DATA REVISIONS, GRADUALISM, AND US INFLATION PRESSURE IN REAL TIME

by

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ABSTRACT

Uncertainties associated with the informational content of real-time data and the impact of policy initiatives on expectations have been offered as rationales for gradualism in monetary policy. Our objective is to assess these potential explanations quantitatively. Focusing on inflation as the key variable of interest to central banks, we construct indices of inflation pressure to characterize the state of the economy before and after the implementation of monetary policy. Using six vintages of US data, we analyze changes in the information content of economic data across revisions and the importance of expectations in determining the impact of monetary policy.

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1. Introduction

Central banks generally implement interest rate changes gradually, rather than in large discrete jumps. A number of recent theoretical contributions suggest that gradualism represents a best response to the informational uncertainties that central banks face when formulating policy. It has also been suggested that gradual implementation ultimately requires smaller adjustments in interest rates because the expectational changes that accompany smaller repeated (unidirectional) changes have a greater reinforcing impact than would result from a single large adjustment.

Our objective, in this article, is to provide a quantitative assessment of the main rationales for gradualism that have been proposed in the literature. To this end, we address three related issues. The first focuses on whether informational uncertainties stemming from data revisions significantly affect the assessment of economic conditions. The second centers on the role that the expectations of forward-looking agents play in determining the effectiveness of monetary policy. The third is concerned with the extent to which using final revised data, rather than real-time data, affects the assessment of both the strength of the monetary authority's stabilization effort and effectiveness of the policies that were implemented.

In order to assess the impact of monetary policy on the economy, we need some means of quantifying the state of the economy before and after the implementation of monetary policy. We accomplish this by focusing on inflation as the key variable of interest to central banks and constructing indices of inflation pressure to characterize the state of the economy. The indices we employ are adapted from indices developed by Weymark and Shintani (2006) to examine the impact of systematic monetary policy decisions in the United States. The proposed indicators possess several desirable attributes. They provide summary measures of inflation pressure, the degree to which monetary policy decisions change inflation pressure, and the overall effectiveness of monetary policy initiatives. While ours are not the only available indicators of

monetary policy performance, we believe that they may be relatively more informative than most about the impact of central bank decisions both before and after action is taken. [1]

The particular era in U.S. monetary history we are interested in covers roughly the period between 1999 and 2004. This period is interesting because it contains periods of sustained interest rate increases as well as decreases. Beginning in June 1999, the Federal Reserve raised the Federal Funds rate five times in succession in increments of 25 basis points. From January 2001 to June 2003 the Federal Funds rate was reduced 550 basis points in thirteen incremental steps (nine 50 basis point increments and four 25 basis point increments).

Orphanides (1998, 2003) has argued persuasively that any assessment of the conduct of monetary policy must take into account the fact that the information available to central banks at the time policy is formulated is inherently noisy.[2] In this paper, we use six vintages of US data, spanning the period 1998 to 2004 to conduct our analysis. Specifically, we use changes in the inflation pressure series associated with revised data series to determine the degree to which the information content of the data series changes with each revision. Our inflation pressure measures also enable us to measure the extent to which expectational changes were responsible for the impact of interest rate changes across data vintages. Finally, we conduct counter-factual experiments to determine the extent to which using final revised data alters the perception of inflation pressure as it was perceived by the Fed at the time policies were actually formulated and implemented.

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[1] A variety of indicators of monetary policy stance can be found in earlier contributions. Many are based on a vector autoregressive (VAR) model (e.g., see Christiano, Eichenbaum, and Evans (2000) for a survey). More recent research has proposed variants that allow for richer information sets to be employed without having to give up some of the advantages of restricting statistical analyses to a smaller number of time series (e.g., Bernanke, Boivin, and Eliasz 2005). However, regardless of the approach taken, existing techniques generally rely on retrospective views of monetary policy actions, and these typically resort to final revised data.

[2] Croushore and Evans (2006) provide a survey of contributions to the real-time literature. Croushore also maintains an up to date list of the literature on real time data at http://oncampus.richmond.edu/~dcrousho/data.htm

The rest of the paper is organized as follows. In section 2 we briefly review some of the hypotheses that have been put forward to explain gradualism in monetary policy. Section 3 describes the three proposed indicators that measure the quality of monetary policy decisions. Section 4 outlines the economic model that must be specified in order to derive a measure of inflation pressure. Section 5 discusses the data and model estimation. The empirical results are discussed in Section 6. Concluding remarks may be found in Section 7.

2. Gradualism in Monetary Policy

Although the debate about the advantages and drawbacks of gradualism in monetary policy is an old one (e.g., see Goodhart 1999, and references therein), it is generally understood today as referring to the interest rate smoothing phenomenon. Hence, even if one accepts the steady state requirement of the Taylor principle,[3] which says that in order to tighten monetary policy the interest rate response must exceed the increase in inflationary expectations, this does not prevent the central bank from doing so in measured steps. Although Taylor's (1993) original rule did not contain a lagged interest rate, it is common practice to include one or more nominal interest rate lags when estimating Taylor rules empirically. Whether this formulation of a central bank reaction function is appropriate or simply a useful data-fitting device has been the subject of considerable debate (Sack 2000). Rudebusch (2002) contends that the observed gradualism in monetary policy occurs because the economy evolves gradually, with a high degree of serial correlation in key variables, causing the monetary policy response of the central bank to exhibit similar gradual, serially correlated adjustment over time.[4] English, Nelson, and Sack (2003)

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[3] See Walsh (2003), and Woodford (2003, p. 254), both of whom regard this long-run principle as a crucial one for the conduct of good monetary policy.

[4] Rudebusch (2002) focuses on the contradiction between estimated Taylor rules with a high degree of interest rate persistence (quite frequently, 0.8 or more) when many other studies report considerable difficulty in predicting policy rates Söderlind, Söderström and Vredin (2002) report that interest rate persistence is a necessary, but not sufficient, condition for predictability. If there is one omitted variable then a high degree of persistence need not imply high predictability.

conclude that Rudebusch's (2002) findings are due to a co-existence of serial correlation and partial adjustment. Hence, it is not possible to unequivocally reject gradualism in the setting of the policy instrument.

A number of rationales have been advanced to explain the interest rate smoothing phenomenon.[5] One explanation centers on the inherent uncertainties that central banks face when formulating monetary policy. In the absence of perfect knowledge about the structure of the economy, the impact of any policy action, in both timing and magnitude, becomes uncertain. This model uncertainty is compounded by the fact that information about the current state of the economy changes continuously, so that policy decisions must, inevitably, be made on the basis of noisy data. In most cases, gradualism provides the best means of implementing effective monetary policy in an uncertain environment.[6] Gradualism allows the policy-maker to observe the impact of a small initial policy change and modify future policy changes as economic conditions evolve. Proceeding in small methodical steps also reduces the policy-maker's reliance on forecasts of unobservable variables such as potential output.[7]

A second justification for gradualism, which was originally proposed by Goodfriend (1991) and subsequently formalized by Woodford (2002, 2003), contends that smaller, repetitive changes in the central bank's short-term interest rate target have a bigger impact on expectations, and therefore on long-term interest rates, than larger discrete changes would have. The greater is the impact on expectations and longer-term rates, the greater will be the impact of a given policy change on private expenditure and investment decisions. Furthermore, gradual interest rate adjustments make monetary policy changes easier to forecast and this may enhance financial stability.

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[5] Goodhart (2005). Sack and Wieland (2000), and Walsh (2003) review various aspects of this literature. Bernanke (2004) also provides a useful summary of the various rationales for gradualism in monetary policy implementation.
[6] See Brainard's (1967) seminal article on the subject of model uncertainty and Orphanides (2003) for an analysis of monetary policy formation with noisy data.
[7] See Orphanides et al (2000) and Orphanides and Williams (2002) for a detailed analysis.

Gradualism is also thought to enhance financial stability in other ways. Central banks that change interest rates too frequently, run the risk of overreacting unnecessarily in the face of constant shocks, thereby giving the impression that they are not competent in implementing monetary policy. The consequence can be a threat to financial stability (Goodfriend 1991). In addition, central banks, such as the U.S. Fed, make decisions in a committee setting, and the desire to reach a consensus can mean taking fewer risks, or implementing policy changes in smaller steps when this is deemed necessary.

The explanation most germane to this paper stems from the observation that some key data series are frequently revised or are, in any event, observed with error.[8] In what follows, we focus on the impact that changing information about key economic variables has on the perception of the current state of the economy and on our assessment of the strength of the central bank's policy response.

3. Measuring the Stance of Monetary Policy: Definitions

Monetary policy decisions are based on the information set available to policymakers at the time decisions are taken. A central bank's policy setting committee must, among other elements of policy making, evaluate the implications of an unchanged policy rate conditional on current economic prospects. This gives rise to a natural definition of *inflation pressure*. Imagine the economy is regularly subjected to random disturbances. These disturbances have the potential to change inflation, unless changes in inflation expectations and/or interest rates can offset the effects of such shocks. For the period considered in this study, agents know ahead of time when monetary policy decisions are to be taken by the Fed since the dates on which the Federal Open

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[8] A recent example is Croushore (2007) who investigates revisions to the personal consumption expenditures index (PCE). The Appendix (not shown) plots inflation in the GDP deflator for the vintages considered in this paper. These revisions are substantial. In what follows, we rely on CPI inflation due in part to data limitations, and focus on the impact of real time revisions of the output gap which are also substantial, as we shall see. However, the various proxies for the real interest rate utilized in this paper can essentially be viewed as amounting to the adoption of different views about the likely future course of inflation.

Market Committee (FOMC) meets and announces the level of the federal funds rate are fixed

well in advance.[9] For the United States, *inflation pressure* can therefore be thought of as the

change in inflation between FOMC meetings due to these random shocks, holding constant

expectations of inflation and the fed funds rate.[10] Any subsequent inflationary pressure cannot be

influenced by the Fed's actions until some time in the future, owing to lags in the effect of

monetary policy.

If the relevant nominal interest rate is denoted by i_t, then a constant interest rate over one

quarter, for example, implies that $i_t = i_{t-1}$. Hence, ex ante inflation pressure (EAIP) is simply

defined as

$$EAIP_t = \pi_t^{\Delta i_t = 0} - \pi_{t-1} \tag{1}$$

where $\pi_t^{\Delta i_t = 0}$ is the inflation rate under the assumption that $i_t = i_{t-1}$, while π_{t-1} represents last

period's inflation rate. It is implicitly assumed that interest rate changes and inflation are

negatively related, as this is one of the core notions that underlies the Taylor principle.

Moreover, because the central bank can change interest rates after the next meeting of the

FOMC, equation (1) can be thought of as an *ex ante* indicator of inflation pressure.[11] In a

quarterly model, ex ante inflation pressure is the inflation rate that would be observed if the Fed

held the nominal interest rate fixed for 2 quarters (or longer, if longer lags are incorporated into

the model) and then returned to the average policy rule thereafter. Ex ante inflation pressure can

only be observed directly in those periods where interest rates are indeed held constant *and this*

interest rate path is fully anticipated by economic agents. Under these circumstances, ex ante

inflation pressure will be equal to observed inflation. In all other circumstances, ex ante inflation

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[9] The FOMC calendar, statements, and minutes (with a lag) are available at
http://www.federalreserve.gov/monetarypolicy/home.htm#calendars.

[10] We exclude from consideration interest rate changes outside the normal meetings calendar.
[11] Central banks in many other countries structure policy reviews and announcements of policy changes in a manner
similar to that employed by the Fed. The concept of inflation pressure we propose can therefore be applied more
broadly to study the inflation experience in a variety of other countries.

pressure must be imputed by means of a counterfactual policy experiment. Details of the methodology we employ are given in Appendix 1.[12]

Suppose that the monetary authority decides to raise interest rates. In an economy with rational, forward-looking agents, the impact of this policy change will depend not only on the size of the interest rate change, but also on the effect that private agents anticipate the policy change will have on future inflation. Consequently, it is the combination of the size of the interest rate change and the magnitude of any accompanying change in inflationary expectations that determines the impact of the monetary policy on inflation. These combined effects will be reflected in the degree to which the observed inflation rate differs from the inflation that would have been observed in the absence of the policy change. These observations suggest that an index measuring the extent to which monetary policy was successful in preventing underlying inflation pressure ($EAIP$) from affecting observed inflation rates, would provide a useful indicator of the overall impact of monetary policy decisions. We call this metric the Policy Induced change in Inflation Pressure ($PIIP$) and propose the following definition

$$PIIP_t = \frac{\pi_t^{\Delta i_t = 0} - \pi_t}{EAIP_t} = 1 - \frac{\Delta \pi_t}{EAIP_t} \, . \tag{2}$$

The numerator in (2) is the level of inflation obtained under a no fed funds rate change scenario relative to the actual inflation rate conditional on Fed actions. Given equation (1), the $PIIP$ can more conveniently be written as 1 less the proportion of $EAIP$ that is represented by the observed change in actual inflation. This formulation is both easier to evaluate and interpret. Thus, when $\Delta \pi_t = 0$, so that inflation is constant, $PIIP = 1$. When $PIIP = 0$, that is, $\Delta \pi_t = EAIP$, the policy initiative was unsuccessful in moderating the impact of ex ante inflation pressure on

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[12] The complexity of the solution of the specified model (see the following section) under the assumption of rational expectations is such that a closed-form solution cannot be obtained for one period deviations from the assumed policy rule. Hence, the solution is approximated by assuming that expectations are formed based on the observed instrument rule.

observed inflation. It is also conceivable that the policy impact on inflation can be either larger or smaller relative to *EAIP*, resulting in values for *PIIP* that can be either negative or exceed 1. For example, a monetary policy that consistently under-reacts to changes in inflation expectations relative to the requirements of the Taylor principle would lead to *PIIP* < 0. An especially aggressive change in the stance of monetary policy, on the other hand, could produce a sufficiently large reduction in inflation to cause the value of *PIIP* to exceed unity. Alternatively, one can think of monetary policy as displaying a form of overshooting as positive or negative *EAIP* values are offset by a change in inflation in the opposite direction. It is fairly clear that negative values of *PIIP* are not consistent with good (i.e., effective) monetary policy practice. The interpretation of *PIIP* values greater than unity is not quite as clear-cut. While it is true that negative *PIIP* values indicate overshooting of the zero inflation target, which would occur if the policy authority underestimated the impact of its policy on expectations, negative *PIIP* values could just as easily be associated with a purposeful effort on the part of the policy authority to alter the mean inflation level. Table 1 summarizes the possible outcomes for the *PIIP* measure.

The *PIIP* index measures the extent to which a policy initiative was successful in preventing potential changes in inflation, which we measure as ex ante inflation pressure, from being realized in the form of observed inflation. While it is conceivable that policy initiatives might be able to prevent temporary changes in inflation pressure from being realized, it is not very likely that this would be possible in the longer term. It seems then that an important aspect of policy effectiveness is the degree to which the policy reduced inflation pressure overall. This leads to a definition of the effectiveness of monetary policy that is given by the ratio of ex post to ex ante inflation pressure. Ex post inflation pressure (*EPIP*) is the level of inflation pressure that remains after a particular monetary policy has been implemented. The difference between *EAIP* and *EPIP*, expressed as a ratio, is an indicator of the extent to which monetary policy altered the

inflationary environment. We write the expression our indicator of Monetary Policy Effectiveness (MPE) as:

$$MPE_t = \frac{EPIP_t}{EAIP_t} \qquad (3)$$

Clearly, if *EPIP* = 0, then monetary policy is completely effective in neutralizing inflation pressure resulting in MPE =0. A monetary policy that leaves ex post and ex ante inflationary pressures the same results in *MPE* = 1 and is completely ineffective in the sense that there has been no discernible impact on the inflationary environment. Partial reductions in inflationary pressure result in values for *MPE* that range between 0 and 1. As in the case of *PIIP* negative values for *MPE*, as well as values that exceed 1, are also possible. A negative value indicates, for example, that ex post inflation pressure or ex ante inflation pressure move in the opposite directions, clearly a sign of policy effectiveness (but possibly also evidence of overshooting the target inflation rate). A value for *MPE* that exceeds unity suggests that *EPIP* exceeds *EAIP*. Therefore, the actual monetary policy has magnified inflation pressure and this is clearly an indication that policy is ineffective. Table 1 also summarizes possible outcomes for the *MPE* indicator.

Ex post inflation pressure cannot generally be observed directly. What we observe instead are the changes in interest rates and inflation rates that result from the policy that was implemented. In order to measure ex post inflation pressure in terms of a single variable, we conduct a measurement experiment that converts the observed changes in interest rates into inflation-equivalent units. Details of this computation are given in Appendix 1.

The definitions of ex ante and ex post inflation pressure that we employ enable us to use our *PIIP* and *MPE* metrics to address two additional issues that are of potential interest.[13] These

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[13] Note that our *PIIP* and *MPE* indices are not defined when *EAIP* = 0. Situations in which *EAIP* is exactly equal to zero can be expected to be quite rare, so this issue is unlikely to be of much practical importance. What could be more troublesome is that as *EAIP* gets very small and *approaches* zero, *PIIP* may approach negative infinity and

are (1) the relative importance of changes in the expectations of private agents in determining the effectiveness of monetary policy and (2) the extent to which monetary policy is anticipated by economic agents. According to our definitions, ex ante inflation pressure measures the change in inflation that would have been observed under a fully (rationally) expected policy of no interest rate change. Ex post inflation pressure, on the other hand, measures the inflation pressure (in inflation equivalent units) associated with a policy initiative, conditional on the expectations actually held by economic agents under that policy. It is straightforward to show that the proportion of ex ante inflation pressure removed by changes in the inflation expectations of private agents can be measured as $[1 - MPE]/PIIP$.[14]

Under special circumstances, it is also possible to use the *MPE* metric to measure the degree to which expectations about inflation change independently of interest rate changes. Specifically, when the central bank's chosen policy is one that holds interest rates constant, the measurement of ex ante and ex post inflation pressure does not involve a counter-factual assumption about interest rates and any difference between the measures reflects the extent to which expectations have changed independently of interest rates.[15] We compute [1-*MPE*] to reflect the degree to which inflation pressure was altered by independent changes in expectations. An additional interesting interpretation of our [1-*MPE*] values is possible if we relax the assumption that all agents are fully rational. Our counterfactual ex ante inflation pressure measure is always calculated under the assumption of full rationality. Ex post inflation

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MPE may approach positive infinity. This difficulty could be avoided by defining indices in terms of imputed price levels rather than changes in price levels, but doing so would make the estimation of our counterfactuals considerably more difficult because of the nonstationarity of price level data. Our preferred solution is simply to be particularly careful to interpret large (absolute) *PIIP* and *MPE* values in light of the underlying magnitude of *EAIP*.

[14] The derivation of this expression is provided in Appendix 1.

[15] It has been pointed out to us that there are potentially two sets of inflation pressure indicators, depending on whether the Fed makes the point by delivering a real time change in the fed funds rate versus implementing a series of interest rate changes. As we shall see below, inflation pressure can, in principle, be re-evaluated each period, conditional on the steps the Fed actually took. In practice, however, we make some simplifying assumptions to reduce the scope of the numerical approximations that must be made. This may indeed affect the accurate measurement of inflation pressure but we believe not in any significant fashion.

pressure, however, is calculated using observed variables that reflect the expectations actually held by economic agents, which may or may not be fully rational.[16] When economic agents exhibit bounded rationality, and the central bank holds interest rates constant, *MPE* measures the extent to which monetary policy is anticipated by private agents and [1- *MPE*] reflects the surprise element in monetary policy.

Because neither ex ante nor ex post inflation pressure are directly observable, it is first necessary to specify a structural model and impute the relevant counterfactuals in order to obtain estimates of *EAIP* and *EPIP*. Since its introduction, the small structural model of the US specified by Clarida, Gali, and Gertler (CGG 1999) has been employed in numerous studies. As there now exists a vast literature that relies on a fairly common structure for a small model of the U.S. economy, we follow the current consensus and estimate a variant of the model specified by Clarida, Gali, and Gertler (CGG 1999). Also, see Fuhrer (2002), Rudebusch (2002), and Svensson (1997).

4. A Model of the U.S. Economy

The CGG (1999) model consists of three equations that describe aggregate demand, supply, and the U.S. Fed's reaction function. All three equations contain both forward and backward-looking elements, attributes that are consistent with Woodford's (2003) view that models ought to contain history dependent components. The following equations then describe the U.S. economy:

$$\tilde{y}_t = -\beta_1[i_t - E_t \pi_{t+1}] + \beta_2 E_t \tilde{y}_{t-1} + u_t \tag{4}$$

$$\pi_t = \alpha_1 E_t \pi_{t+1} + \alpha_2 \pi_{t-1} + \alpha_3 \tilde{y}_t + e_t \tag{5}$$

$$i_t = \gamma_0 + \rho i_{t-1} + (1-\rho)[\gamma_\pi E_t \pi_{t+m} + \gamma_{\tilde{y}} E_t \tilde{y}_{t+n}] + \upsilon_t \tag{6}$$
$$m, n \geq 0$$

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[16] Our method of computing ex post inflation pressure makes no a priori assumptions about the way in which expectations are formulated. This point is discussed in greater detail, in the context of measuring exchange market pressure, in Weymark (1998).

where $\widetilde{y}_t$ is the output gap, i_t is the nominal interest rate, and π_t is the inflation rate.[17] Equation (4) is an IS or aggregate demand curve, equation (5) is the aggregate supply or Phillips curve (PC). The Fed's policy response function is represented as a Taylor rule in equation (6). Both the IS and PC curves are hybrids in the sense of containing both forward and backward-looking components, as opposed to forward-looking models of the pure rational expectations variety. The Taylor rule is written in the standard form wherein interest rate smoothing, captured by the ρ parameter, together with forward-looking inflation and output gap terms jointly determine the current setting of the policy instrument.[18] Note that, for convenience and simplicity, the 'forecasting' horizon of the central bank, that is, *m* and *n* are not specified a priori as this can clearly change as the economic environment dictates. Furthermore, we do not impose the condition, often found in the literature (e.g., see Gali, and Gertler (2007), and references therein), whereby *m=n*. This provides our model with greater flexibility in that it allows the central bank to be more or less forward-looking about inflation vis-á-vis the output gap over time. A similar argument applies, in principle, to the IS and PC curves in equations (4) and (5). However, in keeping with the vast majority of aggregate demand and supply specifications available in the literature, we retain the specifications as shown. Equation (4) is based on the IS curve derived from a representative agent who maximizes an inter-temporal utility function with some habit persistence (Fuhrer 2000). The origin of the aggregate supply or PC curve in (5) can be traced to Calvo (1983) and emerges from the staggered pricing phenomenon. Appendices 1 and 2 describe the methodology that we employ to obtain model-consistent estimates of our *EAIP, EPIP, PIIP,* and *MPE* indicators.

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[17] In estimating (4) and (5) we found that the fit was improved when we allowed for non-zero intercept terms in both equations as well as a lagged real interest rate term in (4). The exact specifications of our estimation equations may be found in Appendix 2.

[18] In what follows we focus on simple or standard Taylor rules. The relevant literature finds that such rules perform nearly as well as optimal rules and have the advantage of being relatively more robust to model misspecification. See Woodford (2003).

There are a number of issues that bear mentioning at this point. First, the methodology we employ to compute our counterfactual indicators requires that we obtain the rational expectations equilibrium solution for our empirical model. As is often the case with rational expectations models, the solution is not unique. We choose to focus on the minimal state variable solution and it is the derivation of this particular solution form that is described in Appendices 1 and 2. Another potential point of concern is the possibility of time-varying model structure, that goes beyond changes in the parameter values from vintage to vintage. Specifically, once inflation, the output gap, and the interest rate, are observed, it is conceivable that the model that best describes the environment as summarized by the IS and PC curves may have changed.[19] In what follows we re-estimate the underlying model for each vintage, and we also allow for modest changes in the model structure (particularly in the case of the Taylor Rule. However, it is beyond the scope of this article to consider alternative rational expectations solutions, variations in the lags of parameters included in the IS and PC equations, and/or time-variation of parameters within each vintage.

5. Data and Model Estimation

5.1 Data Sources and Vintages

The real time data we employ are from the Federal Reserve Bank of Philadelphia Real-Time Data Set (www.philadelphiafed.org/econ/forecast/real-time-data/index.cfm). In the estimates shown below we revised only the output gap and money supply estimates in real-time. Interest rates and consumer prices are from the Federal Reserve Bank of St. Louis' FRED II database (www.research.stlouisfed.org/fred2). Since the IS curve requires estimation of a real interest rate variable we consider several candidates as proxies for $E_t \pi_{t+1}$. They are: the mean one year

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[19] The entire structure of the model may have changed. However, under the circumstances, even a change in *m* or *n* in equation (6) is sufficient.

ahead inflation rate ($(\pi_{t+1} + \pi_{t+2} + \pi_{t+3} + \pi_{t+4})/4$), the Greenbook forecasts, forecasts from the Survey of Professional forecasters (SPF), estimates from the Livingston survey, and the University of Michigan survey. These data are available from the Federal Reserve Bank of Philadelphia (www.philadelphiafed.org/econ/forecast1).[20] A difficulty that we encountered is that the some types of data are not always available for the full sample in each of our chosen vintages (see below). For example, the Greenbook forecasts, widely believed to be superior to other forecasts (e.g., Romer and Romer 2000), are available only until 2001:4, at the time of writing. Accordingly, the available data are supplemented with inflation forecasts from *The Economist* and Consensus forecasts (www.consensuseconomics.com); these two sources are more up to date, but the time span covered by these series is shorter as the data begin in the early 1990s. All forecasts are one-year-ahead forecasts (e.g., four quarter ahead forecasts).[21]

The output gap can also be estimated in several ways. For the most part we rely on estimated based on an H-P filter (with a smoothing parameter of 1600). However, we have also examined estimates relying on data for real potential Gross Domestic Product generated by the Congressional Budget Office (www.cbo.gov/Spreadsheets.shtml), as well as estimates based on quadratic and cubic detrending (also see Siklos and Wohar 2006). Figure 1 illustrates how estimates of the output gap, relying on an H-P filter, can change rather substantially according to the vintage of the data. Correlations between output gaps for vintages that are temporally close to each other are, of course, very high (e.g., August 1998 versus November 1999) but the simple correlation can be as low as 0.695 as is the case between the November 1999 and May 2004 vintages, for the sample shown in Figure 1. Turning points also differ between vintages with

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[20] An additional complication, ignored in the analysis to follow, is that Greenbook forecasts are for the chain-weighted implicit price deflator while other proxies are based on CPI inflation.

[21] It is also the case that many Fed officials favor the price index for personal consumption expenditures and not the CPI. We have estimated all of the equations using the chain-weighted PCE index (not shown) but our conclusions are unchanged. While PCE data are revise significantly (Croushore 2007) this is not the case with CPI data. Clark (1999) argues that improvements in the CPI make it a better index for monetary policy purposes.

once again the greatest differences between output gap vintages that are least correlated with each other.

The interest rate variable is given by the federal funds rate, also obtained from FRED II, while inflation is evaluated at annual rates. Since least squares cannot be used to estimate (4) to (6) we resort, as have others, to GMM. The choice of instruments is a crucial, but often neglected, aspect of GMM estimation (e.g., Jondeau, Le Bihan and Galles 2004). One complication is that the list of instruments could well have changed over time as the U.S. Fed either added or dropped economic indicators that were believed to be statistically relevant or economically meaningful for setting the policy instrument. Nevertheless, in what follows, we have chosen a fixed set of instruments. We employ indicators that are not only likely to be correlated either with inflation or the output gap, but are also believed to capture a wide range of other economic phenomena that the Fed may have been concerned about in recent years (e.g., developments in asset prices). Lastly, in estimating and evaluating the inflation pressure indicators, we must be mindful of the sample period over which equations (4) to (6) are estimated. In particular, it is widely believed that a structural break, or regime shift, may have taken place around the time of Paul Volcker's tenure as Fed Chairman. Therefore, estimates were generated for two samples, one that begins in 1970:1, and another one that begins in 1980:4. The latter sample is chosen because there is considerable evidence of a structural break arising, in part, out of the Monetary Control Act of 1980. Lanne (2006), is just one of several authors who reports evidence of a break in the term structure of US interest rates around 1980. All the models are estimated using quarterly data.[22]

As noted in the introduction, the choice of vintages was dictated by the desire to replicate the environment facing the U.S. Fed between 1998 and 2004. As shown in Figures 2A and 2B,

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[22] We did experiment with other possible breakpoints around the early 1980s but model estimates appeared much less sensitive to sample choice once we move away from a break in 1980.

between 1999 and 2000, the fed funds rate rose steadily before the tech bubble led to the start of a period of expansionary monetary policy. The Fed consistently reduced the fed funds rate beginning in 2001, at first sharply in the midst of a brief recession identified subsequently by the NBER reference cycle, again in the aftermath of the terrorist attacks of 9/11, and then more slowly until 2003. The reference rate was then left unchanged for about a year.

Six vintages are employed to illustrate the potential for the inflation pressure indicators. They are: August 1998, February 1999, May and November 2002, May 2003, and May 2004. Table 1 provides a synopsis of the contents of the minutes released shortly after the meetings, in the months when the vintages chosen for analysis would also have been available to policymakers. In others words, we chose vintages that match the last available dataset that FOMC officials would have seen prior to a particular FOMC meeting. The Table provides selected excerpts, the voting record of the meeting, as well as a summary statement of the FOMC's views concerning the appropriate stance of monetary policy going forward.

It is generally assumed that the current setting of a policy instrument reflects the central bank's outlook over the next two years. Thus the August 1998 vintage, which contains information dated approximately two years prior to the interest rate peak of 2000, provides important insights into the economic conditions that caused the Fed to initiate a period of sustained interest rate increases. The February 1999 vintage reveals that, while FOMC members unanimously decided to leave the policy rate unchanged, there was an expectation that a policy adjutment might be necessary in the near future. The May, and November, 2002 vintages represent the information available to the Fed approximately two years prior to the start of steady rises in the fed funds rate. The May 2003 vintage reveals concerns about the possibility of deflation or, as the Fed minutes famously put it, "…a significant further decline in inflation to an unwelcome level." The May 2004 vintage is the one available roughly two years before the Fed decided to pause making further changes in the fed funds rate. Consequently, the last available

data points for the various vintages are as follows with vintage dates in parenthesis: 1998Q2 (August 1998), 1998Q4 (February 1999), 2002Q1 (May 2002), 2002Q3 (November 2002), 2003Q1(May 2003), 2004Q1 (May 2004). Figure 2B makes clear that all chosen vintages are consistent with FOMC decisions to leave the fed funds rate unchanged. We are therefore able to use our *MPE* index to provide some insight into the potential magnitude of the surprise element of monetary policy.

5.2 Model Estimates for the U.S. Economy

The objective is to produce estimates of equations (4) to (6) with coefficients that are plausible, when judged on a priori grounds, and are also congruent with the data. This implies, for example, that reaction functions should satisfy the Taylor principle, while both the IS and PC curves ought to display a considerable amount of output and inflation persistence. As Orphanides (1998) has shown, models may fail, ex post, to produce estimates consistent with good monetary practice. Because the variables in theoretical models of the economy may have a variety of empirical representations, we estimated numerous alternative versions of IS, PC and Taylor rules based on a variety of proxies for the real interest rate, expected inflation, and covering samples defined previously. As there are far too many estimates to discuss, Table 3 instead provides a general summary of the range of parameter estimates obtained for the key variables in equation (4) to (6) in the post-1980 sample.[23] Recall that it is the point estimates of coefficients in the IS, PC, and Taylor rule equations that serve as inputs into the counterfactuals described above. Clearly, there is some uncertainty around coefficient estimates but as the precise equations used across the vintages may vary, it is not clear that standard error bands would be terribly informative as an indicator of the significance of the differences in inflation pressure given that, in addition to

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[23] An Appendix containing details of all of our estimation results is available from the authors upon request.

parameter uncertainly, there is also model uncertainty. Finally, policy statements, such as the one summarized in Table 2, are also point estimates.

Estimates of the IS curve shown in Table 3 reveal considerable variation in the response of output to the real interest rate. Interestingly, the coefficient on the real interest rate is only consistently negative (and significant) when the Michigan survey of inflation expectations is used, while this is not always the case when, say, Greenbook forecasts are employed (results not shown).[24] There is considerably less diversity in the degree of output gap persistence though the August 1998 vintage appears to stand out as one displaying the least amount of output persistence. Phillips curve estimates reveal that the forward-looking inflation term has generally greater weight than is true of the lagged inflation parameter, especially when the 'min' estimates are considered (these are the smallest coefficient estimates obtained across all estimated versions). Otherwise, current inflation is generally influenced in a balanced manner by both forward and backward-looking elements. Finally, Taylor rule estimates suggest that steady state real interest rates (γ_0) are low throughout the vintages considered, and this is certainly consistent with the view that monetary policy was, more often than not, accommodative (also, see Table 2). The Fed is also seen to respond strongly to inflation (γ_π), as required by the Taylor principle. Nevertheless, the central bank clearly also evinces a concern for output gap developments. As expected, Taylor rule estimates display considerable nominal interest rate persistence (ρ), although it is worth noting that coefficient estimates display significant variation across the vintages examined. Finally, the Table also highlights how Taylor rule estimates are affected by the choice of the proxy for the output gap. This is seen most clearly from estimates of the steady state real interest rate.

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[24] Ang, Bejaert and Win (2007) find evidence that survey based inflation forecasts outperform, for example, forecasts based on asset prices.

As will become clear below, there is strong evidence of a shift in all indicators of inflation pressure when model estimates include data before 1980. This is not terribly surprising as several authors have noted that a major change took place in monetary policy after 1980, following Paul Volcker's appointment. Nevertheless, our results clearly highlight this fact. Other samples do not reveal such dramatic shifts in coefficient estimates.

6. Estimated Indices of Inflation Pressure and Monetary Policy Effectiveness

6.1 Ex Ante Inflation Pressure (EAIP)

Figure 3A plots four estimates of *EAIP* (see equation (1)) for the August 1998 vintage. This serves to illustrate both the sensitivity of the indicators to the sample estimation period as well as the range of estimates that can be obtained depending on the estimated model upon which the counterfactuals are based. The estimates that begin in 1970, of course, are based on full sample estimates of equations (4) through (6), while other estimates are based on a sub-sample that begins in 1980.4. There are a few notable features in the figure. First, estimates of *EAIP* are considerably higher when data since 1970 are employed. In addition, estimates of inflation pressure are relatively more sensitive to model specification. In contrast, estimates of *EAIP* are not sensitive to coefficient estimates of the model in the sub-sample. This is true in spite of the fact that there is a fair amount of diversity in coefficient estimates in the three equation model used here to estimate inflation pressure, as shown in Table 3. Accordingly, in what follows, we concentrate exclusively on estimates based on the post-1980 sample. Clearly, a 'structural' break of some kind took place in the economy or in monetary policy around that time. Indeed, estimates of *EAIP* since the early 1980s do not seem plausible in light of actual Fed policies whereas estimates based on data since 1980 appear more sensible. Nevertheless, regardless of the chosen *EAIP*, the figure shows that there has been a noticeable drop in ex ante inflation pressure since the early 1980s. Therefore, our model picks up quite well the substantial decline in

inflation that is the legacy of the Volcker-Greenspan years. The sharp changes in the fed funds rate target in the early portion of the sample (see Figure 2A) may have contributed to this result.

Figure 3B plots ex ante measures since 1980, based on the six chosen vintages considered in the paper. Three aspects stand out in the Figure. First, differences in *EAIP* across vintages are relatively small in the early part of the sample. By the early 1990s differences become larger. Nevertheless, if one examines at the data in 2002, ex ante inflation pressure is approximately 2% lower based on the November 2002 vintage, relative to the May 2003 vintage. This seems like a fairly sizeable shift in the estimates of inflation pressure over a very short time interval even if we allow for some lack of precision in estimates of *EAIP*. Hence, it is conceivable that such movements might warrant caution on the part of the Fed. Finally, notice that *EAIP* appears to be very high, based on the February 1999 vintage, before falling again sharply by 2002. While the sharp rise may appear implausible, the February 1999 FOMC minutes (see Table 2) suggest that "…normal historical relationships…" seem to have been suspended. The *EAIP* estimates are consistent with this interpretation of economic conditions. Note that the Fed did raise the fed funds rate shortly thereafter (see Figure 2B) before reversing course based on data from subsequent vintages. An analysis based on final revised data would not have been able to reveal this facet of monetary policy making nor would an approach that did not attempt to quantify the unobservable inflation pressure facing Fed policymakers.

By the early 1990s, *EAIP* is fairly stable, after the initial sharp declines in the early 1980s, across all vintages. The minutes themselves, as the highlights provided in Table 2 reveal, show that the Fed became concerned, if not occasionally puzzled, about future prospects for inflation. At least initially, the bias was apparently in favor of higher short-term inflation. Indeed, Figure 1B shows that the fed funds rate rose for a time shortly after the February 1999 meeting. By 2002, inflation pressure fell and then began to rise again, though modestly, and by the time the data from the May 2004 vintage was available for use in setting the policy rate, the Fed's

concern about the prospect of an unwanted deflation had been replaced by an expectation of rising inflation. The sharp fall in the fed funds rate between 2001 and 2002, which followed a decline in *EAIP* was implemented gradually. The reduction in the fed funds rate (see Figure 2B) that took place over this period led to a rise in *EAIP* of up 2%. However, it is also the case that interest rates, during this period, were responding to factors outside the normal course of monetary policy (i.e., 9/11), and this may partly explain the Fed's reluctance to raise the policy rate and its decision to leave the rate unchanged for a considerable period of time, particularly as the rise in inflation pressure was thought to be tolerable.[25]

6.2 Policy Induced Change in Inflation (PIIP)

Figure 4 plots the *PIIP* (see equation (2)) for all six vintages, based exclusively on model estimates for the post 1980 sample. The *PIIP* time series associated with four of the six vintages indicate that the Fed's policies had a tendency to permit inflation to rise. A somewhat different view of Fed policy is provided by the February 1999 and November 2002 vintages. The February 1999 vintage portrays Fed policy as having been quite successful in holding inflation constant; the November 2002 vintage, in contrast, depicts Fed policy as having had little impact on inflation relative to its ex ante value. Although there is considerable variation in the *PIIP* index across most vintages, a common finding across vintages is that the Fed rarely overreacts or acts aggressively to change inflation pressure. Changes are seemingly gradual.

6.3 Monetary Policy Effectiveness (MPE)

Figure 5 plots our measure of the effectiveness of monetary policy (MPE, see equation (3)). Recall that this index measures the degree to which monetary policy changes the inflationary

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[25] It is worth pointing out, however, that shortly after the sample considered in this study ends, the fed began a tightening cycle lasting until the middle of 2007. see Figure 1A.

environment. The constructed index is such that values near 1 indicate policy ineffectiveness as *EAIP = EPIP*, while index values that approach zero indicate that monetary policy was fully effective in eliminating inflationary pressure. The information regarding the degree to which the Fed's policy was effective shows a significant amount of variation across vintages. The *MPE* estimates hover around 1 for both the August 1998 and November 2002 vintages. The November vintage, in which almost 72% of the *MPE* estimates exceed 1, indicates that the Fed's policies magnified inflation pressure much of the time. [26] All of the later vintages show a much greater degree of policy effectiveness. Clearly, the evaluation of the impact of monetary policy is very sensitive to the data series employed in the evaluation. Orphanides (2003) has argued strongly against the use of revised data in evaluating the efficiency of central bank policy. However, the situation is quite different when the objective is to determine the impact of monetary policy initiatives. If one accepts the view that retrospective data revisions lead to informational improvements, then later vintages will provide the more accurate assessments of the impact of past policy actions.

The *MPE* values that we have calculated have two rather striking features. First, for all vintages there is significantly more variation in *MPE* values (within a given vintage) than in the federal funds rate. Second, the degree to which expectational changes are responsible for the difference between ex ante and ex post inflation pressure can be calculated as [1-MPE]/PIIP. This value is close to 100% for time periods across all vintages. These observations lead to two related insights: (1) much of the impact of monetary policy can be traced to its impact on expectations and (2) the impact of policy initiatives on expectations can be quite variable. Together these observations provide a rather compelling argument for gradualism.

The fact that the ending dates of our chosen vintages coincide with FOMC decisions to leave interest rates unchanged allows us to use the *MPE* index to determine the extent to which

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[26] Almost 72% of the estimates of MPE for the November 2002 vintage exceed 1.

monetary policy decisions affect expectations about future inflation. Our analysis assumes that agents are fully rational. If that is the case, and if inflationary expectations are largely conditioned on announced monetary policy, then it should be the case that the estimated *EPIP* and *EAIP* values are approximately equal in the quarters following the FOMC decisions to leave the interest rate unchanged. In these circumstances, the value [1-*MPE*] reflects the degree to which expectations changed independently of monetary policy. Under the assumption that later vintages of data provide more accurate information than earlier ones do, we use the May 2003 and May 2004 vintages to compute [1-*MPE*] values for the last data entry in each vintage. The results of these computations are shown in Table 4. According to the May 2003 vintage, somewhere between 95% and 100% of the changes in inflation expectations occurred independently of interest rate changes.[27] For the May 2004 vintage, the values in Table 4 fall in the 48% to 90% range for 1991(Q1), 2002(Q2), and 2002(Q4), suggesting that the connection between monetary policy decisions and changes in inflation expectations in these quarters is considerably closer than indicated by the May 2003 data. The values reported in Table 4 indicate that (1) inflation expectations may, of their own accord, ameliorate (or exacerbate) inflation pressure to a significant degree and (2) that information about the extent to which expectations change independently of monetary policy may vary considerably both within and across vintages. The element of uncertainty introduced by exogenous expectational changes makes it more difficult for the Fed to assess the inflationary state of the economy, further strengthening the case for gradual policy implementation.

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[27] The value of 107.3% for 2002(Q4) indicates that expectations caused *EPIP* to move in the opposite direction to *EAIP*.

6.4 An Additional Counter-Factual Exercise

One possibility that we have so far not considered, is that the Fed's estimates may not change as much as we have assumed. For example, FOMC members may well have priors about the coefficients in a model such as the one we rely on when evaluating the appropriate stance of monetary policy. Suppose then that the May 2004 vintage, when inflationary pressure was roughly in balance and the economy was going at an appropriate pace, is the benchmark that one might use to assess monetary policy effectiveness over time. We then re-estimated our indicators of policy induced monetary policy effectiveness for all the remaining vintages. The results are shown in Figure 6. Other than for the February 1999 and May 2003 vintages, monetary policy would have been more effective in every one of the remaining vintages considered if the model estimates obtained from the May 2004 vintage had been used as the basis for the assessment of economic conditions and the formulation of policy measures. In some cases, the improvement in policy induced changes in inflation is considerable.[28] For example, if our *PIIP* measure for the November 2002 vintage is considered, the Fed's actions were largely ineffective throughout the sample based on model estimates using the real time data. If, however, the Fed had formulated its policies based on the information contained in the May 2004 vintage, monetary policy would have had a much larger impact on inflationary expectations. At the very least this kind of result confirms the consequences of using real time versus revised data. Had the Fed, in late 2002, had access to the information contained in the revised data that was not available until almost two years later, policy effectiveness would have been much greater. Only the February 1999 and May 2003 vintages contradict these results. Unlike the other vintages perhaps (see Table 2) the February 1999 vintage was released in an environment of relatively strong economic growth while the May 2003 vintage was released at a time when the Fed was pre-occupied with the

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[28] We are unable to ascertain statistical significance over time. Nevertheless, on average, policy is statistically more effective when the May 2004 model estimates are used than when the model is estimated individually for each vintage. Test results not shown.

prospects of deflation. The economic environment of May 2004 likely would not have suited the tenor of the times either in February 1999 or May 2003. On balance, the counter-factual exercise conducted in this section provides further support for the view that there are good reasons for the Fed to be cautious and, when necessary, to act gradually.

6. **Conclusions**

In this article we proposed some indicators that separately characterize (1) the economic environment facing the policy authority at the time monetary policy was implemented and (2) the impact of the policy on the economic environment. Our indicators also enable us to determine how much of the impact of monetary policy is due to the change in the policy instrument itself and how much is attributable to the changes in inflationary expectations that are brought about by the policy initiative.

We use six vintages of real time data spanning the period 1998-2004. Throughout this period the Federal Reserve altered its target federal funds rate methodically, sometimes quite slowly and, at other times, more aggressively. Our analysis of this period results in several interesting conclusions. We find that the assessment of both the inflationary environment and the impact of monetary policy on the inflationary environment are significantly affected by data revisions. Thus our results support the view that data uncertainty is, at least in part, responsible for gradualism. However, we also find that monetary policy has its primary impact on the economy through the changes in expectations that it generates and that estimates of these expectational changes differ across data vintages. These observations suggest a second, complementary, rationale for gradualism. In particular, the Fed may have acted gradually because it could not be certain of the degree to which its policy initiatives would influence expectations of future inflation.

Our results underscore the fact that data uncertainty as it is reflected in the data revisions of our chosen vintages, can lead to rather dramatic changes in our assessment of the conduct of monetary policy. For example, based on the August 1998 and November 2002 vintages, monetary policy was clearly unsuccessful since inflationary pressure ex post was often higher than it was ex ante. Nevertheless, a sharp turnaround took place by the time of the May 2003 vintage. It also appears that models used to evaluate policies based on data that stretch back before 1980 must allow for the fact that a notable structural shift occurred in a widely used version of a small structural model of the US economy. One obvious extension to our present analysis would be to enhance the indicators of inflation pressure by estimating standard error bands. However, this is likely to be rather difficult as there is both parameter uncertainty as well as model uncertainty with which to contend.
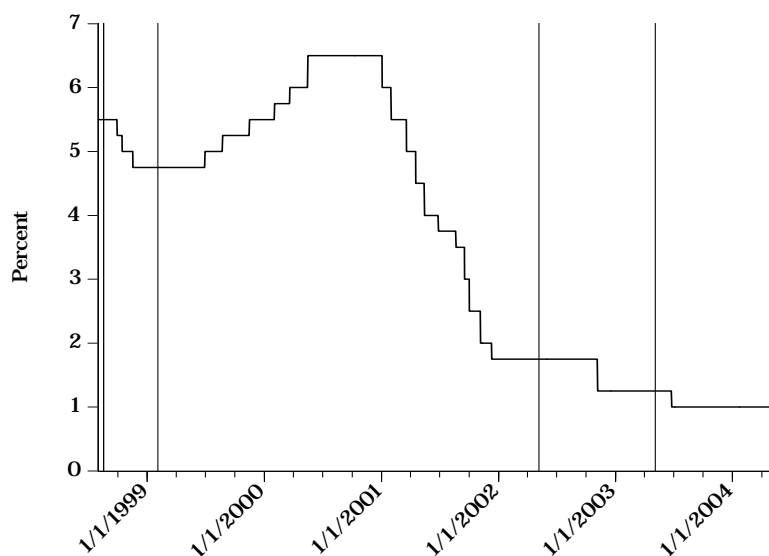
Figure 1 Output Gaps By Vintage of Data
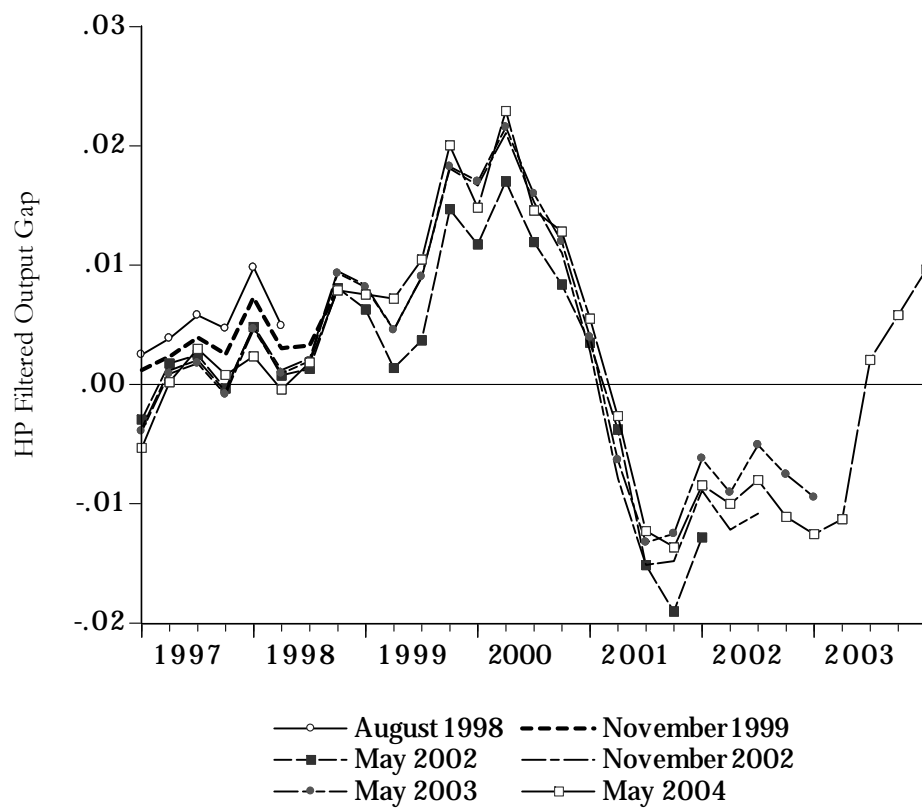
Source: See text for data source. H-P filer applied to the logarithm of real GDP with a smoothing parameter of 1600.

Figure 2A Target Federal Funds Rate: 1982-2007
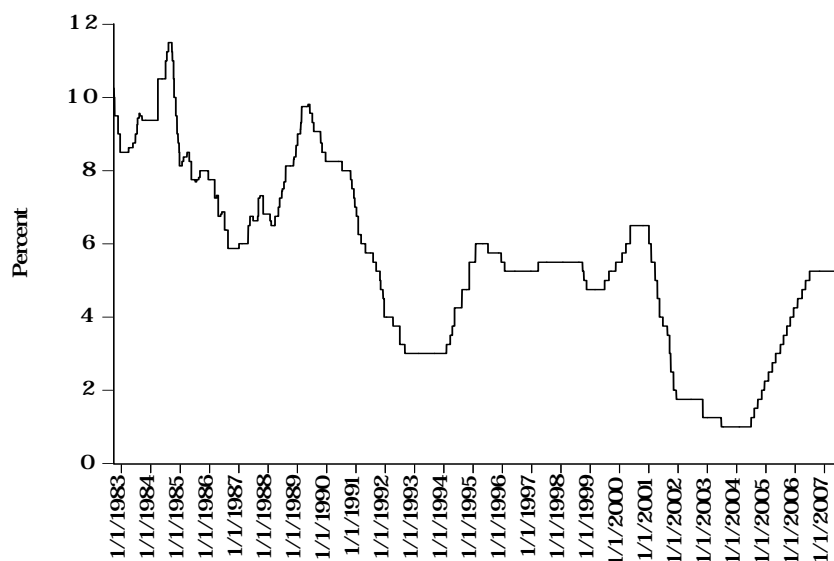
Figure 2B Target Federal Funds Rate: 1998-2004

Source: Series DFEDTAR, from FRED II, daily
(http://research.stlouisfed.org/fred2/series/DFEDTAR/downloaddata?cid=118). The vertical lines
date the vintages employed in the analysis of inflation pressure.

Figure 3 Ex ante Inflation in the United States

A) *Varieties of Ex ante Inflation: August 1998 vintage*
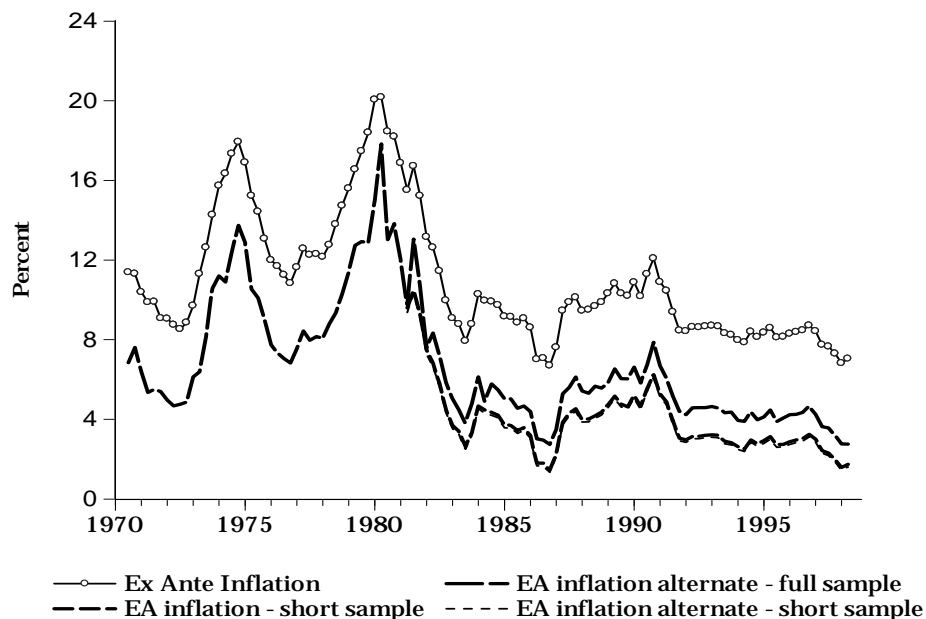
Note: Short sample refers to model estimates estimated beginning with 1980.4 data. Full sample uses data since 1970.1. Differences are due to the variety of coefficient estimates (equations (4) to (6)) used in generating counterfactual estimates.

B) *Ex ante Inflation Across Vintages since 1980*
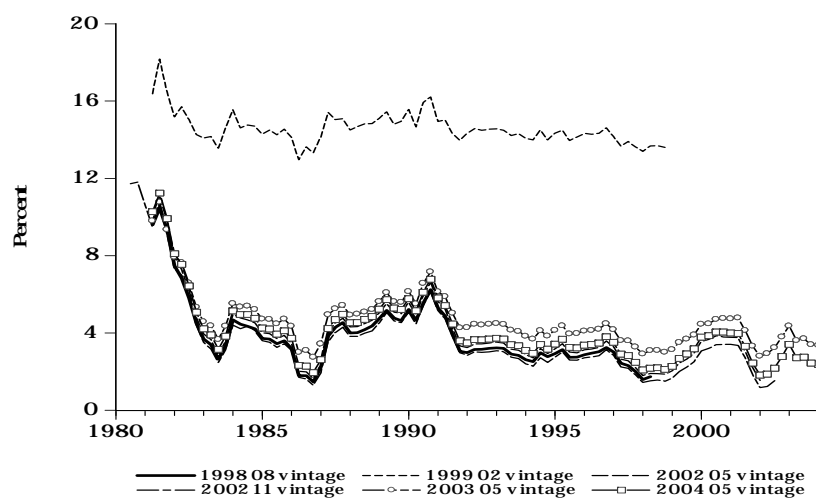
Figure 4 PIIP and the Control of Inflation Pressure
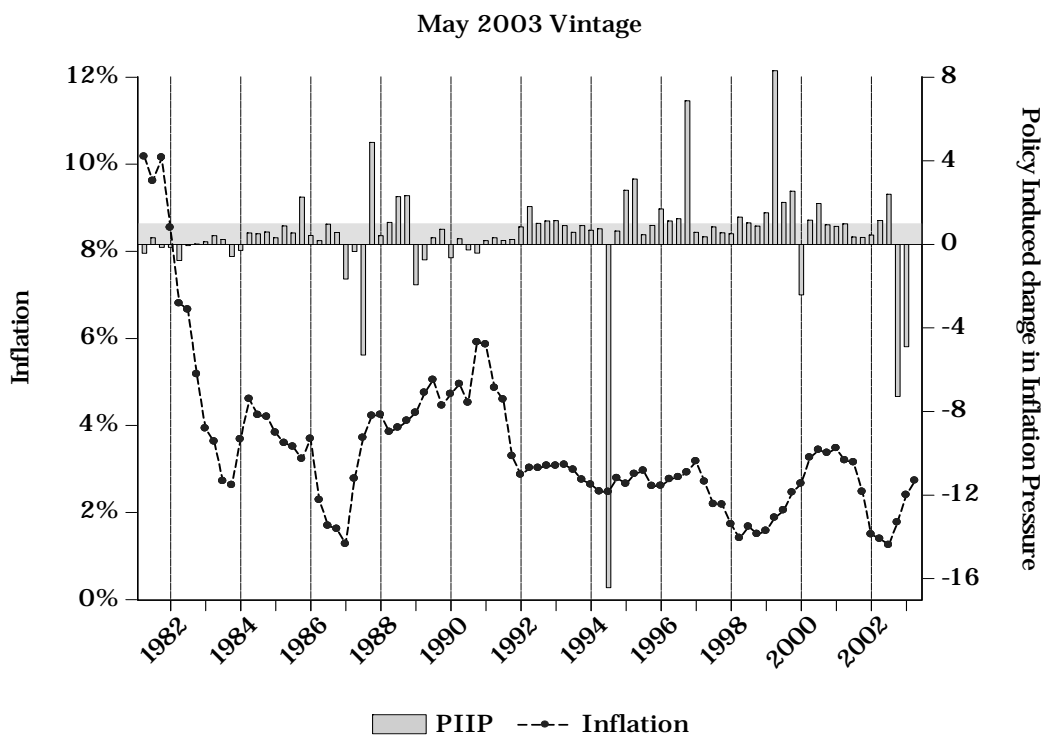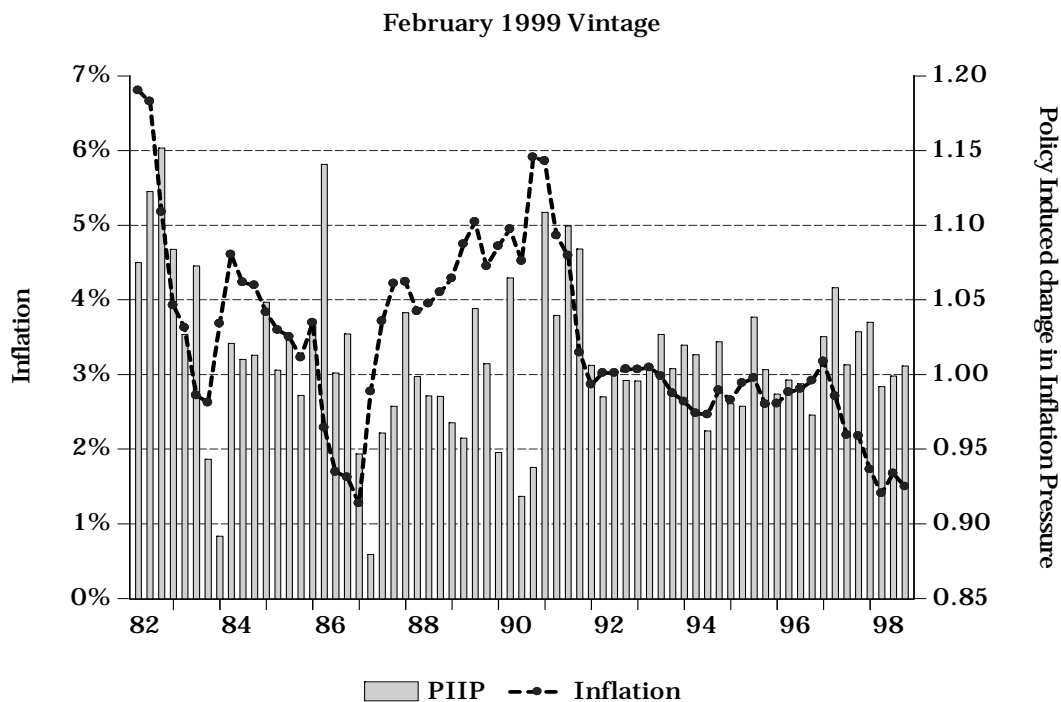
February 1999 Vintage

May 2003 Vintage

Note: The dates refer to the year-month of the vintage used to calculate PIIP. Also see equation (2) for the definition of PIIP.

Figure 5 Monetary Policy Effectiveness in the United States
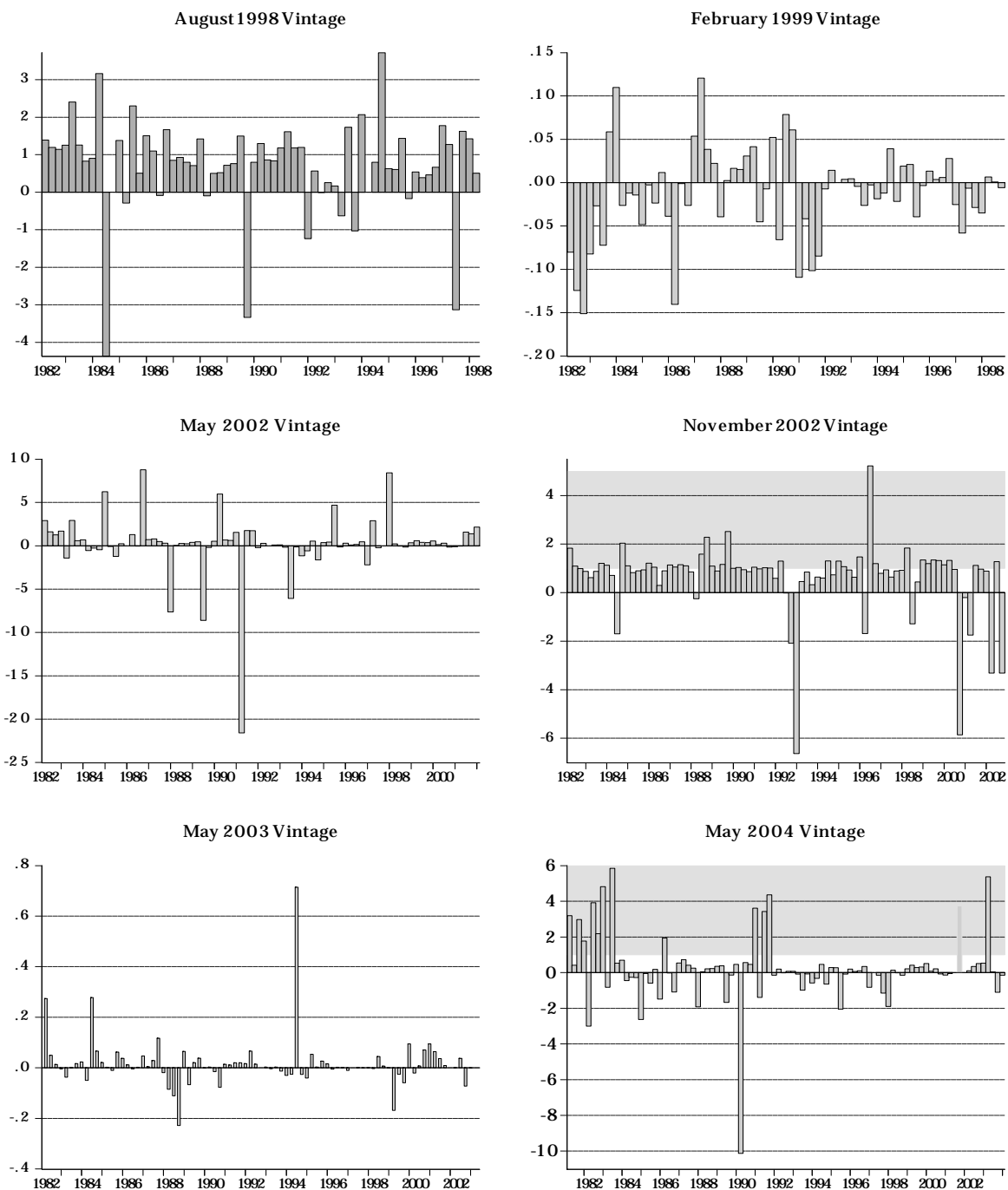
Note: The dates refer to the year-month of the vintage used to calculate PIIP. Also see equation (3) for the definition of MPE. The shaded areas highlight periods when monetary policy is considered to be unsuccessful, as defined in the text.

Table 1 Policy Induced Inflation Pressure and Monetary Policy Effectiveness Indexes

PIIP Index values	MPE Index values
=0 → No change in IP	=0 → MP completely effective
=1 → Inflation held constant	=1 → MP ineffective or 'neutral'
<0 → MP underreacts to IP (actually raises it)	<0 → MP unsuccessful
> 1 → MP 'overshoots' (opposite signs in numerator and denominator)	> 1 → MP 'overshoots' (IP magnified by MP action taken)
0<PIIP<1 → MP reduces some IP	0<MPE<1 → MP partially effective

Note: See text and descriptions of equations (2) and (3).

Table 2 Excerpts from FOMC Minutes

MEETING DATE	HIGHLIGHTS	VOTE	STANCE OF POLICY
August 18, 1998	"…a directive that called for maintaining conditions consistent with an unchanged federal funds rate of about 5 ½ percent." "…members remained persuaded that a significant rise in price inflation was not likely to occur in the nearer term." "…it was clear one the basis of any measure that consumer prices and inflation more generally had remained remarkably subdued in the context of very tight labor markets…" "The members generally anticipated somewhat more moderate growth than they had in their previous forecasts, with prospective expansion at a pace near or somewhat below the growth of economy's potential."	10-1	"…all but one of the members agreed on the desirability of maintaining a steady policy stance."
Feb. 2-3, 1999	"…the Committee believes that prospective developments are equally likely to warrant an increase or a decrease in the federal funds rate operating during the intermediate period." "…the persistence of subdued inflation and the absence of current evidence of accelerating inflation were seen as arguing against a policy tightening move at this point." "Indeed, the conjuncture over an extended period of strong economic growth, very low rates of unemployment, and the absence of any buildup of inflation could not be explained in terms of normal historical relationships." "…members referred to continuing indications of an exceptional economic performance that was characterized by the persistence of quite low inflation despite very high and rapidly rising levels of overall output and employment. The members currently saw few signs that more sustainable rate, but most continued to anticipate substantial showing over the year ahead at a pace close to or somewhat above that of the economy's long-run potential."	11-0	"…all the members favored an unchanged policy stance."
May 7, 2002	"All the members favored the retention of a neutral balance of risks statement to be released shortly after this meeting."	10-0	"…all the members agreed on the desirability of maintaining an

	"…current inflation pressures were subdued and were expected to remain so for a considerable period, thereby providing adequate opportunity to evaluate ongoing developments and tighten policy as needed later." "The outlook for inflation remained favorable." "The current accommodative stance of policy continued to be viewed as appropriate." "…the stance of monetary policy would have to become less accommodative once clearer evidence emerged that a healthy expansion was firmly established." "Nonetheless, activity would remain below the economy's potential for a period ahead and the persistence of underutilized resources was expected to contribute to damped core consumer price inflation."		unchanged policy stance,…"
Nov. 6, 2002	"Members commented that the potential costs of a policy easing action that later proved not to have been needed were quite limited in that there was little risk that such a move would foster inflationary pressures under likely economic conditions over the next several quarters." "A 50 basis point move would tend to have a more pronounced effect than usual in financial markets, at least initially, because it would be largely unexpected and would come after an extended hiatus in implementing policy changes." "…the Committee currently saw a likely need for further easing later." "…a failure to take action that was needed because of a faltering economic performance would increase the odds of a cumulatively weakening economy and possibly even attendant deflation. An effort to offset such a development, should it appear to be materializing, would permit difficult policy implementation problems." "The staff forecast prepared for this meeting suggested that, in light of further weaker-than-expected incoming economic data, the expansion of economic activity would be relatively muted for some time."	12-0	"…the current stance of monetary policy was still quite accommodative and was providing important support to economic activity,…"
May 6, 2003	"…the probability of some disinflation from an already low level exceeded that of a pickup in inflation."	11-0	"…all members indicated that they could support a proposal to

	"They [the members] recognized that the usual summary statement did not allow for the circumstances in which the Committee saw some probability, albeit minor, of a significant further decline in inflation to an unwelcome level." "Members commented that substantial additional disinflation would be unwelcome because of the likely negative effects on economic activity and the functioning of financial institutions and markets, and the increased difficulty of conducting an effective monetary policy, at least potentially in the event the economy was subjected to adverse shocks." "Members anticipated that inflation would remain at a low level for an extended period and indeed that the probability of further disinflation was higher than that that of a pickup in inflation, given the current high levels of excess capacity in labor and product markets, which seemed likely to diminish only gradually."		maintain an unchanged policy stance."
May 4, 2004	"All of the members agreed that, with policy tightening likely to begin sooner than expected, the reference to patience was not longer warranted. The Committee focused instead on a formulation that would emphasize that policy tightening, once it began, probably could proceed at a pace that would be "measure"." "…the statement should again indicate that the upside and downside risk to sustainable growth for the next few quarters seemed to be roughly equal. Members saw both downside and upside risks to prospects for inflation." "Overall, Committee members were now more convinced that recent robust growth would be sustained and most likely at a pace that would be adequate to make appreciable headway in narrowing margins of unutilized resources." "Survey measures of near-term inflation expectations edged up somewhat in March and April, but measures of longer-term expectations decreased."	12-0	"…the Committee saw a continuation of its existing policy stance as providing a degree of support to the economic expansion that was still appropriate."

Source: http://www.federalreserve.gov/fomc/minutes.

Table 3 Range of Estimates for Key Parameters in U.S. Macromodel (equations (4) – (6))

Vintage		IS curve $\beta_1 r_t$	$\beta_2 \tilde{y}_{t-1}$	Phillips curve $\alpha_1 \pi_{t-1}$	$\alpha_2 E_t \pi_{t+1}$	$\alpha_3 \tilde{y}_{t-1}$	ρ	Taylor rule γ_π	$\gamma_{\tilde{y}}$	γ_0
August 1998	Max	-.26	.05	.84	.84	.21	.87	1.62	.45	1.05
	Min	-.11	.02	.21	.57	-1.29	.86	1.35	.39	.86
February 1999	Max	.07	.49	.82	.77	.09	.60	2.96	1.66	-1.78
	Min	-.60	.29	.22	.59	.06	.78	2.55	.82	2.89
May 2002	Max	-.05	.47	.73	.76	.12		1.13	1.82	.22
	Min	-.20	.44	.16	.74	.04	.91 .83	2.67	.77	.65
November 2002	Max	.003	.48	.63	.75	.13	.93	1.34	1.61	.10
	Min	-.36	.37	.20	.70	.10	.82	2.67	.46	.19
May 2003	Max	.06	.48	.60	.74	.13	.57	2.46	3.05	.38
	Min	-.06	.46	.21	.69	.10	.79	2.44	1.88	2.46
May 2004	Max	.09	.49	.59	.75	.12	.81	3.06	.94	.08
	Min	-.15	.44	.20	.70	.10				

Notes: Max refers to the largest estimated coefficient obtained, Min to the smallest estimated coefficient obtained. Detailed estimates are relegated to an Appendix available from the first author. Taylor rule coefficients are steady state parameter estimates, except for the interest rate smoothing parameter. The first line represents estimates based on an H-P filter (smoothing parameter = 1600) while the second line relies on the CBO's estimate of potential output in estimating the output gap. For the May 2004 vintage only one set of plausible Taylor rule estimate was found (using the CBO's potential output measure). All results are based on a sample that begins in 1980.4, before differencing or lags. Note also that $r_t = [i_t - E_t \pi_{t+1}]$.

Table 4
A. Independent Change in Expectations: [1 – *MPE*]*100

Date	May 2003 vintage (%)	May 2004 vintage (%)
1998(Q3)	95.5	100.9
1999(Q1)	100.1	78.9
2002(Q2)	99.9	89.8
2002(Q4)	107.3	48.5
2003(Q2)	NA	96.0

Note: NA means not available or applicable.

B. PIIP: Summary Statistics and the Impact of a Counterfactual Experiment

Vintages	PIIP: mean (S.D.)	PIIP≤0 (%)	0<PIIP≤1 (%)	PIIP>1 (%)	Counterfactual Improved MP (%)	Counterfactual Worse MP (%)
August 1998	0.23 (1.24)	42.9	47.9	14.2	33.3	66.7
February 1999	1.01 (.05)	0	41.8	58.2	57.1	42.9
May 2002	0.86 (3.81)	23.1	44.6	32.3	46.8	53.2
November 2002	0.21(1.31)	43.3	47.7	9.0	27.7	72.3
May 2003	0.40 (2.55)	3.0	73.1	23.9	57.7	42.3
May 2004	0.95 (2.02)	12.1	44	43.9	NA	NA

Note: The columns labelled counterfactual show the fraction of times the differential between MPE under the counterfactual (i.e. May 2004 vintage) and the MPE as shown in Figure 5. A positive differential indicates that policy would have improved while a negative value would have produced a less successful monetary policy. NA means not applicable.

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Appendix 1

Derivation of Inflation Pressure Indices

A1.1 Ex Ante Inflation Pressure

Ex ante inflation pressure, as we define it, characterizes the inflationary conditions produced by forces outside the direct control of the monetary authority. Our concept of ex ante inflation pressure can be more clearly understood with the help of the following simple model:

$$y_t = f(i_t, x_t^e, u_t), \qquad f_i' < 0 \tag{A1.1}$$

$$\pi_t = g(y_t, x_t^e, e_t), \qquad g_y' > 0 \tag{A1.2}$$

where y_t is the output gap in period t, i_t is the interest rate in period t, x_t^e is a vector of private agents' expectational variables, and π_t is the inflation rate in period t. The arguments u_t and e_t represent random disturbances to the economy.

Equations (A1.1) and (A1.2) are general, though simple, representations of the aggregate demand and Phillips curve equations that are typically employed in the monetary policy literature. Together, (A1.1) and (A1.2) imply a negative relationship between inflation and the interest rate

$$\pi_t = h(i_t, x_t^e, e_t, u_t), \qquad h_i' < 0. \tag{A1.3}$$

From (A1.3) it is evident that if central banks can control i_t, then interest rate changes can be used to offset the impact of x_t^e, e_t, and u_t on inflation.

According to (A1.3) there is a trade-off between inflation and the interest rate, for given x_t^e, e_t, and u_t. This trade-off is illustrated graphically in Figure 1 by the curves IR_0, IR_1, and IR_z. The lowest curve, IR_0, represents the trade-off that existed in period $t-1$. The difference in the position of IR_0 and highest curve, IR_z, represents the shift in the trade-off caused by u_t and e_t (we assume for simplicity that there are no exogenous expectational shocks). Ex ante inflation pressure measures the rate of inflation that these shocks would have generated if the monetary authority had held $i_t = i_{t-1}$.
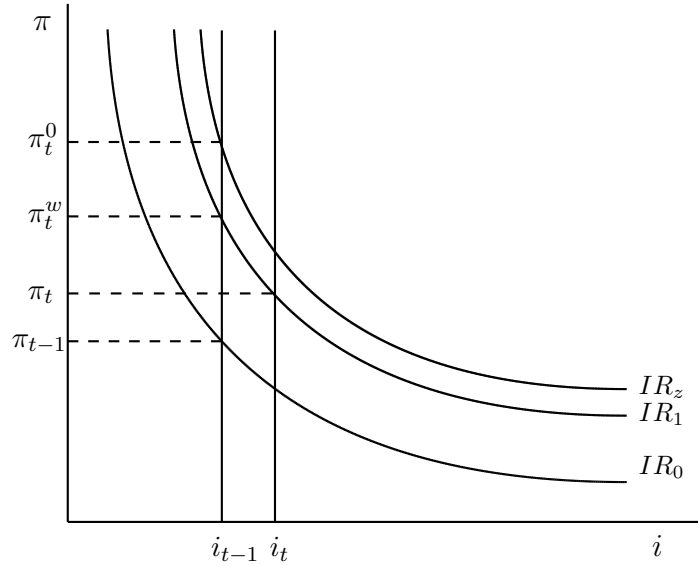
FIGURE 1

When agents form expectations rationally, x_t^e depends on i_t, causing the trade-off between π_t and i_t to shift (from IR_z to IR_1 in Figure 1). By defining inflation pressure as the change in inflation that would have been observed with $i_t = i_{t-1}$, we capture the potential impact of exogenous shocks (which may include exogenous changes in expectations) to the economy on inflation. This ensures that π_t^0 reflects only the impact of exogenous disturbances e_t and u_t, and any exogenous change in expectations that may have occurred in period t. Because π_t^0 reflects the impact of exogenous disturbances on the inflationary environment that existed before the monetary authority changed interest rates in response to those disturbances, we refer to π_t^0 as *ex ante* inflation.

Using the notation in Figure 1, we define our Ex Ante Inflation Pressure (*EAIP*) index as

$$EAIP_t = \pi_t^0 - \pi_{t-1} \tag{A1.4}$$

where π_t^0 denotes the inflation rate that would have been observed in period t if the monetary authority had held $i_t = i_{t-1}$.

Verbally, the definition of *EAIP* can be expressed as: The change in inflation that would have been observed if the policy authority had held interest rates constant, and this policy decision was correctly anticipated by rational economic agents.

A1.2 Ex Post Inflation Pressure

The term ex post inflation pressure refers to the inflation pressure that remains after a policy change has been implemented.

The IR curves shown in Figure 1 represent feasibility constraints that the monetary authority faces. In an economy populated with forward-looking rational agents, changes in the monetary instrument will alter inflation expectations causing the feasibility constraint to shift. Under the assumption that there is a negative relationship between the interest rate and inflationary expectations, an interest rate increase would cause the feasibility constraint to shift inwards. In Figure 1, we show the feasibility constraint shifting inwards, from IR_z to IR_1 when the policy authority increases the interest rate from i_{t-1} to i_t.

Graphically, ex post inflation pressure is represented by the vertical distance between the initial feasibility constraint IR_0 and the feasibility constraint associated with the monetary policy that was implemented IR_1. Ex post inflation pressure in period t is therefore given by the vertical distance between IR_0 and IR_1.

Using the notation in Figure 1, we define our Ex Post Inflation Pressure (*EPIP*) index as

$$EPIP_t \ = \ \pi_t^w \ - \ \pi_{t-1}. \tag{A1.5}$$

Thus *EPIP* can be defined verbally as: The change in inflation that would have occurred if the policy authority had unexpectedly refrained from intervening in the foreign exchange market, given the exptectations generated by the exchange rate policy actually implemented.

A1.3 Illustration of the Methodology

Our ex ante and ex post measures of inflation pressure are counter-factuals which must be imputed. In this section we demonstrate how to derive the expressions for these unobservable variables from a theoretical model. Because the index formulae we obtain from the empirical model are very complex, we use a much simpler aggregate model to illustrate the method by which we obtain our indices. We use Clarida,

Galí, and Gertler's (*JEL* 1999) aggregate rational-expectations model to illustrate the derivation of *EAIP* and *EPIP*.

Our illustrative economy is characterized by the following equations:

$$y_t = -\beta_1[i_t - E_t\pi_{t+1}] + \beta_2 E_t y_{t+1} + u_t \tag{A1.6}$$

$$\pi_t = \alpha_1 E_t \pi_{t+1} + \alpha_2 y_t + e_t \tag{A1.7}$$

$$i_t = \rho i_{t-1} + (1-\rho)[\gamma_\pi E_t \pi_{t+1} + \gamma_y E_t y_{t+1}] \tag{A1.8}$$

where y_t is the output gap in period t, i_t is the nominal interest rate, and π_t is the inflation rate in period t. The variable $E_t\pi_{t+1}$ denotes the expectation that rational agents form in period t about the level of inflation that will prevail in period $t+1$. Similarly, $E_t y_{t+1}$ is the rational, one-period-ahead expectation of the output gap. The random disturbances u_t and e_t are assumed to be independently distributed and to have zero means.

A1.3.1 Derivation of EAIP

The first step in deriving model-consistent measures of ex ante inflation pressure, is to obtain the rational expectations solution for our model. We begin by postulating the following minimal state variable (MSV) solutions for y_t and π_t

$$y_t = q_1 u_t + q_2 e_t + q_3 i_{t-1} \tag{A1.9}$$

$$\pi_t = \delta_1 u_t + \delta_2 e_t + \delta_3 i_{t-1}. \tag{A1.10}$$

Under the assumption that the information sets available to agents at time t contain all lagged variables as well as contemporaneus observations of i_t, y_t, and π_t, (A1.9) and (A1.10) imply the following one-period-ahead expectations

$$E_t y_{t+1} = q_3 i_t \tag{A1.11}$$

$$E_t \pi_{t+1} = \delta_3 i_t. \tag{A1.12}$$

Substituting (A1.8), (A1.11) and (A1.12) into (A1.6) and (A1.7) yields

$$y_t = [-\beta_1 + \beta_1 \delta_3 + \beta_2 q_3]\Lambda^{-1}\rho i_{t-1} + u_t \tag{A1.13}$$

$$\pi_t = \{\alpha_1\delta_3 + \alpha_2[-\beta_1 + \beta_1\delta_3 + \beta_2 q_3]\}\Lambda^{-1}\rho i_{t-1} + \alpha_2 u_t + e_t \qquad (A1.14)$$

where $\Lambda = 1 - (1-\rho)\gamma_\pi\delta_3 - (1-\rho)\gamma_y q_3$.

According to our definition, ex ante inflation pressure measures the inflation rate that would have been observed in a given period if the policy authority had held the interest rate constant at the level observed in the previous period. When the actual value of ρ is less than unity (i.e., $0 \leq \rho < 1$), ex ante inflation pressure therefore measures a fully-anticipated one-period deviation from the observed (average) interest rate rule given in (A1.8). Ex ante inflation pressure in period t can be obtained from (A1.14) by setting $\rho = 1$ in period t. According to our model, holding $i_t = i_{t-1}$ generates the following inflation process

$$\pi_t^0 = [\alpha_2\beta_1(\delta_3^0 - 1) + \alpha_1\delta_3^0 + \alpha_2\beta_2 q_3^0]i_{t-1} + \alpha_2 u_t + e_t \qquad (A1.15)$$

where the superscripts on δ_3 and q_3 indicate that the values of these coefficients were obtained by setting $\rho = 1$ in period t.[1] The variable π_t^0 is a counterfactual, and as such is not directly observable. In order to impute π_t^0 from our model, we need to solve for the undetermined coefficients in (A1.15). In addition, because the random disturbances, u_t and e_t, are not observable, we need to use the model to derive the relationship between the unobservable shocks and the changes in observable endogenous variables that occur in response to these shocks.

Comparing (A1.13) and (A1.14) with (A1.9) and (A1.10), respectively, we obtain $\delta_1 = \alpha_2$, $\delta_2 = q_1 = 1$, $q_2 = 0$. With $\rho_t = 1$, δ_3 and q_3 are given by

$$\delta_3^0 = \frac{-\alpha_2\beta_1}{(1-\alpha_1)(1-\beta_2) - \alpha_2\beta_1} \qquad (A1.16)$$

$$q_3^0 = \frac{-\beta_1(1-\alpha_1)}{(1-\alpha_1)(1-\beta_2) - \alpha_2\beta_1}. \qquad (A1.17)$$

---

[1]Note that in the simple model we have specified, π_t is a function of current and past ρ values only. By setting $\rho_t = 1$ and expressing the RE solution for π_t in terms of i_{t-1}, we implicitly set all past ρ values at their actual (observed) values and ensure that (A1.15) measures the impact of a one-period deviation from the actual policy rule on inflation.

In order to recover the disturbances u_t and e_t from (A1.9) and (A1.10), we need to solve for the undetermined coefficients in these two equations under the interest rate policy actually implemented. The coefficients δ_1, δ_2, q_1, and q_2 are independent of the magnitude of ρ and are therefore identical in value to those obtained above for $\rho_t = 1$. The remaining coefficients, δ_3 and q_3, are not independent of ρ and must therefore be recalculated. It turns out that even in this simple model, δ_3 and q_3 are non-linear functions of each other whose solution requires the application of numerical methods. Obtaining the solutions for δ_3 and q_3 would require estimation of (A1.6)–(A1.8). However, as numerical solutions are not necessary for the purposes of this illustration, we can proceed without them.[2] Under the assumption that solutions for δ_3 and q_3 exist, we may express u_t and e_t as

$$u_t \; = \; y_t \; - \; q_3 i_{t-1} \tag{A1.18}$$

$$e_t \; = \; \pi_t \; - \; \alpha_2 y_t \; + \; [\alpha_2 q_3 - \delta_3] i_{t-1}. \tag{A1.19}$$

Substituting (A1.18) and (A1.19) into (A1.15) yields the operational formula for measuring ex ante inflation pressure that is consistent with our illustrative model:

$$\pi_t^0 \; = \pi_t \; + \; \left\{ [\alpha_1 + \alpha_2 \beta_1] \delta_3^0 \; - \; \alpha_2 \beta_2 q_3^0 \; - \; \delta_3 \; - \; \alpha_2 \beta_1 \right\} i_{t-1}. \tag{A1.20}$$

Ex ante inflation pressure in period t is then given by

$$EAIP_t \; = \; \pi_t^0 \; - \; \pi_{t-1}.$$

A1.3.2 Derivation of EPIP

Ex post inflation pressure is the inflation pressure that remains after the monetary policy response has taken effect. From Figure 1 it is apparent that ex post inflation pressure will not generally be directly observable. What we observe instead, is the combination of inflation and interest rate that reflect the magnitude of the inflation

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[2]The numerical solutions required to estimate the indices in the main text are obtained using a computational program developed by Sims (2001).

pressure that remains following a particular interest rate change. In order to measure ex post infltion pressure we use our theoretical model conduct a counter-factual measurement experiment in which the distance between the feasibility constraints IR_0 and IR_1 is expressed in inflation-equivalent units. This yields an operational formula for ex post inflation pressure that can be calculated on the basis of oberved changes in inflation and interest rate levels.

As a first step, we substitute (A1.6) into (A1.7) to obtain the semi-reduced form for π_t:

$$\pi_t = \alpha_1 E_t \pi_{t+1} - \alpha_2 \beta_1 i_t + \alpha_2 \beta_1 E_t \pi_{t+1} + \alpha_2 \beta_2 E_t y_{t+1} + \alpha_2 u_t + e_t. \quad \text{(A1.21)}$$

In the context of our model, ex post inflation pressure in period t is measured as the change in inflation that would have been generated by u_t, e_t, and i_{t-1}, given the expectations that were formulated under the policy actually implemented (i.e., under i_t). Replacing i_t with i_{t-1} in (A1.21) yields

$$\pi_t^w = \alpha_1 E_t \pi_{t+1} - \alpha_2 \beta_1 i_{t-1} + \alpha_2 \beta_1 E_t \pi_{t+1} + \alpha_2 \beta_2 E_t y_{t+1} + \alpha_2 u_t + e_t. \quad \text{(A1.22)}$$

It follows immediately from (A1.21) and (A1.22) that π_t^w can be measured as

$$\pi_t^w = \pi_t + \alpha_2 \beta_1 \Delta i_t. \quad \text{(A1.23)}$$

Ex post Inflation Pressure in period t is then given by

$$EPIP_t = \pi_t^w - \pi_{t-1}$$

A1.4 Measuring the Impact of Expectational Changes

In Figure 1, we assume that exogenous disturbances shift the interest/inflation trade-off available to the policy authority from IR_0 to IR_z. In our illustrative example, expectational changes account for the shift from IR_z to IR_1. The impact of the expectational change can be quantified in terms of the relative magnitudes of these two shifts. Employing the vertical distances between the trade-off curves for this purpose we have:

$$\frac{\pi_t^0 - \pi_t^w}{\pi_t^0 - \pi_{t-1}}. \quad \text{(A1.24)}$$

By adding and subtracting π_{t-1} to the numerator and denominator of (A1.24), we obtain

$$\frac{EAIP_t - EPIP_t}{EAIP_t - \Delta\pi_t}. \tag{A1.25}$$

Dividing both the numerator and denominator by $EAIP_t$ allows us to express (A1.25) as

$$\frac{1 - MPE_t}{PIIP_t}, \tag{A1.26}$$

which is the expression used to measure the proportion of ex ante inflation removed by changes in private agents' expetations in Section 3 of the main text.

Appendix 2

Quarterly Inflation Pressure Estimates

A2.1 Quarterly Ex Ante Inflation Pressure

Minimal state variable solutions for our quarterly empirical model were obtained using gensys, a computational program developed by Sims (2001). The computations assume that agents are fully rational and result in solutions of the following form for the endogenous variables π_t, y_t, and i_t.

$$\pi_t = \mu_0 + \mu_1\pi_{t-1} + \mu_2 y_{t-1} + \mu_3 i_{t-1} + \mu_4\epsilon_t + \mu_5\eta_t + \mu_6\sigma_t \tag{A2.1}$$

$$y_t = q_0 + q_1\pi_{t-1} + q_2 y_{t-1} + q_3 i_{t-1} + q_4\epsilon_t + q_5\eta_t + q_6\sigma_t \tag{A2.2}$$

$$i_t = \omega_0 + \omega_1\pi_{t-1} + \omega_2 y_{t-1} + \omega_3 i_{t-1} + \omega_4\epsilon_t + \omega_5\eta_t + \omega_6\sigma_t. \tag{A2.3}$$

Our quarterly model specifies a one period control lag between the interest rate and inflation. We therefore construct our quarterly ex ante inflation pressure index by computing the inflation rate that would have been observed in period t if the interest rate in period $t-1$ had been held constant at its period $t-2$ level. As before, when we conduct this counterfactual experiment for a given period, we assume that the interest rate in all other periods was generated by the policy authority's estimated interest rate response function. Consequently, our measure of inflation pressure captures the

impact on inflation of a very specific one-period deviation from the interest rate rule. In the context of the model, we set $\rho = 1$ in period $t - 1$ and $\rho = \hat{\rho}$, where $\hat{\rho}$ is the estimated coefficient value, for all other time periods.[3]

Because the agents in our model are forward looking, counterfactual policy experiments that have an impact on the response coefficient ρ will also affect expectations. In the context of our model, we need to know how setting $\rho = 1$ in period $t - 1$ affects the expectational terms in (4)–(6). We accomplish this by using (A2.1)-(A2.3) to express all of the expectational variables in terms of i_{t-1}, so that we can then use (6) to construct the counterfactual one-period deviation from the interest rate rule.

We begin by using our numerically computed rational expectations solutions to obtain expressions for the necessary expectational variables. In these solutions, future expectations are functions of past expectations. In order to construct our counterfactual ex ante inflation pressure measure we therefore repeatedly replace expectations further into the future with those formed at an earlier date. For example, $E_t \pi_{t+3}$ is a function of $E_t \pi_{t+2}$, $E_t y_{t+2}$, $E_t i_{t+2}$, and $E_t \pi_{t+1}$. Substituting the solutions for $E_t \pi_{t+2}$, $E_t y_{t+2}$, and $E_t i_{t+2}$ into the expression for $E_t \pi_{t+3}$ we express $E_t \pi_{t+3}$ in terms of one-period-ahead expectations. We continue substituting backwards in this way until all of the relevant variables are expressed as functions of i_{t-1}. Because our numerical computations employ the estimated value of ρ, none of these backward substitutions involve a deviation from the observed interest rate rule. [4] It is only when all of

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[3]Note that because (4)–(6) include lagged variables, our quarterly measure of ex ante inflation pressure for any given period captures not only the impact of current exogenous disturbances, but also the impact of past policy actions as they are reflected in the values of lagged endogenous variables. In the context of quarterly empirical model, our ex ante index of inflation pressure measures the inflation rate that would have been observed in period t, *taking policies in period $t - 4$ and earlier as given*, if there had been no change in the interest rate between periods $t - 3$ and $t - 2$. However, to the extent that past policy actions contribute to the inflationary environment that the policy authority faces in any given period, our ex ante inflation pressure index still provides a useful benchmark against which to measure the strength and effectiveness of the monetary authority's policy response.

[4]The RE coefficients that would be obtained under the counterfactual assumption $\rho_t = 1$ can be

the substitutions have been completed that we implement our counterfactual policy experiment by setting $\rho = 1$ in period $t - 1$. This procedure enables us to measure a fully anticipated one-period deviation from the policy rule.

Applying the methodology described above to our quarterly model yields the following formulae for computing ex ante inflation:

$$
\begin{aligned}
\pi_t^0 \;=\; & \Gamma_0^0 + \Gamma_1^0 \pi_{t-1} + \Gamma_2^0 \pi_{t-2} + \Gamma_3^0 y_{t-1} + \Gamma_4^0 y_{t-2} + \Gamma_5^0 i_{t-2} \\
& + \Gamma_6^0 \epsilon_t + \Gamma_7^0 \eta_t + \Gamma_8^0 \eta_{t-1} + \Gamma_9^0 \sigma_t.
\end{aligned} \tag{A2.4}
$$

The coefficients Γ_i^0, $i = 1, ..., 9$, in (A2.4) are complex composites of the parameter estimates in (4)–(6) and (A2.1)–(A2.3). The estimated Γ^0 coefficients obtained for each vintage are given in Table A2.1.

A2.2 Quarterly Ex Post Inflation Pressure

Our empirical model is composed of the following three equations:[5]

$$
\pi_t = \alpha_0 + \alpha_1 \pi_{t-1} + \alpha_2 \mathrm{E}_t \pi_{t+4} + \alpha_3 y_{t-1} + \epsilon_t \tag{A2.5}
$$

$$
y_t = \beta_0 + \beta_1 y_{t-1} + \beta_2 \mathrm{E}_t y_{t+1} + \beta_3 [i_t - \mathrm{E}_t \pi_{t+1}] + \beta_4 [i_{t-1} - \mathrm{E}_{t-1} \pi_t] + \eta_t \tag{A2.6}
$$

$$
i_t = \rho i_{t-1} + (1 - \rho)[\gamma_0 + \gamma_\pi \mathrm{E}_t \pi_{t+2} + \gamma_y y_t + \sigma_t] \tag{A2.7}
$$

The calculation of ex post inflation pressure involves a measurement experiment in which the degree of inflation pressure, reflected in the combined changes in observed

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expected differ from those obtained under the policy rule that was actually implemented. A precise representation of the impact of such a deviation from the policy rule on expectations requires a closed-form RE solution. Because the model we employ is too complex to admit a tractable closed-form solution, we approximate the solution by employing the RE coefficients computed under the observed policy rule. Given that we are only failing to adjust the coefficients for a one-period deviation from the estimated policy rule, this approximation should not have any significant impact on the quantitative results obtained.

[5]The first two equations are common to all vintages. The general form of the Taylor Rule is the same for all vintages also, but we chose the degree of forward-lookingness in the TR based on the fit and plausibility of the estimated coefficients, so these do vary a little among vintages. The TR given here is the one used for the August 1998, Feb 1999, and May 2004 sub-samples.

TABLE A2.1

Estimated Ex Ante Inflation Formulae

	Aug 1998	Feb 1999	May 2002	Nov 2002	May 2003	May 2004
Γ_0^0	4.0155	11.6985	0.1180	-0.9266	-1.1885	0.8177
Γ_1^0	0.7524	0.3733	0.7350	0.9103	0.7942	0.7386
Γ_2^0	0.0020	0.0004	0.0022	0.0035	0.0240	0.0080
Γ_3^0	0.0239	0.0405	0.1165	0.7179	0.1520	0.0567
Γ_4^0	0.0178	0.0208	0.0479	0.0519	0.1286	0.0301
Γ_5^0	0.0033	0.0358	0.0206	0.0869	0.1067	0.0564
Γ_6^0	1.0858	1.0221	1.0772	1.5438	1.1994	1.1527
Γ_7^0	0.0223	0.0563	0.1523	1.7179	0.3346	0.0996
Γ_8^0	0.0361	0.0577	0.0959	0.0950	0.2712	0.0675
Γ_9^0	0.0000	0.0065	-0.0010	0.0086	0.0186	0.0050

inflation and interest rate levels, is expressed in inflation-rate-equivalent-units. Substituting (A2.7) into (A2.6) and lagging the resulting expression one period yields

$$y_{t-1} = \beta_0 + \beta_1 y_{t-2} + \beta_2 E_{t-1} y_t + \beta_3 E_{t-1} \pi_t + \beta_4 [i_{t-2} - E_{t-2} \pi_{t-1}] + \eta_{t-1}$$

$$+\beta_3 [\rho i_{t-2} + (1 - \rho)\{\gamma_0 + \gamma_\pi E_{t-1} \pi_{t+1} + \gamma_y y_{t-1} + \sigma_{t-1}\}]. \qquad (A2.8)$$

The one period control lag between the interest rate and inflation means that our measurement experiment entails setting $i_{t-1} = i_{t-2}$ in period $t - 1$ while holding expectations contstant. Setting $\rho = 1$ in (A2.8) and substituting the resulting expression into (A2.5) results in the following expression for the period t ex post inflation rate π_t^w:

$$\pi_t^w = \alpha_0 + \alpha_1 \pi_{t-1} + \alpha_2 E_t \pi_{t+4} + \epsilon_t + \alpha_3 \{\beta_0 + \beta_1 E_{t-1} y_t - \beta_3 E_{t-1} \pi_t\}$$

$$+\alpha_3 \{\beta_4 [i_{t-2} - E_{t-2} \pi_{t-1}] + \eta_{t-1} + \beta_3 i_{t-2}\}. \qquad (A2.9)$$

But, by substituting (A2.6) into (A2.5), observed π_t is given by

$$\pi_t = \alpha_0 + \alpha_1 \pi_{t-1} + \alpha_2 E_t \pi_{t+4} + \epsilon_t + \alpha_3 \{\beta_0 + \beta_1 E_{t-1} y_t - \beta_3 E_{t-1} \pi_t\}$$

$$+\alpha_3 \{\beta_4 [i_{t-2} - E_{t-2} \pi_{t-1}] + \eta_{t-1} + \beta_3 i_{t-1}\}. \qquad (A2.10)$$

From (A2.9) and (A2.10), it follows directly that

$$\pi_t^w = \pi_t - \alpha_3 \beta_3 \Delta i_{t-1} \qquad (A2.11)$$

and

$$EPIP_t = \Delta \pi_t - \alpha_3 \beta_3 \Delta i_{t-1}. \qquad (A2.12)$$