The Decline of Activist Stabilization Policy: Natural Rate Misperceptions, Learning, and Expectations." *Journal of Economic Dynamics and Control* 29(11) (November) pp. 1,927–1,950.

Orphanides, Athanasios, and John C. Williams. 2006. "Monetary Policy with Imperfect Knowledge." *Journal of the European Economics Association* 4(2–3) pp. 366–375.

Roberts, John M. 1997. "Is Inflation Sticky?" *Journal of Monetary Economics* 39(2) pp. 173–196.

Roley, V. Vance, and Gordon H. Sellon Jr. 1995. "Monetary Policy Actions and Long Term Interest Rates." FRB Kansas City *Economic Quarterly* 1995(Q4) pp. 73–89. http://www.kc.frb.org/publicat/econrev/pdf/4q95role.pdf

Rotemberg, Julio J., and Michael Woodford. 1999. "Interest Rate Rules in an Estimated Sticky Price Model." In *Monetary Policy Rules,* ed. John B. Taylor. Chicago: University of Chicago.

Rudebusch, Glenn. 2002. "Assessing Nominal Income Rules for Monetary Policy with Model and Data Uncertainty." *The Economic Journal* 112(479) (April) pp. 402–432.

Sargent, Thomas J. 1993. *Bounded Rationality in Macroeconomics.* Oxford and New York: Oxford University Press, Clarendon Press.

Sargent, Thomas J. 1999. *The Conquest of American Inflation.* Princeton, NJ: Princeton University Press.

Sheridan, Niamh. 2003. "Forming Inflation Expectations." Unpublished manuscript, Johns Hopkins University (April).

Shiller, Robert J. 1979. "The Volatility of Long-Term Interest Rates and Expectations Models of the Term Structure." *Journal of Political Economy* 87(6) (December) pp. 1,190–1,219.

Smets, Frank. 2003. "Maintaining Price Stability: How Long Is the Medium Term?" *Journal of Monetary Economics* 50(6) (September) pp. 1,293–1,309.

Taylor, John B. 1993. "Discretion versus Policy Rules in Practice." *Carnegie-Rochester Conference Series on Public Policy* 39 (December) pp. 195–214.

Wicksell, Knut. 1898. *Interest and Prices,* 1936 translation from German by R.F. Kahn. London: Macmillan.

Williams, John C. 2005. "Robust Estimation and Monetary Policy with Unobserved Structural Change." In *Models and Monetary Policy: Research in the Tradition of Dale Henderson, Richard Porter, and Peter Tinsley,* eds. Jon Faust, Athanasios Orphanides, and David L. Reifschneider. Washington, DC: Federal Reserve Board of Governors.

Woodford, Michael. 2003. *Interest and Prices: Foundations of a Theory of Monetary Policy.* Princeton, NJ: Princeton University Press.

Zarnowitz, Victor, and Phillip A. Braun. 1993. "Twenty-two Years of the NBER-ASA Quarterly Economic Outlook Surveys: Aspects and Comparisons of Forecasting Performance." In *Business Cycles, Indicators, and Forecasting,* eds. James H. Stock and Mark W. Watson. Chicago: University of Chicago Press.

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

Refet S. Gürkaynak

Assistant Professor
Bilkent University

Andrew N. Marder

Graduate Student
Princeton University

Andrew T. Levin

Assistant Director and Section Chief
Board of Governors of the Federal Reserve System

Eric T. Swanson

Research Advisor
Federal Reserve Bank of San Francisco

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 has reacted significantly to macroeconomic data releases, suggesting that long-run inflation expectations have not been completely anchored. In contrast, the Canadian inflation compensation data have exhibited significantly less sensitivity to Canadian and U.S. macroeconomic news, suggesting that inflation targeting in Canada has helped to anchor long-run inflation expectations in that country. Finally, while the requisite data for Chile are available for only a limited sample period (2002–2005), our results are consistent with the hypothesis that inflation targeting in Chile has helped anchor long-run inflation expectations in that country as well.

1. Introduction

Many central banks have adopted a formal inflation-targeting framework based on the belief and the theoretical predictions that an explicit and clearly communicated numerical objective for the level of inflation over a specified period would, in itself, be a strong communication device that would help anchor long-term inflation expectations.[1] Empirically verifying the success of inflation-targeting regimes in this dimension has been difficult, however, as survey data on long-term inflation expectations tend to be of limited availability and low frequency.[2]

In this paper, we use daily bond yield data for Canada, Chile, and the United States to investigate whether long-term inflation expectations in these countries are anchored, essentially extending the analysis of Gürkaynak, Sack, and Swanson (2005) and Gürkaynak, Levin, and Swanson (2006) to examine comparable data for Canada and Chile. Of these three countries, Canada and Chile have been formal inflation targeters throughout much of the 1990s and 2000s, while the United States has not had an explicit numerical inflation objective. We test the success of inflation targeting in anchoring long-term inflation expectations by

*In compiling the data for this project, we received invaluable assistance from Klaus Schmidt-Hebbel and Mauricio Larraín. The paper also benefited from very helpful discussions, comments, and suggestions from Rick Mishkin, Eric Parrado, Scott Roger, Brian Sack, Klaus Schmidt-Hebbel, Lars Svensson, and Jonathan Wright. We also appreciate the excellent research assistance of Claire Hausman and Oliver Levine. This article is reprinted from the conference volume *Series on Central Banking, Analysis, and Economic Policies X: Monetary Policy under Inflation Targeting,* eds. Frederic Mishkin and Klaus Schmidt-Hebbel. Santiago, Chile: Central Bank of Chile, 2007. Opinions expressed do not necessarily reflect the views of the management of the Federal Reserve Bank of San Francisco or the Board of Governors of the Federal Reserve System.

1. See, for example, Leiderman and Svensson (1995), Bernanke and Mishkin (1997), Svensson (1997), and Bernanke et al. (1999).

2. For an analysis using semiannual survey data on long-run inflation expectations in the 1990s and early 2000s for a panel of countries, see Levin and Piger (2004).

comparing the behavior of long-term nominal and indexed bond yields across these three countries in response to important economic developments. Forward inflation compensation—defined as the difference between forward rates on nominal and inflation-indexed bonds—provides us with a high-frequency measure of the compensation that investors require to cover the expected level of inflation, as well as the risks associated with inflation, at a given horizon. If far-ahead forward inflation compensation is relatively insensitive to incoming economic news, then one could reasonably infer that financial market participants have fairly stable views regarding the distribution of long-term inflation outcomes. This is precisely the outcome one would hope to observe in the presence of an explicit and credible inflation target.

The daily frequency of our bond yield data, together with the frequent release of important macroeconomic statistics and monetary policy announcements, provides a large event-study data set for our analysis. This holds even for samples that span only a few years—the period for which we have inflation-indexed bond data for the United States and long-term nominal bond data for Chile. Thus, in contrast to previous empirical work using quarterly or even semiannual data, we are able to bring to bear thousands of daily observations of the response of long-term bond yields to major economic news releases in Canada, Chile, and the United States.

For the United States, we find that far-ahead forward nominal interest rates and inflation compensation have responded significantly and systematically to a wide variety of macroeconomic data releases and monetary policy announcements. These responses are all consistent with a model in which the private sector's view of the central bank's long-run inflation objective is not strongly anchored, as we show. In Canada, far-ahead forward nominal interest rates and inflation compensation have displayed much less sensitivity to either domestic or foreign economic news. Thus, the anchoring of long-run inflation expectations in Canada appears to have been stronger than in the United States. Finally, the data for Chile are more limited in terms of the sample period, the depth and breadth of fixed income markets, and the availability of domestic macroeconomic data releases. Despite these limitations, we do not find significant responses of far-ahead inflation compensation in Chile with respect to domestic or foreign macroeconomic news.[3]

The remainder of the paper proceeds as follows. Section 2 presents two reference models of the economy to act as benchmarks for comparison with our empirical results. Section 3 investigates the responses of far-ahead forward interest rates and inflation compensation in the United States to economic news and shows that these rates respond by much more than standard models would predict. Section 4 discusses possible explanations for this finding. Section 5 repeats our empirical analysis for Canada and Chile to investigate the extent to which inflation targeting may help anchor the private sector's views regarding the long-run inflation objective of the central bank. Section 6 concludes. An appendix provides a detailed description of all the data used in our analysis.

2. Long-Run Implications of Macroeconomic Models

To aid the interpretation of our econometric results, it is useful to have a reference model as a benchmark. We consider two standard macroeconomic models: a pure New Keynesian model (taken from Clarida, Galí, and Gertler 2000) and a modification of that model that allows for a significant fraction of backward-looking or rule-of-thumb agents (taken from Rudebusch 2001). These two models can be thought of as different parameterizations of the following equations:

$$(1)\quad \pi_t = \mu_\pi \mathrm{E}_t \pi_{t+1} + (1-\mu_\pi) A_\pi(L)\pi_t + \gamma y_t + \varepsilon_t^\pi$$

and

$$(2)\quad y_t = \mu_y \mathrm{E}_t y_{t+1} + (1-\mu_y) A_y(L) y_t - \beta(i_t - \mathrm{E}_t \pi_{t+1}) + \varepsilon_t^y,$$

where π denotes the inflation rate, y the output gap, and i the short-term nominal interest rate, and ε^π and ε^y are independent and identically distributed (i.i.d.) shocks.[4] The parameters μ_π and μ_y describe the degree of forward-looking behavior in the model, and the lag polynomials $A_\pi(L)$ and $A_y(L)$ summarize the parameters governing the dynamics of any backward-looking components of the model.

The two models differ in the extent of their forward-looking behavior. The pure New Keynesian model assumes that agents are completely forward-looking ($\mu_\pi = \mu_y = 1$), and the parameter values for the equations are taken from Clarida, Galí, and Gertler (2000). A number of authors, however, estimate much smaller values of μ_π (around 0.3) to match the degree of inflation persistence observed in U.S. data (for example, Fuhrer 1997, Roberts 1997, Rudebusch 2001, and Estrella and Fuhrer 2002). Thus, in the second model considered, we set $\mu_\pi = 0.3$ and take

3. Ertürk and Özlale (2005) obtain a similar finding of anchored expectations for Chile using a GARCH specification on monthly Chilean data.

4. These variables are all normalized to have steady-state values of zero.

parameter values from Rudebusch (2001).[5] Note that Rudebusch's model is among the most persistent of the hybrid New Keynesian models in the literature, owing to the inclusion of several lags of output and inflation in equations (1) and (2) and a particularly low value of μ_y (Rudebusch assumes $\mu_y = 0$) in the income-spending (IS) equation (equation (2)).

We close these two models with an interest rate rule of the following form:

$$i_t = (1-c)\,[(1+a)\bar{\pi}_t + by_t] + ci_{t-1} + \varepsilon_t^i, \tag{3}$$

where $\bar{\pi}$ denotes the trailing four-quarter moving average of inflation, ε^i is an i.i.d. shock, and *a, b,* and *c* are the parameters of the rule.[6] Note that the policy rule is both backward-looking, in that the interest rate responds to current values of the output gap and inflation rather than their forecasts, and inertial, in that it includes the lagged federal funds rate. Both of these characteristics tend to add inertia to the short rate, which, together with the persistence of the Rudebusch model, generally gives the model the best possible chance to explain the term structure evidence we find below. We include an interest rate shock, ε_t^i, for the purpose of generating impulse response functions.

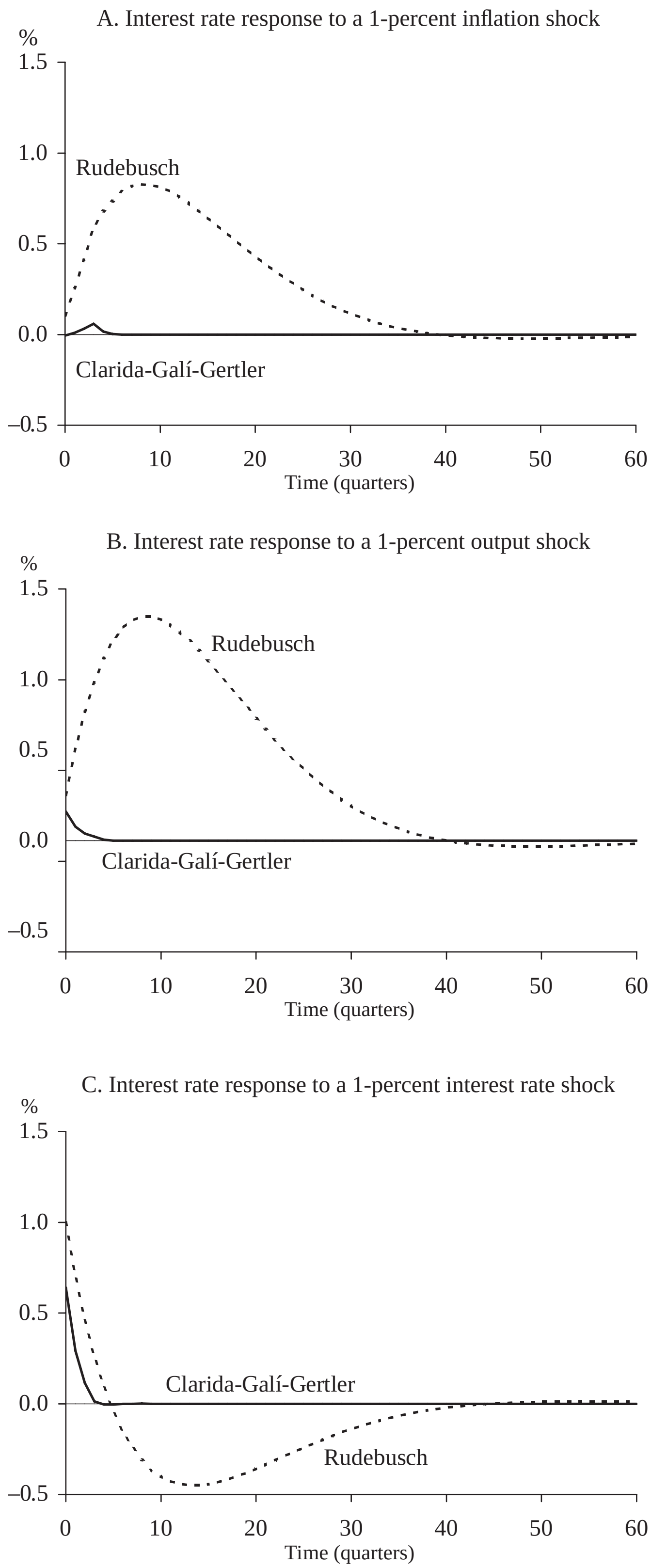
The three panels of Figure 1 show the response of the short-term nominal interest rate to a 1-percent shock to the inflation equation, the output equation, and the interest rate equation, respectively, under our two baseline models.[7] In the pure New Keynesian (Clarida, Galí, and Gertler) model, the effect of the macroeconomic and monetary policy shocks on the short-term interest rate dies out very quickly, generally within a year. The interest rate displays much more persistence in the partially backward-looking (Rudebusch) model. Even in that model, however, the

5. Rudebusch estimates and uses a value of $\mu = 0.29$ in the inflation equation and sets $\mu = 0$ in the output equation, so we use those values as well. There are also some minor timing differences between the specification of Rudebusch's model and our equations (1) and (2). To generate the impulse response functions in Figure 1, we use the model exactly as specified in Rudebusch (2001), but these differences in specification have no discernible effect on our results.

6. We use the values of *a, b,* and *c* estimated by Rudebusch (2002) from 1987:Q4 to 1999:Q4: namely, $a = 0.53$, $b = 0.93$, and $c = 0.73$.

7. In a discussion of our paper at the Central Bank of Chile, Eric Parrado reported impulse response functions using the small open economy international macroeconomic model of Galí and Monacelli (2005), roughly calibrated to match the data in Canada and Chile. The results from those impulse response functions were consistent with our analysis for the standard closed economy New Keynesian models presented here: in particular, short-term interest rates returned to steady state well within ten years of a shock. Indeed, that model returned to steady state even more quickly—within just four or five years, compared to seven or eight years for the Rudebusch model. We believe this difference is due to the persistent parameters of the Rudebusch model, rather than to the lack of an open economy transmission mechanism in that model.

FIGURE 1
IMPULSE RESPONSE FUNCTIONS
FOR STANDARD MACRO MODELS



short-term interest rate essentially returns to its steady-state level well within ten years after each shock.

3. The Sensitivity of U.S. Long-Term Interest Rates to Economic News

We now turn to how well the above model predictions are matched by U.S. data. The models predict that macroeconomic data releases and monetary policy announcements should affect the path of nominal interest rates only in the short run. To examine whether the U.S. data match the predictions of the models, we must look beyond the response of interest rates in the first few years after a shock and instead focus on the behavior of forward interest rates several years ahead.

Forward rates are often a very useful means of interpreting the term structure of interest rates. For a bond with a maturity of m years, the yield $r_t^{(m)}$ represents the rate of return that an investor requires to lend money today in return for a single payment m years in the future (for the case of a zero-coupon bond). By comparison, the k-year-ahead one-year forward rate $f_t^{(k)}$ represents the rate of return from period $t+k$ to period $t+k+1$ that the same investor would require to commit today to a one-year loan beginning at time $t+k$ and maturing at time $t+k+1$. The linkage between these concepts is simple: an m-year (continuously compounded) zero-coupon security can be viewed as a sequence of one-year forward agreements over the next m years:[8]

$$f_t^{(k)} = (k+1)r_t^{(k+1)} - kr_t^{(k)}. \tag{4}$$

For our analysis, we use Federal Reserve Board data on forward interest rates for U.S. Treasury securities.[9] Given our interest in measuring long-term expectations, our analysis focuses on the longest maturity for which we have high-quality bond yield data. The liquidity and breadth of the markets for government securities at and around the ten-year horizon thus lead us to focus on the one-year forward rate nine years ahead (that is, the one-year forward rate ending in ten years). The analysis of the previous section shows that this horizon is sufficiently far out for standard macroeconomic models to largely return to their steady states, so that any movements in forward interest rates or inflation compensation at these horizons should not be due to transitory responses of the economy to an economic shock.

To measure the effects of macroeconomic data releases on interest rates, the unexpected (or surprise) component of each macroeconomic data release must be computed, since the expected component of macroeconomic data releases should have no effect in forward-looking financial markets.[10] Using the surprise components of macroeconomic data releases, where expectations are measured just a few days before the actual release, also removes any possible issue of endogeneity arising from interest rates feeding back to the macroeconomy. Any such effects, to the extent that they are systematic or predictable, will be incorporated into the market forecast for the statistical release.

To measure the surprise component of each data release, we compute the difference between the actual release and the median forecast of that release made by professional forecasters just a few days prior to the release date. For the United States, we use data on professional forecasts of the next week's statistical releases, published every Friday by Money Market Services for 39 different macroeconomic data series.[11] Not all 39 of these macroeconomic statistics have a significant impact on interest rates, even at the short end of the yield curve. Thus, to conserve space and reduce the number of exogenous variables in our regressions, we restrict our attention to the macroeconomic variables that Gürkaynak, Sack, and Swanson (2005) identify as having statistically significant effects on the one-year Treasury bill rate over the 1990–2002 period: capacity utilization, consumer confidence, the core consumer price index (CPI), the employment cost index (ECI), the advance (that is, first) release of real GDP, initial claims for unemployment insurance, the National Association of Purchasing Managers (NAPM)/Institute for Supply Management (ISM) survey of manufacturing activity, new home sales, employees on nonfarm payrolls, retail sales, and the unemployment rate.[12]

---

8. If we could observe zero-coupon yields directly, computing forward rates would be as simple as this. In practice, however, most government bonds in the United States and abroad make regular coupon payments, and thus the size and timing of the coupons must be accounted for to translate observed yields into the implied zero-coupon yield curve. In the results presented below, we also investigate whether the use of U.S. Treasury STRIPS (which are zero-coupon securities that thus do not require fitting a yield curve first) alters the estimated response of far-ahead forward nominal rates in the United States. We find that the STRIPS data yield essentially identical results.

9. Federal Reserve Board staff compute implied zero-coupon yields from observed, off-the-run U.S. Treasury yields using the extension of Nelson-Siegel described in Svensson (1994). Details are available in Gürkaynak, Sack, and Wright (2006).

10. Kuttner (2001) tests and confirms this hypothesis for the case of monetary policy announcements.

11. Several authors find the Money Market Services data to be of high quality (for example, Balduzzi, Elton, and Green 2001, Andersen et al. 2003, and Gürkaynak, Sack, and Swanson 2005).

12. In addition to these 11 variables, Gürkaynak, Sack, and Swanson (2005) also included leading indicators and the core producer price index (PPI) in their analysis. We originally included these two variables as well, but they never entered significantly into any of our regressions at even the shortest horizon at even the 10-percent level. We therefore

As with macroeconomic data releases, we must compute the surprise component of monetary policy announcements in each of our countries in order to measure the effects of these announcements on interest rates. We measure monetary policy surprises for the United States using federal funds futures rates, which provide high-quality, virtually continuous measures of market expectations for the federal funds rate (Krueger and Kuttner 1996, Rudebusch 1998, Brunner 2000).[13] The federal funds futures contract for a given month settles at the end of the month based on the average federal funds rate that was realized over the course of that month. Thus, daily changes in the current-month futures rate reflect revisions to the market's expectations for the federal funds rate over the remainder of the month. As explained in Kuttner (2001) and Gürkaynak, Sack, and Swanson (2002), the change in the current month's contract rate on the day of a Federal Open Market Committee (FOMC) announcement, scaled up to account for the timing of the announcement within the month, provides a measure of the surprise component of the FOMC decision.[14] We compute the surprise component associated with every FOMC meeting and intermeeting policy action by the FOMC over our sample.[15]

3.1. *The Sensitivity of U.S. Interest Rates to Economic News*

Table 1 reports results for nominal interest rates in the United States over the 1994–2005 period.[16] Each column provides results from a regression of daily changes in the corresponding interest rate on the surprise component of

TABLE 1
U.S. FORWARD RATE RESPONSES TO DOMESTIC ECONOMIC NEWS, 1994–2005

Explanatory variable	1-year nominal rate	1-year forward nominal rate ending in 10 yrs.	1-year forward nominal rate ending in 10 yrs. from STRIPS
Capacity utilization	1.76*** (3.78)	1.24** (2.05)	0.80 (1.21)
Consumer confidence	1.36*** (3.13)	1.04* (1.85)	0.88 (1.43)
Core CPI	1.92*** (3.29)	1.47* (1.94)	1.80** (2.16)
Employment cost index	1.66** (2.28)	1.87** (1.98)	1.24 (1.20)
Real GDP (advance)	1.37* (1.95)	0.36 (0.40)	–0.08 (–0.08)
Initial jobless claims	–0.91*** (–4.16)	–0.59** (–2.07)	–0.62** (–2.00)
NAPM/ISM mfg. survey	2.40*** (5.58)	2.54*** (4.55)	2.79*** (4.56)
New home sales	0.77* (1.88)	0.85 (1.60)	1.01* (1.73)
Nonfarm payrolls	4.63*** (10.24)	2.51*** (4.28)	2.62*** (4.08)
Retail sales (excl. autos)	2.15*** (3.75)	1.69** (2.26)	1.36* (1.66)
Unemployment rate	–1.63*** (–3.32)	0.38 (0.60)	–0.52 (–0.74)
Monetary policy	0.30*** (4.78)	–0.17** (–2.14)	–0.24*** (–2.71)
No. obs.	1,371	1,371	1,371
R^2	0.16	0.06	0.05
Joint test *p* value	0.000***	0.000***	0.000***

*Statistically significant at the 10 percent level.
**Statistically significant at the 5 percent level.
***Statistically significant at the 1 percent level.

Notes: The sample is from January 1994 to October 2005, at daily frequency on the dates of macroeconomic and monetary policy announcements. Regressions also include a constant, a Y2K dummy that takes on the value of 1 on the first business day of 2000, and a year-end dummy that takes on the value of 1 on the first business day of any year (coefficients not reported). Macroeconomic data release surprises are normalized by their standard deviations, so these coefficients represent a basis point per standard deviation response. Monetary policy surprises are in basis points, so these coefficients represent a basis point per basis point response. Joint test *p* value is for the hypothesis that all coefficients (other than the constant and dummy variables) are zero. *T* statistics are reported in parentheses.

omit them from the results below to save space and reduce the number of explanatory variables. Nonetheless, our results are essentially identical whether we include these additional variables in the regressions or not.

13. Gürkaynak, Sack, and Swanson (2002) show that, among the many possible financial market instruments that potentially reflect expectations of monetary policy, federal funds futures are the best predictor of future policy actions.

14. To avoid very large scale factors, if the monetary policy announcement occurs in the last seven days of the month, we use the next-month contract rate instead of scaling up the current-month contract rate.

15. The only exception is that we exclude the intermeeting 50-basis-point easing on September 17, 2001, because financial markets were closed for several days prior to that action and because that easing was a response to a large exogenous shock to the U.S. economy and financial markets. We would thus have difficulty disentangling the effect of the monetary policy action from the effect of the shock itself on financial markets that day.

16. Our STRIPS data begin in 1994, so we restrict analysis in Table 1 to the post-1994 period. Gürkaynak, Sack, and Swanson (2005) report very similar results for the 1990–2002 period using forward rates from a fitted yield curve.

the macroeconomic data releases and monetary policy announcements listed at the left.[17] We regress the change in interest rates on all of our macroeconomic and monetary policy surprises jointly to properly account for days on which more than one piece of economic news was released. To facilitate interpreting our coefficient estimates, we normalize each macroeconomic surprise by its standard deviation. Each coefficient in the table thus estimates the interest rate response in basis points per standard deviation surprise in the corresponding macroeconomic statistic. The one exception to this rule is the monetary policy surprises, which we leave in basis points, so that these coefficients represent a basis point per basis point response.

The first column of Table 1 reports the responses of the one-year Treasury spot rate to the economic releases as a benchmark for comparison. As one might expect from a Taylor-type rule or from casual observation of U.S. financial markets, interest rates at the short end of the term structure exhibit highly significant responses to surprises in macroeconomic data releases and monetary policy announcements. Moreover, these responses are generally consistent with what one would expect from a Taylor-type rule: upward surprises in inflation, output, or employment lead to increases in short-term interest rates, and upward surprises in initial jobless claims (a countercyclical economic indicator) cause short-term interest rates to fall. The magnitudes of these estimates seem reasonable, with a two-standard-deviation surprise leading to about a 3- to 10-basis-point change in the one-year rate (depending on the statistic) on average over our sample. Monetary policy surprises lead to about a one-for-three or one-for-two response of the one-year yield to the federal funds rate. This is consistent with the view that a surprise change in the federal funds rate is often not a complete surprise to markets, but rather a moving forward or pushing back of policy changes that were already expected to have some chance of occurring in the future.

The middle column of Table 1 shows the response of far-ahead forward interest rates in the United States to economic news. If ten years is a sufficient amount of time for the U.S. economy to return largely to steady state following an economic shock, as our simulations above suggest, and if long-term inflation expectations were firmly anchored in the United States, then one would expect to see little or no response of these rates to economic news. This is not the case, however: far-ahead forward nominal rates in the United States respond significantly to nine of the twelve macroeconomic data releases we consider, often with a very high degree of statistical significance, and a test of the joint hypothesis that all coefficients in the regression are zero is rejected with a p value on the order of 10^{-10}. Not only are the estimated coefficients statistically significant, but their magnitudes are large, often more than half as large as the effect on the short-term interest rate. Finally, the signs of these coefficients are not random, but rather they closely resemble the effect on short-term interest rates and the short-term inflation outlook. This resemblance is consistent with markets expecting some degree of pass-through of short-term inflation to the long-term inflation outlook. The case of monetary policy surprises offers perhaps the most striking example of this pattern: the estimated effect of monetary policy surprises on far-ahead nominal interest rates is opposite to the effect of surprises on the one-year spot rate—that is, a surprise monetary policy tightening causes far-ahead forward nominal rates to fall. This result echoes the finding by Gürkaynak, Sack, and Swanson (2005) for their 1990–2002 and 1994–2002 samples. It is also consistent with financial markets expecting a pass-through of the short-term inflation outlook to long-term inflation, as we demonstrate in Section 4, below.

The right-hand column of Table 1 reports a robustness check on the above results, in which we computed the response of the one-year forward rate ending in ten years using U.S. Treasury STRIPS (Separate Trading of Registered Interest and Principal Securities) rather than the Federal Reserve's smoothed yield curve data.[18] STRIPS are pure zero-coupon securities whose yields provide a direct, market-based measure of forward rates that does not require any yield curve fitting or smoothing. (On the other hand, STRIPS are less liquid than Treasury notes and bonds and thus suffer from larger bid-ask spreads and trading costs, making observed prices a less clean measure of the true shadow value of the securities and introducing some noise into our estimates.) The results in the right-hand column of Table 1 are very much in line with those from the middle column: seven of the twelve macroeconomic news releases we consider lead to significant responses of ten-year-ahead forward interest rates, with estimated magnitudes that are very similar to those from

17. Although we have almost 1,000 daily observations in each of these regressions, most of the elements of any individual regressor are zero, because any given macroeconomic statistic is only released once a month (or once a quarter in the case of GDP and once a week in the case of initial claims). We restrict attention in all our regressions to those days on which some macroeconomic statistic was released or a monetary policy announcement was made, but our results are not sensitive to this restriction.

18. U.S. Treasury STRIPS are created by decoupling the individual coupon and principal payments from U.S. Treasury notes and bonds into pure zero-coupon securities. See Sack (2000) for more details on the potential usefulness of STRIPS for estimating the Treasury yield curve. In this paper, we compute the one-year forward rate ending in ten years using the nine-year STRIPS security and ten-year STRIPS security and applying equation (1).

our yield-curve-based estimates, and the joint hypothesis that all coefficients are equal to zero is likewise rejected at extremely high levels of statistical significance (p value on the order of 10^{-9}). All of these observations suggest that our results are not due to any artifact of yield curve fitting involved in computing forward rates from Treasury coupon securities.

3.2. *The Sensitivity of U.S. Interest Rates and Inflation Compensation to Economic News*

The United States has issued inflation-indexed Treasury securities since 1997. A natural question arising from our estimates above, then, is to what extent the strong responses in far-ahead forward interest rates are due to changes in real interest rates, as opposed to changes in inflation compensation—the difference between nominal and real interest rates. Table 2 investigates this interesting question.

U.S. Treasury inflation-indexed securities—commonly referred to as TIPS—were issued for the first time in January 1997 and only annually for the first few years after that date. We therefore cannot compute a far-ahead forward real rate for the United States until January 1998, giving us a sample that covers only about eight years. Nonetheless, the high frequency of the data still leaves us with almost a thousand observations with which to perform our analysis.

We obtained data on the forward real interest rates implied by TIPS from Federal Reserve Board staff.[19] We define forward inflation compensation as the difference between the forward nominal rate and forward real rate at each horizon. This measure captures the compensation that investors demand both for expected inflation at the given horizon and for the risks or uncertainty associated with that inflation.[20]

In the first two columns of Table 2, we repeat the regressions of the one-year spot rate and the ten-year-ahead one-year rate on our macroeconomic surprises over the sample of TIPS data (1998–2005). Our results over this sample are very similar to those in Table 1, although the statistical significance is reduced for our coefficient estimates in both regressions. For example, only five of our twelve coefficients for the ten-year-ahead nominal rate are signi-

Table 2
U.S. Forward Rate Responses to Domestic Economic News, 1998–2005

Explanatory variable	1-yr. nominal rate	1-yr. forward nom. rate ending 10 yrs.	1-yr. forward real rate ending 10 yrs.	1-yr. forward inflation compensation ending 10 yrs.
Capacity utilization	1.55***	0.91	0.51	0.40
	(2.92)	(1.33)	(1.31)	(0.66)
Consumer confidence	1.34**	0.50	0.18	0.32
	(2.57)	(0.75)	(0.47)	(0.55)
Core CPI	1.01	1.25	–0.37	1.63**
	(1.58)	(1.53)	(–0.80)	(2.28)
Employment cost index	1.14	1.13	–0.10	1.23
	(1.48)	(1.15)	(–0.17)	(1.43)
Real GDP (advance)	2.37***	1.91*	0.02	1.89**
	(2.92)	(1.84)	(0.04)	(2.08)
Initial jobless claims	–1.06***	–0.74**	–0.20	–0.54*
	(–4.25)	(–2.32)	(–1.09)	(–1.94)
NAPM/ISM mfg. survey	2.26***	2.96***	1.74***	1.22**
	(4.39)	(4.49)	(4.59)	(2.12)
New home sales	0.23	0.67	–0.32	0.99*
	(0.51)	(1.15)	(–0.94)	(1.93)
Nonfarm payrolls	4.45***	1.79**	1.26***	0.54
	(8.02)	(2.52)	(3.07)	(0.88)
Retail sales (excl. autos)	1.60***	1.52*	0.68	0.84
	(2.55)	(1.88)	(1.46)	(1.18)
Unemployment rate	–1.20*	0.89	0.84*	0.05
	(–1.95)	(1.13)	(1.85)	(0.07)
Monetary policy	0.36***	–0.01	0.01	–0.02
	(4.35)	(–0.13)	(0.18)	(–0.26)
No. obs.	950	950	950	950
R^2	0.15	0.06	0.04	0.04
Joint test p value	0.000***	0.000***	0.000***	0.010**

*Statistically significant at the 10 percent level.
**Statistically significant at the 5 percent level.
***Statistically significant at the 1 percent level.

Notes: The sample is from January 1998 to October 2005, at daily frequency on the dates of macroeconomic and monetary policy announcements. Regressions also include a constant, a Y2K dummy that takes on the value of 1 on the first business day of 2000, and a year-end dummy that takes on the value of 1 on the first business day of any year (coefficients not reported). Macroeconomic data release surprises are normalized by their standard deviations, so these coefficients represent a basis point per standard deviation response. Monetary policy surprises are in basis points, so these coefficients represent a basis point per basis point response. Inflation compensation is the difference between nominal and real rates. Joint test p value is for the hypothesis that all coefficients (other than the constant and dummy variables) are zero. T statistics are reported in parentheses.

19. The Federal Reserve Board provides real yield curve estimates beginning in January 1999. We extend the nine- to ten-year forward rate series back to January 1998 by taking the nine- and ten-year TIPS rates and computing the implied forward rate between the two using the Shiller, Campbell, and Schoenholtz (1983) approximation.

20. Forward real rates, nominal rates, and inflation compensation may also be affected by other factors, such as term premiums and premiums for liquidity. We discuss the robustness of all of our results with respect to these types of risk premiums in the next section.

ficant over this shorter sample, compared with nine of twelve in Table 1, although the joint hypothesis that all coefficients are zero in that regression is still rejected at very high levels of statistical significance.[21] The signs and magnitudes of the coefficients in these two columns are also very similar to those we estimated over the larger 1994–2005 period.

In the third and fourth columns of Table 2, we decompose the response of forward nominal rates into its constituent real rate and inflation compensation components. We find some evidence that part of the estimated responsiveness of nominal forward rates is actually due to movements in real interest rates, particularly for the NAPM/ISM manufacturing survey and nonfarm payrolls releases.[22] In the majority of cases, however, the responsiveness of long-term nominal interest rates can be directly linked to changes in inflation compensation. Five of our twelve estimated coefficients are statistically significant, and the joint hypothesis that all coefficients are zero is rejected with a p value of about 1 percent.

4. Possible Explanations for the Behavior of U.S. Long-Term Interest Rates

In steady state, the short-term nominal interest rate, i, equals the steady-state real interest rate, r^*, plus the steady-state level of inflation, π^*, by Fisher's equation:

$$i^* = r^* + \pi^*. \tag{5}$$

As mentioned above, standard asset-pricing theory indicates that forward rates with sufficiently long horizons—that is, $f_t^{(N)}$ for N large, where $f_t^{(N)}$ is the forward rate ending in N years' time—equal the expected steady-state short-term rate plus a risk premium, ρ :

$$f_t^{(N)} = r^* + \pi^* + \rho. \tag{6}$$

The fact that $f_t^{(N)}$ responds to many macroeconomic data releases and monetary policy surprises indicates that one (or more) of r^*, π^*, and ρ is changing in response to these surprises.

21. The significance of the negative response of forward nominal rates to monetary policy surprises is notably absent over this later sample, perhaps reflecting the fact that these surprises become generally smaller and less frequent in the later part of our sample (Swanson 2006). Another possible explanation for the smaller number of significant coefficients over the later sample is that long-term interest rates have gradually become better anchored in the United States. We leave this as an interesting question for future research.

22. We do not take a stand on why far-ahead real rates might move in response to economic news, although one possible explanation is that markets view the particular data release as informative about the economy's long-run rate of productivity growth and, hence, about the equilibrium real interest rate.

4.1. Some Nonexplanations for the Excess Sensitivity Puzzle: r^* and ρ

In our search for a solution to the excess sensitivity puzzle documented above, we consider but ultimately discard two possible causes: changes in r^* (the long-run equilibrium real interest rate) and changes in ρ (the risk premium). Although r^* is a potentially time-varying component of steady-state short-term rates, our empirical results are not well-described by changes in r^* for two reasons. First, TIPS provide a measure of far-ahead forward real rates, and as we showed in Table 2, the sensitivity of nominal rates in the United States to economic news was often linked to changes in inflation compensation rather than to changes in real rates. Second, many of the nominal interest rate responses that we estimate are difficult to interpret in terms of changes in r^*. For example, it is difficult to explain why a surprise uptick in inflation (of either the CPI or the PPI) would lead the market to revise upward its estimate of r^*, the long-run equilibrium real rate of interest.[23] Similarly, a surprise monetary policy tightening is not likely to lead the market to revise its estimate of r^* downward—presumably, a surprise tightening of policy, to the extent that it provides any information about r^*, indicates that the FOMC views r^* as being higher than the market estimate.

This is not to say that changes in the market's perception of r^* are necessarily unimportant. Indeed, changes in r^* may have had some effect on long-term interest rates in our sample, particularly in the late 1990s, when market estimates of the long-run rate of productivity growth in the United States were largely in flux. Relying solely on changes in r^* to explain our empirical results, however, is likely to cause difficulties for precisely the reasons described above.

Alternatively, one might argue that changes in the risk premium, ρ, are the most likely explanation for our findings of excess sensitivity in long-term interest rates. While some authors find little evidence for time-varying risk premiums in the data (for example, Bekaert, Hodrick, and Marshall 2001), a number of prominent studies (such as Fama and Bliss 1987, Campbell and Shiller 1991) document strong violations of the expectations hypothesis for a wide variety of samples and securities, suggesting that the risk premiums embedded in long-term bond yields may, in fact, vary substantially over time. A time-varying risk premium is often offered as an explanation for the excess

23. Even if one regards surprises in inflation as being informative about productivity growth in the late 1990s, the usual story that is told is that surprisingly low inflation was indicative of high productivity growth, which would, in turn, be related to a higher equilibrium real rate, r^*.

volatility puzzle and as a likely factor in the failure of the expectations hypothesis for longer maturities.

For our analysis, however, as long as the variation in risk premiums is small enough at the very high frequencies we consider, the change in bond yields over the course of the day will effectively difference out the risk premium at each point in our sample, allowing us to interpret the change in yields as being driven primarily by the change in expectations. While there is no a priori reason why risk premiums should vary only at lower frequencies, the predictors of excess returns on bonds emphasized in the studies above generally have this feature—that is, the variation from one day to the next is very small, while the large variations in premiums that they estimate occur at much lower frequencies, particularly business cycle frequencies (Cochrane and Piazzesi 2005, Piazzesi and Swanson 2006). Thus, the failure of the expectations hypothesis alone is not sufficient to call our analysis into question.

Moreover, in order for changes in risk premiums to explain our results, one would have to explain why they would move so systematically in the way that we document, being positively correlated with output and inflation news while moving inversely with surprises in monetary policy. For example, Cochrane and Piazzesi (2005) and Piazzesi and Swanson (2006) find that risk premiums in Treasury securities and interest rate futures move countercyclically over the business cycle, which is exactly opposite to the direction that would be needed to explain our findings and the findings of Gürkaynak, Levin, and Swanson (2006) (that far-ahead forward interest rates in the United States and in the United Kingdom before central bank independence comove positively with surprises in output and employment). Finally, one would have to explain why we do not find similar movements in risk premiums in the United Kingdom or Sweden, as documented in Gürkaynak, Levin, and Swanson (2006)—if anything, one would expect the importance of risk premiums to be greater in these smaller, less liquid markets—or why the behavior of risk premiums in the United Kingdom would have changed after the Bank of England gained independence from Parliament in 1997 (Gürkaynak, Sack, and Swanson 2003, Gürkaynak, Levin, and Swanson 2006).

Of course, given that current theory puts little structure on the behavior of term premiums, one could always write an ad hoc model of the term premium that would match our empirical findings. However, the fact that we did not observe a strong response of real interest rates to economic news in the United States suggests that if changes in risk premiums are responsible for the excess sensitivity of the forward nominal rates, any such risk seems to be more closely related to inflation compensation than to real rates. This is in line with our interpretation that it is the perceived distribution of future inflation outcomes (and not necessarily only its mean) that is unanchored.

4.2. A Possible Explanation for Excess Sensitivity: Changes in π^*

While we do not wish to discount the importance of changes in market perceptions of r^* or changes in risk premiums that are unrelated to inflation, we find each of them inadequate on its own to explain all of our empirical results. We now show that changes in the market's perception of π^*, the long-run inflation objective of the central bank, helps explain all of our findings. Thus, changes in π^* are not only necessary for explaining at least some of our results, they are also sufficient.[24]

4.2.1. Model with time-varying π^* and perfect information

We demonstrate the sufficiency of changes in π^* by augmenting the benchmark model from Section 2 to include an additional equation that permits the central bank's inflation objective to vary over time, without taking a stand on why this might be so. In this alternative specification, past values of inflation affect the central bank's longer-run inflation objective, according to

$$\pi_t^* = \pi_{t-1}^* + \theta(\bar{\pi}_{t-1} - \pi_{t-1}^*) + \varepsilon_t^{\pi^*}, \tag{7}$$

where $\bar{\pi}_{t-1}$ is the trailing four-quarter moving average of inflation. Thus, persistently low (high) inflation will, over time, tend to decrease (increase) the central bank's long-run inflation target.[25] Exogenous changes in the central bank's inflation objective, π^*, are captured by the shock $\varepsilon_t^{\pi^*}$.

Our benchmark model with time-varying π^* thus takes the form:

$$\pi_t = \mu_\pi \mathrm{E}_t \pi_{t+1} + (1-\mu_\pi) A_\pi(L)\pi_t + \gamma y_t + \varepsilon_t^\pi, \tag{8}$$

$$y_t = \mu_y \mathrm{E}_t y_{t+1} + (1-\mu_y) A_y(L) y_t - \beta(i_t - \mathrm{E}_t \pi_{t+1}) + \varepsilon_t^y, \tag{9}$$

$$i_t = (1-c)\left[\bar{\pi}_t + a(\bar{\pi}_t - \pi_t^*) + b y_t\right] + c i_{t-1} + \varepsilon_t^i, \text{ and} \tag{10}$$

$$\pi_t^* = \pi_{t-1}^* + \theta(\bar{\pi}_{t-1} - \pi_{t-1}^*) + \varepsilon_t^{\pi^*}, \tag{11}$$

24. While the model presented below is based on time variance in the perceived mean of the steady-state inflation distribution, the results would go through if other moments of that distribution were time varying, as well. These would be reflected in the inflation term premium.

25. This has some similarities to the idea of opportunistic disinflation described in Orphanides and Wilcox (2002).

where equation (10) now explicitly recognizes the existence of a non-constant inflation target. We use the same parameter values for the model as for the Rudebusch specification in Section 2, and we select a value for θ to roughly calibrate our impulse response functions to match the estimated responsiveness of long-term forward rates in our data. It turns out that we require relatively small values for θ (the loading of the central bank's inflation target on the past year's inflation) to match the term structure evidence. We thus set θ equal to 0.02 for the simulations below, implying that annual inflation 1 percentage point above target leads the central bank to raise its target by 2 basis points. This may seem negligibly small, but the persistence of inflation—particularly the four-quarter trailing average that enters into equation (11)—leads to cumulative effects on π^* that are nonnegligible, as we now show.

Figure 2 plots the impulse responses of inflation, the output gap, the short-term interest rate, and π^* to a 1-percent shock to each of equations (8) through (11).[26] The qualitative features of our empirical findings are reproduced very nicely. For example, after a 1-percent inflation shock (the first column), the short-term nominal interest rate rises gradually, peaks after a few years, and then returns to a long-run steady-state level that is about 35 basis points higher than the original steady state. This is due to the fact that the higher levels of inflation on the transition path cause the central bank's long-run objective, π^*, to rise. A similar response of short-term nominal interest rates and inflation can be seen in response to a 1-percent shock to output (the second column). For the federal funds rate shock (the third column), as inflation in the economy falls in response to the monetary tightening, the central bank's longer-run objective π^* gradually falls, as well. In the long run, the short-term nominal interest rate and inflation settle below their initial levels, producing exactly the kind of inverse relation between far-ahead forward rates and short rates that we found in the data.

4.2.2. Model with time-varying π^* and imperfect information

The above model can also be extended to include the case in which the private sector does not directly observe the central bank's inflation objective, π^*, and thus must infer it from the central bank's actions, as in Kozicki and Tinsley (2001), Ellingsen and Söderström (2001), and Erceg and Levin (2003). The advantages of a model with imperfect information are threefold. First, it emphasizes that the behavior of the term structure is driven by private sector expectations of future outcomes, which in the case of imperfect information can differ from the actual impulse responses to a particular (unobserved or imperfectly observed) shock. Second, a model with imperfect information provides a more realistic description of long-term interest rate behavior in the United States, since the Federal Reserve's long-term objective for inflation, π^*, is unknown to financial markets. Third, the presence of imperfect information increases the importance and effects of monetary policy shocks in the model, which allows for a better calibration to our empirical results than the model with perfect information can provide.

To consider the case of imperfect information, equations (8) through (11) must be augmented to include a private sector Kalman filtering equation:

$$(12) \qquad \hat{\pi}_t^* = \hat{\pi}_{t-1}^* + \theta(\bar{\pi}_{t-1} - \hat{\pi}_{t-1}^*) - \kappa(i_t - \hat{i}_t).$$

For simplicity and tractability, we assume that the forms of equations (8) through (11), all parameter values, and the shocks ε^π and ε^y are perfectly observed by the private sector. Thus, only π^*, ε^{π^*}, and ε^i are unobserved. Private agents update their estimate of the central bank's inflation target, denoted $\hat{\pi}_t^*$, using equation (12).[27] In particular, agents observe the deviation of the interest rate from their expectation, $i_t - \hat{i}_t$, where $\hat{i}_t$ is obtained by substituting $\pi_t^* = \hat{\pi}_{t-1}^* + \theta(\bar{\pi}_{t-1} - \hat{\pi}_{t-1}^*)$ and $\varepsilon_t^i = 0$ into equation (10), and they revise $\hat{\pi}_t^*$ by an amount determined by the Kalman gain parameter, κ. Again, we choose (rather than estimate) a value for κ of 0.1, which is meant to be illustrative and matches the data.[28]

Figure 3 presents the private sector's expected impulse responses to inflation, the output gap, the short-term interest rate, and the central bank's inflation objective following a shock to each of equations (8) through (11). Because this version of the model features imperfect information, the impulse responses expected by the private sector on impact may differ from the actual impulse responses from a shock. In particular, the private sector is initially unable to distinguish between the temporary shock, ε^i, and the permanent

26. The model has no indexation to steady-state inflation, so the central bank's π^* does not enter the private sector's equations directly. Rather, it only enters indirectly through the private sector's forecasts of π_{t+1} and y_{t+1}, which depend on the current and expected future path for the interest rate (which depends on π^*).

27. This procedure is optimal under the assumptions of normally distributed shocks and a normally distributed prior for the inflation target. For other shock distributions, the Kalman filter is the optimal linear inference procedure.

28. Alternatively, one could derive the optimal value for κ from the variance of the shocks to π^* and to i, but this value would have to be indirectly inferred anyway since π^* is unobserved. The value of 0.1 that we use for κ corresponds to a ratio of $\sigma_i/\sigma_{\pi^*} = 3$.

FIGURE 2
IMPULSE RESPONSES WITH TIME-VARYING π^* (PERFECT INFORMATION)

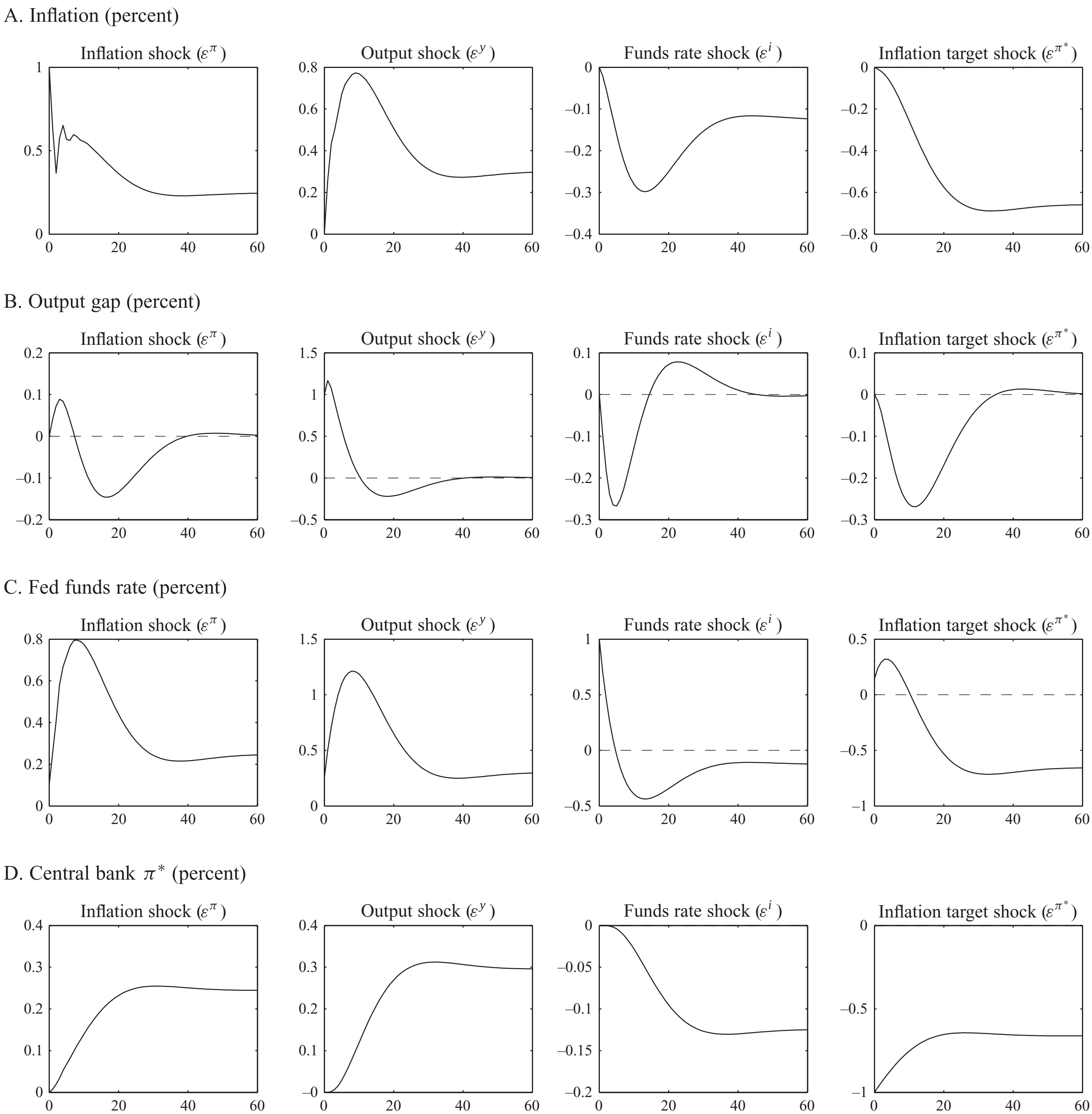
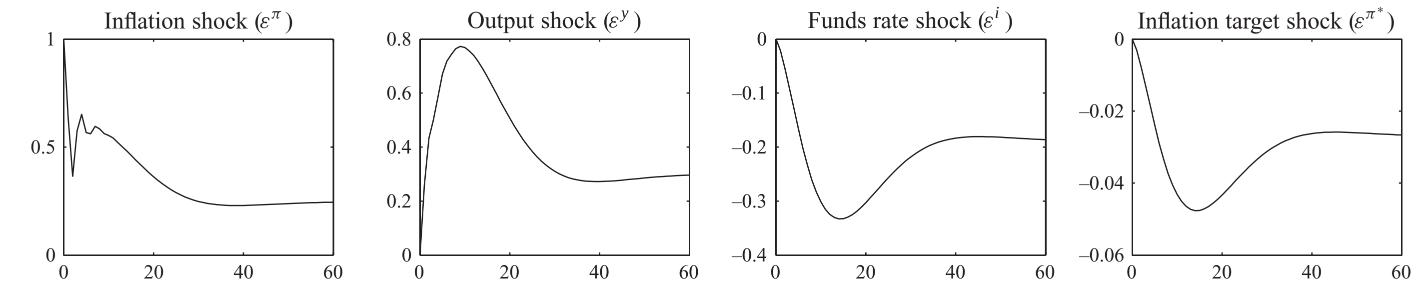
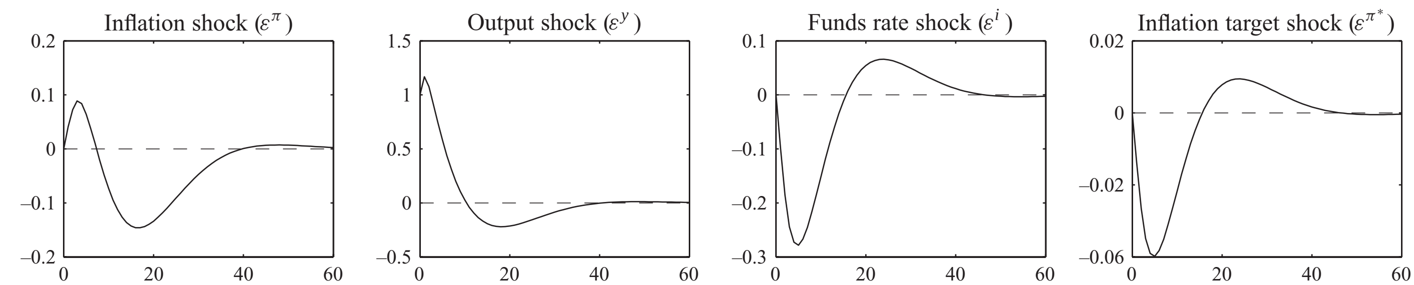


FIGURE 3
EXPECTED IMPULSE RESPONSES WITH TIME-VARYING π^* (IMPERFECT INFORMATION)

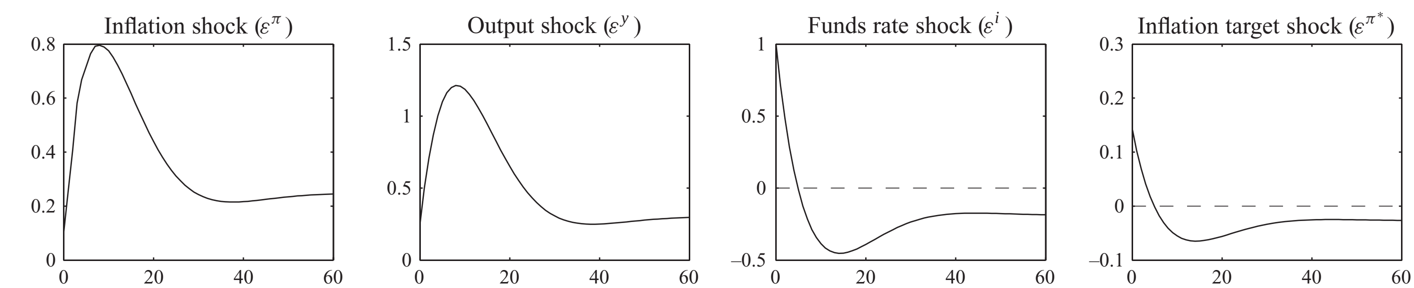
A. Inflation (percent)



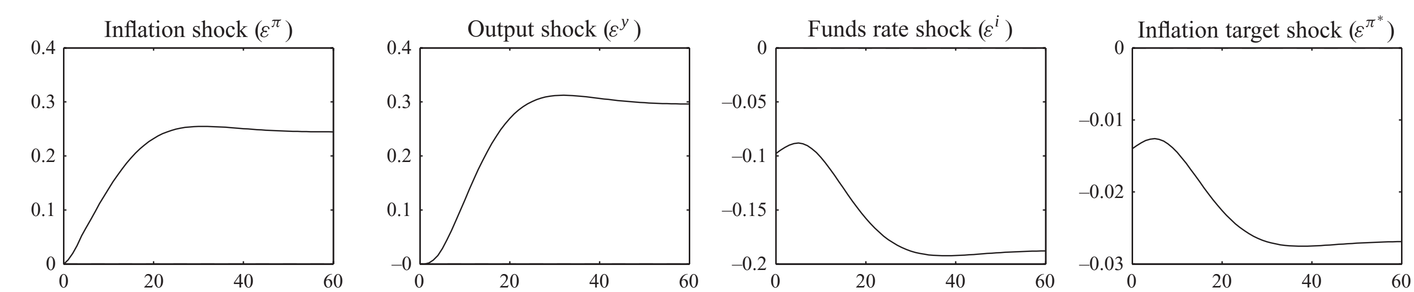
B. Output gap (percent)



C. Fed funds rate (percent)



D. Central bank π^* (percent)



central bank preference shock, ε^{π^*}. The expected impulse responses to those two shocks are therefore identical up to a scale factor, even though the actual impulse responses to those two shocks play out quite differently over time.[29]

The expected impulse responses in Figure 3 again reproduce the qualitative features of our empirical findings nicely. The responses to an inflation shock (the first column) or an output shock (second column) are identical to the perfect information case in Figure 2, because we have assumed that the private sector has perfect information regarding those two variables. For the case of the federal funds rate shock (third column), however, two effects are now present. First, when the private sector agents see the surprise tightening in the short-term interest rate, they cannot tell whether the shock is purely temporary (ε^i) or reflects a more permanent change in π^*, so they respond to the shock by partially revising downward their estimate of the central bank's π^*. Inflation in the economy thus falls in response to both the monetary tightening and the fall in inflation expectations, leading to larger effects than in the perfect information case. Second, the central bank's long-run objective, π^*, falls over time as inflation comes in below target, as was true in the perfect information case. The effect of the additional channel arising from imperfect information is to increase the relative size and importance of the effects of the interest rate shock on the term structure, allowing for a better calibration to our empirical results and providing a more realistic model of long-term interest rates in the United States.

Note that imperfect information about the central bank's target, π^*, plays a role only in the third and fourth columns of the figure. A model based solely on imperfect information or imperfect credibility, as in Kozicki and Tinsley (2001) or Erceg and Levin (2003), would be unable to reproduce our findings of excess sensitivity of U.S. interest rates to output and inflation surprises as long as shocks to ε^π and ε^y are observed.

For reference, the actual impulse responses of the model with imperfect information are depicted in Figure 4. The figure illustrates how the differing effects of shocks to i and to π^* play out over time. Panel E depicts the evolution of the private sector's estimate, $\hat{\pi}^*$, in response to each shock. Shocks to inflation or output, about which there is no imperfect information, lead to responses of $\hat{\pi}^*$ that are identical to those of π^*, but the two variables evolve differently for the imperfectly observed cases of shocks to i and π^*.

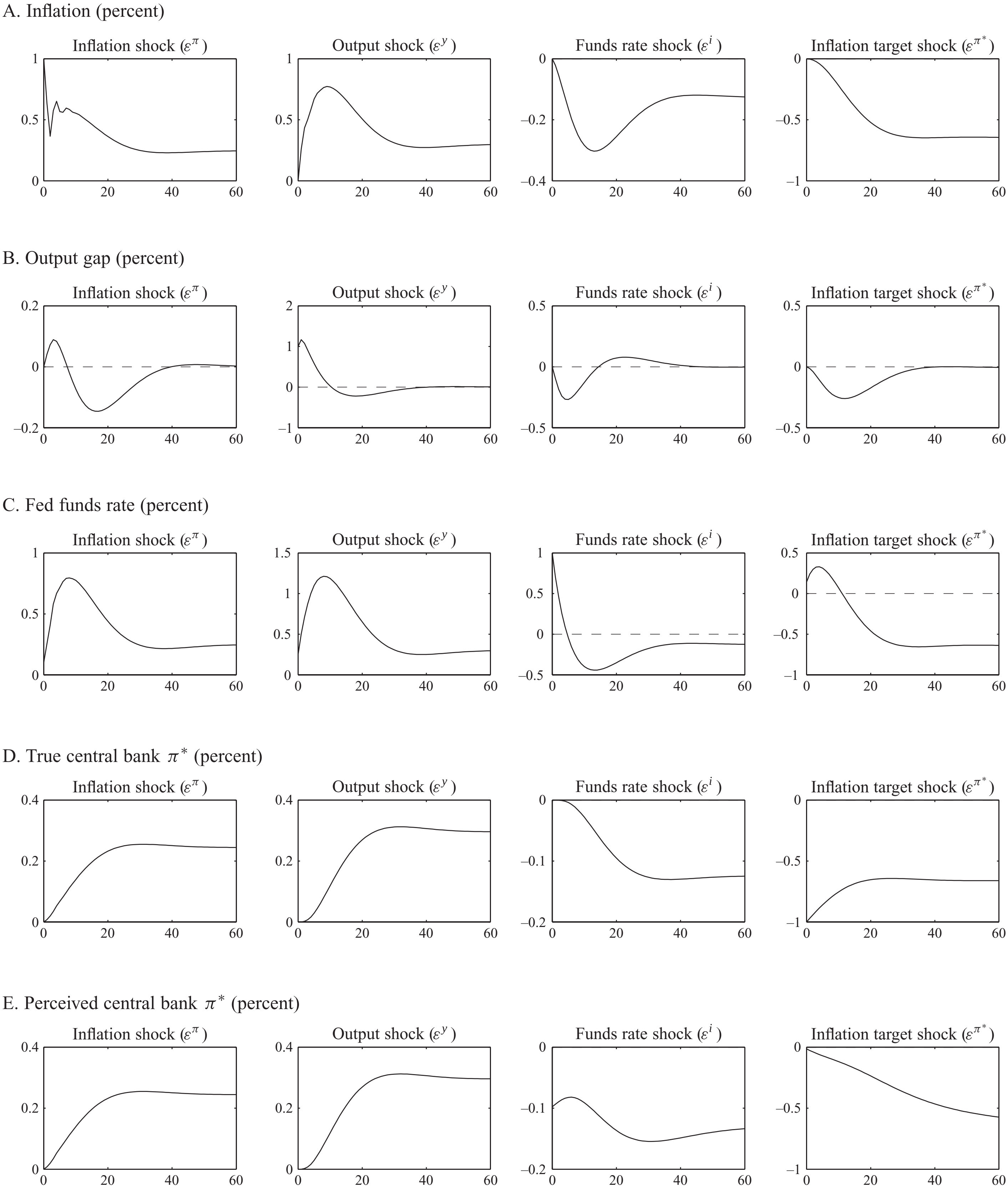
Finally, our hypothesis that the private sector's expectations of the central bank's long-run inflation objective, π^*, have varied over time is also consistent with measures of these expectations derived from survey data. For example, the median ten-year CPI inflation forecast in the Federal Reserve Bank of Philadelphia's Survey of Professional Forecasters fell from 4 percent in the fourth quarter of 1991 (the first time the long-run forecast question was asked) to a little under 2.5 percent by the end of 2002. This decline of about 1.5 percentage points compares with a fall of about 2.5 percentage points in ten-year nominal forward interest rates over the same period.

5. The Sensitivity of Long-Term Interest Rates in Canada and Chile

We have shown that U.S. long-term interest rates are excessively sensitive to economic news, and that this sensitivity is well explained by changes in financial market perceptions of a long-run inflation objective in the United States that is not well anchored. We now explore whether long-term interest rates are any more stable in countries that are explicit inflation targeters than in the United States. Gürkaynak, Levin, and Swanson (2006) consider the cases of Sweden and the United Kingdom and find that far-ahead forward interest rates are better anchored in those two countries than in the United States. In this paper, we extend

29. Expected and actual impulse responses for the case of imperfect information are calculated as follows. If, starting from steady state, the model is hit by a shock to π or to y, then the private sector observes those two shocks, so there is no imperfect information and the impulse responses are just like in the perfect information case. If, instead, there is a shock to i or to the central bank's π^*, then the private sector does not observe the true shock and must estimate what the shock was from the observed change in i. The private sector optimally assigns part of the change in i to ε^i and part of the change in i to ε^{π^*}. Knowing the true structure of the economy, the private sector then projects the economy forward using its above two estimates for the shocks to i and to π^*. This yields the *expected* impulse response functions at time t. This solution also yields the *actual* equilibrium of the model at time t (and time t only). In period $t+1$, the economy will evolve slightly differently than the private sector had expected the previous period (because the private sector did not observe the true shocks to i and π^*). In particular, i will be a little different again from what the private sector was expecting, so agents will think that their previous estimate of π^* may have been wrong or that there may have been another shock to i or another shock to π^*. (Of course, in an impulse response function, we do not hit the model with any additional shocks, but the private sector does not know this). The private sector thus optimally updates its estimate of π^* again and projects the economy forward again using the true structure. This solution yields the equilibrium of the model at time $t+1$ (and time $t+1$ only). Come period $t+2$, the economy will evolve slightly differently than the private sector had expected the previous period, and so forth. We repeat this procedure to obtain the entire actual response of interest rates to the shock (which we plot in Figure 4). Again, the private sector's estimate of π^* does not enter the private sector's equations directly, but only indirectly through the private sector's forecast of π_{t+1} and y_{t+1}, which depends on the current and expected future path of the interest rate, which in turn depends on the private sector's estimate of π^*.

Figure 4
Actual Impulse Responses with Time-Varying π^* (Imperfect Information)



the comparison to Canada and Chile, which have been formal inflation targeters throughout much of the 1990s and 2000s.[30] Despite this relatively short sample period, our high-frequency methodology provides us with several hundred to a thousand observations for each of these countries for our analysis.

5.1. The Sensitivity of Long-Term Interest Rates in Canada

We obtained data on Canadian macroeconomic news releases and financial market expectations of those releases from two sources: Money Market Services and Bloomberg. When those data sets overlap, they agree very closely. Between these two sources, we have data on Canadian capacity utilization, the consumer price index, core consumer price index, employment, real GDP, retail sales, the unemployment rate, and wholesale trade. Most of these series go back to 1996, and a few go back even farther.[31] To measure the surprise component of Canadian monetary policy announcements, we obtained the dates of changes in the Bank of Canada's target overnight interbank rate back to 1995 from the Bank of Canada's web site, and we measured the surprise component of these changes as the change in the three-month Canadian Treasury bill on the dates of these monetary policy changes.

We obtained data on Canadian nominal bond yields from the Bank of Canada's web site and data on real bond yields from Bloomberg. The Bank of Canada provides nominal zero-coupon yield curve estimates extending back to the 1980s. Inflation-indexed bond data for Canada is more limited: Canada issued its first inflation-indexed bond in 1991 and its second in 1996, implying that we cannot compute a forward real rate for Canada until 1996. Moreover, Canada has issued indexed bonds only at the 30-year maturity. These securities thus have extremely long durations and appeal primarily to pension funds, insurance companies, and individual investors, resulting in low levels of secondary market liquidity, high transaction costs, and observed real interest rates that are noisy, particularly in the earlier years of our sample.[32] Thus, in order to reduce the noisiness of the data and to facilitate comparison with the United States, we begin our analysis of Canada in January 1998.[33]

The results of our analysis for Canada are presented in Tables 3 and 4. Table 3 investigates the sensitivity of Canadian far-ahead forward interest rates and inflation compensation to domestic economic news. As in previous tables for the United States, the first column reports the response of the one-year Canadian nominal spot rate to domestic news releases. Short rates respond significantly to several of the statistics we consider, with signs and magnitudes that are consistent with our earlier estimates for the United States. In sharp contrast to the United States, however, far-ahead forward nominal rates in Canada (in the second column) do not respond significantly to any of these news releases. We find very similar results when we look at far-ahead forward inflation compensation (the fourth column). Here again, none of the coefficients are statistically significant at even the 10-percent level. The joint hypothesis that all coefficients in the regression are equal to zero in these two regressions is not rejected at any standard level of significance.

In Table 4, we explore whether Canadian far-ahead forward interest rates and inflation compensation respond to U.S. economic data releases and monetary policy announcements. Because Canada is a relatively small open

30. Both Canada and Chile adopted an inflation-targeting framework in which the target was not firmly anchored at first but rather was successively lowered during a transition period. Canada adopted its inflation-targeting framework in 1991, but the target was not stabilized at the current level of 1–3 percent until early 1995. Chile, in turn, adopted its inflation-targeting framework in 1991, but the target was not stabilized at the current level of 2–4 percent until early 2001. For our purposes, the later dates are the more relevant ones. Finally, the adoption of an inflation-targeting range rather than a point makes very little difference in theory, because the optimal monetary policy is always to aim for inflation to lie at the midpoint of the range, as discussed, for example, by Orphanides and Wieland (2000).

31. Details of the data are provided in the appendix.

32. To compute far-ahead forward real rates in Canada, we use as many of the 2021, 2026, 2031, and 2036 maturity coupon bond yields as are available on any given date and compute the far-ahead forward rates between pairs of securities using the Shiller, Campbell, and Schoenholtz (1983) approximation. We use the average one-day change in these forward rates in our regressions. We use a longer (20- to 30-year-ahead) horizon to proxy for the nine-year-ahead real one-year forward rate in Canada, because we simply do not have nine-year-ahead Canadian indexed bond data. Although we could use a 20- or 30-year-ahead horizon for our nominal Canadian forward rate as well, we judged that the lower liquidity and higher trading costs of these longer-horizon securities would more than offset any gains from having a precise match in maturity.

33. In 1996 and 1997, there are seven forward real rate changes in Canada of 100 basis points or more in a single day, and 17 changes of 50 basis points or more. We believe that these observations are due to low trading volumes and low liquidity for these securities, rather than to perceived changes in economic fundamentals. After January 1998, there are no changes of 50 basis points or more. While noise and low liquidity may still be an issue in the indexed bond data after January 1998, we found that problems related to regression outliers were essentially eliminated by restricting attention to the post-1997 period. Moreover, this period matches our sample for the United States, allowing for closer comparability between our U.S. and Canadian results.

TABLE 3
CANADIAN FORWARD RATE RESPONSES TO DOMESTIC MACROECONOMIC NEWS, 1998–2005

Explanatory variable	1-yr. nominal rate	1-yr. forward nom. rate ending 10 yrs.	1-yr. forward real rate ending 10 yrs.	1-yr. forward inflation compensation ending 10 yrs.
Capacity utilization	0.19	0.61	0.59	0.02
	(0.16)	(0.39)	(0.85)	(0.01)
CPI	1.49*	–0.27	–0.79	0.53
	(1.68)	(–0.24)	(–1.61)	(0.47)
Core CPI	1.22	–0.23	–1.07**	0.84
	(1.58)	(–0.23)	(–2.49)	(0.86)
Employment	3.07***	0.65	0.34	0.31
	(4.48)	(0.75)	(0.90)	(0.35)
Real GDP	–1.01	–2.35	0.25	–2.60
	(–0.58)	(–1.08)	(0.26)	(–1.19)
Retail sales	1.48**	–0.29	0.00	–0.30
	(2.28)	(–0.36)	(0.01)	(–0.36)
Unemployment rate	0.31	–0.29	0.11	–0.40
	(0.50)	(–0.37)	(0.32)	(–0.51)
Wholesale trade	0.09	–0.55	–0.28	–0.27
	(0.13)	(–0.59)	(–0.69)	(–0.29)
Monetary policy	0.81***	–0.28	–0.06	–0.22
	(5.77)	(–1.57)	(–0.76)	(–1.25)
No. obs.	327	327	327	327
R^2	0.19	0.02	0.10	0.03
Joint test *p* value	0.000***	0.806	0.006***	0.732

*Statistically significant at the 10 percent level.
**Statistically significant at the 5 percent level.
***Statistically significant at the 1 percent level.

Notes: The sample is from January 1998 to October 2005, at daily frequency on the dates of macroeconomic and monetary policy announcements. Regressions also include a constant, a Y2K dummy that takes on the value of 1 on the first business day of 2000, and a year-end dummy that takes on the value of 1 on the first business day of any year (coefficients not reported). Macroeconomic data release surprises are normalized by their standard deviations, so these coefficients represent a basis point per standard deviation response. Monetary policy surprises are in basis points, so these coefficients represent a basis point per basis point response. Inflation compensation is the difference between nominal and real rates. Joint test *p* value is for the hypothesis that all coefficients (other than the constant and dummy variables) are zero. *T* statistics are reported in parentheses.

TABLE 4
CANADIAN FORWARD RATE RESPONSES TO U.S. MACROECONOMIC NEWS, 1998–2005

U.S. explanatory variable	1-yr. nominal rate	1-yr. forward nom. rate ending 10 yrs.	1-yr. forward real rate ending 10 yrs.	1-yr. forward inflation compensation ending 10 yrs.
Capacity utilization	1.42**	0.72	0.12	0.60
	(2.13)	(0.81)	(0.26)	(0.63)
Consumer confidence	1.35*	–0.00	0.62	–0.62
	(1.91)	(–0.00)	(1.32)	(–0.61)
Core CPI	0.96	2.07**	–0.30	2.37**
	(1.22)	(1.98)	(–0.59)	(2.10)
Employment cost index	1.11	2.09	0.62	1.47
	(1.13)	(1.60)	(0.96)	(1.04)
Real GDP (advance)	2.40**	0.40	–0.06	0.46
	(2.49)	(0.32)	(–0.09)	(0.34)
Initial jobless claims	–0.99***	–0.72	–0.27	–0.45
	(–2.85)	(–1.56)	(–1.20)	(–0.89)
NAPM/ISM mfg. survey	1.72**	1.88*	1.18**	0.69
	(2.18)	(1.79)	(2.27)	(0.61)
New home sales	–0.66	0.60	–0.52	1.12
	(–1.22)	(0.85)	(–1.47)	(1.46)
Nonfarm payrolls	4.32***	1.66*	1.78***	–0.13
	(6.63)	(1.92)	(4.16)	(–0.14)
Retail sales (excl. autos)	1.12	0.47	0.18	0.29
	(1.39)	(0.44)	(0.35)	(0.25)
Unemploymt. rate	–1.04	–1.72	0.42	–2.13*
	(–1.31)	(–1.63)	(0.80)	(–1.87)
Monetary policy	0.37***	–0.20	0.14**	–0.34**
	(3.52)	(–1.45)	(2.03)	(–2.27)
No. obs.	939	939	939	939
R^2	0.16	0.03	0.06	0.02
Joint test *p* value	0.000***	0.148	0.001***	0.361

*Statistically significant at the 10 percent level.
**Statistically significant at the 5 percent level.
***Statistically significant at the 1 percent level.

Notes: See notes to Table 3. Regressions also include Canadian macroeconomic news releases (coefficients not reported since they are very similar to Table 3).

economy, it is reasonable to think that short-term interest rates and even long-term real rates in Canada might be largely determined by developments in the rest of the world, particularly developments in the United States. We would still expect the long-run values of purely nominal variables, such as inflation and inflation expectations, to be determined primarily by domestic monetary policy, particularly at the far-ahead horizons we are considering in this paper. Thus, while short-term rates and perhaps long-term real interest rates in Canada might be expected to respond to U.S. economic news, we would still expect far-ahead forward inflation compensation and perhaps nominal rates to remain largely invariant, if financial markets view the distribution of long-run inflation outcomes in Canada as being well anchored.

The regressions in Table 4 include both Canadian and U.S. macroeconomic data releases and monetary policy announcements, although coefficients on the Canadian releases are not reported to save space (they are very similar to those reported in Table 3). The first column of Table 4 shows that short-term interest rates in Canada are indeed significantly affected by U.S. monetary policy announcements and by many U.S. macroeconomic data releases. Still, far-ahead forward nominal rates (in the second column) are not very responsive to these U.S. economic news releases, with three coefficients exhibiting only a marginal degree of statistical significance. The joint hypothesis that all coefficients are zero in this far-ahead forward nominal rate regression is not rejected at any standard level of statistical significance. The same observations generally remain true when we look at far-ahead forward inflation compensation (the fourth column): although this period includes three U.S. data releases that are significantly related to Canadian far-ahead forward inflation compensation at the 10-percent level or better, the joint test that all coefficients are equal to zero is not rejected at any standard level of significance.

These findings for Canada are reminiscent of those reported by Gürkaynak, Levin, and Swanson (2006) for the United Kingdom and Sweden, which were both inflation targeters over much of the 1990s. In their analysis, the United Kingdom and Sweden displayed a much greater anchoring of far-ahead forward nominal rates and inflation compensation in response to economic news than did the United States. Finally, in the case of the United Kingdom, the Bank of England was granted operational independence from Parliament in 1998. Gürkaynak, Levin, and Swanson show that, while the United Kingdom has had substantially better-anchored long-term inflation expectations than the United States since that date, the data for the early 1990s display a sensitivity of forward nominal rates and inflation compensation that is very similar to what we observe in the United States. All of these findings support the conclusion that a credible inflation-targeting framework significantly helps to anchor the private sector's perception of the distribution of future long-run inflation outcomes.

5.2. The Sensitivity of Long-Term Interest Rates in Chile

Chile has a much less extensive set of monthly macroeconomic data releases than are available in a more industrialized country such as the United States or Canada. We obtained data on Chilean monthly macroeconomic data releases and ex ante private sector forecasts of these releases from the Central Bank of Chile for four macroeconomic statistics: consumer price index inflation, monetary policy announcements, real GDP growth in the current quarter, and real GDP growth in the previous quarter. However, whereas our forecast data for the United States and Canada are at most a few days old on release, the Chilean data can be as much as two or even three weeks old by the time of the actual release, because the private sector macroeconomic forecast is only collected every few weeks. Thus, our measure of macroeconomic surprises for Chile is likely to suffer from measurement error, which will diminish our chances of finding statistically significant effects of releases on interest rates at even the short end of the yield curve.[34]

The Central Bank of Chile also provided us with Chilean real and nominal yield curve data. In contrast to the United States and Canada, there were no long-term nominal government bonds outstanding in Chile until 2002—all long-term government debt issued prior to that date was inflation indexed, at least in the last 30 years. This lack of long-term nominal debt presumably reflects the fact that the Chilean government was unwilling to pay the large risk premiums that investors would have demanded to hold such long-term nominal liabilities during a period in which markets viewed the government and the central bank as being greater credit and inflation risks than they are today. Thus, our sample for Chile is restricted to the 2002–2005 period, which, although very short, still provides us with about 400 observations for our analysis given the high frequency of the data. Moreover, even with ideal data, it would be difficult to extend our sample for Chile further back than 2001: although Chile formally adopted an inflation-targeting framework in 1991, the inflation target itself was revised downward throughout the 1990s and only stabilized at the current range of 2–4 percent in the first quarter of 2001. Finally, the Chilean yield curves are based on a relatively small number of securities, owing to the smaller size of Chilean financial markets, so that implied forward rates for Chile are generally much noisier than in the United States and Canada, again posing a challenge for empirical analysis.

We report the results of our analysis for Chile in Tables 5 and 6. Table 5 reports the response of Chilean interest rates and inflation compensation to domestic economic news. The first column of the table reports the estimated responses of short-term Chilean interest rates to economic news over this period. Only one of our four Chilean macroeconomic data releases—monetary policy announcements—is statistically significant, which is consistent with the idea that measurement error and a shorter sample make estimation difficult. That one statistic is highly significant, however, with a sign and magnitude similar to our estimates for the United States. Moreover, the joint hypothesis that all

34. Our data on U.S. macroeconomic data releases remain relatively free of measurement error, however. We consider the response of Chilean interest rates to these U.S. releases, just as we did for Canada in the preceding section.

Table 5
Chilean Forward Rate Responses
to Domestic Macroeconomic News, 2002–2005

Explanatory variable	1-yr. nominal rate	1-yr. forward nom. rate ending 10 yrs.	1-yr. forward real rate ending 10 yrs.	1-yr. forward inflation compensation ending 10 yrs.
CPI	0.40	1.86	–1.37	3.23
	(0.64)	(0.84)	(–0.53)	(0.97)
Real GDP	0.25	1.10	2.13	–1.03
	(0.30)	(0.38)	(0.62)	(–0.23)
Real GDP, prev. quarter	–0.69	1.91	2.83	–0.92
	(–0.49)	(0.39)	(0.49)	(–0.13)
Monetary policy	0.15***	0.22	0.06	0.16
	(3.92)	(1.61)	(0.37)	(0.78)
No. obs.	98	98	98	98
R^2	0.16	0.04	0.02	0.02
Joint test p value	0.005***	0.406	0.703	0.773

*Statistically significant at the 10 percent level.
**Statistically significant at the 5 percent level.
***Statistically significant at the 1 percent level.

Notes: The sample is from August 2002 to October 2005, at daily frequency on the dates of macroeconomic and monetary policy announcements. Regressions also include a constant and a year-end dummy that takes on the value of 1 on the first business day of any year (coefficients not reported). Macroeconomic data release surprises are normalized by their standard deviations, so these coefficients represent a basis point per standard deviation response. Monetary policy surprises are in basis points, so these coefficients represent a basis point per basis point response. Inflation compensation is the difference between nominal and real rates. Joint test p value is for the hypothesis that all coefficients (other than the constant and dummy variables) are zero. T statistics are reported in parentheses.

Table 6
Chilean Forward Rate Responses
to U.S. Macroeconomic News, 2002–2005

U.S. explanatory variable	1-yr. nominal rate	1-yr. forward nom. rate ending 10 yrs.	1-yr. forward real rate ending 10 yrs.	1-yr. forward inflation compensation ending 10 yrs.
Capacity utilization	–0.16	2.27	–1.06	3.33
	(–0.23)	(1.02)	(–0.39)	(0.96)
Consumer confidence	–0.05	–0.59	–0.02	–0.57
	(–0.08)	(–0.27)	(–0.01)	(–0.17)
Core CPI	0.86	2.12	–4.19	6.31
	(1.11)	(0.85)	(–1.39)	(1.63)
Employment cost index	0.78	0.65	4.00	–3.35
	(0.81)	(0.21)	(1.07)	(–0.70)
Real GDP (advance)	–0.44	–4.92	2.95	–7.87
	(–0.32)	(–1.14)	(0.57)	(–1.17)
Initial jobless claims	–0.36	0.80	–0.65	1.46
	(–0.93)	(0.66)	(–0.44)	(0.76)
NAPM/ISM mfg. survey	–0.60	–0.26	5.23	–5.49
	(–0.66)	(–0.09)	(1.50)	(–1.22)
New home sales	0.38	0.38	–2.53	2.92
	(0.80)	(0.25)	(–1.39)	(1.24)
Nonfarm payrolls	–1.35*	1.55	–3.50	5.06
	(–1.72)	(0.62)	(–1.16)	(1.30)
Retail sales (excl. autos)	1.68**	–2.46	0.48	–2.94
	(2.20)	(–1.01)	(0.16)	(–0.77)
Unemployment rate	3.78***	–8.70***	2.98	–11.68***
	(4.20)	(–3.03)	(0.86)	(–2.61)
Monetary policy	0.25	–0.81	0.67	–1.48*
	(1.46)	(–1.51)	(1.04)	(–1.77)
No. obs.	399	399	399	399
R^2	0.10	0.05	0.03	0.05
Joint test p value	0.001***	0.234	0.688	0.167

*Statistically significant at the 10 percent level.
**Statistically significant at the 5 percent level.
***Statistically significant at the 1 percent level.

Notes: See notes to Table 5. Regressions also include Chilean macroeconomic news releases (coefficients not reported since they are very similar to Table 5).

coefficients in the regression are zero can be rejected at the 1-percent significance level. We thus have evidence that our analysis still has power despite the limitations of the data. Nevertheless, in contrast to the behavior of Chilean short rates, neither far-ahead forward nominal rates nor inflation compensation respond significantly to Chilean monetary policy announcements, which suggests some degree of anchoring. The hypothesis that all of the coefficients in these regressions are zero cannot be rejected at any standard level of significance.

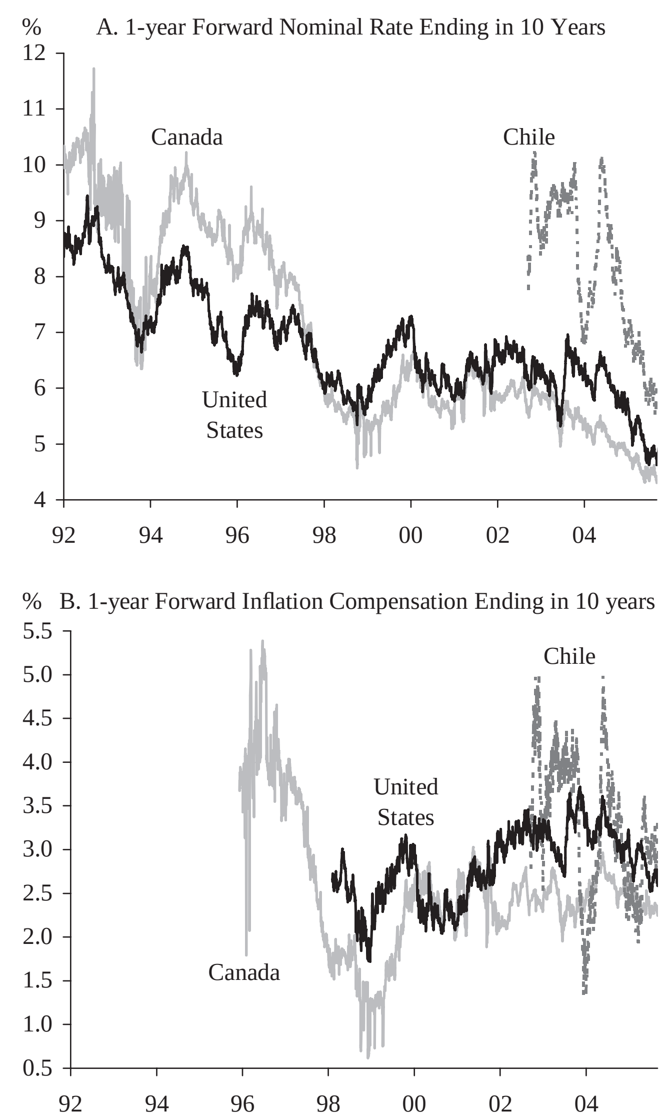
In Table 6, we address the response of Chilean interest rates to U.S. macroeconomic and monetary policy announcements. A few U.S. statistics are estimated to have significant effects on Chilean short rates, although some of the coefficients (on U.S. nonfarm payrolls and unemployment) have signs that are perhaps puzzling. The joint hypothesis that all coefficients in the short-rate regression are zero is rejected at the 1-percent level. Again, in contrast to short rates, far-ahead forward nominal rates and inflation compensation in Chile respond to almost no U.S. macroeconomic data releases, with the exception of the U.S. unemployment rate release and perhaps U.S. monetary policy surprises. The hypothesis that all coefficients in the regression are zero is also not rejected at standard significance levels in either case. While the Chilean data are clearly much noisier and more problematic than the data for more industrialized countries such as Canada, Sweden, the United Kingdom, and the United States, our results for Chile are all consistent with those other countries. The exercise suggests that the commitment of the central bank to a credible long-run inflation objective significantly helps to anchor private sector expectations about long-run inflation outcomes.

5.3. Time-Series Behavior of Forward Rates in Canada, Chile, and the United States

Our analysis in the previous sections focused on the conditional volatility of forward rates in Canada, Chile, and the United States, by which we mean the movement of these rates in response to specific data releases. Although we took care to include as many variables as possible and any macroeconomic data release that seemed important, our regressions have nonetheless omitted many factors that influence the daily behavior of interest rates at both the short and long ends of the yield curve. The R^2 values in our regressions are in every case below 20 percent, even for short-term interest rates.[35] Given our argument that the relative responsiveness of forward rates in different countries to macroeconomic data releases and monetary policy announcements is due to different degrees of stability of private sector long-run inflation expectations, one might expect to see that other economically relevant news that we have omitted would lead to a similar contrast in far-ahead forward interest rate behavior across our three countries. In other words, one might expect to see forward rates in the United States that would tend to be more volatile unconditionally as well as conditionally, to the extent that long-run inflation expectations in the United States are unanchored.

Figure 5 presents unconditional time series plots of far-ahead forward nominal rates and inflation compensation for Canada, Chile, and the United States. We find a number of interesting observations. First, far-ahead nominal rates and inflation compensation are not completely stable in any of the three countries: Both high and low frequencies exhibit clear variation. The source of this variation remains an open question. Possible explanations include the following: high transaction costs in Canadian and Chilean markets that drive observed prices away from true shadow values; errors in yield curve estimation resulting from a small number of securities outstanding;[36] time-varying risk or liquidity premiums; variations in financial market per-

FIGURE 5
TIME SERIES PLOTS OF FORWARD NOMINAL RATES AND INFLATION COMPENSATION



35. This observation is all the more remarkable in light of the fact that we have restricted our attention in the regression to only those days on which at least one of our right-hand-side variables was nonzero; the R^2 values are even lower (though our coefficient estimates are very similar) if we perform the regression on all days. Thus, even on the days on which important macroeconomic news was released, we can only explain a relatively small fraction of the variance of interest rates at even the short end of the yield curve. One reason for the low R^2 values is that macroeconomic data releases often contain much more information than just the simple headline number that we must focus on in our analysis. For example, monetary policy announcements by the Federal Reserve often discuss the motivation for the move and even the future outlook for monetary policy; GDP releases contain information about its various components, which can independently influence private sector forecasts of future output; and inflation releases contain a detailed breakdown of constituent components, which may independently influence forecasts of future inflation.

36. As mentioned in the preceding sections, Chile has only a few nominal and indexed government bonds outstanding, and Canada has only a few highly illiquid indexed government securities outstanding. Thus, estimates of forward rates in these two countries can be noisy, particularly in Chile and in the early years of the Canadian indexed market, when there were only two bonds outstanding and their liquidity was very low. (A third Canadian real bond was introduced in 1999 and liquidity in that market has improved steadily over time.)

ceptions of the central bank's credibility and commitment to its long-run inflation objective; changes in the official inflation target itself (both Canada and Chile lowered their official targets several times in the early 1990s) or perceptions that the central bank's inflation target might change in the future; changes in tax rates or market perceptions that tax rates might change in the future; market perceptions that the central bank's preferred measure of inflation might change in the future; and differences between the consumption deflator of the marginal investor and the price index that is being targeted by the central bank.

Second, despite the variation in our estimates of far-ahead forward nominal rates and inflation compensation, Canadian forward rates have improved spectacularly vis-à-vis the United States. In the first half of the 1990s, far-ahead forward rates in Canada were clearly and consistently higher and more volatile than in the United States. From the late 1990s onward, that situation has completely reversed: far-ahead forward nominal rates and inflation compensation in Canada have been clearly and consistently lower and less volatile than in the United States. This is all the more remarkable considering that liquidity is lower and transaction costs higher in Canada, and the number of outstanding securities with which to estimate a yield curve is much smaller; thus, all else equal, one would tend to expect risk premiums and measurement error to produce more volatile forward rates in Canada. These observations exactly parallel the findings of Gürkaynak, Levin, and Swanson (2006) for the United Kingdom and Sweden. The sample period for our Chilean data is shorter, but it also shows a remarkable fall in these far-ahead forward rates over time, bringing them toward levels that are becoming increasingly comparable to those in the United States.

Third, inflation targeting by itself is not a silver bullet that suddenly lowers and stabilizes far-ahead forward nominal rates and inflation compensation. Canada officially adopted an inflation-targeting framework in February 1991, but the improved stability of far-ahead forward rates and inflation compensation in Canada seem to have come gradually. Why this is so remains an open question, but it may be partly due to the fact that, although Canada adopted a formal inflation-targeting framework in 1991, the official inflation target was revised lower on several occasions in the early 1990s. One would hardly expect long-term inflation expectations to be anchored around the central bank's target if that target itself were perceived by markets to be in transition to an unspecified long-run level. Thus, the true date of adoption of a fixed long-run inflation target in Canada might be identified as 1995, the date at which the current range of 1–3 percent was adopted and regarded as likely to persist (Mishkin and Schmidt-Hebbel (2007) make this point for a number of inflation-targeting adopters).[37] In addition, the initial announcement of an inflation-targeting regime in Canada and the initial announcement of the 1–3 percent target may have been regarded with some skepticism by financial markets, and only gradually did the feasibility of—and the central bank's commitment to—the new targeting regime become clear. These factors may also help explain why far-ahead forward nominal rates and inflation compensation in Chile remain fairly volatile and have exhibited somewhat of a downward trend in the past few years.

Finally, the figure provides direct evidence against the critique by Ball and Sheridan (2003) that there are no visible benefits from inflation targeting once initial conditions and mean reversion are taken into account. The Ball and Sheridan argument would predict that Canada, which began from high levels of inflation expectations in the early 1990s, would tend to converge back toward the levels in the United States over the 1990s. In contrast to this prediction, however, we find that inflation expectations in Canada actually drop below those in the United States in 1997 and then remain lower thereafter. This is a much stronger performance than can be accounted for simply by a tendency for reversion to the mean.

6. Conclusions

As in Gürkaynak, Sack, and Swanson (2005) and Gürkaynak, Levin, and Swanson (2006), we find that U.S. long-term nominal interest rates and inflation compensation are excessively sensitive to macroeconomic data releases and monetary policy announcements. In contrast, we find that long-term nominal interest rates and inflation compensation in Canada display much less sensitivity to economic news, while the unconditional volatility of these series over the past decade has been markedly lower than in the United States. These results are consistent with the findings of Gürkaynak, Levin, and Swanson (2006) for Sweden and the United Kingdom, two countries that have also maintained explicit inflation targets in recent years.

In the case of Chile, the available sample period is fairly short and only a limited set of macroeconomic news releases are readily available. Nevertheless, our regression analysis does not indicate any excess sensitivity of far-ahead forward interest rates and inflation compensation, which is consistent with the hypothesis that inflation targeting in Chile has been reasonably successful in anchoring long-run inflation expectations. The unconditional volatility

37. The adoption of a target range for inflation (as opposed to a point) is not, in itself, a reason for variability of long-term inflation expectations, since the optimal monetary policy is always to aim for the midpoint of the range, as noted previously in this paper and discussed in detail in Orphanides and Wieland (2000).

of these series, however, appears to be much higher in Chile than in either Canada or the United States, perhaps underscoring the extent to which the Chilean economy is still in the process of converging to the economic and financial conditions of the more industrialized economies. In particular, only a small number of Chilean government securities are actively traded in bond markets, and the yields on these securities may be quite sensitive to variations in liquidity and other market frictions. While not entirely conclusive, these results suggest that the presence of a transparent and credible inflation objective can play an important role in anchoring long-run inflation expectations in both emerging market economies and industrialized countries.

Our findings suggest that the potential welfare gains from reduced bond market volatility would be an important subject for future research. Although we have not demonstrated any such welfare gains in this paper, existing macroeconomic and finance theory identifies several possibilities: for example, less persistent deviations of inflation from target in the short and medium run as a result of firmer anchoring of expectations at the long end (Woodford 2003); a greater ability of the central bank to control inflation in the short and medium run (Woodford 2003); less volatile long-term nominal interest rates and lower risk premiums on nominal rates, which would improve the efficiency of investment decisions (Ingersoll and Ross 1992); and a reduced chance of either a 1970s-style expectations trap for inflation (Albanesi, Chari, and Christiano 2003) or an imperfect-information-driven inflation scare (Orphanides and Williams 2005). To the extent that these benefits are important in practice as well as in principle, adopting a more explicit inflation objective could improve U.S. economic performance and U.S. monetary policy even beyond the successes of the past 20 years.

Appendix

Data on U.S. macroeconomic statistical releases and forecasts were obtained from Money Market Services (MMS) through July 2003, when that company merged with a larger financial institution. Beginning in December 2003, the same survey was produced again by Action Economics (AE). Both data sets can be obtained from Haver Analytics at www.haver.com. From August through November 2003, we fill in the holes in the MMS/AE survey data using the releases and forecasts reported by Bloomberg Financial Services. For additional details about individual macroeconomic series, see Gürkaynak, Sack, and Swanson (2003).

We obtained data on Canadian macroeconomic news releases and financial market expectations of those releases from two sources: Money Market Services and Bloomberg. When those data sets overlap, they agree very closely. Between these two data sources, we have data on Canadian capacity utilization, the consumer price index, core consumer price index, employment, real GDP, retail sales, the unemployment rate, and wholesale trade. Most of these series go back to 1996, and a few go back even farther. To measure the surprise component of Canadian monetary policy announcements, we obtained the dates of changes in the Bank of Canada's target overnight interbank rate back to 1995 from the Bank of Canada's web site, and we measured the surprise component of these changes using the change in the three-month Canadian Treasury bill on the dates of these monetary policy changes. The exact statistics we use, including Bloomberg and MMS mnemonics for those series, are reported in Table A1.

Data for Chile were obtained from the Bank of Chile, as discussed in Section 5.

Table A.1
Data Sources for Canada

Series	Data source	Mnemonic[a]	Notes
Capacity utilization	MMS	{L,D,M}156CU	Level, percent
Consumer price index	Bloomberg	cacpiyoy	Year-on-year change, percent
Core CPI	MMS	{L,D,M}156CPXY	Year-on-year change, percent
Employment	MMS	{L,D,M}156ED	Month-on-month change, thousands
Real GDP	MMS	{L,D,M}156GPA	Quarter-on-quarter change, percent
Retail sales	Bloomberg	carsmom	Month-on-month change, percent
Unemployment rate	Bloomberg	caunemp	Level, percent
Wholesale trade	Bloomberg	cawtmom	Month-on-month change, percent
Monetary policy	Bank of Canada		Authors' calculations from policy change dates and 3-month Canadian Treasury bill rate

a. This column reports the mnemonic used in the Bloomberg database for series obtained from Bloomberg and from the MMS database for series obtained from Money Market Services.

References

Albanesi, Stefania, V.V. Chari, and Lawrence J. Christiano. 2003. "Expectation Traps and Monetary Policy." *Review of Economic Studies* 70(4), pp. 715–741.

Andersen, Torben G., Tim Bollerslev, Francis X. Diebold, and Clara Vega. 2003. "Micro Effects of Macro Announcements: Real-Time Price Discovery in Foreign Exchange." *American Economic Review* 93(1), pp. 38–62.

Balduzzi, Pierluigi, Edwin J. Elton, and T. Clifton Green. 2001. "Economic News and Bond Prices: Evidence from the U.S. Treasury Market." *Journal of Financial and Quantitative Analysis* 36(4), pp. 523–543.

Ball, Laurence, and Niamh Sheridan. 2003. "Does Inflation Targeting Make a Difference?" In *The Inflation Targeting Debate,* eds. Ben Bernanke and Michael Woodford. Chicago: University of Chicago Press.

Bekaert, Geert, Robert J. Hodrick, and David A. Marshall. 2001. "Peso Problem Explanations for Term Structure Anomalies." *Journal of Monetary Economics* 48(2), pp. 241–270.

Bernanke, Ben S., Thomas Laubach, Frederic S. Mishkin, and Adam S. Posen. 1999. *Inflation Targeting: Lessons from the International Experience.* Princeton, NJ: Princeton University Press.

Bernanke, Ben S., and Frederic S. Mishkin. 1997. "Inflation Targeting: A New Framework for Monetary Policy?" *Journal of Economic Perspectives* 11(2), pp. 97–116.

Brunner, Allan. 2000. "On the Derivation of Monetary Policy Shocks: Should We Throw the VAR Out with the Bath Water?" *Journal of Money, Credit, and Banking* 32(2), pp. 254–279.

Campbell, John Y., and Robert J. Shiller. 1991. "Yield Spreads and Interest Rate Movements: A Bird's Eye View." *Review of Economic Studies* 58(3), pp. 495–514.

Clarida, Richard, Jordi Galí, and Mark Gertler. 2000. "Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory." *Quarterly Journal of Economics* 115(1), pp. 147–180.

Cochrane, John H., and Monika Piazzesi. 2005. "Bond Risk Premia." *American Economic Review* 95(1), pp. 138–160.

Ellingsen, Tore, and Ulf Söderström. 2001. "Monetary Policy and Market Interest Rates." *American Economic Review* 91(5), pp. 1,594–1,607.

Erceg, Christopher J., and Andrew T. Levin. 2003. "Imperfect Credibility and Inflation Persistence." *Journal of Monetary Economics* 50(4), pp. 915–944.

Ertürk, Burak, and Ümit Özlale. 2005. "Do Inflation Targeting Regimes Affect Inflation Expectations and Uncertainty?" Working paper, Bilkent University.

Estrella, Arturo, and Jeffrey Fuhrer. 2002. "Dynamic Inconsistencies: Counterfactual Implications of a Class of Rational Expectations Models." *American Economic Review* 92(4), pp. 1,013–1,028.

Fama, Eugene F., and Robert R. Bliss. 1987. "The Information in Long-Maturity Forward Rates." *American Economic Review* 77(4), pp. 680–692.

Fuhrer, Jeffrey C. 1997. "The (Un)Importance of Forward-Looking Behavior in Price Specifications." *Journal of Money, Credit, and Banking* 29(3), pp. 338–350.

Galí, Jordi, and Tommaso Monacelli. 2005. "Monetary Policy and Exchange Rate Volatility in a Small Open Economy." *Review of Economic Studies* 72(3), pp. 707–734.

Gürkaynak, Refet S., Andrew T. Levin, and Eric T. Swanson. 2006. "Does Inflation Targeting Anchor Long-Run Inflation Expectations? Evidence from Long-Term Bond Yields in the U.S., U.K., and Sweden." FRBSF Working Paper 2006-04. http://www.frbsf.org/publications/economics/papers/2006/wp06-04bk.pdf

Gürkaynak, Refet S., Brian Sack, and Eric T. Swanson. 2002. "Market-Based Measures of Monetary Policy Expectations." Federal Reserve Board of Governors, Finance and Economics Discussion Series 2002-40. http://www.federalreserve.gov/pubs/feds/2002/200240/200240abs.html

Gürkaynak, Refet S., Brian Sack, and Eric T. Swanson. 2003. "The Excess Sensitivity of Long-Term Interest Rates: Evidence and Implications for Macroeconomic Models." Federal Reserve Board of Governors, Finance and Economics Discussion Series 2003-50. http://www.federalreserve.gov/pubs/feds/2003/200350/200350abs.html

Gürkaynak, Refet S., Brian Sack, and Eric T. Swanson. 2005. "The Sensitivity of Long-Term Interest Rates to Economic News: Evidence and Implications for Macroeconomic Models." *American Economic Review* 95(1), pp. 425–436.

Gürkaynak, Refet S., Brian Sack, and Jonathan H. Wright. 2006. "The U.S. Treasury Yield Curve: 1961 to the Present." Federal Reserve Board of Governors Finance and Economics Discussion Series 2006-28 (June). http://www.federalreserve.gov/pubs/feds/2006/200628/200628abs.html

Ingersoll, Jonathan E., Jr., and Stephen A. Ross. 1992. "Waiting to Invest: Investment and Uncertainty." *Journal of Business* 65(1), pp. 1–29.

Kozicki, Sharon, and Peter A. Tinsley. 2001. "Shifting Endpoints in the Term Structure of Interest Rates." *Journal of Monetary Economics* 47(3), pp. 613–652.

Krueger, Joel T., and Kenneth N. Kuttner. 1996. "The Fed Funds Futures Rate as a Predictor of Federal Reserve Policy." *Journal of Futures Markets* 16(8), pp. 865–879.

Kuttner, Kenneth N. 2001. "Monetary Policy Surprises and Interest Rates: Evidence from the Fed Funds Futures Market." *Journal of Monetary Economics* 47(3), pp. 523–544.

Leiderman, Leonardo, and Lars E.O. Svensson, eds. 1995. *Inflation Targets.* London: Centre for Economic Policy Research.

Levin, Andrew, and Jeremy Piger. 2004. "Is Inflation Persistence Intrinsic in Industrial Economies?" European Central Bank working paper 334.

Mishkin, Frederic, and Klaus Schmidt-Hebbel. 2007. "Does Inflation Targeting Make a Difference?" In *Series on Central Banking, Analysis, and Economic Policies X: Monetary Policy under Inflation Targeting,* eds. Frederic Mishkin and Klaus Schmidt-Hebbel. Santiago, Chile: Central Bank of Chile, 2007.

Orphanides, Athanasios, and Volker Wieland. 2000. "Inflation Zone Targeting." *European Economic Review* 44(7), pp. 1,351–1,387.

Orphanides, Athanasios, and David Wilcox. 2002. "The Opportunistic Approach to Disinflation." *International Finance* 5(1), pp. 47–71.

Orphanides, Athanasios, and John C. Williams. 2005. "Inflation Scares and Forecast-Based Monetary Policy." *Review of Economic Dynamics* 8(2), pp. 498–527.

Piazzesi, Monika, and Eric T. Swanson. 2006. "Futures Prices as Risk-Adjusted Forecasts of Monetary Policy." FRBSF working paper 2006-23. http://www.frbsf.org/publications/economics/papers/2006/wp06-23bk.pdf

Roberts, John M. 1997. "Is Inflation Sticky?" *Journal of Monetary Economics* 39(2), pp. 173–196.

Rudebusch, Glenn D. 1998. "Do Measures of Monetary Policy in a VAR Make Sense?" *International Economic Review* 39(4), pp. 907–931.

Rudebusch, Glenn D. 2001. "Is the Fed Too Timid? Monetary Policy in an Uncertain World." *Review of Economics and Statistics* 83(2), pp. 203–217.

Rudebusch, Glenn D. 2002. "Term Structure Evidence on Interest Rate Smoothing and Monetary Policy Inertia." *Journal of Monetary Economics* 49(6), pp. 1,161–1,187.

Sack, Brian. 2000. "Using Treasury STRIPS to Measure the Yield Curve." Federal Reserve Board of Governors, Finance and Economics Discussion Series 2000-42. http://www.federalreserve.gov/pubs/feds/2000/200042/200042abs.html

Shiller, Robert, John Y. Campbell, and Kermit Schoenholtz. 1983. "Forward Rates and Future Policy: Interpreting the Term Structure of Interest Rates." *Brookings Papers on Economic Activity* 1983(1), pp. 173–217.

Svensson, Lars E.O. 1994. "Estimating and Interpreting Forward Interest Rates for Sweden." Discussion paper 1051. London: Centre for Economic Policy Research.

Svensson, Lars E.O. 1997. "Inflation Forecast Targeting: Implementing and Monitoring Inflation Targets." *European Economic Review* 41(6), pp. 1,111–1,146.

Swanson, Eric T. 2006. "Have Increases in Federal Reserve Transparency Improved Private Sector Interest Rate Forecasts?" *Journal of Money, Credit, and Banking* 38(3), pp. 791–819.

Woodford, Michael. 2003. *Interest and Prices: Foundations of a Theory of Monetary Policy.* Princeton, NJ: Princeton University Press.

Educational Attainment, Unemployment, and Wage Inflation*

Mary C. Daly

Vice President
Federal Reserve Bank of San Francisco

Osborne Jackson

University of Michigan and
Visiting Research Associate, Federal Reserve Bank of San Francisco

Robert G. Valletta

Research Advisor
Federal Reserve Bank of San Francisco

We investigate the impact of rising educational attainment on wage inflation and the equilibrium (non-inflationary) rate of unemployment. Rising educational attainment may reduce wage pressures by shifting the composition of the labor force towards groups with lower equilibrium unemployment rates, or it may increase wage pressures through increased reliance on groups whose wages are relatively responsive to changes in unemployment. A measure of aggregate unemployment adjusted for changes in the age and education structure of the labor force performs well in Phillips curve estimates of the wage inflation process but does not substantially improve the ability to forecast wages or materially alter the estimates of the equilibrium unemployment rate. We also estimate models of wage inflation that are disaggregated by educational attainment and find that college-educated workers face a sharper trade-off between labor market tightness and wage growth than do other groups. We find that forecasts of wage inflation derived from the disaggregated relationships perform better than those from aggregate wage equations.

1. Introduction

The U.S. labor force has undergone significant changes during the past several decades. Compared to 30 years ago, the average worker today is older, more likely to be female, and more educated. A key question for macroeconomic forecasters and policymakers is whether and to what extent these changes have influenced the values and patterns of key aggregate measures of economic performance such as the unemployment rate and wage inflation. While considerable research has documented the importance of changing age structure and the entry of women for labor market outcomes, much less is known about the influence of educational attainment on these variables.

In this paper, we examine how changes in the educational attainment of the U.S. labor force may affect aggregate labor market outcomes and whether these effects are sufficiently large to warrant ongoing attention from researchers. Following past research that examined the effects of changes in age structure on unemployment and wage inflation, we consider two basic methods for incorporating educational attainment into models of wage inflation. Our empirical investigation begins with an adjustment to the aggregate unemployment rate based on rising educational attainment, which appears empirically valid but does not alter predictions of wage inflation obtained from aggre-

*The authors thank John Williams for his comments and guidance in developing this research and Fred Furlong for helpful comments. They are not responsible for any errors. They also thank Terence McMenamin from the Bureau of Labor Statistics for providing data. For research assistance, the authors thank Jaclyn Hodges, Meryl Motika, and Monica Ortiz. Opinions expressed do not necessarily reflect the views of the management of the Federal Reserve Bank of San Francisco or the Board of Governors of the Federal Reserve System.

gate Phillips curve estimates over our sample time frame (1982–2006).

We also estimate Phillips curve models of wage inflation that are disaggregated by educational attainment. We consider first whether the unemployment–wage inflation relationship differs by group and second whether accounting for these differences improves model fit and forecast performance. Our results point to important influences of educational attainment on the relationship between unemployment and wage inflation.

2. Background and Literature Review

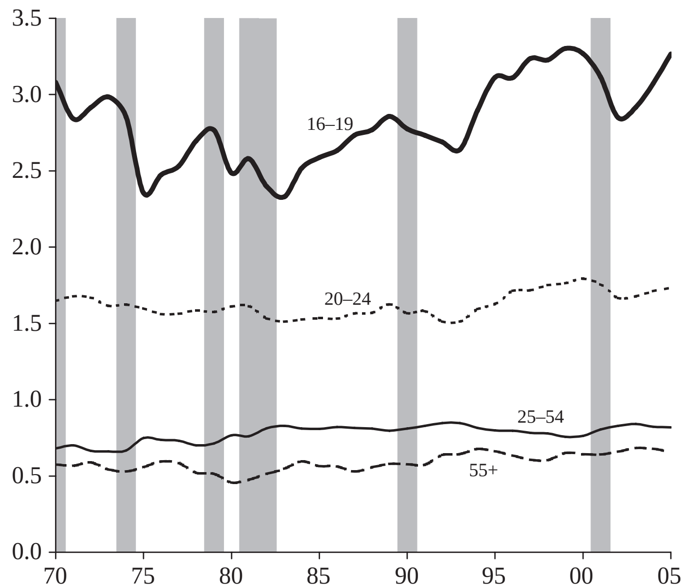
2.1. Demographic Adjustments

The idea that demographic changes can have important influences on aggregate unemployment was first highlighted in work by George Perry (1970). It is now common practice in macroeconomic analysis and modeling to adjust the aggregate unemployment rate as reported by the Bureau of Labor Statistics (BLS) for changes in the age and/or gender composition of the labor force (e.g., Brayton, Roberts, and Williams 1999, Tulip 2004). These adjustments are based on the idea that the amount of slack in the aggregate labor market depends partly on the demographic composition of the labor force, since equilibrium unemployment rates vary systematically across demographic groups.

The clearest and most empirically important example of demographic adjustment pertains to changes in labor force shares across age groups. Unemployment rates vary widely across age groups, with rates for young adults and teenagers typically running about two to three times those for prime-age workers (ages 25 to 54) (see Figure 1). As such, it is likely that shifts in the age structure of the population caused by the maturation of the baby boom generation over the past few decades have substantially influenced the aggregate unemployment rate, causing an increase in the 1960s and 1970s when young baby boomers were flooding the labor market and declines in subsequent decades as the baby boomers eased into their prime working years.

Shimer (1999) provided an extensive empirical analysis of the contribution of changing age structure to U.S. unemployment. He found that the rising share of young workers accounted for an increase in the aggregate unemployment rate of nearly 2 percentage points between 1959 and 1980 and a decline of nearly $1^1/_2$ percentage points in subsequent years. Most of this pattern is attributable to the direct impact of changing labor force shares on overall unemployment, although Shimer also identified important indirect effects of changing labor force shares on relative unemployment rates, which reinforced the direct effects. As noted by Katz and Krueger (1999), however, the aging of the baby boom was important for explaining declining unemployment in the 1980s but explains little of the additional decline in the observed unemployment rate in the 1990s.

Figure 1
Unemployment Rates by Age (Relative to Aggregate), 1970–2005



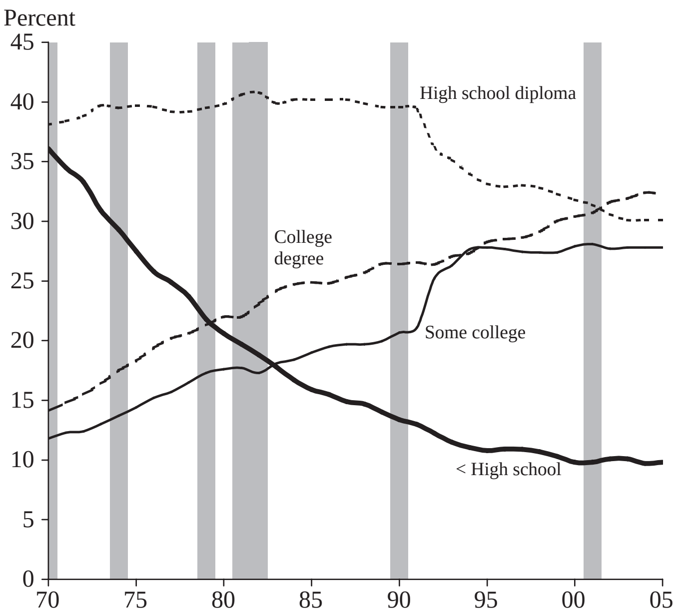
Note: Gray bars denote NBER recession periods.
Source: U.S. Bureau of Labor Statistics.

Researchers also have adjusted the aggregate unemployment rate for the rising labor force share of women (e.g., Perry 1970, Gordon 1982). However, as Shimer (1999) shows, unemployment rates for women largely converged with those for men after 1980, so that adjustments for women's changing labor force share have little impact on the aggregate unemployment rate since then. Similar reasoning applies to adjustments for race: although unemployment rates tend to be higher for blacks than for whites in the United States, relative stability in blacks' labor force share implies that adjusting for race has little impact on the aggregate unemployment rate (Shimer 1999).

2.2. Education Adjustments

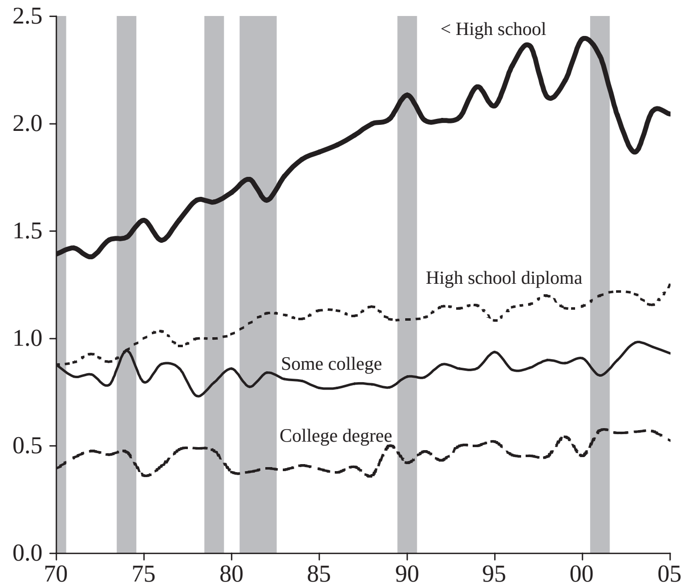
The same reasoning underlying adjustments for changes in labor force composition due to population aging could also apply to the educational composition of the labor force. The educational attainment of the labor force has increased substantially since 1970, primarily reflecting the rising

Figure 2
Labor Force Shares by Educational Attainment, 1970–2005



Note: Gray bars denote NBER recession periods.
Source: U.S. Bureau of Labor Statistics.

Figure 3
Unemployment Rates by Educational Attainment (Relative to Aggregate), 1970–2005



Note: Gray bars denote NBER recession periods.
Source: U.S. Bureau of Labor Statistics.

labor force share of individuals possessing a college degree and the declining share of individuals who lack a high school diploma (Figure 2).[1] It is possible that these trends have been important for the trend in aggregate unemployment, given the relatively low unemployment rate for college-educated individuals and high rate for those lacking a high school diploma (Figure 3). The pattern of unemployment rates by educational attainment has been largely constant since 1978, with the exception of a pronounced upward trend in the relative unemployment rate of individuals lacking a high school diploma through the year 2000 that was partly offset by a decline in their relative unemployment rate after 2000.

Despite the potential importance of rising educational attainment for aggregate unemployment, economists generally have rejected the use of educational adjustments to the aggregate unemployment rate (e.g., Summers 1986, Shimer 1999, Katz and Krueger 1999). These authors have argued that *relative* educational attainment is likely to matter more for unemployment differentials than does *absolute* educational attainment. For example, a rising share of college-educated workers increases job competition among this group and also may increase employers' unfavorable treatment of workers with less education. As such, the unemployment rates of both groups may rise, keeping overall unemployment relatively constant despite the rising labor force share of the group with lower unemployment. Alternatively, an increase in individual productivity associated with higher educational attainment may cause workers' reservation (asking) wages to rise as well, offsetting the direct effect of greater educational attainment on unemployment rates. In any case, the empirical evidence on longer-term trends suggests relatively modest effects of changes in educational attainment on unemployment: rising educational attainment has been observed over long time periods in many countries without any clearly associated reduction in average or equilibrium unemployment rates.

Despite these reservations about the impact of rising educational attainment on equilibrium unemployment, other research has discussed a possible causal link between education and unemployment. In particular, Ashenfelter and Ham (1979) and subsequent research has identified and analyzed systematic behavioral differences across workers with different levels of educational attainment. Most importantly, workers with higher education tend to exhibit

1. Thanks to Terence McMenamin from BLS for providing the data used in these figures. The discontinuous shift in the shares of individuals with high school diplomas and "some college" in 1992 is due to a change in household survey definitions.

greater job stability, which can arise due to the higher level of training embodied in such workers (Mincer 1993, Francesconi et al. 2000). This research suggests that rising educational attainment may be systematically associated with declining unemployment rates over time, thereby supporting the application of educational adjustments to the aggregate unemployment rate.

Ultimately, the validity and importance of education adjustments to the unemployment rate is an empirical issue. To understand this point, it is important first to understand how unemployment rate adjustments for changing labor force composition are formed. In general, they are constructed by calculating the aggregate unemployment rate if labor force shares for demographic or education groups are held to a base-period value. If the actual labor force share of low-unemployment groups rises subsequent to the base year, the adjusted unemployment rate will rise relative to the actual unemployment rate over time, because the adjusted rate is calculated under the counterfactual assumption that the share of low-unemployment groups does not rise.

This procedure implicitly relies on the assumption that group-specific unemployment rates do not respond to changes in group-specific labor force shares (i.e., an "exogeneity" assumption). If this assumption does not hold, the fixed-weight adjustment may overstate or understate changes in the aggregate unemployment rate associated with changing labor force shares per se. Contrary to this exogeneity assumption, past work has found systematic correlations between changes in labor force shares and unemployment rates by demographic group. For example, Shimer (1999) found a positive correlation in general between changes over time in labor force shares and unemployment rates by age group. This finding suggests a "crowding" effect, whereby competition for jobs intensifies within demographic groups that grow relative to the labor force as a whole and diminishes for groups that shrink.[2] Conversely, Shimer also uncovered a negative relationship between changes in labor force shares and unemployment rates by educational group. This suggests that an adjustment based on rising education alone is likely to overstate the direct contribution of rising educational attainment to declining unemployment rates, because the high-unemployment groups (e.g., those lacking a high school diploma) have experienced an increase in their relative unemployment rate.

Even ignoring this past evidence about indirect effects of rising educational attainment on relative unemployment rates, simply adding age and education adjustments together may be misleading due to cohort effects that attenuate or reinforce the separate effects of changing age and education. For example, since rising educational attainment is most pronounced in younger cohorts, its limiting influence on aggregate unemployment may be muted because younger workers tend to have high unemployment rates (Figure 1). By contrast, adjusting the aggregate unemployment rate based on changing shares of groups defined jointly by age and education may be more defensible than summing separate adjustments based on demographics and education. In addition to the elimination of cohort effects within educational attainment groups, a joint adjustment can exploit the higher labor market substitutability between groups defined jointly by age and education than groups defined by age or education alone. Older workers and those possessing college degrees may not be readily replaced by younger workers or those with less education, whereas it may be more possible to substitute young workers with college degrees for older workers without college degrees, for example. Such substitutability across labor market groups will limit the impact of changing labor force shares on relative unemployment rates: if a particular labor market group grows substantially, the crowding effect on that group's unemployment rate will be attenuated by the labor market spillovers to substitutable groups.

These considerations suggest that an unemployment rate series that is jointly adjusted for the changing age composition and educational attainment of the labor force may have substantial empirical validity. This validity depends on the exogeneity assumption noted earlier—i.e., that group-specific unemployment rates do not respond to changes in group-specific labor force shares. The validity of this assumption can be investigated empirically by examining the correlation between changes in group-specific unemployment rates and labor force shares for specific pairs of comparison years; under pure exogeneity, the correlation will be zero. The appendix presents the results of this analysis. Confirming Shimer's results, there is a strong positive correlation between changes in labor force shares and unemployment rates for groups defined by age and in most cases a strong negative correlation for groups defined by education.[3] However, for groups defined jointly by age and education, there is very little correlation between changes in labor force shares and changes in unemployment rates, consistent with a relatively high degree of labor market

2. This pattern forms the basis for Shimer's (1999) finding for a net effect (direct plus indirect) of changing age structure on equilibrium unemployment that exceeds the direct effect alone.

3. We use five age groups for this analysis and for the age-adjusted unemployment rate formed subsequently: 16 to 19, 20 to 24, 25 to 34, 35 to 54, and 55 and older. Our education breakdown uses the same four groups displayed in Figures 2 and 3. For the joint age/education breakdown, we use four age groups and four education groups; see the appendix for further details.

substitutability or supply responsiveness across these groups.[4] These findings suggest that an adjustment to the aggregate unemployment rate that jointly incorporates the changing age and education structure of the labor force provides a gauge of labor market tightness that is relatively consistent over time.

2.3. Adjusted Unemployment Rates

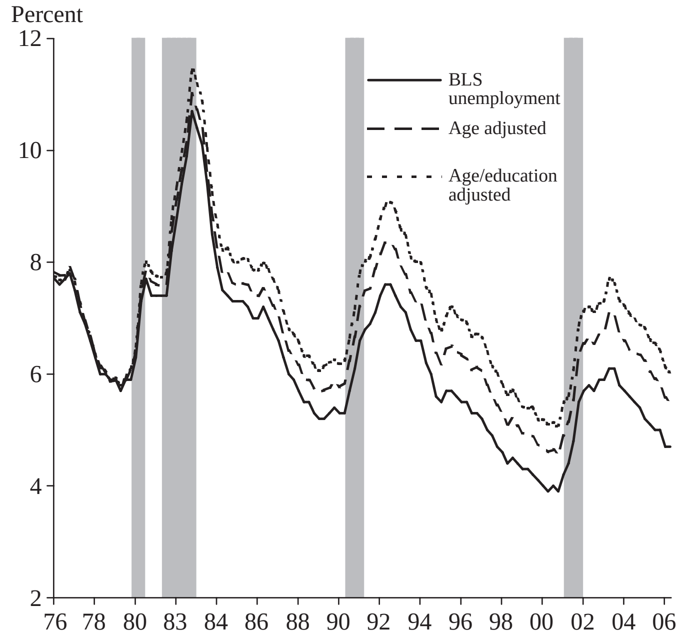
Based on the considerations described in the preceding subsection, we produce two alternative adjusted unemployment rate series for use in aggregate Phillips curve specifications: the first is adjusted for changes in labor force shares for groups defined only by age, and the second is adjusted for changes in labor force shares for groups defined jointly by age and education. These adjusted unemployment series (U^a) are formed according to the following formula:

$$U_t^a \equiv \sum_{i \in I} \omega_{i0} \times u_{it}\,, \tag{1}$$

where t denotes an arbitrary time period and 0 represents the base period, i represents a particular group within the entire set of groups I, and u_{it} represents the unemployment rate for group i in period t. The weighting term ω_{i0} represents the labor force share of a particular group in the base period (if the weights are set equal to labor force shares at time t, this formula produces the observed unemployment rate). Thus, the adjusted unemployment rate represents the unemployment rate if the labor force shares of a complete set of age or age and education groups had remained fixed at their base-year values.[5]

For purposes of systematic comparison and the empirical analysis in Section 3, we also use the official unemployment rate from BLS. Figure 4 displays the three aggregate unemployment rate series that we use for the period 1976 through the first quarter of 2006; in this figure, the adjusted series are normalized to equal the official series in 1978.[6] The figure shows that, as expected, the gap between the actual aggregate unemployment rate and the rate adjusted jointly for changing age and education has increased, although the pace of increase has moderated over time; the gap was 0.9 percentage point in 1989 and rose to 1.4 percentage points in 2006. Growth in the gap between the actual rate and the rate adjusted for age also slowed over time, rising from 0.5 percentage point in 1989 to 0.8 percentage point in 2006.

FIGURE 4
UNEMPLOYMENT RATES, 1976:Q1–2006:Q2



Note: Gray bars denote NBER recession periods.
Source: U.S. Bureau of Labor Statistics and authors' calculations.

2.4. Disaggregated Estimates

While adjustments for changes in educational attainment matter substantially for measurement of the aggregate unemployment rate, such adjustments may not fully capture the labor market changes associated with rising education levels. In particular, the wage inflation process embodied in the Phillips curve may differ across worker groups defined by characteristics such as age or education; the impact of such differences will not be captured by an aggregate unemployment rate variable that is adjusted for changing educational attainment.

4. This is not an artifact of the offsetting positive and negative correlations evident for groups defined respectively by age and education; see the appendix.

5. The approach to demographically adjusted unemployment series developed by Perry (1970) and also used by Gordon (1982) is similar to the one described here but weights groups based on their total annual earnings rather than their labor force shares. Shimer (1999) showed that an age adjustment based on labor force shares is consistent with a model in which younger workers experience more unemployment due to lower job attachment, which is similar to the arguments made here about unemployment differences by educational status. Perry's earnings-based weights are more consistent with a model of wage inflation (based on the "wage push" created by shortages of workers earning different wage rates) rather than equilibrium unemployment.

6. Shimer (1999) identified 1978 as the year in which the age structure of the U.S. population was the most conducive to high unemployment rates of any year during the post-World War II period.

Baily and Tobin (1977) examined the possibility of different wage inflation processes with specific reference to teenagers vs. adults, analyzing the conditions under which policy interventions such as wage subsidies targeted at teenagers can exploit the differences in Phillips curve slopes across the two groups and lower the equilibrium unemployment rate. Their analysis relies on the generally accepted notion that teenagers and adults largely work in separate (segmented) labor markets—i.e., that in general they do not compete for the same jobs. Similar reasoning applies to groups defined by education, perhaps with greater force: a specified minimum level of educational attainment is a key requirement for many jobs, especially for college graduates.

Francesconi et al. (2000) provided a theoretical framework and empirical analysis of segmented labor markets across educational groups based on systematic differences in training costs and turnover across these groups. Their results imply that groups defined by educational attainment will face different Phillips curve relationships, implying lower equilibrium unemployment rates for more-educated groups.

The analysis of Francesconi et al. provides some support for the hypothesis that the equilibrium unemployment rate declines as educational attainment rises. By contrast, some authors have emphasized the role of technological change in recent decades, which may interact with rising educational attainment to increase overall unemployment. In particular, to the extent that the rising share of highly educated workers reflects rising skill demand associated with technological change, the flip side is stagnant demand for low-skilled workers, which may increase their unemployment rates and the aggregate equilibrium rate as well (Juhn, Murphy, and Topel 1991, Blanchard and Katz 1997, Trehan 2003).

These opposing views of the relationship between rising educational attainment and equilibrium unemployment call for an empirical assessment of the relationship between aggregate wage inflation and labor markets segmented by educational status. To this end, in addition to our aggregate Phillips curve equations, in Section 4 we estimate separate (disaggregated) Phillips curve equations by educational attainment groups and assess whether they provide improved forecasts of wage inflation compared with aggregate equations.

3. Phillips Curve Estimates and the Natural Rate

We now turn to estimates of the aggregate Phillips curve relationship between wage inflation and unemployment. For estimation purposes, we rely on a standard "wage-wage-price" Phillips curve (see, e.g., Fuhrer 1995, Gordon 1998, and Staiger, Stock, and Watson 2001), which posits that wage inflation is a function of past wage inflation and price inflation as well as a measure of labor market tightness (the unemployment rate) and a limited set of other control variables. Our intent is not to identify and estimate the "best" forecasting model for wage inflation, but rather to assess the role of incorporating measures of educational attainment in a standard Phillips curve specification. As such, we focus on a general model that we found fits the data well, without claiming that it fits better than all available alternatives. We also performed some robustness checks based on another broad model, as described below.

For our aggregate Phillips curve analysis, we regress the quarterly percentage change in wages (expressed at an annual rate) on lagged wage changes, lagged price changes, lagged values of trend productivity growth, a measure of employer contributions to social security taxes, and a measure of the unemployment rate.[7] Based on past conventions and our own specification checks, these equations include eight lags of the dependent variable with the coefficients on lags five through eight set to be equal, one lag of the sum of the four-quarter change in core personal consumption expenditure (PCE) prices and a measure of trend productivity growth, with a unity constraint imposed on the sum of the coefficients on lagged wage inflation and productivity-adjusted price inflation, a measure of employment insurance taxes, and an unemployment rate variable. We also constrained the sum of the coefficients on the lagged dependent variables to equal one; this follows standard convention and is consistent with a relatively stable rate of wage growth relative to price inflation and productivity growth over our sample time frame.

We estimate our models for two dependent variables, one measuring total compensation and the other wage compensation. Both measures come from the employment cost index (ECI) published by BLS. The total ECI series measures total compensation for private sector workers; this series includes the value of employee benefits such as health insurance but does not include nonstandard compensation components such as stock options and bonuses. The wage ECI series excludes benefits. The ECI series are "fixed weight" indices that eliminate compensation changes due to shifts in the job mix over time.[8]

7. Relative to past work such as Fuhrer (1995) and Gordon (1998), we do not include measures of supply shocks such as energy and import prices, because these are not substantively important over our sample time frame.

8. We also performed the estimation on two other BLS compensation series: compensation per hour (CPH) and average hourly earnings (AHE). The results were qualitatively and quantitatively similar to those reported below for the ECI series. Ritter (1996) provides a useful discussion of

We measure trend productivity growth using a 40-quarter moving average of quarterly productivity growth.[9] For price inflation, we use a "core" measure—the PCE deflator excluding food and energy—to minimize the influence of short-run volatility in overall price inflation that introduces noise relative to the underlying inflation trend. The sample period is 1982:Q2 through 2006:Q2; this start date is necessitated by the availability of the ECI beginning in the first quarter of 1980 and the presence of eight lags in our estimating equations.[10]

For each wage variable, we estimated three separate equations using the three different unemployment rates described in Section 2.3: the official BLS unemployment rate, the age-adjusted unemployment rate, and the unemployment rate jointly adjusted for age and education.[11] A comparison of results based on these three variables indicates the incremental impact of adjusting for changes in age structure and changes in educational attainment. The equilibrium or "non-accelerating (wage) inflation" rate of unemployment (NAIRU) is the rate of unemployment that exerts neither downward nor upward pressure on wage inflation, given expectations of price inflation. In line with the standard computation, in our framework the estimated NAIRU is equal to the negative ratio of the constant term to the coefficient on the unemployment rate (see, e.g., Staiger, Stock, and Watson 1997). Below, we transform the estimated NAIRUs based on models using each of the adjusted unemployment rates into the terms of the observed unemployment rate. As such, we estimate a constant NAIRU in models that include the official unemployment rate but a NAIRU that varies based on the gap between the adjusted and observed unemployment rate for models using the adjusted variables.

The estimates based on this equation are displayed in Table 1. The results indicate virtually no difference in fit across the three equations and no improvement from incorporating adjustments for educational attainment. The coefficient on the unemployment rate is around −0.5 to −0.75 and precisely estimated in general, achieving statistical significance at better than the 1 percent level in almost all cases. The root mean squared error (RMSE) of the residuals is lowest when the official unemployment rate is used, indicating that including this variable makes the equation fit best. The difference in fit is quite small, however. To examine the issue of relative fit in more detail, Figures 5 and 6 display residual plots (actual minus predicted rates of wage inflation) for the three unemployment rates for the ECI total and ECI wage series.[12] Consistent with the fit statistics in the table, the residual plots for the models adjusted for demographics and education generally track each other. The specification including adjustments for educational attainment fits better in the mid-1990s, a period when many models were overpredicting wage inflation. However, this advantage has unwound over the past several years, during which both models generally overpredict wage inflation.

Despite the minimal difference in fit across the equations using different unemployment rates, the NAIRUs implied by the official and adjusted series are noticeably different. Notably, the NAIRU obtained from the equations including adjustments for educational attainment fluctuate more over time than the one based on the simple demographic adjustment. The time-series patterns in the NAIRUs are displayed in Figures 7 and 8, which parallel

Table 1
Phillips curve Models by Alternative Measures of Unemployment, 1982:Q2–2006:Q2

	Employment cost index, total compensation	Employment cost index, wages
Official BLS unemployment rate coefficient	−0.55 (0.12)	−0.76 (0.14)
RMSE	0.861	0.818
Mean NAIRU	5.32	5.52
Age-adjusted unemployment rate coefficient	−0.55 (0.13)	−0.72 (0.15)
RMSE	0.868	0.832
Mean NAIRU	5.38	5.56
Age/education-adjusted unemployment rate coefficient	−0.51 (0.13)	−0.63 (0.14)
RMSE	0.876	0.849
Mean NAIRU	5.41	5.58

Note: See text for complete specification. Coefficient standard errors are in parentheses. Each NAIRU is expressed in terms of the official BLS unemployment rate.

the differences between these series; for additional information, see the technical materials that accompany the relevant BLS data releases.

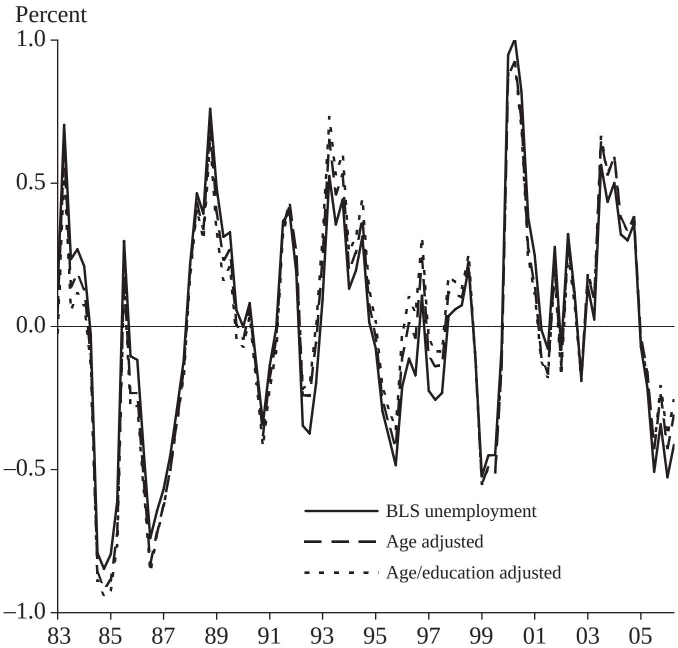
9. We use the moving average specification rather than sample mean productivity because past results suggest that accounting for the increase in trend productivity growth in the 1990s is important for the stability of estimated Phillips curves in samples that include this period (e.g., Staiger, Stock, and Watson 2001).

10. We performed similar analyses over the longer sample periods enabled by the AHE and CPH variables, without any substantive change in our results.

11. We use the contemporaneous value of the unemployment rate, which provides a better fit than any combination of lagged values in our primary specification.

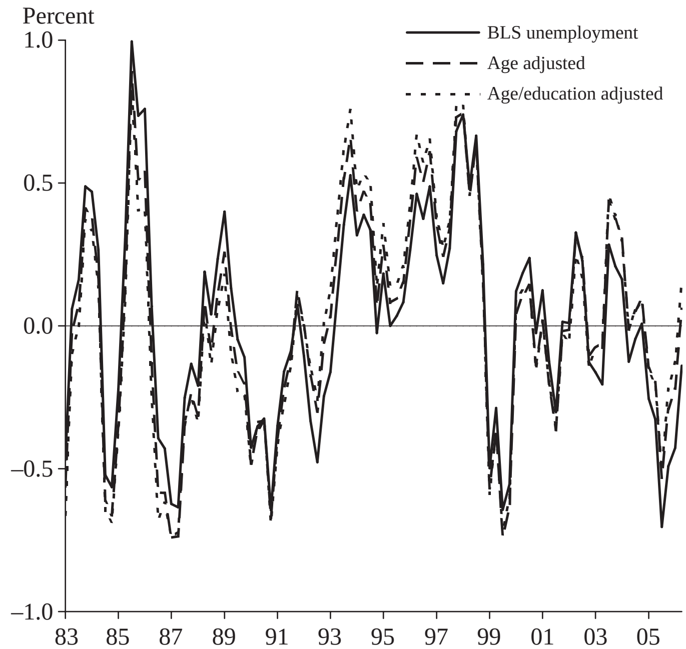
12. There is weak evidence of upward trends in the residuals in these models, which is slightly more pronounced in the models that use the unemployment rate adjusted for changing age and education. However, this tendency towards trended residuals is not a specific feature of that variable; see the discussion of our alternative specification below.

Figure 5
Residuals, ECI Total Model, 1983:Q1–2006:Q2



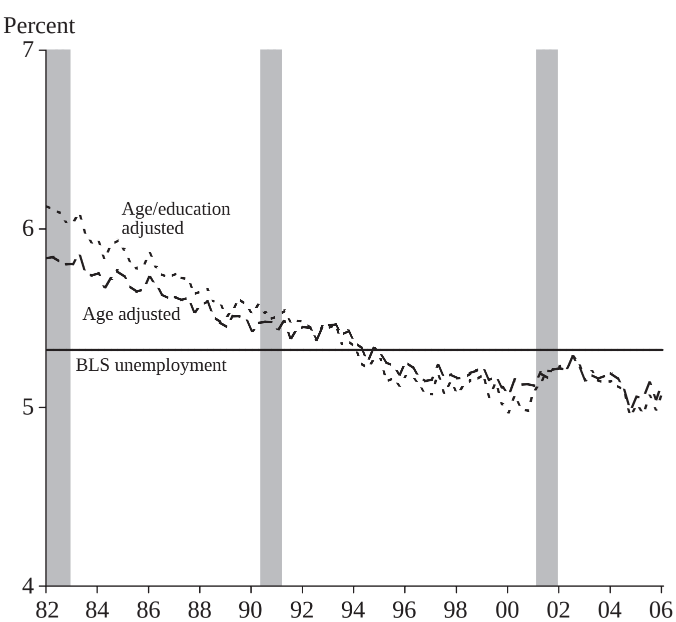
Note: Residuals are expressed as four-quarter moving averages.

Figure 6
Residuals, ECI Wage Model, 1983:Q1–2006:Q2



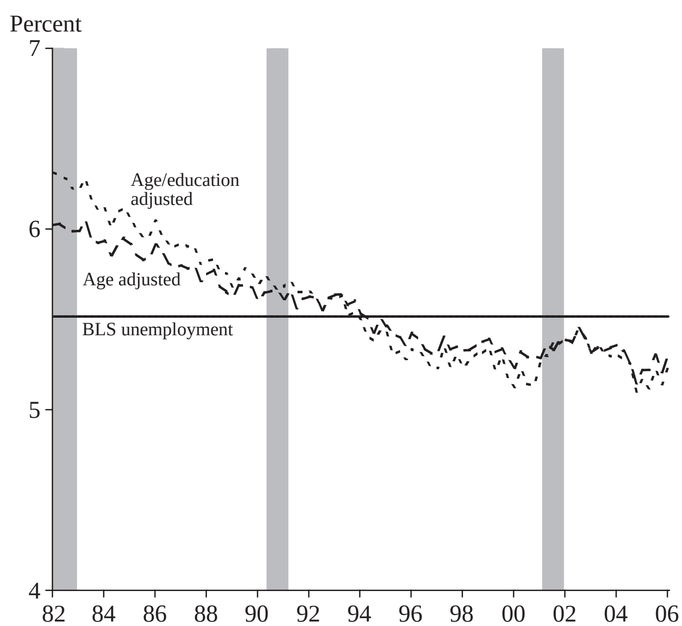
Note: Residuals are expressed as four-quarter moving averages.

Figure 7
NAIRUs, ECI Total Model, 1982:Q1–2006:Q2



Note: Gray bars indicate NBER recession periods.

Figure 8
NAIRUs, ECI Wage Model, 1982:Q1–2006:Q2



Note: Gray bars indicate NBER recession periods.

the residual plots in Figures 5 and 6. Although the equations are specified to yield time-invariant NAIRUs, the NAIRUs in the figures are expressed in terms of the observed unemployment rate and as such reflect the movement over time in the gaps between the adjusted and actual unemployment rates. The NAIRUs obtained from equations using the official unemployment rate series vary from 5.3 to 5.5 percent. By contrast, the NAIRU series obtained using the adjusted unemployment rates generally drop from just over 6 percent at the start of our sample time frame down to about 5 to $5^1/_4$ percent at the end. These NAIRUs implied by the adjusted unemployment rates are generally within or near the range of commonly used estimates. For example, in its economic analyses and projections, the U.S. Congressional Budget Office (CBO) has assumed that the NAIRU has equaled 5.0 percent since the third quarter of 2000, down from a peak of about $6^1/_4$ percent in the late 1970s (U.S. CBO 2007). The NAIRU series implied by the unemployment series adjusted for age and that adjusted jointly for age and education differ little, suggesting that accounting for education makes little difference for estimates of the relationship between labor market tightness and wage inflation.

The NAIRU obtained from the model with educational attainment exhibits greater variability due to the cyclical sensitivity of labor force shares for groups defined by age and educational attainment. Further investigation of this variability shows that in economic downturns the secular decline in the labor force share of less-educated workers accelerates for some demographic groups, as they disproportionately exit the labor force. In economic expansions, the pattern reverses, offsetting the secular decline and resulting in little change in labor force shares for these groups. In the late 1990s, this general pattern changed, as the entry of less-educated workers picked up substantially. The pickup likely reflects the unusually tight labor market conditions of those years and institutional factors such as welfare reform, elimination of Supplemental Security Income for immigrants, and changes in eligibility rules for disability benefits. These developments reduced the gap between the unemployment rate adjusted for educational attainment and the unemployment rate adjusted for demographics alone. More generally, the relatively low level of the NAIRU incorporating educational attainment explains why this model does a slightly better job predicting wage inflation in the mid-1990s than the other unemployment series.

The substantially lower NAIRUs obtained when using the adjusted unemployment rates versus the observed rate may seem surprising. For example, by early 2006 the NAIRUs implied by the adjusted rates were about four-tenths of a point lower than the NAIRU obtained using the official rate, suggesting that the rate of wage growth implied by the models relying on the adjusted unemployment rates should be lower than that obtained using the official rate. The residual plots in Figures 5 and 6 show that this is indeed the case, with generally higher residual values evident in recent years for the models using the adjusted series. However, the difference in residuals is quite small in general, because the estimated coefficients on the unemployment rate translate into variation in the rate of wage inflation that is smaller than the gap between the observed unemployment rate and the NAIRU. In early 2006, the four-tenths of a point spread in the NAIRUs implies a spread of about two-tenths of a point in the predicted rates of wage growth, which is approximately the spread evident in the residuals.

For comparison, we also estimated these models using the alternative specification of Staiger, Stock, and Watson (2001; SSW). This specification has a less-complicated lag structure (four lags of the dependent variable) and is more restrictive with respect to the relationship between growth in wages, productivity, and prices than our primary model (i.e., it is estimated in terms of growth in unit labor costs). As in our primary model, we imposed the restriction that the lags on the dependent variable sum to one. Relative to the results discussed above, the residuals show less tendency to trend in the SSW specification, and the residual trend is especially limited for the unemployment series that is adjusted jointly for age and education. This model fit best with two lags of the unemployment rate replacing the contemporaneous values used in our primary specification. However, the overall fit generally is poorer in this alternative specification than in our primary specification, except for the runs that use compensation per hour as the dependent variable. Beyond these differences in fit, our primary finding that adjusting for education makes little difference for predicted wage inflation is maintained. However, this alternative specification produces noticeably lower NAIRUs than our primary specification, with implied NAIRUs based on the adjusted series generally in the range of 4.5 to 5.0 percent in recent years.

Overall, the results from our aggregate analyses suggest that the inclusion of an educational adjustment does not improve forecasts of wage inflation obtained from aggregate Phillips curve estimates. Indeed, incorporating education causes the fit to deteriorate slightly, and the NAIRU implied by the series adjusted jointly for age and education differs little from that implied by the series adjusted only for age.

4. Disaggregated Estimates

As discussed in Section 2.4, the influence of rising educational attainment on wage inflation may not be fully captured by an adjustment to the aggregate unemployment rate, due to segmentation across labor markets and corresponding differences in the wage inflation process across groups defined by educational attainment. Such differences and their implication for forecasts of wage inflation can be more fully investigated in a disaggregated framework. To explore further the information provided by the labor market outcomes for different education groups, we turn to Phillips curve models that are disaggregated by educational attainment.

Our specification for the disaggregated analysis is a simplified version of our aggregate Phillips curve specification described in the previous section. For each of the four educational attainment groups identified earlier, we estimate separate wage-price Phillips curve equations based on annual data.[13] In these models, annual wage inflation for each group is regressed on overall price inflation (current and lagged) and the group-specific unemployment rate. The wage inflation term is defined as the annual percentage change in average hourly earnings; these series are obtained from the Employment Policy Institute (EPI) and are based on their tabulations from the monthly files from the Current Population Survey (CPS).[14] Price inflation is defined as the 12-month percent change in the core consumer price index for all urban consumers (CPI-U), which excludes food and energy prices. Our specification checks indicate that the best fit is obtained when we include the contemporaneous value of price inflation and its first lag. Unemployment rates and labor force shares by educational attainment are tabulated from the monthly CPS files. Our sample period is 1983–2006; values for 2006 are based on the average of the first two quarters.

Our disaggregated analysis involves two parts. First, for each group, we estimate the simplified model and test for the equality of the coefficients on the unemployment rate across equations. The equations are estimated using the technique of "seemingly unrelated regression" (SUR), which accounts for arbitrary correlation across the error terms in the separate group equations (Zellner 1962). In the second part of our examination, we aggregate the results (weighted by labor force shares) and compare them with the estimates from an aggregate model using the same data and specification.

Consistent with theories of labor market segmentation by educational attainment, the results of our disaggregated analysis indicate sizeable differences in the estimated slope of the Phillips curves by educational attainment (Table 2, top panel, four-group model). The sensitivity of wages to the group-specific unemployment rate is higher for individuals at the college degree level than for other workers. The results of the chi-squared test displayed in the table show that these differences in the slopes of the Phillips curves across education groups are significant at about the 5-percent level, suggesting that the aggregate Phillips curve model is misspecified and that the disaggregated specification provides added information for predicting aggregate wage growth. Our robustness checks include estimating a two-group model that combines individuals possessing less than a four-year college degree into a single group (see the bottom panel of Table 2)—to focus on demand shifts toward college-educated workers over our sample frame (see e.g. Lemieux 2006)—and using wage shares in place of labor force shares to aggregate the results (see the standard error of the regression (SER) for wage weights listed in both panels of Table 2). Neither of these changes makes a qualitative difference to our findings. However, the chi-squared test does not reject equality of the unemployment rate coefficients at conventional significance levels in the two-group model, suggesting that the four-group model is preferred.

Turning to comparisons of the aggregate and the fully disaggregated models, Table 2 and Figure 9 provide quantitative and visual evidence on the added information obtained through disaggregation. The last row of the table (both panels) reports the SER for the aggregate and disaggregated models. The SER values are noticeably lower for the four-group disaggregation (using either labor force weights or wage weights for aggregation) than for the aggregate equation, indicating that the disaggregated equations provide more precise in-sample forecasts of overall wage inflation. Figure 9 plots the time series of the residuals in the two models. While these plots generally track each other, the superior fit of the disaggregated model is reflected in the more limited residual spikes in the early and late 1990s. This pattern suggests that the disaggregated approach does a better job of capturing increases in the rate of wage inflation when the labor market tightens (i.e., the disaggregated model shows less tendency to underpredict the pace of wage growth during these periods).

Finally, as in the aggregate analysis, it is useful to consider how accounting for education affects estimates of the NAIRU. Consistent with the notion that there are barriers across labor markets defined by educational attainment, we

13. Compared with the quarterly frequency used for the aggregate analyses in the preceding section, the annual data used for the disaggregated analyses yield more reliable estimates of average hourly earnings by educational attainment. In addition, reliance on a simplified Phillips curve model allows us to sidestep complex issues such as estimating trend productivity growth by educational attainment; this specification is similar to the specification of the aggregate Phillips curve used by Blanchard and Katz (1997).

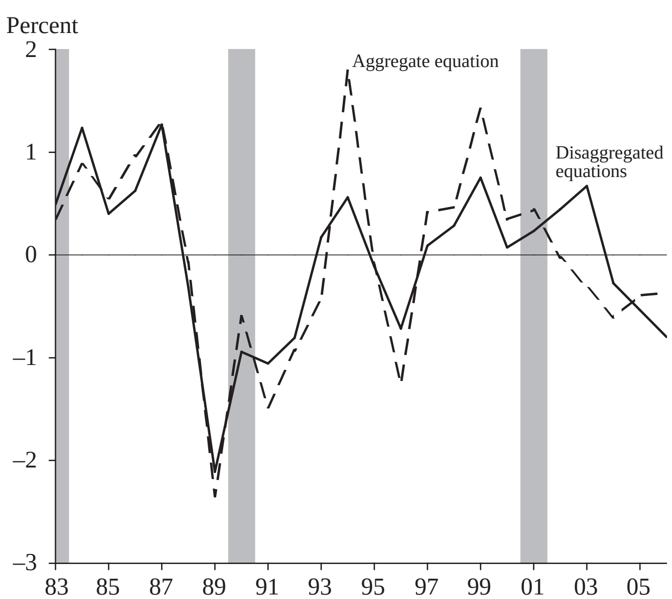
14. The data files and a detailed description can be found at www.epinet.org. These data have been used by other researchers doing similar analysis, e.g., Katz and Krueger (1999).

TABLE 2
PHILLIPS CURVE MODELS, FULLY DISAGGREGATED BY EDUCATION: ANNUAL DATA, 1983–2006

		Educational attainment of wage earner (SUR)			
		Four educational groups			
Independent variable	Aggregate equation	Less than high school diploma	High school diploma	Some college	College degree or more
Unemployment rate	–0.91 (0.21)	–0.73 (0.14)	–0.94 (0.11)	–1.24 (0.20)	–1.71 (0.47)
Constant	4.93 (1.08)	8.13 (1.70)	5.55 (0.71)	5.70 (0.92)	5.12 (1.21)
RMSE	0.835	1.203	0.744	0.832	1.150
		Test of cross-equation equality on unemployment rate coefficients			
		$\chi^2(3) = 7.68$			
		Prob $> \chi^2 = 0.0530$			
Standard error of the regression (SER)	0.915	SER (labor force weights)	0.752		
		SER (wage weights)	0.818		
		Two educational groups			
		Less than college degree		College degree or more	
Unemployment rate		–0.83 (0.14)		–1.43 (0.59)	
Constant		5.05 (0.92)		4.41 (1.51)	
RMSE		0.732		1.147	
		Test of cross-equation equality on unemployment rate coefficients			
		$\chi^2(1) = 1.13$			
		Prob $> \chi^2 = 0.2870$			
		SER (labor force weights)	0.724		
		SER (wage weights)	0.935		

Note: Coefficient standard errors in parentheses. Disaggregated results based on SUR framework (see text).

FIGURE 9
RESIDUALS, DISAGGREGATED AND AGGREGATE PHILLIPS CURVES (FOUR GROUPS, 1983–2006)

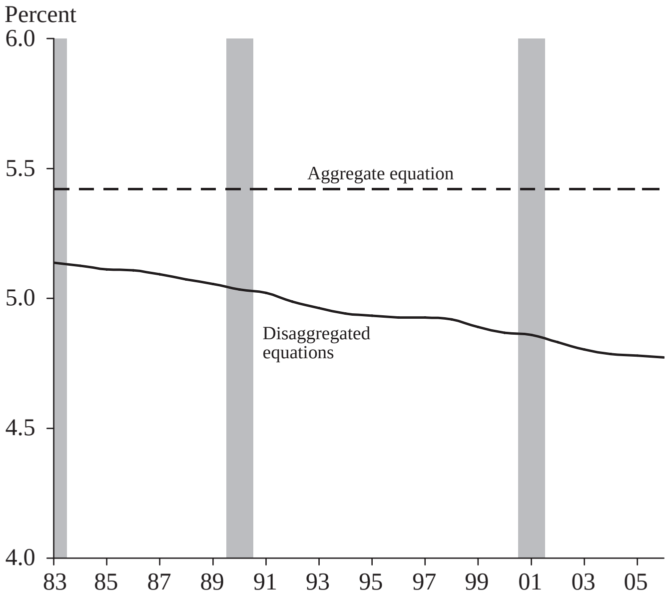


Note: Disaggregated results from SUR model, aggregated by labor force shares. Gray bars indicate NBER recession dates.

find sizeable differences in the NAIRUs estimated for each group. Based on the model presented in Table 2 we find a NAIRU of about 3 percent for college-educated workers compared with a NAIRU of about 11 percent for workers lacking a high school diploma. By contrast, the NAIRU obtained from the aggregate equation is 5.4 percent, which hides considerable variation in equilibrium labor market conditions across groups.

Moreover, it is possible to combine the group-specific NAIRUs to produce an aggregate NAIRU based on the disaggregated results (again using labor force weights for aggregation). As displayed in Figure 10, the overall NAIRU obtained from the disaggregated equations is below the aggregate NAIRU over our entire sample frame and falling over time. This pattern arises because the disaggregate equations more accurately capture the overall sensitivity of wages to the unemployment rate than does the aggregate equation. This can be seen in Table 2, where the coefficients on the group-specific unemployment rates in the four-group model in general are larger in absolute value than the corresponding coefficient from the aggregate equation (with the sole exception of the equation for individuals lacking a high school diploma). This higher sensitivity of group-specific wages to the unemployment rate is consistent with labor market segmentation by educational

Figure 10
NAIRUs, Disaggregated and Aggregate Phillips Curves (Four Groups, 1983–2006)



Note: Disaggregated results from SUR model, aggregated by labor force shares. Gray bars indicate NBER recession dates.

attainment, and it is critical for the better in-sample predictions obtained using the disaggregated framework.

5. Conclusions

We find that incorporating an educational adjustment into the aggregate unemployment rate does not improve the fit of a standard Phillips curve specification, despite the finding that rising educational attainment has reduced equilibrium aggregate unemployment over the past three decades. The limited impact of an aggregate educational adjustment arises due to the limited sensitivity of wage inflation to differences in the unemployment rate in standard Phillips curve models.

On the other hand, we find that disaggregating the Phillips curve estimates by educational group improves the in-sample predictions of wage inflation. Underlying this improvement in fit are significant differences in the slopes of the group-specific Phillips curves. These results suggest that our understanding of the dynamics of unemployment and wage inflation may be improved through consideration of the role of educational attainment, particularly in the context of disaggregated analyses. Additional investigation with expanded data and more elaborate models seems warranted, along with analysis of out-of-sample forecast accuracy.

Appendix

Validating Adjustments to Aggregate Unemployment

Simple demographic adjustments to the aggregate unemployment rate are formulated by calculating what the aggregate unemployment rate would be if labor force shares for demographic groups remained fixed at a base period value. A similar procedure can be applied to groups defined jointly by demographic characteristics and educational attainment.

In the paper, we focus on two adjusted unemployment rate series:

(1) the unemployment rate adjusted for age. The adjustment is based on the labor force shares in 1978 of five groups defined by age: 16 to 19, 20 to 24, 25 to 34, 35 to 54, and 55 and older.

(2) the unemployment rate adjusted jointly for age and education. The adjustment is based on the 1978 labor force shares of groups defined by the interaction of age groups and education groups. The age groups used are the same as in (1), but with ages 25 to 34 and 35 to 54 combined. The education groups consist of individuals without a high school diploma, those with a high school diploma, those with some college experience, and those with a college degree or more. This four-by-four breakdown produces 16 groups defined by their age range and educational attainment. To account for age limitations on the distribution of educational attainment and consequent sparse cells, individuals aged 16 to 19 who report educational attainment of "some college" or a college degree are included in the "high school graduate" group, yielding a total of 14 groups.

The adjustment procedure relies in part on the assumption that group-specific unemployment rates do not respond to changes in group-specific labor force shares (i.e., an "exogeneity" assumption; see Shimer 1999). If this assumption does not hold, the fixed-weight adjustment may overstate or understate changes in the aggregate unemployment rate associated with changing labor force shares per se. The exogeneity assumption can be investigated empirically by examining the correlation between changes in group-specific unemployment rates and labor force shares for specific pairs of comparison years; under pure exogeneity, the correlation will be zero. As shown in Table A1, this correlation in general is substantially smaller (in absolute value) for groups defined jointly by age and education than for groups defined separately by age and education, indicating that the joint breakdown by age and education fulfills the exogeneity condition better than do separate breakdowns by age and education.[15] This finding is not a

15. These calculations are based on annual averages of the underlying non-seasonally adjusted quarterly series. The criteria used to choose the

Table A1
Correlations between Changes in Group Shares and Unemployment Rates

	Group definition		
Years	Age	Education	Age/education
1979–2005	0.609	−0.454	−0.243
1979–2000	0.483	−0.147	0.073
1989–2005	−0.013	0.061	−0.023
1989–2000	0.467	0.602	0.193
1982–2003	0.614	0.791	0.399

mechanical artifact of the generally offsetting positive and negative correlations for groups defined separately by age and education: for changes between 1989 and 2000, the correlations are positive for age and education groups but substantially smaller for groups defined jointly by age and education.

References

Ashenfelter, Orley, and John Ham. 1979. "Education, Employment, and Earnings." *Journal of Political Economy* 87(5, no. 2), pp. S99–S116.

Baily, Martin Neil, and James Tobin. 1977. "Macroeconomic Effects of Selective Public Employment and Wage Subsidies." *Brookings Papers on Economic Activity* 1977(2), pp. 511–544.

Blanchard, Olivier, and Lawrence F. Katz. 1997. "What We Know and Do Not Know about the Natural Rate of Unemployment." *Journal of Economic Perspectives* 11(1), pp. 51–72.

Brayton, Flint, John M. Roberts, and John C. Williams. 1999. "What's Happened to the Phillips Curve?" Federal Reserve Board of Governors, Finance and Economics Discussion Series 1999-49 (September). http://www.federalreserve.gov/pubs/feds/1999/199949/199949abs.html

Francesconi, Marco, J. Michael Orszag, Edmund S. Phelps, and Gylfi Zoega. 2000. "Education and the Natural Rate of Unemployment." *Oxford Economic Papers* 52, pp. 204–223.

Fuhrer, Jeffrey C. 1995. "The Phillips Curve Is Alive and Well." *New England Economic Review,* March/April, pp. 41–56.

Gordon, Robert J. 1982. "Inflation, Flexible Exchange Rates, and the Natural Rate of Unemployment." In *Workers, Jobs, and Inflation,* ed. Martin Neil Baily. Washington, DC: Brookings Institute.

Gordon, Robert J. 1998. "Foundations of the Goldilocks Economy: Supply Shocks and the Time-Varying NAIRU." *Brookings Papers on Economic Activity* 1998(2), pp. 297–346.

Juhn, Chinhui, Kevin M. Murphy, and Robert Topel. 1991. "Why Has the Natural Rate of Unemployment Increased Over Time?" *Brookings Papers on Economic Activity* 1991(2), pp. 75–142.

Katz, Lawrence F., and Alan Krueger. 1999. "The High-Pressure U.S. Labor Market of the 1990s." *Brookings Papers on Economic Activity* 1999(1), pp. 1–65.

Lemieux, Thomas. 2006. "Postsecondary Education and Increasing Wage Inequality." *American Economic Review* 96(2) (May), pp. 195–199.

Mincer, Jacob. 1993. "Education and Unemployment." *Collected Essays of Jacob Mincer, Volume 1. Studies in Human Capital.* United Kingdom: Elgar.

Perry, George. 1970. "Changing Labor Markets and Inflation." *Brookings Papers on Economic Activity*, pp. 411–448.

Ritter, Joseph A. 1996. "Opening Pandora's Box: The Measurement of Average Wages." FRB St. Louis *Review,* March/April, pp. 15–22. http://research.stlouisfed.org/publications/review/96/03/9603jr.pdf

Shimer, Robert. 1999. "Why Is the U.S. Unemployment Rate So Much Lower?" In *NBER Macroeconomics Annual 1998,* eds. Ben S. Bernanke and Julio J. Rotemberg. Cambridge, MA: MIT Press.

Staiger, Douglas, James H. Stock, and Mark W. Watson. 1997. "The NAIRU, Unemployment, and Monetary Policy." *Journal of Economic Perspectives* 11(1) (Winter), pp. 33–49.

Staiger, Douglas, James H. Stock, and Mark W. Watson. 2001. "Prices, Wages, and the U.S. NAIRU in the 1990s." In *The Roaring Nineties: Can Full Employment Be Sustained?,* eds. Alan B. Krueger and Robert M. Solow. New York: Russell Sage Foundation.

Summers, Lawrence. 1986. "Why Is the Unemployment Rate So Very High Near Full Employment?" *Brookings Papers on Economic Activity* 1986(2), pp. 339–383.

Trehan, Bharat. 2003. "Productivity Shocks and the Unemployment Rate." FRB San Francisco *Economic Review* 2003, pp. 13–27. http://www.frbsf.org/publications/economics/review/2003/article2.pdf

Tulip, Peter. 2004. "Do Minimum Wages Raise the NAIRU?" *Topics in Macroeconomics* 4(1), article 7.

U.S. Congressional Budget Office. 2007. "Key Assumptions in CBO's Projection of Potential Output" (spreadsheet), January. http://www.cbo.gov/Spreadsheet/7731_table2-2.xls (accessed February 2007).

Zellner, Arnold. 1962. "An Efficient Method of Estimating Seemingly Unrelated Regression Equations and Tests for Aggregation Bias." *Journal of the American Statistical Association* 57, pp. 348–368.

year pairs displayed included similar points on the business cycle, similar unemployment rates, years that fall within or near our sample time frame, and use of the most recent full year of data, 2005. Shimer (1999) defined and used a "pseudo-correlation" that produces only slightly different results than the simple correlation used here.

Working Papers Series Abstracts

Complete texts of papers in this series are available on the Bank's website at
http://www.frbsf.org/publications/economics/papers/index.php
Electronic subscriptions are available through this site; paper copies are no longer available.

WP 2006-01

Higher-Order Perturbation Solutions to Dynamic, Discrete-Time Rational Expectations Models

Eric T. Swanson, *FRB San Francisco*
Gary Anderson, *Federal Reserve Board of Governors*
Andrew Levin, *Federal Reserve Board of Governors*

We present an algorithm and software routines for computing *n*th-order Taylor series approximate solutions to dynamic, discrete-time rational expectations models around a nonstochastic steady state. The primary advantage of higher-order (as opposed to first- or second-order) approximations is that they are valid not just locally but often globally (i.e., over nonlocal, possibly very large compact sets) in a rigorous sense that we specify. We apply our routines to compute first- through seventh-order approximate solutions to two standard macroeconomic models, a stochastic growth model and a life-cycle consumption model, and discuss the quality and global properties of these solutions.

WP 2006-02

Monetary Policy Shocks, Inventory Dynamics, and Price-setting Behavior

Yongseung Jung, *Kyunghee University*
Tack Yun, *Federal Reserve Board of Governors*

In this paper, we estimate a VAR model to present an empirical finding that an unexpected rise in the federal funds rate decreases the ratio of sales to stocks available for sales, while it increases finished goods inventories. In addition, dynamic responses of these variables reach their peaks several quarters after a monetary shock. In order to understand the observed relationship between monetary policy and finished goods inventories, we allow for the accumulation of finished goods inventories in an optimizing sticky price model, where prices are set in a staggered fashion. In our model, holding finished inventories helps firms to generate more sales at given prices. We then show that the model can generate the observed relationship between monetary shocks and finished goods inventories. Furthermore, we find that allowing for inventory holdings leads to a Phillips curve equation, which makes the inflation rate depend on the expected present-value of future marginal cost as well as the current periodicals marginal cost and the expected rate of future inflation.

WP 2006-03

Could Capital Gains Smooth a Current Account Rebalancing?

Michele Cavallo, *FRB San Francisco*
Cédric Tille, *FRB New York*

A narrowing of the U.S. current account deficit through exchange rate movements is likely to entail a substantial depreciation of the dollar, as stressed in the widely cited contribution by Obstfeld and Rogoff (2005). We assess how the adjustment is affected by the high degree of international financial integration in the world economy. A growing body of research stresses the increasing leverage in international financial positions, with industrialized economies holding substantial and growing financial claims on each other. Exchange rate movements then lead to valuation effects as the currency compositions of a country's assets and liabilities are not matched. In particular, a dollar depreciation generates valuation gains for the U.S. by boosting the dollar value of the large amount of its foreign-currency denominated assets. We consider an adjustment scenario in which the U.S. net external debt is held constant. The 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 U.S. 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.

WP 2006-04
Market-Based Measures of Monetary Policy Expectations

Refet Gürkaynak, *Bilkent University*
Brian Sack, *Federal Reserve Board of Governors*
Eric T. Swanson, *FRB San Francisco*

Forthcoming in
Journal of Business and Economic Statistics.
See p. 88 for the abstract of this paper.

WP 2006-05
Sovereign Debt, Volatility, and Insurance

Kenneth Kletzer, *University of California, Santa Cruz*

External debt increases the vulnerability of indebted emerging market economies to macroeconomic volatility and financial crises. Capital account reversals often lead to sovereign debt repayment crises that are only resolved after prolonged and difficult debt restructuring. Foreign indebtedness exacerbates domestic financial distress in crisis, increasing both the incidence and severity of emerging market crises. These outcomes contrast with the presumption that access to international capital markets should help countries to smooth domestic consumption and investment against macroeconomic shocks. This paper uses models of sovereign to reconsider the role of sovereign debt renegotiation for international risk-sharing and presents an approach for analyzing contractual innovations for implementing contingent debt repayments. The financial innovations that might allow risk-sharing rather than risk-inducing capital flows go beyond contractual changes that ease debt renegotiation by separating contingent payments from bonds.

WP 2006-06
Five Open Questions about Prediction Markets

Justin Wolfers, *University of Pennsylvania*
Eric Zitzewitz, *Stanford University*

Interest in prediction markets has increased in the last decade, driven in part by the hope that these markets will prove to be valuable tools in forecasting, decisionmaking, and risk management—in both the public and private sectors. This paper outlines five open questions in the literature, and we argue that resolving these questions is crucial to determining whether current optimism about prediction markets will be realized.

WP 2006-07
Pegged Exchange Rate Regimes—A Trap?

Joshua Aizenman, *University of California, Santa Cruz*
Reuven Glick, *FRB San Francisco*

Forthcoming in *Journal of Money, Credit, and Banking.*
See p. 79 for the abstract of this paper.

WP 2006-08
Partisan Impacts on the Economy: Evidence from Prediction Markets and Close Elections

Erik Snowberg, *Stanford University*
Justin Wolfers, *University of Pennsylvania*
Eric Zitzewitz, *Stanford University*

Political economists interested in discerning the effects of election outcomes on the economy have been hampered by the problem that economic outcomes also influence elections. We sidestep these problems by analyzing movements in economic indicators caused by clearly exogenous changes in expectations about the likely winner during election day. Analyzing high frequency financial fluctuations on November 2 and 3 in 2004, we find that markets anticipated higher equity prices, interest rates, and oil prices and a stronger dollar under a Bush presidency than under Kerry. A similar Republican-Democrat differential was also observed for the 2000 Bush-Gore contest. Prediction market-based analyses of all presidential elections since 1880 also reveal a similar pattern of partisan impacts, suggesting that electing a Republican president raises equity valuations by 2 to 3 percent and that, since Reagan, Republican presidents have tended to raise bond yields.

WP 2006-09

Does Inflation Targeting Anchor Long-Run Inflation Expectations? Evidence from Long-Term Bond Yields in the U.S., U.K., and Sweden

Refet Gürkaynak, *Bilkent University*
Andrew T. Levin, *Federal Reserve Board of Governors*
Eric T. Swanson, *FRB San Francisco*

We investigate the extent to which inflation targeting helps anchor long-run inflation expectations by comparing the behavior of daily bond yield data in the United Kingdom and Sweden—both inflation targeters—to that in the United States, a non-inflation-targeter. Using the difference between far-ahead forward rates on nominal and inflation-indexed bonds as a measure of compensation for expected inflation and inflation risk at long horizons, we examine how much, if at all, far-ahead forward inflation compensation moves in response to macroeconomic data releases and monetary policy announcements. In the U.S., we find that forward inflation compensation exhibits highly significant responses to economic news. In the U.K., we find a level of sensitivity similar to that in the U.S. prior to the Bank of England gaining independence in 1997, but a striking absence of such sensitivity since the central bank became independent. In Sweden, we find that forward inflation compensation has been insensitive to economic news over the whole period for which we have data. Our findings support the view that a well-known and credible inflation target helps to anchor the private sector's perceptions of the distribution of long-run inflation outcomes.

WP 2006-10

Methods for Robust Control

Richard Dennis, *FRB San Francisco*
Kai Leitemo, *Norwegian School of Management*
Ulf Söderström, *Bocconi University*

Robust control allows policymakers to formulate policies that guard against model misspecification. The principal tools used to solve robust control problems are state-space methods (see Hansen and Sargent 2006 and Giordani and Soderlind 2004). In this paper we show that the structural-form methods developed by Dennis (2006) to solve control problems with rational expectations can also be applied to robust control problems, with the advantage that they bypass the task, often onerous, of having to express the reference model in state-space form. Interestingly, because state-space forms and structural forms are not unique, the two approaches do not necessarily return the same equilibria for robust control problems. We apply both state-space and structural solution methods to an empirical New Keynesian business cycle model and find that the differences between the methods are both qualitatively and quantitatively important. In particular, with the structural-form solution methods, the specification errors generally involve changes to the conditional variances in addition to the conditional means of the shock processes.

WP 2006-11

Interpreting Prediction Market Prices as Probabilities

Justin Wolfers, *University of Pennsylvania*
Eric Zitzewitz, *Stanford University*

While most empirical analysis of prediction markets treats prices of binary options as predictions of the probability of future events, Manski (2004) has recently argued that there is little existing theory supporting this practice. We provide relevant analytic foundations, describing sufficient conditions under which prediction markets prices correspond with mean beliefs. Beyond these specific sufficient conditions, we show that for a broad class of models prediction market prices are usually close to the mean beliefs of traders. The key parameters driving trading behavior in prediction markets are the degree of risk aversion and the distribution on beliefs, and we provide some novel data on the distribution of beliefs in a couple of interesting contexts. We find that prediction markets prices typically provide useful (albeit sometimes biased) estimates of average beliefs about the probability of an event occurring.

WP 2006-12

Keeping Up with the Joneses and Staying Ahead of the Smiths: Evidence from Suicide Data

Mary Daly, *FRB San Francisco*
Daniel J. Wilson, *FRB San Francisco*

This paper empirically assesses the theory of interpersonal income comparison using a unique data set on suicide deaths in the United States. We treat suicide as a choice variable, conditional on exogenous risk factors, reflecting

one's assessment of current and expected future utility. Using this framework we examine whether differences in group-specific suicide rates are systematically related to income dispersion, controlling for sociodemographic characteristics and income level. The results strongly support the notion that individuals consider relative income in addition to absolute income when evaluating their own utility. Importantly, the findings suggest that relative income affects utility in a two-sided manner, meaning that individuals care about the incomes of those above them (the Joneses) and those below them (the Smiths). Our results complement and extend those from studies using subjective survey data or data from controlled experiments.

WP 2006-13

What Determines Technological Spillovers of Foreign Direct Investment: Evidence from China

Galina Hale, *FRB San Francisco*
Cheryl Long, *Colgate University*

Using the World Bank survey of 1,500 firms in five Chinese cities, we study whether the presence of foreign firms produces technology spillovers on domestic firms operating in the same city and industry. We find positive spillovers for more technologically advanced firms and no or negative spillovers for more backward firms. We analyze the channels of such spillovers and find that the transfer of technology occurs through movement of high-skilled workers from FDI firms to domestic firms as well as through network externalities among high-skilled workers. Moreover, these two channels fully account for the spillover effects we find, which demonstrate the importance of well-functioning labor markets in facilitating FDI spillovers. Insofar as our results can be generalized to other countries, they reconcile conflicting evidence found in other studies.

WP 2006-14

Inflation Targeting under Imperfect Knowledge

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

Published in *Series on Central Banking, Analysis and Economic Policies X: Monetary Policy under Inflation Targeting,* eds. Frederic Mishkin and Klaus Schmidt-Hebbel. Santiago, Chile: Central Bank of Chile, 2007.

This article is published in this volume, pp. 1–24.

WP 2006-15

Time-Varying U.S. Inflation Dynamics and the New Keynesian Phillips Curve

Kevin J. Lansing, *FRB San Francisco*

This paper introduces a form of boundedly rational expectations into an otherwise standard New Keynesian Phillips curve. The representative agent's perceived law of motion allows for both temporary and permanent shocks to inflation, the latter intended to capture the possibility of evolving shifts in the central bank's inflation target. The agent's perceived optimal forecast rule defined by the Kalman filter is parameterized to be consistent with the observed moments of the inflation time series. From the agent's perspective, the use of a variable Kalman gain parameter is justified by movements in the perceived "signal-to-noise ratio," which measures the relative variances of the permanent and temporary shocks to inflation. I show that this simple model of inflation expectations can generate time-varying inflation dynamics similar to those observed in long-run U.S. data. The U.S. signal-to-noise ratio identified using the model's methodology exhibits an upward drift during the 1970s, followed by downward drift from the mid-1990s onwards. This pattern suggests that the perceived signal-to-noise ratio might be viewed as an inverse measure of the central bank's credibility for maintaining a constant inflation target. Model-based values for expected inflation track quite well with movements in survey-based measures of U.S. expected inflation.

WP 2006-16

The Bond Yield "Conundrum" from a Macro-Finance Perspective

Glenn D. Rudebusch, *FRB San Francisco*
Eric T. Swanson, *FRB San Francisco*
Tao Wu, *FRB Dallas*

Published in *Monetary and Economic Studies* 24(S-1) (December 2006), pp. 83–128.
See p. 84 for the abstract of this paper.

WP 2006-17

Measuring the Miracle: Market Imperfections and Asia's Growth Experience

John Fernald, *FRB San Francisco*
Brent Neiman, *Harvard University*

The newly industrialized economies (NIEs) of Asia are the fastest-growing economies in the world since 1960. A clear understanding of their rapid development remains elusive, with continuing disputes over the roles of technology growth, capital accumulation, and international trade and investment. We reconcile seemingly contradictory explanations by accounting for imperfections in output and capital markets. For instance, in Singapore, growth-accounting studies using quantities (the primal approach) find rising capital–output ratios and a constant labor share, but studies using real factor prices (the dual approach) find a constant user cost. We provide evidence that "favored" firms reaped economic profits and received preferential tax treatment, subsidies, and access to capital—market imperfections that are difficult to capture when implementing the dual approach. Further, declining pure profits can reconcile the constant or rising labor shares in revenue in the NIEs with theories of international trade that predict falling labor shares in cost. We provide empirical support for the quantitative importance of profits and heterogeneous user costs, describe the two-sector dynamics, and derive measures of technology growth, corrected for the imperfections that we quantify. We then discuss implications for broader disputes about Asian development.

WP 2006-18

Labor Supply and Personal Computer Adoption

Mark Doms, *FRB San Francisco*
Ethan Lewis, *FRB Philadelphia*

The positive correlations found between computer use and human capital are often interpreted as evidence that the adoption of computers have raised the relative demand for skilled labor, the widely touted skill-biased technological change hypothesis. However, several models argue the skill intensity of technology is endogenously determined by the relative supply of skilled labor. We use instruments for the supply of human capital coupled with a rich data set on computer usage by businesses to show that the supply of human capital is an important determinant of the adoption of personal computers. Our results suggest that great caution must be exercised in placing economic interpretations on the correlations often found between technology and human capital.

WP 2006-19

Quantitative Easing and Japanese Bank Equity Values

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

Published in *Journal of the Japanese and International Economies* 20(4) (December 2006) pp. 699–721.
See p. 86 for the abstract of this paper.

WP 2006-20

The Relative Price and Relative Productivity Channels for Aggregate Fluctuations

Eric T. Swanson, *FRB San Francisco*

Published in *The B.E. Journal of Macroeconomics* 6(1) (Contributions), Article 10. Berkeley Electronic Press, www.bepress.com.
See p. 88 for the abstract of this paper.

WP 2006-21
Sovereign Debt Crises and Credit to the Private Sector

Carlos Arteta, *Federal Reserve Board of Governors*
Galina Hale, *FRB San Francisco*

We argue that, through its effect on aggregate demand and country risk premia, sovereign debt restructuring can adversely affect the private sector's access to foreign capital markets. Using fixed effect analysis, we estimate that sovereign debt rescheduling episodes are indeed systematically accompanied by a decline in foreign credit to emerging market private firms, both during debt renegotiations and for over two years after the agreements are reached. This decline is large (over 20 percent), statistically significant, and robust when we control for a host of fundamentals. We find that this effect is different for financial sector firms, for exporters, and for nonfinancial firms in the non-exporting sector. We also find that the effect depends on the type of debt rescheduling agreement.

WP 2006-22
The Frequency of Price Adjustment and New Keynesian Business Cycle Dynamics

Richard Dennis, *FRB San Francisco*

The Calvo pricing model that lies at the heart of many New Keynesian business cycle models has been roundly criticized for being inconsistent both with time series data on inflation and with micro-data on the frequency of price changes. In this paper I show that a modified version of the Galí and Gertler (1999) model, which allows for "rule-of-thumb" price setters, and whose structure can be interpreted in terms of menu costs and information gathering/processing costs, largely resolves both criticisms. Moreover, the resulting Phillips curve shares the explanatory power of the partial-indexation model and dominates the full-indexation model and the Calvo model. Estimating a small-scale New Keynesian business cycle model, my results indicate that the share of firms that change prices each quarter is just over 60 percent, broadly in line with the Bils and Klenow (2004) study of Bureau of Labor Statistics price data. Reflecting the importance of information gathering/processing costs, I find that most firms that change prices are rule-of-thumb price setters. Finally, compared to specifications containing either the Calvo model or the full-indexation model, the data provide much greater support for the Galí-Gertler model.

WP 2006-23
Futures Prices as Risk-Adjusted Forecasts of Monetary Policy

Monika Piazzesi, *University of Chicago*
Eric T. Swanson, *FRB San Francisco*

Many researchers have used federal funds futures rates as measures of financial markets' expectations of future monetary policy. However, to the extent that federal funds futures reflect risk premia, these measures require some adjustment. In this paper, we document that excess returns on federal funds futures have been positive on average and strongly countercyclical. In particular, excess returns are surprisingly well predicted by macroeconomic indicators such as employment growth and financial business cycle indicators such as Treasury yield spreads and corporate bond spreads. Excess returns on eurodollar futures display similar patterns. We document that simply ignoring these risk premia significantly biases forecasts of the future path of monetary policy. We also show that risk premia matter for some futures-based measures of monetary policy shocks used in the literature.

WP 2006-24
Endogenous Skill Bias in Technology Adoption: City-Level Evidence from the IT Revolution

Paul Beaudry, *University of British Columbia*
Mark Doms, *FRB San Francisco*
Ethan Lewis, *Dartmouth College*

This paper focuses on the bi-directional interaction between technology adoption and labor market conditions. We examine cross-city differences in personal computer (PC) adoption, relative wages, and changes in relative wages over the period 1980–2000 to evaluate whether the patterns conform to the predictions of a neoclassical model of endogenous technology adoption. Our approach melds the literature on the effect of the relative supply of skilled labor on technology adoption to the often distinct literature on how technological change influences the relative demand for skilled labor. Our results support the idea that differences in technology use across cities and its effects on wages reflect an equilibrium response to local factor supply conditions. The model and data suggest that cities initially endowed with relatively abundant and cheap skilled labor adopted PCs more aggressively than cities with rela-

tively expensive skilled labor, causing returns to skill to increase most in cities that adopted PCs most intensively. Our findings indicate that neoclassical models of endogenous technology adoption can be very useful for understanding where technological change arises and how it affects markets.

WP 2006-25

FDI Spillovers and Firm Ownership in China: Labor Markets and Backward Linkages

Galina Hale, *FRB San Francisco*
Cheryl Long, *Colgate University*

Using firm-level data, we find that the presence of foreign firms in China is positively associated with the performance of domestically owned private firms but is negatively associated with the performance of state-owned enterprises (SOEs). In particular, we find (1) the presence of foreign direct investment (FDI) is associated with larger differences in the wages and the quality of skilled workers between SOEs and private firms, and (2) FDI presence is positively associated with private firms' sales to foreign firms and foreign consumers, but not with the sales of SOEs. We argue that these differences could be due to the fact that private firms have more flexible wage and personnel policies, which allows them to attract talent that facilitates positive FDI spillovers.

WP 2006-26

Aggregate Shocks or Aggregate Information? Costly Information and Business Cycle Comovement

Laura Veldkamp, *New York University*
Justin Wolfers, *University of Pennsylvania*

When similar patterns of expansion and contraction are observed across sectors, we call this a business cycle. Yet explaining the similarity and synchronization of these cycles across industries remains a puzzle. Whereas output growth across industries is highly correlated, identifiable shocks, like shocks to productivity, are far less correlated. While previous work has examined complementarities in production, we propose that sectors make similar input decisions because of complementarities in information acquisition. Because information about driving forces has a high fixed cost of production and a low marginal cost of replication, it can be more efficient for firms to share the cost of discovering common shocks than to invest in uncovering detailed sectoral information. Firms basing their decisions on this common information make highly correlated production choices. This mechanism amplifies the effects of common shocks relative to sectoral shocks.

WP 2006-27

Safe and Sound Banking, 20 Years Later: What Was Proposed and What Has Been Adopted

Frederick T. Furlong, *FRB San Francisco*
Simon Kwan, *FRB San Francisco*

Forthcoming in *FRB Atlanta Economic Review.*
See p. 78 for the abstract of this paper.

WP 2006-28

Measuring Oil-Price Shocks Using Market-Based Information

Michele Cavallo, *FRB San Francisco*
Tao Wu, *FRB Dallas*

We develop two measures of exogenous oil-price shocks for the period 1984 to 2006 based on market commentaries on daily oil-price fluctuations. Our measures are based on exogenous events that trigger substantial fluctuations in spot oil prices and are constructed to be free of endogenous and anticipatory movements. We find that the dynamic responses of output and prices implied by these measures are "well behaved." We also find that the response of output is larger than the one implied by a conventional measure of oil-price shocks proposed in the literature.

WP 2006-29

Information and Communications Technology as a General-Purpose Technology: Evidence from U.S Industry Data

Susanto Basu, *Boston College*
John Fernald, *FRB San Francisco*

Many people point to information and communications technology (ICT) as the key to understanding the acceleration in productivity in the United States since the mid-1990s. Stories of ICT as a "general-purpose technology" (GPT) suggest that measured total factor productivity (TFP) should rise in ICT-using sectors (reflecting either unobserved accumulation of intangible organizational capital, spillovers, or both), but with a long lag. Contemporaneously, however, investments in ICT may be associated with lower TFP as resources are diverted to reorganization and learning. We find that U.S. industry results are consistent with GPT stories: the acceleration after the mid-1990s was broadbased—located primarily in ICT-using industries rather than ICT-producing industries. Furthermore, industry TFP accelerations in the 2000s are positively correlated with (appropriately weighted) industry ICT capital growth in the 1990s. Indeed, as GPT stories would suggest, after controlling for past ICT investment, industry TFP accelerations are negatively correlated with increases in ICT usage in the 2000s.

WP 2006-30

Monetary Policy in a Low Inflation Economy with Learning

John C. Williams, *FRB San Francisco*

Published in *Monetary Policy in an Environment of Low Inflation: Proceedings of the Bank of Korea International Conference 2006.* Seoul: The Bank of Korea, 2006.
See p. 89 for the abstract of this paper.

WP 2006-31

Revealing the Secrets of the Temple: The Value of Publishing Central Bank Interest Rate Projections

Glenn D. Rudebusch, *FRB San Francisco*
John C. Williams, *FRB San Francisco*

Forthcoming in *Asset Prices and Monetary Policy,* ed. John Campbell. Chicago: University of Chicago Press.
See p. 85 for the abstract of this paper.

WP 2006-32

Moderate Inflation and the Deflation-Depression Link

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

In a recent paper, Atkeson and Kehoe (2004) demonstrated the lack of a robust empirical relationship between inflation and growth for a cross section of countries with 19th and 20th century data, concluding that the historical evidence only provides weak support for the contention that deflation episodes are harmful to economic growth. In this paper, we revisit this relationship by allowing for inflation and growth to have a nonlinear specification dependent on inflation levels. In particular, we allow for the possibility that high inflation is negatively correlated with growth, while a positive relationship exists over the range of negative-to-moderate inflation. Our results confirm a positive relationship between inflation and growth at moderate inflation levels and support the contention that the relationship between inflation and growth is nonlinear over the entire sample range.

WP 2006-33

Non-Economic Engagement and International Exchange: The Case of Environmental Treaties

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

We examine the role of non-economic partnerships in promoting international economic exchange. Since farsighted countries are more willing to join costly international partnerships such as environmental treaties, environmental en-

gagement tends to encourage international lending. Countries with such non-economic partnerships also find it easier to engage in economic exchanges since they face the possibility that debt default might also spill over to hinder their non-economic relationships. We present a theoretical model of these ideas and then verify their empirical importance using a bilateral cross section of data on international cross-holdings of assets and environmental treaties. Our results support the notion that international environmental cooperation facilitates economic exchange.

WP 2006-34

Computer Use and the U.S. Wage Distribution, 1984–2003

Robert G. Valletta, *FRB San Francisco*

Given past estimates of wage increases associated with workplace computer use and higher usage rates among more-skilled workers, the diffusion of computers has been interpreted as a mechanism for skill-biased technological change and consequent widening of the earnings distribution. I investigate this link by testing for direct effects of rising computer use on the distribution of wages in the United States. Analysis of data from the periodic current population survey (CPS) computer use supplements over the years 1984–2003 reveals that the positive association between workplace computer use and wages declines at higher skill levels, with the notable exception of a higher return to computer use for highly educated workers that emerged after 1997. Over my complete sample frame, however, the net association between rising computer use and the distribution of wages was quite limited. For broad groups defined by educational attainment, rising computer use was associated with rising between-group inequality that was offset by falling within-group inequality, suggesting that computers have exerted a "leveling" rather than a "polarizing" effect on wages.

WP 2006-35

Incomplete Information Processing: A Solution to the Forward Discount Puzzle

Philippe Bacchetta, *University of Lausanne*
Eric van Wincoop, *University of Virginia*

The uncovered interest rate parity equation is the cornerstone of most models in international macroeconomics. However, this equation does not hold empirically since the forward discount, or interest rate differential, is negatively related to the subsequent change in the exchange rate. This forward discount puzzle implies that excess returns on foreign currency investments are predictable. In this paper, we investigate to what extent incomplete information processing can explain this puzzle. We consider two types of incompleteness: infrequent and partial information processing. We calibrate a two-country general equilibrium model to the data and show that incomplete information processing can fully match the empirical evidence. It can also account for several related empirical phenomena, including that of "delayed overshooting." We show that incomplete information processing is consistent both with evidence that little capital is devoted to actively managing short-term currency positions and with a small welfare gain from active portfolio management. The gain is small because exchange rate changes are very hard to predict. The welfare gain is easily outweighed by a small cost of active portfolio management.

WP 2006-36

Dual Labor Markets and Business Cycles

David Cook,
Hong Kong University of Science and Technology
Hiromi Nosaka, *Kansai University*

In this paper, we model a dynamic general equilibrium model of a small open developing economy. We model labor markets as including both formal and informal urban employment as well as rural employment. We find that modeling dual labor markets helps explain why output in developing economies may fall even as labor inputs remain constant during financial crises. An external financial shock may lead to a reallocation of labor from productive formal sectors of the economy to less productive informal sectors.

WP 2006-37

A Quantitative Analysis of China's Structural Transformation

Robert Dekle, *University of Southern California*
Guillaume Vandenbroucke,
University of Southern California

Between 1978 and 2003, the Chinese economy experienced a remarkable 5.7 percent annual growth of GDP per labor. At the same time, there has been a noticeable transformation of the economy: the share of workers in agriculture decreased from over 70 percent to less than 50 percent. We distinguish three sectors: private agriculture and nonagriculture and public nonagriculture. A growth accounting exercise reveals that the main source of growth was total factor productivity (TFP) in the private nonagricultural sector. The reallocation of labor from agriculture to nonagriculture accounted for 1.9 percent out of the 5.7 percent growth in output per labor. The reallocation of labor from the public to the private sector also accounted for a significant part of growth in the 1996–2003 period. We calibrate a general equilibrium model where the driving forces are public investment and employment, as well as sectoral TFP derived from our growth accounting exercise. The model tracks the historical employment share of agriculture and the labor productivities of all three sectors quite well.

WP 2006-38

The U.S. Current Account Deficit and the Expected Share of World Output

Charles Engel, *University of Wisconsin*
John Rogers, *Federal Reserve Board of Governors*

We investigate the possibility that the large current account deficits of the U.S. are the outcome of optimizing behavior. We develop a simple long-run world equilibrium model in which the current account is determined by the expected discounted present value of its future share of world GDP relative to its current share of world GDP. The model suggests that under some reasonable assumptions about future U.S. GDP growth relative to the rest of the advanced countries—more modest than the growth over the past 20 years—the current account deficit is near optimal levels. We then explore the implications for the real exchange rate. Under some plausible assumptions, the model implies little change in the real exchange rate over the adjustment path, though the conclusion is sensitive to assumptions about tastes and technology. Then we turn to empirical evidence. A test of current account sustainability suggests that the U.S. is not keeping on a long-run sustainable path. A direct test of our model finds that the dynamics of the U.S. current account—the increasing deficits over the past decade—are difficult to explain under a particular statistical model (Markov-switching) of expectations of future U.S. growth. But, if we use survey data on forecasted GDP growth in the G-7, our very simple model appears to explain the evolution of the U.S. current account remarkably well. We conclude that expectations of robust performance of the U.S. economy relative to the rest of the advanced countries is a contender—though not the only legitimate contender—for explaining the U.S. current account deficit.

WP 2006-39

Saving and Interest Rates in Japan: Why They Have Fallen and Why They Will Remain Low

R. Anton Braun, *University of Tokyo*
Daisuke Ikeda, *Bank of Japan*
Douglas Joines, *University of Southern California*

This paper quantifies the role of alternative shocks in accounting for the recent declines in Japanese saving rates and interest rates and provides some projections about their future course. We consider three distinct sources of variation in saving rates and real interest rates: changes in fertility rates, changes in survival rates, and changes in technology. The empirical relevance of these factors is explored using a computable dynamic overlapping generations model. We find that the combined effects of demographics and slower total factor productivity growth successfully explain both the levels and the magnitudes of the declines in the saving rate and the after-tax real interest rate during the 1990s. Model simulations indicate that the Japanese savings puzzle is over.

WP 2006-40

Global Current Account Adjustment: A Decomposition

Michael Devereux, *University of British Columbia*
Amartya Lahiri, *University of British Columbia*
Ke Pang, *University of British Columbia*

The rising current account deficit in the United States has attracted considerable attention in recent years. We use the "business cycle accounting" methodology to identify the principal distortions that have affected the external accounts of the U.S. In particular, we measure distortions in the optimality conditions of a simple two-country general equilibrium model using data from the U.S. and the other G-7 countries. We then feed these measured distortions into the model individually and use the simulated counterfactual paths of the current account to determine the contribution of each of these "wedges" to the overall external imbalance of the U.S. We find that no single wedge in isolation can account closely for the observed current account. However, a combination of productivity differences and deviations from risk-sharing between the U.S. and the rest of the G-7 does the best job in accounting for most of the measured movement of the U.S. current account.

WP 2006-41

Exchange-Rate Effects on China's Trade: An Interim Report

Jaime Marquez, *Federal Reserve Board of Governors*
John Schindler, *Federal Reserve Board of Governors*

Though China's share of world trade is comparable to that of Japan, little is known about the response of China's trade to changes in exchange rates. The few estimates available suffer from two limitations. First, the data for trade prices are based on proxies for prices from other countries. Second, the estimation sample includes the period of China's transformation from a centrally planned economy to a market-oriented system. To address these limitations, this paper develops an empirical model explaining the shares of China's exports and imports in world trade in terms of the real effective value of the renminbi. The specifications control for foreign direct investment and for the role of imports of parts to assemble merchandise exports. Parameter estimation uses disaggregated monthly trade data and excludes the period during which most of China's decentralization occurred. The estimation results suggest that a 10 percent real appreciation of the renminbi lowers the share of aggregate Chinese exports by a half of a percentage point. The same appreciation lowers the share of aggregate imports by about a tenth of a percentage point.

WP 2006-42

Evidence on the Costs and Benefits of Bond IPOs

Galina Hale, *FRB San Francisco*
João A.C. Santos, *FRB New York*

This paper investigates whether it is costly for nonfinancial firms to enter the public bond market, and whether firms benefit from their bond IPOs. We find that both gross spreads and ex ante credit spreads are higher for IPO bonds, suggesting that firms pay higher underwriting costs on their first public bond. We also find that underpricing in the secondary market is higher for IPO bonds, further suggesting that it is costly to enter the public bond market. The costs of entering the public bond market are economically meaningful and are higher for risky firms. We investigate the benefits from entering the public bond market, by looking at the costs firms pay to raise external funding subsequent to their bond IPOs. Our results show that these benefits exist, but they accrue only to safe firms. These firms benefit from a reduction both in the interest rates they pay on bank loans and the costs they incur to issue private bonds after they enter the public bond market. Together with our previous findings, these results lend support to the thesis that bond IPOs are unique.

WP 2006-43

The Impact of Divorce Laws on Marriage-Specific Capital

Betsey Stevenson, *University of Pennsylvania*

This paper considers how divorce law alters the incentives for couples to invest in their marriage, focusing on the impact of unilateral divorce laws on investments in new marriages. Differences across states between 1970 and 1980 provide useful quasi-experimental variation with which to consider incentives to invest in several types of marriage-specific capital: spouse's education, children, household specialization, and homeownership. I find that adoption of unilateral divorce—regardless of the prevailing property-division laws—reduces investment in all types of marriage-specific capital considered except homeownership. In contrast, results for homeownership depend on the underlying property division laws.

WP 2006-44

Beyond the Classroom: Using Title IX to Measure the Return to High School Sports

Betsey Stevenson, *University of Pennsylvania*

Previous research has found that male high school athletes experience better outcomes than non-athletes, including higher educational attainment, more employment, and higher wages. Students self-select into athletics, however, so these may be selection effects rather than causal effects. To address this issue, I examine Title IX which provides a unique quasi-experiment in female athletic participation. Between 1972 and 1978, U.S. high schools rapidly increased their female athletic participation rates (to approximately the same level as their male athletic participation rates) in order to comply with Title IX. This paper uses variation in the level of boys' athletic participation across states before Title IX as an instrument for the change in girls' athletic participation over the 1970s. Analyzing differences in outcomes for both the pre- and post-Title IX cohorts across states, I find that a 10 percentage point rise in state-level female sports participation generates a 1 percentage point increase in female college attendance and a

1 to 2 percentage point rise in female labor force participation. Furthermore, greater opportunities to play sports leads to greater female participation in previously male-dominated occupations, particularly for high-skill occupations.

WP 2006-45

Foreign Bank Lending and Bond Underwriting in Japan during the Lost Decade

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

We examine foreign intermediation activity in Japan during the so-called "lost decade" of the 1990s, contrasting the behavior of lending by foreign commercial banks and underwriting activity by foreign investment banks over that period. Foreign bank lending is shown to be sensitive to domestic Japanese conditions, particularly Japanese interest rates, more so than their domestic Japanese bank counterparts. During the 1990s, foreign bank lending in Japan fell, both in overall numbers and as a share of total lending. However, there was marked growth in foreign underwriting activity in the international yen-denominated bond sector. A key factor in the disparity between these activities is their different clienteles: While foreign banks in Japan lent primarily to domestic borrowers, international yen-denominated bond issuers were primarily foreign entities with yen funding needs or opportunities for profitable swaps. Indeed, low interest rates that discouraged lending activity in Japan by foreign banks directly encouraged foreign underwriting activity tied to the so-called "carry trades." Regulatory reforms, particularly the "big bang" reforms of the 1990s, also play a large role in the growth of foreign underwriting activity over our sample period.

WP 2006-46

Macroeconomic Implications of Changes in the Term Premium

Glenn D. Rudebusch, *FRB San Francisco*
Brian P. Sack, *Macroeconomic Advisers, LLC*
Eric T. Swanson, *FRB San Francisco*

Forthcoming in FRB St. Louis *Review.*
See p. 84 for the abstract of this paper.

WP 2006-47

State Investment Tax Incentives: A Zero-Sum Game?

Robert S. Chirinko, *Emory University*
Daniel J. Wilson, *FRB San Francisco*

Though the U.S. federal investment tax credit (ITC) was permanently repealed in 1986, state-level ITCs have proliferated over the last few decades. The proliferation of state ITCs and other investment tax incentives raises two important questions: (1) Are these tax incentives effective in achieving their stated objective, to increase investment within the state? and (2) To the extent these incentives raise investment within the state, how much of this increase is due to investment drawn away from other states? To begin to answer these questions, we construct a detailed panel data set for 50 states for 20-plus years (depending on the series). The data set contains series on output and capital, their relative prices, and the number of establishments. The effects of tax parameters on capital formation and establishments are measured by the Jorgensonian user cost of capital that depends in a nonlinear manner on federal and state tax parameters. Cross-jurisdiction differences in state investment tax credits and state corporate tax rates entering the user cost, combined with a panel that is long in the time dimension, are key to identifying the effectiveness of state investment incentives. Three models are estimated: (1) a capital demand model motivated by the first-order condition for profit-maximization; (2) a spatial discontinuity model developed by Holmes (1998) that exploits the spatial discontinuity in tax policies that occurs at state borders; and (3) a twin-counties model that matches a county to a cross-border "twin" and relates between-county differentials in manufacturing activity to between-county differentials in tax policy. The first model relies on state-level data, while the latter two use county-level data. On balance, the models find a significant channel for state tax incentives on own-state economic activity and document the importance of interstate capital flows, a necessary element for meaningful tax competition. Whether state investment incentives are a zero-sum game among the states is less certain and depends on the definition of the set of competitive states.

WP 2006-48

Unemployment Insurance and the Uninsured

Tali Regev, *FRB San Francisco*

Under federal-state law workers who quit a job are not entitled to receive unemployment insurance benefits. To show how the existence of the uninsured affects wages and employment, I extend an equilibrium search model to account for two types of unemployed workers: those who are currently receiving unemployment benefits and for whom an increase in unemployment benefits reduces the incentive to work, and those who are not currently insured. For these, work provides an added value in the form of future eligibility, and an increase in unemployment benefits increases their willingness to work. Incorporating both types into a search model permits me to solve analytically for the endogenous wage dispersion and insurance rate in the economy. I show that, in general equilibrium when firms adjust their job creation margin, the wage dispersion is reduced and the overall effect of benefits can be signed: higher unemployment benefits increase average wages and decrease the vacancy-to-unemployment ratio.

WP 2006-49

State Investment Tax Incentives: What Are the Facts?

Robert S. Chirinko, *Emory University*
Daniel J. Wilson, *FRB San Francisco*

There is an ongoing debate in the U.S. among policymakers and the courts concerning the practical effects of state investment tax incentives. However, this debate often suffers from a lack of clear information on the extent of such incentives among states and how these incentives have evolved over time. This paper takes a first step toward addressing this shortcoming. Compiling information from all 50 states and the District of Columbia over the past 40 years, we are able to paint a picture of the variation in state investment tax incentives across states and over time. In particular, we document three stylized facts: (1) Over the last 40 years, state investment tax incentives have become increasingly large and increasingly common among states; (2) these incentives, as well as the level of the overall after-tax price of capital, are to a large extent clustered in certain regions of the country; and (3) states that enact investment tax credits tend to do so around the same time as their neighboring states.

WP 2006-50

Global Price Dispersion— Are Prices Converging or Diverging?

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

Forthcoming in
Journal of International Money and Finance.
See p. 79 for the abstract of this paper.

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

Government Consumption Expenditures and the Current Account

Michele Cavallo

Published in *Public Finance and Management* 7(1) (2007).

This paper focuses on the effects on the current account of changes to two distinct components of government consumption expenditures, expenditure on goods and expenditure on hours worked. I find that changes to government expenditure on hours do not directly affect the current account and that their effect is considerably smaller—one order of magnitude—than the effect of changes to government expenditure on goods. These findings indicate that considering government consumption as entirely expenditure on goods can lead to overestimating its role in accounting for movements in the current account balance.

Regional Economic Conditions and Aggregate Bank Performance

Mary C. Daly
John Krainer
Jose A. Lopez

Forthcoming in *Research in Finance.*

The idea that a bank's overall performance is influenced by the regional economy in which it operates is intuitive and broadly consistent with historical bank performance. Yet, micro-level research on the topic has borne mixed results, failing to find a consistent link between various measures of bank performance and regional economic variables. This paper attempts to reconcile the intuition with the micro-level data by aggregating bank performance, as measured by nonperforming loans, up to the state level. This level of aggregation reduces the influence of idiosyncratic bank effects sufficiently so as to examine more clearly the influence of state-level economic variables. We show that regional variables, such as employment growth and changes in real estate prices, are not particularly useful for predicting changes in bank performance, but that coincident indicators developed to track a state's gross output are quite useful. We find that these coincident indicators have a statistically significant and economically important influence on state-level aggregate bank performance. In addition, the coincident indicators potentially contribute to the out-of-sample forecasts of the relative riskiness of state-level bank portfolios, which should be of interest to bankers and bank supervisors.

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

Inequality and Poverty in the United States: The Effects of Rising Dispersion of Men's Earnings and Changing Family Behavior

Mary C. Daly
Robert G. Valletta

Published in *Economica* 73(289) (February 2006) pp. 75–98.

Using semiparametric density estimation techniques, we analyze the effect of rising dispersion of men's earnings and related changes in family behavior on increasing inequality in the distribution of family income in the United States. For the period 1969–1989, the growing dispersion of men's earnings and changing family structure can account for most of the rise in family income inequality. By contrast, the increase in labor force participation by women offset this trend. Inequality grew at a slower rate in the 1990s than in earlier decades, largely because of stabilization in the relative earnings of men from low-income families.

The Policy Preferences of the U.S. Federal Reserve

Richard Dennis

Published in *Journal of Applied Econometrics* 21(1) (January 2006) pp. 55–77.

In this paper I model and explain U.S. macroeconomic outcomes subject to the discipline that monetary policy is set optimally. Exploiting the restrictions that come from optimal policymaking, I estimate the parameters in the Federal Reserve's policy objective function together with the parameters in its optimization constraints. For the period following Volcker's appointment as chairman, I estimate the implicit inflation target to be around 1.4 percent and show that policymakers assigned a significant weight to interest rate smoothing. I show that the estimated optimal policy provides a good description of U.S. data for the 1980s and 1990s.

How Important Is Precommitment for Monetary Policy?

Richard Dennis, with
Ulf Söderström, *Bocconi University*

Published in *Journal of Money, Credit, and Banking* 38(4) (June 2006) pp. 847–872.

We quantify the welfare differential between precommitment and discretionary monetary policy in three estimated models of the U.S. economy by calculating the permanent deviation of inflation from target that in welfare terms is equivalent to moving from discretion to precommitment. Using a range of reasonable central bank preference parameters, this "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.

Safe and Sound Banking, 20 Years Later: What Was Proposed and What Has Been Adopted

Frederick T. Furlong
Simon H. Kwan

Forthcoming in
FRB Atlanta Economic Review.

In 1986, a task force of banking academics organized and sponsored by the American Bankers Association convened to examine the banking industry and the efficacy of its regulatory system. The group was charged with reviewing the problems of ensuring the safety and soundness of the banking system and evaluating a number of policy options to improve the efficiency, performance, and safety of the system by changing the structure of the deposit insurance system and the bank regulatory and supervisory process. The results of the work of the task force were published by the MIT Press as the book, *Perspectives on Safe and Sound Banking* (ed. Benston et al. 1986, the Report), which includes a set of principal options and recommendations. The purpose of this article is to assess the extent to which changes in public policy regarding depository institutions have been aligned with the recommendations of the Report. We find that over the past 20 years, several legislative initiatives and changes in regulations and the bank supervisory process have been in keeping with the specific recommendations of the Report or with the analytic framework underlying the recommendations. At the same time, other recommendations in the Report have not been taken up and some proposals rejected in the Report have been put in place by legislative and regulatory initiatives. Overall, public policy and private sector initiatives appear to have contributed to safer and sounder banking and thrift sectors over the past 20 years. Consistent with what we see as the main theme of the Report, a likely contributing factor is the more appropriate alignment of incentives for risk-taking among larger depository institutions. Developments affecting risk-taking by depository institutions likely include higher capitalizations, greater risk exposure of private sector stakeholders more generally, improvements in risk management, and supervision and regulation that is focused on overall risk.

Military Expenditure, Threats, and Growth

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

Published in *Journal of International Trade and Economic Development* 15(2) (June 2006) pp. 129–155.

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.

Pegged Exchange Rate Regimes—A Trap?

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

Forthcoming in
Journal of Money, Credit, and Banking.

This paper studies the empirical and theoretical association between the duration of a pegged exchange rate and the cost experienced upon exiting the regime. We confirm empirically that exits from pegged exchange rate regimes during the past two decades have often been accompanied by crises, the cost of which increases with the duration of the peg before the crisis. We explain these observations in a framework in which the exchange rate peg is used as a commitment mechanism to achieve inflation stability, but multiple equilibria are possible. We show that there are ex ante large gains from choosing a more conservative monetary authority, not only in order to mitigate the inflation bias from the well-known time inconsistency problem but also to steer the economy away from the high inflation equilibria. These gains, however, come at a cost in the form of the monetary authority's lesser responsiveness to output shocks. In these circumstances, using a pegged exchange rate as an anti-inflation commitment device can create a "trap" whereby the regime initially confers gains in anti-inflation credibility, but ultimately results in an exit occasioned by a big enough adverse real shock that creates large welfare losses to the economy. We also show that the more conservative is the regime in place and the larger is the cost of regime change, the longer will be the average spell of the fixed exchange rate regime, and the greater the output contraction at the time of a regime change.

Global Price Dispersion—Are Prices Converging or Diverging?

Reuven Glick, with
Paul Bergin,
University of California, Davis

Forthcoming in *Journal of International Money and Finance.*

This paper documents significant time variation in the degree of global price convergence over the last two decades. In particular, there appears to be a general U-shaped pattern with price dispersion first falling and then rising in recent years, a pattern which is remarkably robust across country groupings and commodity groups. This time variation is difficult to explain in terms of the standard gravity equation variables common in the literature, as these tend not to vary much over time or have not risen in recent years. However, regression analysis indicates that this time-varying pattern coincides well with oil price fluctuations, which are clearly time-varying and have risen substantially since the late 1990s. As a result, this paper offers new evidence on the role of transportation costs in driving international price dispersion.

A Model of Endogenous Nontradability and Its Implications for the Current Account

Reuven Glick, with
Paul Bergin,
University of California, Davis

Forthcoming in
Review of International Economics.

This paper analyzes how a model where goods are endogenously nontraded can help explain the relationship between the current account and real exchange rate fluctuations. We formulate a small open economy two-period model in which goods switch endogenously between being traded and nontraded. The model demonstrates how movements in the real exchange rate and real interest rate can impose significant costs on intertemporal trade. The model also shows that a variety of nonlinear relationships is possible between the current account and real exchange rate, depending on the relative transport costs and substitutability in preferences between goods. In contrast to recent work, our analysis implies that such costs of intertemporal trade may be a concern for many countries, not just those with large current account imbalances. Panel regression analysis of interest rate and current account data is consistent with our conclusions.

Tradability, Productivity, and International Economic Integration

Reuven Glick, with
Paul Bergin,
University of California, Davis

Forthcoming in *Journal of International Economics.*

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.

Productivity, Tradability, and the Long-Run Price Puzzle

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

Published in
Journal of Monetary Economics 53(8)
(November 2006) pp. 2,041–2,066.

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 (BS) effect. But looking back 50 years, this effect virtually disappears from the data. What is often assumed to be a universal property is actually quite specific to recent times, emerging a half century ago and growing steadily over time. What might potentially explain this historical pattern? We develop an updated BS model inspired by recent developments in trade theory, where a continuum of goods are differentiated by productivity and where tradability is endogenously determined. Firms experiencing productivity gains are more likely to become tradable and crowd out firms not experiencing productivity gains. As a result the usual BS assumption—that productivity gains are concentrated in the traded goods sector—emerges endogenously, and the BS effect on relative price levels likewise evolves gradually over time.

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

Published in
Review of Economics and Statistics 88(4)
(November 2006) pp. 698–714.

Are countries with unregulated capital flows more vulnerable to currency crises? Efforts to answer this question properly must control for self-selection bias, because countries with liberalized capital accounts may also have sounder 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.

Bonds or Loans? The Effect of Macroeconomic Fundamentals

Galina B. Hale

Published in *The Economic Journal* 117 (January 2007) pp. 196–215.

The costs of debt crises are not invariant to the foreign debt instrument composition: bank loans or bonds. The lending boom of the 1990s witnessed considerable variation over time and across countries in the debt instrument used by emerging market (EM) borrowers. This article tests how macroeconomic fundamentals affect the composition of international debt instruments used by EM borrowers. Analysis of micro-level data using an ordered probability model shows that macroeconomic fundamentals explain a significant share of variation in the ratio of bonds to loans for private borrowers but not for the sovereigns.

Rating Agencies and Sovereign Debt Rollover

Galina B. Hale, with
Mark Carlson,
Federal Reserve Board of Governors

Published in *The B.E. Journal of Macroeconomics* 6(2) (Topics), article 10.

In order to explore how credit ratings may affect financial markets, we analyze a global game model of debt rollover in which heterogeneous investors act strategically. We find that the addition of the rating agency has a nonmonotonic effect on the probability of default and the magnitude of the response of capital flows to changes in fundamentals. We also establish that introducing a rating agency can bring multiple equilibria to a market that otherwise would have a unique equilibrium.

The X-Efficiency of Commercial Banks in Hong Kong

Simon H. Kwan

Published in *Journal of Banking and Finance* 30(4) (April 2006) pp. 1,127–1,147.

Using the stochastic frontier approach to investigate the cost efficiency of commercial banks in Hong Kong, this paper found that the average X-efficiency of Hong Kong banks was about 16 to 30 percent of observed total costs. However, X-efficiency was found to decline over time, indicating that Hong Kong banks were operating closer to the cost frontier than before, consistent with technological innovations in the banking industry. Furthermore, the average large bank was found to be less efficient than the average small bank, but the size effect appears to be related to differences in portfolio characteristics among different size banks.

Using County-Based Markets to Support and Federal Reserve Markets to Implement Bank Merger Policy

Elizabeth S. Laderman, with
Steven J. Pilloff, *Federal Reserve Board of Governors*

Forthcoming in the *Journal of Competition Law and Economics.*

In this paper, we consider three issues raised by the apparent inconsistency between the current research practice of using county-based markets (metropolitan statistical areas (MSAs) and non-MSA counties) to investigate the validity of the theoretical underpinnings of bank merger policy and the current regulatory practice of using Federal Reserve (FR) banking markets, which often do not follow county lines, to implement that policy. Using a national sample of bank and thrift branch deposit data, we find that county-based areas cannot simply substitute for FR markets in the implementation of bank merger policy. For example, numerous potential mergers would raise competitive issues in county-based areas, but not in FR markets, and vice versa. We also conclude that, because of the relative difficulty of assembling demographic data for non-county-based areas, it is impractical to consistently use FR markets in bank merger policy research. However, we do find that, despite the inconsistencies, analysis that uses county-based areas is relevant for bank merger policy that is implemented with FR markets. For example, we find that profitability regression results using variables based on FR markets are similar to those found using variables based on MSAs and non-MSA counties.

Lock-in of Extrapolative Expectations in an Asset Pricing Model

Kevin J. Lansing

Published in
Macroeconomic Dynamics 10(3)
(June 2006) pp. 317–348.

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.

Tax Reform with Useful Public Expenditures

Kevin J. Lansing, with
Stephen P. Cassou,
Kansas State University

Published in
Journal of Public Economic Theory 8(4)
(October 2006) pp. 631–676.

This paper examines the economic effects of tax reform in an endogenous growth model that allows for two types of useful public expenditures; one type contributes to human capital formation while the other provides direct utility to households. We show that the optimal fiscal policy calls for full expensing of private investment, which shifts the tax base to private consumption. The efficient levels of public investment and public consumption relative to output are uniquely pinned down by parameters that govern both technology and preferences. In general, implementing the optimal fiscal policy requires a change in the size of government. If a tax reform holds the size of government fixed to satisfy a revenue-neutrality constraint, then the reform will be suboptimal; theory alone cannot tell us if welfare will be improved. For some calibrations of the model, we find that commonly proposed versions of revenue-neutral tax reforms can result in large welfare

gains. For other quite plausible calibrations, the exact same reform can result in tiny or even negative welfare gains as the revenue-neutrality constraint becomes more severely binding. Comparing across calibrations, we find that the welfare rankings of various reforms can change, depending on parameter values. Overall, our results highlight the uncertainty surrounding the potential welfare benefits of fundamental U.S. tax reform.

Maintenance Expenditures and Indeterminacy under Increasing Returns to Scale

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

Forthcoming in *International Journal of Economic Theory.*

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.

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

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

Published in
Journal of Banking and Finance 30(6)
(June 2006) pp. 1,687–1,711.

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 model 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 model provides a reasonable COE estimate, which is needed to impute costs and set prices for the Reserve Banks' payments business.

Monetary Policy Inertia: Fact or Fiction?

Glenn D. Rudebusch

Published in *International Journal of Central Banking* 2(4)
(December 2006) pp. 85–135.

Many interpret estimated monetary policy rules as suggesting that central banks conduct very sluggish partial adjustment of short-term policy interest rates. In contrast, others argue that this appearance of policy inertia is an illusion and simply reflects the spurious omission of important persistent influences on the actual setting of policy. Similarly, the real-world implications of the theoretical arguments for policy inertia are open to debate. However, empirical evidence on policy gradualism obtained by examining expectations of future monetary policy embedded in the term structure of interest rates is definitive and indicates that the actual amount of policy inertia is quite low.

The Macroeconomy and the Yield Curve: A Dynamic Latent Factor Approach

Glenn D. Rudebusch, with
Francis X. Diebold,
University of Pennsylvania
S. Boragan Aruoba,
University of Maryland

Published in
Journal of Econometrics 131(1–2)
(March 2006) pp. 309–338.

We estimate a model that summarizes the yield curve using latent factors (specifically, level, slope, and curvature) and also includes observable macroeconomic variables (specifically, real activity, inflation, and the monetary policy instrument). Our goal is to provide a characterization of the dynamic interactions between the macroeconomy and the yield curve. We find strong evidence of the effects of macro variables on future movements in the yield curve and evidence for a reverse influence as well. We also relate our results to the expectations hypothesis.

Macroeconomic Implications of Changes in the Term Premium

Glenn D. Rudebusch and
Eric T. Swanson, with
Brian Sack,
Macroeconomic Advisers, LLC

Forthcoming in
FRB St. Louis *Review.*

Linearized New Keynesian models and empirical no-arbitrage macro-finance models offer little insight regarding the implications of changes in bond term premiums for economic activity. We investigate these implications using both a structural model and a reduced-form framework. We show that there is no structural relationship running from the term premium to economic activity, but a reduced-form empirical analysis does suggest that a decline in the term premium has typically been associated with stimulus to real economic activity, which contradicts earlier results in the literature.

The Bond Yield "Conundrum" from a Macro-Finance Perspective

Glenn D. Rudebusch and
Eric T. Swanson, with
Tao Wu, *FRB Dallas*

Published in
Monetary and Economic Studies 24(S-1)
(December 2006), pp. 83–128.
http://www.imes.boj.or.jp/english/publication/mes/2006/abst/me24-s1-6.html

In 2004 and 2005, long-term interest rates remained remarkably low despite improving economic conditions and rising short-term interest rates, a situation that then Federal Reserve Board Chairman Alan Greenspan dubbed a "conundrum." We document the extent and timing of this conundrum using two empirical no-arbitrage macro-finance models of the term structure of interest rates. These models confirm that the recent behavior of long-term yields has been unusual—that is, it cannot be explained within the framework of the models. Therefore, we consider other macroeconomic factors omitted from the models and find that some of these variables, particularly declines in long-term bond volatility, may explain a portion of the conundrum. Foreign official purchases of U.S. Treasuries appear to have played little or no role.

Revealing the Secrets of the Temple: The Value of Publishing Central Bank Interest Rate Projections

Glenn D. Rudebusch
John C. Williams

Forthcoming in *Asset Prices and Monetary Policy,* ed. John Campbell. Chicago: University of Chicago Press.

The modern view of monetary policy stresses its role in shaping the entire yield curve of interest rates in order to achieve various macroeconomic objectives. A crucial element of this process involves guiding financial market expectations of future central bank actions. Recently, a few central banks have started to explicitly signal their future policy intentions to the public, and two of these banks have even begun publishing their internal interest rate projections. We examine the macroeconomic effects of direct revelation of a central bank's expectations about the future path of the policy rate. We show that, in an economy where private agents have imperfect information about the determination of monetary policy, central bank communication of interest rate projections can help shape financial market expectations and may improve macroeconomic performance.

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

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

Published in
Review of International Economics 14(4) (September 2006) pp. 683–697.

This paper models and tests the implications of institutional efficiency on the pattern of 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. Under these circumstances, FDI is more sensitive to increases in enforcement costs. We then test this prediction, comparing institutional efficiency levels for a large cross-section of countries in 1989 to subsequent FDI flows through the period of 1990–1999, finding 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.

Human Capital and Technology Diffusion

Mark M. Spiegel, with
Jess Benhabib, *New York University*

Published in *Handbook of Economic Growth,* eds. Philippe Aghion and Steven Durlauf. Amsterdam: North Holland, 2006, Chap. 13, pp. 935–966.

This paper generalizes the Nelson-Phelps catch-up model of technology diffusion. We allow for the possibility that the pattern of technology diffusion can be exponential, which would predict that nations would exhibit positive catch-up with the leader nation, or logistic, in which a country with a sufficiently small capital stock may exhibit slower total factor productivity growth than the leader nation. We derive a nonlinear specification for total factor productivity growth that nests these two specifications. We estimate this specification for a cross-section of nations from 1960 through 1995. Our results support the logistic specification and are robust to a number of sensitivity checks. Our model also appears to predict slow total factor productivity growth well. Of the 27 nations that we identify as lacking the critical human capital levels needed to achieve faster total factor productivity growth than the leader nation in 1960, 22 did achieve lower growth over the next 35 years.

Quantitative Easing and Japanese Bank Equity Values

Mark M. Spiegel, with
Takeshi Kobayashi, *Chukyo University*
Nobuyoshi Yamori, *Nagoya University*

Published in
Journal of the Japanese and International Economies 20(4) (December 2006) pp. 699–721.

One of the primary motivations offered by the Bank of Japan (BOJ) for its quantitative easing program—whereby it maintained a current account balance target in excess of required reserves, effectively pegging short-term interest rates at zero—was to maintain credit extension by the troubled Japanese financial sector. We conduct an event study concerning the anticipated impact of quantitative easing on the Japanese banking sector by examining the impact of the introduction and expansion of the policy on Japanese bank equity values. We find that excess returns of Japanese banks were greater when increases in the BOJ current account balance target were accompanied by "nonstandard" expansionary policies, such as raising the ceiling on BOJ purchases of long-term Japanese government bonds. We also provide cross-sectional evidence that suggests that the market perceived that the quantitative easing program would disproportionately benefit financially weaker Japanese banks.

Offshore Financial Centers: Parasites or Symbionts?

Mark M. Spiegel, with
Andrew Rose,
University of California, Berkeley

Forthcoming in *Economic Journal.*

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.

Determinants of Voluntary Bank Disclosure: Evidence from Japanese Shinkin Banks

Mark M. Spiegel, with
Nobuyoshi Yamori, *Nagoya University*

Published in *Japan's Great Stagnation,* eds. M. Hutchison and F. Westermann. Cambridge, MA: MIT Press, 2006, pp. 103–128.

Disclosure is widely regarded as a necessary condition for market discipline in a modern financial sector. However, the determinants of disclosure decisions are still unknown, particularly among banks. This paper investigates the determinants of disclosure by Japanese Shinkin banks in 1996 and 1997. This period is unique because disclosure of nonperforming loans was voluntary for Shinkin banks at this time. We find that banks with more serious bad loan problems, more leverage, and less competitive pressure and smaller banks were less likely to choose to disclose voluntarily. These results suggest that there may be a role for compulsory disclosure, as weak banks appear to avoid voluntary disclosure disproportionately.

Market Price Accounting and Depositor Discipline: The Case of Japanese Regional Banks

Mark M. Spiegel, with
Nobuyoshi Yamori, *Nagoya University*

Forthcoming in
Journal of Banking and Finance.

We examine the determinants of Japanese regional bank decisions concerning pricing unrealized losses or gains to market. We also examine the impact of these decisions on the intensity of depositor discipline, in the form of the sensitivity of deposit growth to bank financial conditions. To obtain consistent estimates of depositor discipline, we first model and estimate the bank pricing-to-market decision and then estimate the intensity of depositor discipline after conditioning for that decision. We find that banks were less likely to price to market the larger were their unrealized securities losses. We also find statistically significant evidence of depositor discipline among banks that elected to price their assets to market. Our results indicate that depositor discipline was more intense for the subset of banks that priced-to-market, suggesting that increased transparency may enhance depositor discipline.

Have Increases in Federal Reserve Transparency Improved Private Sector Interest Rate Forecasts?

Eric T. Swanson

Published in *Journal of Money, Credit, and Banking* 38(3)
(April 2006) pp. 791–820.

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.

The Relative Price and Relative Productivity Channels for Aggregate Fluctuations

Eric T. Swanson

Published in *The B.E. Journal of Macroeconomics* 6(1) (Contributions), article 10.

This paper demonstrates that sectoral heterogeneity itself, without additional bells or whistles, has first-order implications for the transmission of aggregate shocks to aggregate variables in an otherwise standard dynamic stochastic general equilibrium model. The effects of sectoral heterogeneity on this transmission are decomposed into two channels: a "relative price" channel and a "relative productivity" channel. The relative price channel results from changes in the relative prices of aggregates, such as investment vs. consumption, in response to a shock. The relative productivity channel arises from changes in the distribution of inputs across sectors. I show that, for standard multi-sector models, this latter channel is second-order, but becomes first-order if I consider a nontraded input such as capital utilization or introduce a wedge that thwarts the steady-state equalization of marginal products of a traded input across sectors. For reasonable parameterizations, the relative productivity channel causes aggregate productivity to vary procyclically in response to even nontechnological shocks, such as changes in government purchases.

Market-Based Measures of Monetary Policy Expectations

Eric T. Swanson, with
Refet Gürkaynak, *Bilkent University*
Brian Sack,
Macroeconomic Advisers, LLC

Forthcoming in *Journal of Business and Economic Statistics.*

A number of recent papers have used different financial market instruments to measure near-term expectations of the federal funds rate and the high-frequency changes in these instruments around Federal Open Market Committee announcements to measure monetary policy shocks. This paper evaluates the empirical success of a variety of financial market instruments in predicting the future path of monetary policy. All of the instruments we consider provide forecasts that are clearly superior to those of standard time series models at all of the horizons considered. Among financial market instruments, we find that federal funds futures dominate all the other securities in forecasting monetary policy at horizons out to six months. For longer horizons, the predictive power of many of the instruments we consider is very similar. In addition, we present evidence that monetary policy shocks computed using the current-month federal funds futures contract are influenced by changes in the timing of policy actions that do not influence the expected course of policy beyond a horizon of about six weeks. We propose an alternative shock measure that captures changes in market expectations of policy over slightly longer horizons.

Time-Varying Equilibrium Real Rates and Monetary Policy Analysis

Bharat Trehan, with
Tao Wu, *FRB Dallas*

Forthcoming in *Journal of Economic Dynamics and Control.*

Although it is generally recognized that the equilibrium real interest rate (ERR) varies over time, most recent work on policy analysis has been carried out under the assumption that this rate is constant. We show how this assumption can affect inferences about the conduct of policy in two different areas. First, if the ERR moves in the same direction as the trend growth rate (as is suggested by theory), the probability that an unperceived change in trend growth will lead to a substantial change in inflation is noticeably lower than is suggested by recent analyses (of inflation in the 1970s, for example) that assume a constant ERR. Second, if the monetary authority targets a time-varying ERR but the econometrician assumes otherwise, estimated policy rules will tend to exaggerate the degree of interest rate smoothing as well as the weight that the monetary authority places upon inflation.

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

Diego Valderrama

Forthcoming in *Journal of Economic Dynamics and Control.*

The cyclical components of U.S. macroeconomic time series exhibit significant nonlinearities. Standard equilibrium models of business cycles cannot replicate nonlinear features of the data. Applying the efficient method of moments (Gallant and Tauchen 1996) to build an algorithm that searches over the model's parameter space establishes the parameterization that best allows replication of all statistical properties of the data. The results show that under this parameterization, the model captures nonlinearities in investment but fails to account for observed properties of consumption.

The Ins and Outs of Poverty in Advanced Economies: Government Policy and Poverty Dynamics in Canada, Germany, Great Britain, and the United States

Robert G. Valletta

Published in *Review of Income and Wealth* 52, pp. 261–284.

Comparative analysis of poverty dynamics—transitions and persistence—can yield important insights about the nature of poverty and the effectiveness of alternative policy responses. This manuscript compares poverty dynamics in four advanced industrial countries (Canada, unified Germany, Great Britain, and the United States) for overlapping six-year periods in the 1990s, focusing on the impact of government policies. The data indicate that relative to measured cross-sectional poverty rates, poverty persistence is higher in North America than in Europe. Most poverty transitions, and the prevalence of chronic poverty, are associated with employment instability and family dissolution in all four countries. However, government tax-and-transfer policies are more effective at reducing poverty persistence in Europe than in North America.

Monetary Policy in a Low Inflation Economy with Learning

John C. Williams

Published in *Monetary Policy in an Environment of Low Inflation: Proceedings of the Bank of Korea International Conference 2006.* Seoul: The Bank of Korea, 2006, pp. 199–228.

In theory, monetary policies that target the price level, as opposed to the inflation rate, should be highly effective at stabilizing the economy and avoiding deflation in the presence of the zero lower bound on nominal interest rates. With such a policy, if the short-term interest rate is constrained at zero and the inflation rate declines below its trend, the public expects that policy will eventually engineer a period of above-trend inflation that restores the price level to its target level. Expectations of future monetary accommodation stimulate output and inflation today, mitigating the effects of the zero bound. The effectiveness of such a policy strategy depends crucially on the alignment of the public's and the central bank's expectations of future policy actions. In this paper, I consider an environment where private agents have imperfect knowledge of the economy and therefore continuously reestimate the forecasting model that they use to form expectations. I find that imperfect knowledge on the part of the public, especially regarding monetary policy, can undermine the effectiveness of price-level targeting strategies that would work well if the public had complete knowledge. For low inflation targets, the zero lower bound can cause a dramatic deterioration in macroeconomic performance with severe recessions occurring with alarming frequency. However, effective communication of the policy strategy that reduces the public's confusion about the future course of monetary policy significantly reduces the stabilization costs associated with the zero bound. Finally, the combination of learning and the zero bound implies the need for a stronger policy response to movements in the price level than would otherwise be optimal, and such a rule is effective at stabilizing both inflation and output in the presence of learning and the zero bound even with a low inflation target.

Learning and Shifts in Long-Run Productivity Growth

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

Forthcoming in
Journal of Monetary Economics.

An extensive literature has analyzed the macroeconomic effects of shocks to the *level* of aggregate productivity; however, there has been little corresponding research on sustained shifts in the *growth rate* of productivity. In this paper, we examine the effects of shocks to productivity growth in a dynamic general equilibrium model where agents do not directly observe whether shocks are transitory or persistent. We show that an estimated Kalman filter model using real-time data describes economists' long-run productivity growth forecasts in the United States extremely well and that filtering has profound implications for the macroeconomic effects of shifts in productivity growth.

Monetary Policy under Uncertainty in Micro-Founded Macroeconomic Models

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

Published in *NBER Macroeconomics Annual* 2005, eds. M. Gertler and K. Rogoff. Cambridge, MA: MIT Press, April 2006, pp. 229–287.

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.

Inflation Targeting under Imperfect Knowledge

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

Published in *Series on Central Banking, Analysis, and Economic Policies X: Monetary Policy under Inflation Targeting,* eds. F. Mishkin and K. Schmidt-Hebbel. Santiago, Chile: Central Bank of Chile, 2007.

A central tenet of inflation targeting is that establishing and maintaining well-anchored inflation expectations are essential. In this paper, we reexamine the role of key elements of the inflation targeting framework towards this end, in the context of an economy where economic agents have an imperfect understanding of the macroeconomic landscape within which the public forms expectations and policymakers must formulate and implement monetary policy. Using an estimated model of the U.S. economy, we show that monetary policy rules that would perform well under the assumption of rational expectations can perform very poorly when we introduce imperfect knowledge. We then examine the performance of an easily implemented policy rule that incorporates three key characteristics of inflation targeting: transparency, commitment to maintaining price stability, and close monitoring of inflation expectations, and find that all three play an important role in assuring its success. Our analysis suggests that

simple difference rules in the spirit of Knut Wicksell excel at tethering inflation expectations to the central bank's goal and in so doing achieve superior stabilization of inflation and economic activity in an environment of imperfect knowledge.
This article is published in this volume, pp. 1–24.

Monetary Policy with Imperfect Knowledge

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

Published in *Journal of the European Economic Association* 4(2–3) (April 2006).

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.

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*

Published in *A New Architecture for the U.S. National Accounts,* ed. by Dale Jorgenson, J. Steven Landefeld, and William Nordhaus. Chicago: University of Chicago Press, 2006, pp. 541–609 (Chapter 12).

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 underway 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.

Conferences

Labor Markets and the Macroeconomy

2006 Annual Pacific Basin Conference

Safe and Sound Banking: Past, Present, and Future

Financial Innovations and the Real Economy

The San Francisco Fed's Research Department organized four conferences in 2006.

The Department's annual macroeconomic conference, "Labor Markets and the Macroeconomy," focused on how labor market behavior can influence the broader macroeconomy. Three of the papers addressed aspects of wage bargaining and its consequences for wage and employment volatility over the business cycle; a fourth paper developed a model of labor market mobility. A fifth paper focused on trends in how people allocate their time. A final paper summarized the International Wage Flexibility project to understand the costs and benefits of inflation for the labor market.

Last year's Center for Pacific Basin Studies Annual Conference brought together ten papers on a variety of international topics, including the determinants of the U.S. current account deficit, the interest rate parity puzzle, monetary integration in East Asia, and other developments in Asia.

The "Safe and Sound Banking" conference evaluated how recommendations from a 1986 task force, published as *Perspectives on Safe and Sound Banking,* have fared during the past 20 years: How many have been adopted in one form or another, how many have been rejected, and how many are still under consideration? The conference also updated the menu of recommendations to deal with the challenges confronting the banking system over the next 20 years.

The Bank's Center for the Study of Innovation and Productivity (CSIP) sponsored the conference "Financial Innovations and the Real Economy." The conference focused on three areas: how innovations in financial markets affect consumer spending and borrowing; how new financial instruments help firms mitigate risk but may also increase the risk to the overall financial system; and how financial innovations affect business borrowing behavior, which may have implications for real economic variables such as employment and output.

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.*

Labor Markets and the Macroeconomy

Federal Reserve Bank of San Francisco
March 3–4, 2006

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/0603/index.html

Keynote Speaker	Alan Krueger, *Princeton University*
The Interaction of Labor Markets and Inflation: Analysis of Micro Data from the International Wage Flexibility Project	William Dickens, *Brookings Institution* Lorenz Goette, *University of Zurich* Erica Groshen, *FRB New York* Steinar Holden, *University of Oslo* Julian Messina, *European Central Bank* Jarkko Turunen, *European Central Bank* Melanie Ward, *European Central Bank* Mark Schweitzer, *FRB Cleveland* Discussants: Paul Beaudry, *University of British Columbia* Jeffrey Fuhrer, *FRB Boston*
Measuring Trends in Leisure	Mark Aguiar, *FRB Boston* Erik Hurst, *University of Chicago* Discussants: Valerie Ramey, *University of California, San Diego* Justin Wolfers, *University of Pennsylvania*
The Labor Market and Macro Volatility: A Nonstationary General-Equilibrium Analysis	Robert Hall, *Stanford University* Discussants: Russell Cooper, *University of Texas, Austin* Martin Eichenbaum, *Northwestern University*
Mismatch	Robert Shimer, *University of Chicago* Discussants: Eva Nagypal, *Northwestern University* Garey Ramey, *University of California, San Diego*
Unemployment Fluctuations with Staggered Nash Wage Bargaining	Mark Gertler, *New York University* Antonella Trigari, *Bocconi University* Discussants: Lawrence Christiano, *Northwestern University* Carl Walsh, *University of California, Santa Cruz*
Cyclical Wages in a Search and Bargaining Model with Large Firms	Julio Rotemberg, *Harvard University* Discussants: V.V. Chari, *University of Minnesota* Thomas Lubik, *Johns Hopkins University*

2006 Annual Pacific Basin Conference

Federal Reserve Bank of San Francisco
June 16–17, 2006

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/0606/agenda.pdf

Keynote Speech: Currency Manipulation and IMF Reforms

Morris Goldstein, *Institute for International Economics*

Incomplete Information Processing: A Solution to the Forward Discount Puzzle

Philippe Bacchetta, *University of Lausanne*
Eric van Wincoop, *University of Virginia*

Discussants: Eric Fisher, *California Polytechnic State University*
Richard Lyons, *University of California, Berkeley*

The U.S. Current Account Deficit and the Expected Share of World Output

Charles Engel, *University of Wisconsin*
John Rogers, *Federal Reserve Board of Governors*

Discussants: Maurice Obstfeld, *University of California, Berkeley*
Mario Crucini, *Vanderbilt University*

Global Current Account Adjustment: A Decomposition

Michael Devereux, *University of British Columbia*
Amartya Lahiri, *University of British Columbia*

Discussants: Christopher Gust, *Federal Reserve Board of Governors*
Ken Kasa, *Simon Fraser University*

A Quantitative Analysis of China's Structural Transformation

Robert Dekle, *University of Southern California*
Guillaume Vandenbroucke, *University of Southern California*

Discussants: Chang-Tai Hsieh, *University of California, Berkeley*
Kar-yiu Wong, *University of Washington*

Panel Discussion on Asian Integration

Mark Spiegel, *FRB San Francisco*
Peter Kenen, *Princeton University*
Sergio Schmukler, *World Bank*
Peter Petri, *Brandeis University*

Savings and Interest Rates in Japan: Why They Have Fallen and Why They Will Remain Low

R. Anton Braun, *University of Tokyo*
Daisuke Ikeda, *Bank of Japan*
Douglas Joines, *University of Southern California*

Discussants: David Weinstein, *Columbia University*
Michael Hutchison, *University of California, Santa Cruz*

Exchange Rate Effects on China's Trade: An Interim Report	Jaime Marquez, *Federal Reserve Board of Governors* John W. Schindler, *Federal Reserve Board of Governors* Discussants: James Harrigan, *FRB New York* Susan M. Collins, *Georgetown University*
Dual Labor Markets and Business Cycles	David Cook, *Hong Kong University of Science and Technology* Hiromi Nosaka, *Kansai University* Discussants: Amartya Lahiri, *University of British Columbia* Diego Valderrama, *FRB San Francisco*

Safe and Sound Banking: Past, Present, and Future

Federal Reserve Bank of San Francisco
August 17–18, 2006

Jointly sponsored by the Federal Reserve Banks of San Francisco and Atlanta and the founding editors of the Journal of Financial Services Research

Some papers presented at this conference can be found on the website
http://www.frbsf.org/economics/conferences/0608/index.html

Keynote Speaker

Randall Kroszner, *Federal Reserve Board of Governors*

Safe and Sound Banking, 20 Years Later: What Was Proposed and What Has Been Adopted

Fred Furlong, *FRB San Francisco*
Simon Kwan, *FRB San Francisco*

Discussants: James Wilcox, *University of California, Berkeley*
Eric Rosengren, *FRB Boston*

The Emerging Dominance of Transactions Banking and Its Implications for the Banking System

Robert DeYoung, *Federal Deposit Insurance Corporation*

Discussants: Loretta Mester, *FRB Philadelphia*
Myron Kwast, *Federal Reserve Board of Governors*

Supervising Bank Safety and Soundness: Some Open Issues

Mark Flannery, *University of Florida*

Discussants: Harvey Rosenblum, *FRB Dallas*
Dwight Jaffee, *University of California, Berkeley*

Panel Discussion: Regulatory Reform Issues— Key Concerns and Policy Implications

Simon Kwan, *FRB San Francisco*
George Benston, *Emory University*
Robert Eisenbeis, *FRB Atlanta*
Paul Horvitz, *University of Houston*
Edward Kane, *Boston College*
George Kaufman, *Loyola University*

Financial Innovations and the Real Economy

Federal Reserve Bank of San Francisco
November 16–17, 2006

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

Papers presented at this conference can be found on the website
http://www.frbsf.org/economics/conferences/0611/index.html

The Macroeconomic Transition to High Household Debt	Jeffrey Campbell, *FRB Chicago* Zvi Hercowitz, *Tel Aviv University* Discussants: Eric Hurst, *University of Chicago* Richard Rogerson, *Arizona State University*
Financial Innovation and the Great Moderation: What Do Household Data Say?	Karen Dynan, *Federal Reserve Board of Governors* Douglas Elmendorf, *Federal Reserve Board of Governors* Daniel Sichel, *Federal Reserve Board of Governors* Discussants: Chris Carroll, *Johns Hopkins University* Paul Willen, *FRB Boston*
The Supply and Demand Side Impacts of Credit Market Information	Craig McIntosh, *University of California, San Diego* Alain de Janvry, *University of California, Berkeley* Elisabeth Sadoulet, *University of California, Berkeley* Discussants: Steve Boucher, *University of California, Davis* Atif Mian, *University of Chicago*
Has the Development of the Structured Credit Market Affected the Cost of Corporate Debt?	Adam Ashcraft, *FRB New York* Joao Santos, *FRB New York* Discussants: Simon Gilchrist, *Boston University* Christine Parlour, *University of California, Berkeley*
Financial Innovation, Macroeconomic Stability, and Systemic Crises	Prasanna Gai, *Bank of England* Sujit Kapadia, *Bank of England* Stephen Millard, *Bank of England* Ander Perez, *London School of Economics* Discussants: Arvind Krishnamurthy, *Northwestern University* William Nelson, *Federal Reserve Board of Governors*
Financial Innovations and Macroeconomic Volatility	Urban Jermann, *The Wharton School* Vincenzo Quadrini, *University of Southern California* Discussants: Wouter den Haan, *University of Amsterdam* Giorgio Primiceri, *Northwestern University*

Financial Innovations, Idiosyncratic Risk, and the Joint Evolution of Real and Financial Volatilities	Christina Wang, *FRB Boston* Discussants: Brad DeLong, *University of California, Berkeley* Richard Rosen, *FRB Chicago*

Labor Markets and the Macroeconomy: Conference Summary

Reprinted from FRBSF Economic Letter *2006-17, July 21, 2006.*

This *Economic Letter* summarizes the papers presented at a conference on "Labor Markets and the Macroeconomy" held at the Federal Reserve Bank of San Francisco on March 3 and 4, 2006.

This year's conference brought academic researchers and policymakers together to discuss six research papers that focused on labor markets and how labor market behavior can influence the broader macroeconomy.

Three of the papers addressed aspects of wage bargaining and its consequences for wage and employment volatility over the business cycle. Hall studied a suite of models to understand why employment and unemployment are so volatile. Rotemberg showed that shocks to pricing power can help explain why wages are not strongly correlated with the business cycle, using a model in which large firms bargain simultaneously with many workers. Gertler and Trigari also sought to understand why wages are relatively smooth and employment fluctuations are relatively large over the business cycle, showing that a model with staggered multiperiod wage bargaining can replicate these features of the data.

Shimer developed a model of labor market mobility, one in which some workers may move among labor markets in the event that they become unemployed. With some unemployed workers leaving labor markets that have too few jobs, Shimer showed that the model could capture the strong negative correlation between the unemployment rate and the vacancy rate found in U.S. data.

Aguiar and Hurst looked at five decades of time-use surveys to uncover trends in how people allocate their time. They found that between 1965 and 2003, leisure time for men has increased by six to eight hours per week while leisure time for women has increased by four to eight hours per week.

The sixth paper summarized the International Wage Flexibility project, an ambitious undertaking that includes contributions from over 40 researchers, whose goal is to collect and document cross-country micro-level data on wages and earnings in an effort to understand the costs and benefits of inflation for the labor market.

The labor market and macro volatility

An important question in macroeconomics is why employment and unemployment are so volatile. This volatility cannot be explained adequately using standard real business cycle models, models in which labor and product markets are assumed to clear and are perfectly competitive. More generally, in real business cycle models, quantities, such as hours worked, are not that volatile because wages and prices do much of the adjusting needed to clear markets following shocks. However, as shown by Shimer (2005), the standard matching model, in which workers search and then bargain with firms over wages before forming a match, with the firm making a take-it-or-leave-it offer to the worker, also fails to explain why employment and unemployment are so volatile.

Hall studies two mechanisms that may make employment and unemployment more volatile. The first mechanism allows for a form of equilibrium wage stickiness in which the outcome of the wage bargain between a firm and a worker is a combination of the Nash-bargain wage and a constant wage. The second mechanism replaces Nash bargaining with a form of alternating offers. Thus, rather than having one party make a take-it-or-leave-it offer to be accepted or rejected, as occurs with Nash bargaining, an offer by one party can be countered by an alternative offer by the other party, but at the cost of a longer bargaining period. With either of these modifications to the standard search-and-matching model, Hall showed that employment and unemployment became more volatile. Underlying these increases in the volatilities of employment and unemployment is the fact that both mechanisms serve to make wages "sticky," that is, less responsive to shocks. The implication of this wage stickiness is that employment and unemployment must do more of the adjusting needed for the labor market to clear.

Unemployment fluctuations with staggered wage-setting

Gertler and Trigari also take up the issue of why employment and unemployment are so volatile in the context of a fully specified macroeconomic model in which workers and firms bargain before making a match. They note that the main problem with the standard matching model, with period-by-period Nash bargaining over wages by workers and firms, is that wages are too volatile and too procyclical, with wage adjustments over the business cycle moderating firms' demand for labor. Their approach to correct this problem with the standard matching model is to introduce staggered Nash wage bargaining, a form of wage rigidity that limits the flexibility of wages and the role of employment and unemployment adjustments in labor market clearing.

With staggered Nash wage bargaining, a proportion of randomly selected firms negotiate a wage contract with its existing workforce with the negotiated wage in force until a renegotiation occurs. Workers hired between negotiation dates receive the wage prevailing for that firm. A consequence of this bargaining arrangement is that the aggregate wage rate becomes less responsive to shocks, such as those to productivity. Building this labor market structure into an otherwise standard business cycle model, the authors show that their model can replicate important features of U.S. macroeconomic data. Specifically, their model is able to capture the volatility in wages, unemployment, vacancies, and labor productivity well, but does less well with respect to the volatility of employment.

Wage cyclicality in a search-and-bargaining model

Rotemberg also takes as motivation the fact that the standard search-and-matching model and models with competitive labor markets generate too much wage volatility and too little employment and unemployment volatility relative to the data but, departing from previous exercises, Rotemberg analyzes a search-and-matching model in which firms are large and have pricing power. In his model, firms are able to post multiple job vacancies cheaply, but they must contend with shocks to their pricing power in addition to productivity shocks.

The fact that large firms can cheaply advertise multiple job vacancies means that workers have less bargaining power, so a positive productivity shock does not translate into a large wage increase. As a consequence, wages become less volatile and less procyclical than in the standard search-and-matching model. Similarly, a shock that lowers a firm's pricing power will cause that firm to increase its output and employment, and the rise in employment will damp or even lower real wages. Through these mechanisms, and without introducing any wage rigidity, real wages become less volatile and less procyclical, while the volatilities of employment and unemployment are magnified.

Mismatch

In models with perfectly competitive labor markets the real wage adjusts so that the demand and supply for labor are in balance. Disturbances, such as technology and oil price shocks, change the wage rate and the number of hours worked, but they do not cause unemployment. Of course, unemployment is an important feature of the economic landscape in actual economies, and so, too, are job vacancies, but why do unemployment and job vacancies coexist? The paper by Shimer advances an answer to this important question.

In Shimer's model, workers are associated with particular jobs and with particular geographic locations, so a vacancy for a dental technician cannot be filled by an unemployed carpenter and a vacancy in Phoenix cannot be filled by someone unemployed living in Atlanta. In this framework, unemployment and vacancies can coexist due to a mismatch between the skills and geographic location of the unemployment and the skills and geographic location of available jobs. Of course, there is some mobility between labor markets in actual economies, and the model allows for this.

With this apparatus, Shimer shows that the model can replicate important features of labor market outcomes. The model allows unemployment and vacancies to coexist and it is able to replicate closely the Beveridge curve, the strong inverse relationship between the unemployment rate and the vacancy rate found in U.S. macroeconomic data. In addition, the model predicts that an increase in the ratio of the vacancy rate to the unemployment rate should lead to an increase in the job-finding rate, which is also qualitatively consistent with U.S. macroeconomic data.

Measuring trends in leisure

Understanding how and why people allocate their time between work and leisure is important for understanding both labor market outcomes and household well-being. While it is possible to measure the time someone spends working for a firm it is much more difficult to measure leisure time. The simplest approach is to simply attribute all time not spent working in a formal labor market to leisure. Of course, this approach ignores the fact that people can spend a lot of time working at home on "home production." Thus, time spent watching TV or playing cards might reasonably be considered leisure time, but time spent mowing the lawn or cleaning the drapes should probably be attributed to home production, not leisure.

To investigate how leisure time has changed over time, Aguiar and Hurst study data from time-use surveys that reveal how much time respondents spend in market work and how they allocate their time outside of market work. Among other results, after adjusting for changing demographics, they find that between 1965 and 2003, leisure has increased by 7.9 hours for men and by 6.0 hours for women. Interestingly, for men this increase in leisure time has come about through a decline in market work, while for women the increased leisure time has come about through a large decline in time allocated to home production and has occurred despite a rise in time spent in market work.

The interaction between labor markets and inflation

The interaction between wage changes and inflation is an important one for macroeconomics and for monetary policy. For example, rigidities in nominal wages make price adjustment, inflation, and, hence, monetary policy, important for employment outcomes. Dickens et al. study the evidence on nominal and real wage rigidity across a wide set of countries.

This study analyzes 31 different data sets, covering 16 countries and 27 million people, on changes over time in individuals' wages or earnings. Applying a common protocol to all 31 data sets and correcting the data for measurement error, the authors find that dispersion in nominal wage changes across individuals is positively correlated with the level of inflation, a feature that is consistent with downward rigidity in nominal wages and with distortions caused by inflation. More generally, to a greater or lesser extent, the authors find evidence for both nominal wage rigidity and real wage rigidity in nearly every country. In particular, nominal wage rigidity was most prevalent in Portugal, followed by the U.S., and least prevalent in Germany, while real wage rigidity was most prevalent in Sweden, followed by Finland, and least prevalent in Greece.

Richard Dennis
Economist

John C. Williams
Senior Vice President and Advisor

Conference papers

Papers are available in pdf format at
http://www.frbsf.org/economics/conferences/0603/index.html

Aguiar, Mark, and Erik Hurst. 2006. "Measuring Trends in Leisure: The Allocation of Time over Five Decades." National Bureau of Economic Research Working Paper 12082.

Dickens, William, Lorenz Goette, Erica Groshen, Steinar Holden, Julian Messina, Mark Schweitzer, Jarkko Turunen, and Melanie Ward. 2005. "The Interaction of Labor Markets and Inflation: Micro Evidence from the International Wage Flexibility Project." Unpublished manuscript.

Gertler, Mark, and Antonella Trigari. 2006. "Unemployment Fluctuations with Staggered Nash Wage Bargaining." Unpublished manuscript.

Hall, Robert. 2005. "The Labor Market and Macro Volatility: A Nonstationary General-Equilibrium Analysis." National Bureau of Economic Research Working Paper #11684.

Rotemberg, Julio. 2006. "Cyclical Wages in a Search-and-Bargaining Model with Large Firms." Unpublished manuscript.

Shimer, Robert. 2005. "Mismatch." National Bureau of Economic Research Working Paper 11888.

Reference

Shimer, Robert. 2005. "The Cyclical Behavior of Equilibrium Unemployment and Vacancies." *American Economic Review* 95, pp. 25–49.

2006 Annual Pacific Basin Conference: Summary

Reprinted from FRBSF Economic Letter *2007-04, February 9, 2007.*

This *Economic Letter* summarizes the papers presented at the annual Pacific Basin Conference held at the Federal Reserve Bank of San Francisco on June 16 and 17, 2006, under the sponsorship of the Bank's Center for Pacific Basin Studies (CPBS).

This year's Pacific Basin conference brought together ten papers on a variety of international topics, including the determinants of the U.S. current account deficit, the interest rate parity puzzle, monetary integration in East Asia, and other developments in Asia.

U.S. current account deficit

The rising current account deficit in the U.S., now running at about 7 percent of GDP, has attracted considerable attention in recent years. Two papers at the conference analyzed the determinants of the U.S. current account position.

Charles Engel of the University of Wisconsin and John H. Rogers at the Board of Governors of the Federal Reserve System investigate the possibility that the U.S. current account deficit, large as it is, may nonetheless be the outcome of optimizing behavior. They develop a simple model in which a country's current account is determined by the expected discounted present value of its future share of world GDP relative to its current share of world GDP. They show that higher expected output growth in the U.S. relative to that abroad can generate large deficits, as the high U.S. output path supports increased lending from foreigners with which to finance these deficits. Moreover, under reasonable assumptions about future U.S. GDP growth relative to other countries, a high U.S. current account deficit may be sustainable for some time to come. Correspondingly, they foresee little depreciation of the real value of the dollar in the near term, though this conclusion is sensitive to assumptions about tastes and technology.

Michael Devereux, Amartya Lahiri, and Ke Pang at the University of British Columbia try to throw light on the value of different explanations for the U.S. current account deficit. For instance, it may reflect higher underlying productivity growth in the U.S., as Engel and Rogers argue, or it may simply reflect a trend increase in U.S. consumption and fall in saving, independent of the path of productivity. To identify the determinants of the deficit, Devereux et al. use a standard two-country general equilibrium model and obtain quantitative estimates of various "wedges," that is, the extent to which various relationships associated with the model, such as the conditions for optimal consumption, employment, investment, and production, deviate from actual data. They then feed each of these measured wedges into the model and simulate the counterfactual path of the current account in order to determine the contributions of each to the overall external imbalance of the U.S. They find that a combination of higher U.S. productivity and consumption than abroad does the best job in accounting for most of the measured movement of the U.S. current account.

Interest rate parity

The uncovered interest rate parity equation relationship is a cornerstone of most models in international macroeconomics. This relation predicts that a country with an interest rate higher than abroad should be associated with expected depreciation of its currency in order to equalize the returns to investing in foreign versus domestic assets. In fact, it has long been a puzzle why this relation does not hold empirically, in that relatively higher domestic interest rates have been found to be followed by ongoing currency appreciations.

Philippe Bacchetta of the University of Lausanne and Eric van Wincoop at the University of Virginia investigate the extent to which incomplete information processing by financial investors can explain this puzzle. Most models assume that all investors instantaneously incorporate all new information into their portfolio decisions. The authors consider two forms of incomplete information processing: (i) infrequent portfolio adjustment by investors, where investors make changes in their portfolios slowly over time, and (ii) partial information processing, where investors use only a subset of all available information. They argue that evidence on the costs of portfolio management can justify such incomplete processing behavior and that it explains the interest parity puzzle. In their framework, an increase in the domestic interest rate leads to an increase in demand for the domestic currency and therefore an initial appreciation of the currency as well. But when investors make infrequent portfolio decisions based on limited information, they will continue to buy the currency as time goes on. This can cause a continuing appreciation of the currency.

China growth and trade balance

Since 1978 China's GDP has grown almost 10 percent per year, while its GDP per capita has grown almost 6 percent annually. At the same time, there has been a noticeable transformation of the economy, with the share of workers in agriculture decreasing from over 70 percent to less than 50 percent.

Robert Dekle and Guillaume Vandenbroucke at the University of Southern California formulate a quantitative, general equilibrium growth model to try to capture China's recent growth and structural transformation. Their model distinguishes three sectors: the agricultural sector, the nonagricultural private sector, and the nonagricultural public (government) sector. They use this model to measure the relative contributions of productivity improvements and the transfer of labor out of agriculture into high-productivity activities. They find that between 1978 and 1995 the reallocation of labor from agriculture to nonagriculture accounted for over one-third of China's average annual increase in output per capita (that is, 2.0 percentage points of total labor productivity growth of 5.2 percent), while productivity growth in the public sector and private nonagricultural sector contributed 1.6 and 0.6 percentage points, respectively. Over the more recent period 1996–2003, however, the reallocation of labor from the public to the private nonagricultural sector accounted for a significant part of growth, contributing 1 percentage point of total labor productivity growth of 5.8 percent per year, while public and private nonagricultural sector productivity growth contributed 1.0 and 2.7 percentage points, respectively.

China's current account surplus as a percent of GDP rose from 2.4 percent in 2002 to 7.2 percent in 2005 and is on pace to rise even higher in 2006. Some have attributed this development to an undervalued currency that makes Chinese goods unduly cheap in world markets, such as the United States. However, it is unclear how much even a substantial appreciation of the renminbi would work to reduce China's trade imbalance.

Jaime Marquez and John Schindler at the Board of Governors analyze the response of China's trade to a change in the renminbi's value. They first point out that such an exercise is hampered by two factors: first, the data available on the prices of China's traded goods are limited, and, second, the estimation sample includes the period of China's transformation from a centrally planned economy to a market-oriented system. To address these limitations, they use a more sensible sample period (1997–2004), and assess the impact of changes in the real effective value of the renminbi on the shares of China's exports and imports in world trade, thereby avoiding the need for trade price proxies to compute quantity measures of trade. Marquez and Schindler develop an empirical model explaining the shares of China's exports and imports in world trade in terms of the real effective value of the renminbi. The estimation results suggest that a 10 percent real appreciation of the renminbi lowers the share of aggregate Chinese exports by a half of a percentage point. The same appreciation lowers the share of aggregate imports by about a tenth of a percentage point.

Monetary integration in Asia

Three panelists discussed monetary integration in East Asia. Many countries in East Asia are planning or negotiating regional trade agreements, and there is increasing interest in financial integration and a common currency. Peter Kenen at the Council on Foreign Relations and Princeton University and Ellen Meade at American University describe the history of increasing monetary integration within the region since the Asia financial crisis, as well as policy options ahead, ranging from independently floating currencies to a monetary union. They argue that an Asian monetary union is unlikely to span the whole region, primarily because of the continued lack of willingness to promote formal delegation of national authority to common institutions. They foresee that China and Japan, as the largest countries in the region, are likely to keep their national currencies, while the ASEAN countries or a subset of its members might be able to form a monetary union of their own. Peter Petri of Brandeis University shows that East Asia interdependence, defined as the preference for trade among regional partners, actually fell in the 1980s, but has been growing in the last decade. He points out that most of this increasing interdependence is attributable to trade relationships fostered by greater specialization in production.

Philip Lane of Trinity College in Dublin and Sergio Schmukler at the World Bank highlight several features that characterize the international financial integration of China and India. First, these countries are large holders of official reserves, while having only a small global share of privately held external assets and liabilities (with the exception of China's foreign direct investment liabilities). Second, their international balance sheets are highly asymmetric: both countries primarily hold low-return foreign reserves on the asset side, together with higher-yielding equity and debt liabilities. Third, China and India have improved their net external positions over the last decade, although, based on their level of economic development, neoclassical models would predict them to be large net borrowers. Lane and Schmukler project that domestic financial reforms and capital account liberalization in both countries will lead them to restructure their international balance sheets and become major international investors, with important consequences for global private financial markets.

Other developments in Asia

R. Anton Braun at the University of Tokyo, Daisuke Ikeda at the Bank of Japan, and Douglas Joines at the University of Southern California investigate the explanation for recent declines in Japanese saving rates and interest rates. They consider several explanations, including changes in fertility rates, changes in survival rates, and changes in technology. They explore the empirical relevance of these factors using a computable dynamic overlapping generations model. They find that the combined effects of an aging population and slower total factor productivity growth successfully explain the declines in Japan's saving rate and after-tax real interest rate during the 1990s.

David Cook at the Hong Kong University of Science and Technology and Hiromi Nosaka at Kansai University analyze the behavior of labor markets in Indonesia at the time of the 1997–1998 Asia crisis. They try to explain why output in Indonesia (and other affected countries as well) fell, even as employment remained relatively constant during the crisis. They do so with a dynamic general equilibrium model of a small open developing economy in which labor markets include both urban employment and rural employment. They show how an external financial shock can lead to migration of labor from the productive urban sector of the economy to the less productive rural sector, leaving overall employment unchanged even as aggregate output declines.

Reuven Glick
Group Vice President

Conference papers

Papers are available in pdf format at
http://www.frbsf.org/economics/conferences/0606/agenda.pdf

Bacchetta, Philippe, and Eric van Wincoop. "Incomplete Information Processing: A Solution to the Forward Discount Puzzle."

Braun, R. Anton, Daisuke Ikeda, and Douglas Joines. "Saving and Interest Rates in Japan: Why They Have Fallen and Why They Will Remain Low."

Cook, David, and Hiromi Nosaka. "Dual Labor Markets and Business Cycles."

Dekle, Robert, and Guillaume Vandenbroucke. "A Quantitative Analysis of China's Structural Transformation."

Devereux, Michael, Amartya Lahiri, and Ke Pang. "Global Current Account Adjustment: A Decomposition."

Engel, Charles, and John H. Rogers "The U.S. Current Account Deficit and the Expected Share of World Output."

Kenen, Peter, and Ellen Meade. "Monetary Integration in East Asia: Why East Asia Is Different and Why That Matters."

Lane, Philip, and Sergio Schmukler. "The International Financial Integration of China and India."

Marquez, Jaime, and John Schindler. "Exchange-Rate Effects on China's Trade: An Interim Report."

Petri, Peter. "Is East Asia Becoming More Interdependent?"

Safe and Sound Banking: Past, Present, and Future

Reprinted from "Safe and Sound Banking, 20 Years Later"
FRBSF Economic Letter *2006-26, October 6, 2006*

The U.S. banking industry has enjoyed record profitability and very low failure rates in recent years. This scenario is a welcome contrast to the 1980s, when turbulent economic conditions, the crisis in the savings and loan industry, and a highly volatile interest rate environment put the banking industry under severe stress.

In those dark days, analysts and policymakers debated a variety of ways to address the factors that arguably precipitated the dire situation. Among the most comprehensive and influential sets of proposals was one developed by a task force of five academic researchers that was organized and sponsored by the American Bankers Association in 1986. In their Report (published as *Perspectives on Safe and Sound Banking: Past, Present, and Future,* Benston et al. 1986), they identified the underlying problem as follows: the administration of the federal safety net at that time, especially deposit insurance, provided incentives for excessive risk-taking by insured depository institutions. The Report also recommended measures that could reduce the overall risk exposure of the deposit insurance system, align accountabilities for the administration of deposit insurance with those for prudential supervision and regulation, and help ensure that the deposit insurance system would be compensated for its risk exposure. To this end, the Report focused on changes in regulatory policies dealing with a wide range of issues including deposit insurance, lender-of-last-resort, market discipline, bank examinations and supervision, and expansion of banking powers.

On the twentieth anniversary of this Report, the Federal Reserve Banks of San Francisco and Atlanta, along with the founding editors of the *Journal of Financial Services Research,* held a conference named after the Report (http://www.frbsf.org/economics/conferences/0608/). This *Economic Letter* (based on Furlong and Kwan 2006) highlights four major areas of banking reform during the period, reviewing both the analysis and recommendations in the Report and comparing them to the actual outcomes.

Deposit insurance

Deposit insurance reform was viewed as an especially critical area for ensuring the safety and soundness of the U.S. banking system. A key shortcoming was the so-called moral hazard problem, in which the pricing and administration of deposit insurance distort depository institutions' incentive for taking risk. To remove the distortions and ensure that the deposit insurance system would be appropriately compensated for its risk exposure, the Report recommended using risk-related charges for coverage, including risk-related deposit insurance premiums and risk-adjusted capital standards. In addition, the Report argued that the risk assessment should be based on the consolidated banking organization—not just the bank subsidiaries; furthermore, it should also include off-balance-sheet risks.

Consistent with these recommendations, the Federal Deposit Insurance Corporation Improvement Act (FDICIA) of 1991 required the FDIC to establish a risk-based assessment system. However, the Deposit Insurance Funds Act of 1996 prohibited the FDIC from charging well-managed and well-capitalized institutions deposit insurance premiums when the deposit insurance fund is at or above the Designated Reserve Ratio (DRR). As a result, the risk-based assessment system, bounded by the DRR requirement, did not have a meaningful sensitivity to risks. Indeed, in 2005, only about 6 percent of the almost 8,000 commercial banks paid deposit insurance premiums. The Federal Deposit Insurance Reform Act of 2005 (FDIRA) grants the FDIC more discretion to price deposit insurance according to risk by replacing the fixed DRR with a range.

In keeping with the Report's recommendations on risk-based capital requirements, the first Basel Capital Accord (1988) formally introduced them and included extending them to off-balance-sheet activities. The Accord has since been found to be vulnerable to capital arbitrage, which has been addressed in part by several supervisory initiatives, but its shortcomings have prompted changes that have been proposed in the new Basel II framework.

The Report also recommended keeping the insurance coverage at $100,000 and letting it decline in real terms with inflation. The rationale was to increase market discipline by gradually exposing more depositors to the risk of default. In real terms, the $100,000 coverage limit that was established in 1980 has been roughly halved by inflation since then. Recently, FDIRA raised the retirement account insurance coverage from $100,000 to $250,000, and it allowed the FDIC to adjust the general account coverage levels to keep pace with inflation starting in 2010.

To protect the insurance fund and uninsured creditors, the Report recommended closing a failing depository institution when its market-value net worth falls below some low, but still positive, number such as 1 or 2 percent of assets. While the FDICIA embodied the concept of early intervention with the Prompt Corrective Action provision, the triggers for regulatory intervention are based on book-value capital ratios. Relying on book-value capital ratios may undermine the usefulness of early intervention when they lag their true economic values. However, in the absence of full market-value accounting (which the Report also recommended), using the book value ratios is necessary for implementation purposes. Going beyond early intervention, FDICIA's Least Cost Resolution provision requires the FDIC to resolve bank failures using the method that is least costly to the insurance fund. Furthermore, the act also clarified and formalized the conditions for protecting uninsured depositors or creditors at large banking organizations whose failure would have serious adverse effects on economic conditions or financial stability.

Market discipline

Under market discipline, a firm has private sector stakeholders, including management, shareholders, and uninsured depositors and other creditors, who are at risk of financial loss from the firm's decisions and who can take actions to "discipline" the firm or influence its behavior. The Report recommended increasing the reliance on market discipline by imposing costs on stakeholders as disincentives for taking risk. More specific recommendations included those for greater reliance on subordinated debt. The Report also recommended expanding the use of current-value measures for internal use by depository institutions, for deposit insurance purposes, and for public disclosures. The Report argued that one benefit of increased market discipline is that it can supplement supervision and thus lower the agencies' expenses. One recommendation also calls for examination reports to be shared with bank management.

Some of these recommendations for increasing reliance on market discipline are embodied in the collection of changes that have increased regulatory emphasis on bank capital, starting from the first Basel Capital Accord to the newly proposed Basel II capital regulation framework. Coincident with this has been the substantial turnaround in book-value capitalization in the banking industry, with nearly all U.S. banks being classified as well-capitalized by their regulators.

In addition, subordinated debt has become part of Tier 2 capital, which is counted towards meeting regulatory capital requirements. Contrary to the Report's recommendations, the debt can have restrictive covenants and its issuance need not be staggered. The current environment is more conducive to the use of such debt in meeting capital requirements. In fact, as part of the recapitalization of the banking industry in the early 1990s, banking organizations as a group did increase their reliance on subordinated debt. More recently, policymakers also have allowed trust preferred securities to meet part of Tier I capital requirements.

Several steps have been taken to improve public disclosure by financial institutions. At the policy level, improved disclosure is one of the three pillars in the Basel II proposal. Banking agencies also have improved disclosure by expanding the scope of regulatory reports, accelerating the release of the reports, and making the information more readily available.

Prudential supervision

The Report recommended several revisions to the bank examination process. It argued that, because fraud and insider abuse were major problems, the examination process should focus on uncovering them. Other recommendations included: directing examinations at verifying accounting and estimates of the current value of assets and liabilities; using existing data, statistical methods, and computer models to monitor risk, to predict risk, and to identify problems; increasing the reporting of significant information using computer technology.

Over time, the agencies have, indeed, taken advantage of advances in computer technology. A notable change directly affecting the examination process has been the adoption of the so-called risk-focused approach. This approach was formally announced by the Federal Reserve in 1997 and was supplemented with traditional transactions-testing of a sample of a banking organization's assets.

While improved risk management in banking could help protect the insurance fund, that was not the motivation for adopting risk-focused supervision. The motivation instead rested on the assumption that banks have incentives to measure risk accurately and to manage it. In fact, the risk-focused approach can be seen as arising out of financial institutions' own innovations in risk management.

The risk-focused approach, which emphasizes internal controls at banking organizations, is consistent with the Report's attention on fraud detection, as is the move toward more continuous supervision for larger banking organizations. Aside from having staff on-site at the very largest banking organizations and regular off-site monitoring for other banks, supervision involves a series of targeted examinations leading up to full examinations. The targeted examinations can focus on particular areas of risk, including credit risk, market risk, compliance risk, and operational risk.

At the same time, off-site monitoring among the federal banking agencies has been expanded and improved substantially, as the agencies have taken advantage of statistical models and advances in information technology. At the Federal Reserve, for example, off-site monitoring models are used to estimate probabilities of failures and to predict supervisory ratings, and new models that incorporate market-based variables are currently being developed.

Expansion of banking powers

The Report recommended that the main criterion for authorizing new activities should be the insurance agency's ability to monitor and to assess the total risk implications of the new activity for the consolidated entity as well as to price the risk to the consolidated entity. It viewed the legal separation of commercial and investment banking, and the separation of banking and insurance, as neither necessary nor desirable for reducing conflicts of interest. It also rejected the idea of housing the new activities in nonbank subsidiaries or affiliates because doing so would not protect the insurance agency from the risk of the new activities so long as the holding company can shift risk to insured bank subsidiaries.

Regulatory and legislative actions over the past 20 years have allowed greater affiliation of banking and other financial services. Even under the Glass-Steagall Act of 1933, bank holding companies were permitted to engage in securities underwriting and dealing on a limited basis through their so-called Section 20 subsidiaries approved by the Federal Reserve. On the insurance side, national banks exploited loopholes in the law by conducting insurance agency activities in small towns.

In 1999, the Gramm-Leach-Bliley Act formally repealed provisions of Glass-Steagall, allowing banking firms to be affiliated with securities firms and insurance companies. However, the new securities activities and the insurance activities of the banking organization must be conducted outside of the bank subsidiaries in nonbank affiliates. These measures allowing greater affiliation of banking with other financial activities are consistent with the views in the Report that such affiliation should not lead to conflicts of interest that are harmful to consumers. Even the continued restrictions on mixing banking and commerce could be seen as consistent with the Report's views, to the extent that the ban could be motivated by concerns over the ability of the supervisory agencies to assess and monitor the associated risks. Nevertheless, the use of the holding company framework for expanding banking powers is clearly at odds with the Report.

Conclusions

The task force Report, written 20 years ago when the nation's banking and thrift sectors were in serious distress, took a broad and deep look at the underlying contributory causes. Its recommendations were based on sound economic principles, including the theory underlying options pricing models and agency theory in finance. Today, we have much healthier banking and thrift sectors, and there seems to be little question that the safety and soundness of the banking system has improved substantially—at least for now. Looking back, one can point to several major developments that have shaped the U.S. banking system during the last two decades, including the recapitalization of the banking industry, the greater reliance on market discipline, and increased sophistication of risk management. These developments are broadly consistent with, and to some extent connected to, public policy measures recommended by the task force, whose primary thesis was to align risk-taking incentives among depository institutions more appropriately and to limit the scope of the bank safety net.

Simon Kwan
Vice President

Conference papers

Some papers are available in pdf format at
http://www.frbsf.org/economics/conferences/0608/

DeYoung, Robert. 2006. "The Emerging Dominance of Transactions Banking and Its Implications for the Banking System."

Flannery, Mark. 2006. "Supervising Bank Safety and Soundness: Some Open Issues."

Furlong, Fred, and Simon Kwan. 2006. "Safe and Sound Banking, 20 Years Later: What Was Proposed and What Has Been Adopted."

References

Some papers presented at this conference are available in pdf format at
http://www.frbsf.org/economics/conferences/0608/index.html

Benston, George J., Robert A. Eisenbeis, Paul M. Horvitz, Edward J. Kane, and George G. Kaufman. 1986. *Perspectives on Safe and Sound Banking: Past, Present, and Future.* Cambridge, MA: MIT Press.

Furlong, Fred, and Simon Kwan. 2006. "Safe and Sound Banking, 20 Years Later: What Was Proposed and What Has Been Adopted. Mimeo. Federal Reserve Bank of San Francisco. http://www.frbsf.org/economics/conferences/0608/kwan_furlong.pdf

Financial Innovations and the Real Economy: Conference Summary

Reprinted from FRBSF Economic Letter *2007-05, March 2, 2007.*

This *Economic Letter* summarizes the papers presented at the conference "Financial Innovations and the Real Economy" held at the Federal Reserve Bank of San Francisco by the Bank's Center for the Study of Innovation and Productivity (CSIP) on November 16 and 17, 2006.

This conference featured seven papers that address the impact of innovations in the financial sector on the real economy. The papers can be divided roughly into three groups. The first group examines how innovations in financial markets affect consumer spending and borrowing. The second group focuses on how new financial instruments may help firms mitigate risk but, in so doing, may also increase the risk to the overall financial system. The third group explores how financial innovations affect business borrowing behavior, and how that behavior may increase the volatility of financial variables but decrease the volatility of real variables, such as employment and output.

Financial innovations and the consumer

The paper by Campbell and Hercowitz begins by observing several facts about the composition of U.S. household debt and the ways it has changed over time. One stylized fact is that household debt has increased sharply since the 1980s. The authors argue that deregulation (in particular, several laws passed in the early 1980s) increased competition in the consumer lending market, spurring financial firms to provide more services at lower cost to households. For instance, as the costs of tapping into home equity were greatly reduced and down payment requirements were lowered, many households may have become more willing to acquire a greater amount of debt that is collateralized by their houses (the single largest source of debt for U.S. households).

One way to gauge the potential importance of financial innovation on consumer borrowing behavior is to develop a model that analyzes how changes in regulations would affect consumer behavior and then see if the model's predictions match what is observed in the data. To that end, the authors construct a general equilibrium model of savers and borrowers. The general equilibrium concept is important because it recognizes that, for every dollar of money borrowed, someone must be willing to lend that dollar. It has been documented that many U.S. households are net borrowers, while a minority are net savers. Therefore, in the Campbell-Hercowitz model, there are two types of consumers: net borrowers and net savers. They show, through a variety of exercises, that their model is consistent with much of the data.

The paper by Dynan, Elmendorf, and Sichel addresses how financial innovation may help consumers smooth consumption over time. In their previous research (2006), these authors argued that innovations in financial markets could be one of the reasons that the economy has become less volatile since the mid-1980s. Their argument is that financial innovations have enhanced the ability of businesses and consumers to smooth their spending in the face of swings in income.

In this paper, they focus on the household level. They analyze income and spending from a data set that tracks individual households over time and find several interesting patterns. Among these, the volatility of annual income at the household level was higher after 1984 than before, even though aggregate volatility in the economy declined. They explore possible reconciliations of these divergent patterns. Finally, the authors find that, at the household level, spending has become less responsive to changes in income, especially when income falls. Financial innovations, such as easier access to home equity, may account for this last fact.

The final paper in this group differs substantially from others in that it focuses on financial services provided to the very poor in Guatemala. Authors de Janvry, McIntosh, and Sadoulet examine the role of credit bureaus (institutions that gather and make available people's credit histories) and the information consumers have about credit bureaus in the demand and supply of credit.

It has long been recognized that the poor in developing countries have little, if any, access to credit. One of the many reasons is that banks are unsure about which borrowers would be good credit risks, a situation that credit bureaus might help alleviate. In addition, if consumers were aware that credit bureaus exist, they might be more likely to pay back their loans and to undertake less risky activities to avoid having an adverse credit report that would lessen the prospects for future borrowing. To measure the extent to which the introduction of credit bureaus affects borrower and lender behavior, the authors exploit a randomized experiment in Guatemala. Their results suggest that credit bureaus do indeed help lenders identify low-risk borrowers and increase the supply of credit. They also find that those borrowers who are educated about the role of credit bureaus in providing credit ratings are more likely to pay back their loans than less educated borrowers.

Financial innovations and firms: Risk-sharing and systemic risk

Financial innovations arguably have improved lenders' risk management and have made firms that want to borrow less dependent on particular lenders. Ashcraft and Santos look for empirical support of this notion by focusing on a particular innovation, namely, the credit default swap (CDS) market, where a CDS is an insurance contract that pays the insured party if a specific borrower defaults. Specifically, they examine whether CDS transactions, which supposedly lower corporate funding costs, have led firms to issue more debt and operate with higher leverage ratios. Using market data starting in 2001, they do find that a firm's borrowings in the syndicated loan market and its operating leverage both increase after the firm begins having its name traded in the CDS market. However, they do not find any evidence that this increase in credit supply is being driven by lower spreads or weaker nonprice terms on syndicated bank loans. Hence, the mechanism by which this financial innovation facilitates increased corporate borrowing requires further analysis.

Similarly, the larger systemic effects of financial innovation in corporate lending are not yet fully understood. New financial instruments like CDS are widely believed to facilitate risk-sharing across financial intermediaries and, hence, to have reduced the probability that difficulties at a single intermediary could affect the entire financial system. However, because financial innovation is spreading financial risks more widely, some observers have raised concerns that new, unforeseen risk concentrations among less-prepared market participants could amplify certain adverse shocks, which would increase systemic financial risk. Some commentators also have argued that these concerns are particularly strong in the current environment, since many of the markets for the recent financial innovations have not yet been through a prolonged period of stress, such as a deep economic recession.

Gai, Kapadia, Millard, and Perez lay out a model economy in which adverse macroeconomic shocks could lead to asset "fire sales" that raise the probability of a systemic financial crisis. Financial innovations should diminish this probability, since they give firms greater access to funding and thereby diminish firms' need to sell their assets so quickly during a recession. However, this greater liquidity also leads firms to borrow more than before, which makes them more vulnerable to adverse shocks. The model's trade-off between a reduced frequency of systemic shocks and a potential increase in their severity perfectly reflects the overall uncertainty that policymakers face regarding the current rapid pace of financial innovation.

Financial innovations and firms: Borrower and lender behavior

In many models of the real economy, the financial sector plays no important role. The assumption is that asset prices simply reflect real fundamentals, with no feedback from financial markets to the real economy. However, models with financing frictions suggest that innovations in financial markets should have important macroeconomic implications.

Jermann and Quadrini discuss the impact of financial innovation on the volatility of debt, equity, and output. They argue that, although the real sector of the economy has become less volatile in the past few decades, the volatility of the financial structure of firms has increased. To explain this observation, they construct an economic model where business cycle fluctuations are driven by asset price shocks. Because of financial frictions, increases in asset prices affect firms' ability to produce, which then affects the real side of the economy. For example, lenders who are worried about default will limit the size of their loan exposure relative to the borrower's net worth; if asset prices rise, the borrowing constraint is relaxed and firms can increase employment and investment. Innovations in financial markets that allow for greater financial flexibility of firms—reflecting either increased ability to borrow or increased ability to substitute equity for debt—thus reduce the volatility of employment, investment, and output.

Wang also argues that innovations in financial markets should lead to higher financial volatility but lower real volatility. In her model, firms face shocks to demand for their products. In the face of these shocks, firms would like to use inventories to smooth production, which would, in turn, minimize overall production costs. However, smoothing production would cause cash flow to be highly volatile. If firms face an increasing premium for obtaining external financing—reflecting, perhaps, the difficulty that lenders have in verifying exactly why the firm wants to borrow—then firms would also like to smooth cash flow. This incentive to smooth cash flow thus restricts the extent to which firms choose to smooth production. Financial innovations that affect the size of the external financing premium (and its relationship to the amount of financing) allow firms to have more volatile cash flow but smoother employment and output. Wang then models how information technology has affected the premium charged by banks and other financial institutions. In particular, she argues that advances in information and communication technology have greatly lowered the marginal cost of collecting, processing, and transmitting information in general and credit information in particular (for example, by using computer-based credit scoring models). As a result, banks today make loans not only to more borrowers but also to smaller borrowers.

Mark Doms
Senior Economist

John Fernald
Vice President

Jose A. Lopez
Senior Economist

Conference papers

Papers are available in pdf format at
http://www.frbsf.org/economics/conferences/0611/index.html

Ashcraft, Adam, and Joao Santos. “Has the Development of the Structured Credit Market Affected the Cost of Corporate Debt.”

Campbell, Jeffrey, and Zvi Hercowitz. “The Macroeconomic Transition to High Household Debt.”

Dynan, Karen, Douglas Elmendorf, and Daniel Sichel. “Financial Innovation and the Great Moderation: What Do Household Data Say?”

Gai, Prasanna, Sujit Kapadia, Stephen Millard, and Ander Perez. “Financial Innovation, Macroeconomic Stability and Systemic Crises.”

de Janvry, Alain, Craig McIntosh, and Elisabeth Sadoulet. “The Supply and Demand Side Impacts of Credit Market Information.”

Jermann, Urban, and Vincenzo Quadrini. “Financial Innovations and Macroeconomic Volatility.”

Wang, Christina. “Financial Innovations, Idiosyncratic Risk, and the Joint Evolution of Real and Financial Volatilities.”

Reference

Dynan, Karen, Douglas Elmendorf, and Daniel Sichel. 2006. “Can Financial Innovation Help to Explain the Reduced Volatility of Economic Activity?” *Journal of Monetary Economics* 53(1) (January) pp. 123–150.

2006 *FRBSF Economic Letters*

Complete texts of *FRBSF Economic Letters* are available on the Bank's website at http://www.frbsf.org/publications/economics/letter/index.html

Subscriptions to the *FRBSF Economic Letter* are available via e-mail or postal delivery.

To subscribe, register at http://www.frbsf.org/tools/allsubscriptions/login.html

or send requests to

Public Information Department
Federal Reserve Bank of San Francisco
PO Box 7702
San Francisco, CA 94120
phone (415) 974-2163
fax (415) 974-3341

06-23	The Exchange Rate–Consumer Price Puzzle / *Diego Valderrama*
06-24	Oil Prices and the U.S. Trade Deficit / *Michele Cavallo*
06-25	Health Insurance Costs and Declining Coverage / *Tom Buchmueller and Rob Valletta*
06-26	Safe and Sound Banking, 20 Years Later / *Simon Kwan*
06-27	Inflation Persistence in an Era of Well-Anchored Inflation Expectations / *John C. Williams*
06-28	Did Quantitative Easing by the Bank of Japan "Work"? / *Mark Spiegel*
06-29	What Are the Risks to the United States of a Current Account Reversal? / *Diego Valderrama*
06-30	The Rise in Homeownership / *Mark Doms and Meryl Motika*
06-31	Interest Rates, Carry Trades, and Exchange Rate Movements / *Michele Cavallo*
06-32	Is a Recession Imminent? / *John Fernald and Bharat Trehan*
06-33-34	Economic Inequality in the United States / *Janet L. Yellen*
06-35	The Mystery of Falling State Corporate Income Taxes / *Daniel Wilson*
06-36	The Geographic Scope of Small Business Lending: Evidence from the San Francisco Market / *Elizabeth Laderman*
06-37	Will Moderating Growth Reduce Inflation? / *Kevin J. Lansing*
06-38	Mortgage Innovation and Consumer Choice / *John Krainer*