Preliminary

NEAR-RATIONALITY AND INFLATION IN TWO MONETARY REGIMES

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I. INTRODUCTION

How can we explain the short-run behavior of output and inflation? Since Fischer (1978), many researchers have sought to do so with models that combine nominal price stickiness and rational expectations. Currently, the most popular models of this kind are Taylor's (1980) and Calvo's (1983) models of staggered price adjustment. Unfortunately, recent work shows that these models fail to fit key facts about the macroeconomy. In particular, the models are inconsistent with the inertia in real-world inflation -- the persistent effects of shocks to inflation, and the output costs of reducing inflation (e.g. Fuhrer and Moore, 1995; Roberts, 1998; Estrella and Fuhrer, 1998).

In searching for better models, some authors suggest relaxing the assumption of rational expectations. They argue that some or all agents have "backward-looking" expectations: expected inflation equals past inflation (e.g. Ball, 1991; Roberts, 1997; Rudebusch and Svensson, 1998). Roberts (1998) and Fuhrer (1998) show that the canonical staggered-price-setting model fits the data much better when backward-looking behavior is introduced. However, backward-looking models were rejected in the 1970s for a good reason: the Lucas (1976) critique. While the models fit the behavior of inflation in the current monetary regime, expectations are likely to change if monetary policy changes. Therefore, backward-looking models produce misleading predictions about the effects of policy shifts.

Thus researchers face a dilemma: rational-expectations models fail to fit key facts, but backward-looking models are subject to the Lucas critique. This paper looks for a solution to this dilemma. I propose a less-than-fully-rational model of expectations that is applicable to any monetary regime. The deviation from rationality is that agents use only a limited set of information to forecast future variables. Specifically, in forecasting inflation, they use only the past behavior of inflation. They use this univariate information optimally, but they do not use information on other variables, such as output or interest rates. Following Akerlof and Yellen (1985a), I interpret this behavior as a "near-rational" approach to forecasting that reduces the costs of gathering and processing information.

For the postwar United States, my assumption is close to the assumption of backward-looking expectations. For this period, the univariate behavior of inflation is close to a random walk; thus lagged inflation is close to an optimal univariate forecast of inflation. In other monetary regimes, however, the univariate process for inflation can be quite different. In such regimes, expected inflation differs greatly from lagged inflation.

After proposing my theory of expectations, I embed it in a simple sticky-price model and test its implications. Since the goal is to predict shifts in behavior across regimes, I test the model using data from two different periods in U.S. history. The first is the period from 1960 to the present, when inflation has been highly persistent. The second is the period from 1879 through

1914, when the U.S. had a gold standard. In that period, the univariate process for inflation was close to white noise. As a result, my assumption of univariate forecasts implies that expected inflation was close to a constant.

My main approach to testing the model follows Fuhrer-Moore and Roberts. For each of the periods I consider, I summarize the behavior of the economy with a vector autoregression for output, inflation, and a short-term interest rate. I compare impulse responses for this system to those for a system with the unrestricted inflation equation replaced by the inflation equation from my model. Under the assumption of optimal univariate expectations, the restricted and unrestricted impulse responses are similar. This finding contrasts with the results under rational expectations: like previous authors, I find that rational expectations has counterfactual implications. For the gold-standard period, the univariate-forecast assumption also fits better than backward-looking expectations. Backward-looking expectations imply inflation persistence that did not exist in the gold-standard era.

The rest of this paper contains six sections. Section II discusses current models of expectations and Section III proposes my new approach. Section IV presents the macroeconomic model, Section V discusses the two historical periods I study, and Section VI presents the main empirical results. Section VII concludes.

II. INFLATION INERTIA AND CURRENT MODELS OF EXPECTATIONS

Inflation inertia is a central feature of the postwar economy. Inflation is inertial in the sense that shocks have highly persistent effects on inflation, and reducing inflation requires substantial output losses. These stylized facts are captured by both vector autoregressions (e.g. Christiano, et al. 1994) and historical studies (e.g. Romer and Romer, 1989; Ball 1994a). When theorists attempt to explain these facts, assumptions about expectations play a central role in their models.

A. Rational-Expectations Models

Since the 1970s, most researchers studying inflation dynamics have used models with rational expectations. To capture the interactions of inflation and output, they often assume frictions in wage- and price-setting. In recent years, many researchers have converged on a particular price-setting model: the Taylor-Calvo model of staggered adjustment. According to Goodfriend and King (1998), the Taylor-Calvo model with rational expectations is part of the "new synthesis" in macroeconomics, and the model has become a standard tool for analyzing alternative monetary policies (e.g. McCallum and Nelson, 1999).

In the past, some authors have claimed that the staggering in the Taylor-Calvo model generates inflation inertia (e.g. Blanchard and Summers, 1988). Recent research has shown, however, that this is incorrect. The model produces inertia in the price *level*; for example, prices respond slowly to a one-time shift in the money stock. But the model does not produce the inertia in the inflation rate -- the rate of change of prices -- that is observed in the data (Ball, 1994b). Because it lacks inflation inertia, the rational-expectations Taylor-Calvo model produces a number of counterfactual predictions (see Roberts, 1998, and Estrella and Fuhrer, 1998.) One prediction is that shocks to inflation die out quickly, even if there is no policy response. Another is that a monetary contraction produces a sharp drop in inflation before the policy has any effect on output. These predictions conflict with empirical evidence in previous work and in the analysis below.

Of course, what the data reject is the combination of rational expectations with a particular model of price setting. In principle, the Taylor-Calvo model might be modified to make it fit the data under rational expectations. Researchers such as Fuhrer and Moore (1995), Rotemberg and Woodford (1997), and Gali and Gertler (1999) explore variations on the model. However, no consensus has emerged on whether these variations are successful in fitting the facts. Thus other researchers, and this paper, take a different approach: relaxing the assumption of rational expectations.

B. Backward-Looking Expectations

Until the 1970s, the standard model of expectations was backward-looking: expected inflation was assumed to equal lagged inflation (or an average of several lags). Given the empirical failures of rational-expectations models, some researchers have suggested a return to backward-looking models, or models with both backward-looking and rational agents (e.g. Ball, 1991; Roberts, 1997). Backward-looking behavior helps to explain inflation inertia: since firms choose prices based on expected inflation, backward-looking expectations make current inflation depend on lagged inflation. Roberts (1998) shows that the Taylor-Calvo model fits the data much better when he assumes that some price setters have backward-looking expectations than when he assumes rational expectations for all.

But can one justify the assumption of backward-looking expectations theoretically? If we examine only the postwar United States, the answer is yes. During the postwar era, the persistence of inflation has been strong enough that current inflation is a good predictor of future inflation. Thus backward-looking expectations have been fairly close to rational. Inflation usually changes slowly, and the occasional large changes are often the result of unforecastable shocks, such as OPEC price rises. Consequently, backward-looking inflation forecasts are not much worse than forecasts that use information optimally.

This reasoning suggests that we can interpret backward-looking expectations as a "near-rational rule of thumb" (Akerlof and Yellen, 1985a). It is costly to gather and process the information needed for fully rational inflation forecasts. Some large firms pay these costs -- they hire economists to build forecasting models and monitor the Fed. For the local pizza parlor, however, the costs of these activities are larger than the gains from improved inflation forecasts. So the pizza parlor uses the inexpensive and reasonably accurate rule of setting expected inflation equal to past inflation. This justification for near-rational inflation forecasting parallels justifications for near-rational behavior in price adjustment (Akerlof and Yellen, 1985b) and in consumption (Cochrane, 1989).

The empirical results below support the view that backward-looking expectations are near-rational in the current regime. If one forecasts inflation to equal past inflation, the forecast error is simply the change in inflation. For annual data on the GDP deflator from 1960-97, the standard deviation of inflation changes is 1.17 percentage points. If one forecasts inflation over 1960-97 with a vector autoregression including output, inflation, and a short-term interest rate, the standard error of the forecasts is 0.86 percentage points. Thus a substantial increase in the sophistication of forecasts reduces the typical error by only a few tenths of a percentage point. This improvement gives firms little incentive to abandon backward-looking expectations.

C. The Lucas Critique

A limitation of the preceding argument is that it relies on a feature of the economy -- the persistence of inflation -- that arises in a particular monetary regime. In other possible regimes, inflation would not be persistent, and so backward-looking expectations would be far from rational. For example, if the Federal Reserve adopted a strict price-level target, inflation would have negative serial correlation, because policy would reverse deviations from the target. In such a regime, the expectation that inflation will equal past inflation would be obviously unreasonable, and would produce large forecast errors. Firms with backward-looking expectations would have strong incentives to change their behavior.

This idea is more than a theoretical possibility. The inflation persistence in the postwar United States does not extend to earlier historical periods. In particular, the serial correlation of inflation in the decades before 1914 is close to zero (Barsky, 1987). As documented below, this fact implies that backward-looking expectations produce large forecast errors for that period. The pre-1914 behavior of expectations is likely to differ from its recent behavior, leading to different inflation dynamics. This idea is supported by the finding that Phillips curves for the pre-1914 period have smaller coefficients on lagged inflation than postwar Phillips curves (e.g. Gordon, 1980).

Because of the Lucas Critique, it is dangerous to assume backward-looking expectations in comparing different monetary regimes. The usual response to the Lucas Critique is to assume rational expectations -- but in models of inflation dynamics, this assumption produces unrealistic predictions about the current regime. We need a new model that fits the current regime and also makes plausible predictions about how expectations would behave in other regimes.

III. A NEW MODEL OF EXPECTATIONS

What is the right near-rational model of expectations? There is inevitably some arbitrariness in answering this question. Part of the appeal of rational expectations is that it has an unambiguous definition. When one relaxes this assumption, rationality can fail in many ways -- agents can ignore various pieces of information, or make various systematic errors. (To paraphrase Tolstoy, all rational models are rational in the same way, but every non-rational model is non-rational in a different way.) One can imagine a deep theory of information gathering and processing that predicts deviations from rational expectations, but we are far from having such a theory. The best one can do at present is to propose plausible but ad hoc types of behavior and see whether they fit the data.

This paper examines one type of near-rational behavior. I assume that agents predicting inflation make optimal univariate forecasts. The deviation from rationality is the fact that forecasts are univariate: agents ignore relevant variables such as output and interest rates. Aside from this limitation, agents' forecasts are optimal: they use inflation data as best they can. Metaphorically, one can imagine firms who use Box-Jenkins techniques to select an ARIMA model for inflation, but who do not go to the added trouble of using multivariate techniques.

The justification for this kind of rule is the same as the earlier justification for backward-looking expectations: the rule is a near-rational rule of thumb that performs fairly well. It economizes on information costs because it involves examining only a single, obvious variable, and it produces only modest increases in forecast errors compared to full rationality. Here, however, the justification is not specific to a particular monetary regime.

For the current period (post-1960), Barsky and others show that inflation is close to a random walk. Thus an optimal univariate forecast of inflation is approximately equal to lagged inflation, making my assumption close to the assumption of backward-looking expectations. In regimes with less inflation persistence, however, expectations in my model adjust to the behavior of inflation. In the gold-standard era, near-white-noise inflation means that the optimal univariate forecast is close to a constant. As detailed below, univariate forecasts lead to errors that are only modestly larger than multivariate forecasts in the gold-standard era as well as the current period. Thus the behavior of expectations that I assume is near-rational in two different monetary regimes.

Another motivation for my model of expectations comes from past work on the U.S. Phillips curve. As discussed above, Gordon (1980) and others find that the Phillips-curve coefficient on lagged inflation is small in the gold-standard period. Gordon interprets the lagged-inflation term as a proxy for expected inflation, and argues that the low coefficient reflects the adjustment of expectations to low serial correlation in inflation. Gordon’s finding is sometimes interpreted as evidence of rational expectations, but it is also consistent with my assumption that expectations are determined by the univariate behavior of inflation.

My model is just one kind of near-rationality; future research should explore alternatives. One can imagine expectations that are closer to full rationality; for example, agents might use data on output as well as inflation to forecast future inflation, while still ignoring interest rates. Or expectations could be farther from rationality; agents might use AR-1 models of inflation rather than optimal ARIMA models. Another possibility is Roberts's (1998) model of "stubborn" expectations, in which expected inflation adjusts slowly to new information. This paper is a first pass at examining one reasonable model of near-rationality.

Another possible variation is to introduce heterogeneity in expectations. Recent work has considered models in which some agents have rational expectations and others do not; for example, Roberts (1998) and Gali-Gertler (1998) consider mixtures of rational and backward-looking expectations. In this paper, I assume that <u>all</u> agents make univariate forecasts, and find that my model captures broad features of the data. Future work can see whether the model's fit improves further when one combines univariate and fully rational expectations.

Akerlof and Yellen's idea of near rationality is one inspiration for my model. Another is Lucas's (1973) imperfect-information model of the Phillips curve. In Lucas's model, agents ignore certain information -- they ignore data on the price level in estimating relative prices -- but they use the information they do have optimally. I, too, assume that agents make optimal forecasts based on limited information, although the details of the information restiction are different. (In my model, agents do observe the price level but ignore other variables). Lucas and Akerlof-Yellen are often viewed as leaders of opposing macroeconomic schools, but they are barking up the same tree in exploring deviations from full-information rationality. This paper builds on the common theme in their work.

IV. A SIMPLE MODEL OF PRICE SETTING

This section describes a simple macroeconomic model with sticky prices. In the empirical work below, I test the model under alternative assumptions about expectations.

The model is based on the canonical macroeconomic model of imperfect competition (Romer, 1996, Ch. 6). The economy contains a large number of firms; each firm's desired relative price is given by

$$(1) \qquad p^* - p = vy , \qquad v>0 ,$$

where p^* is the desired nominal price, p is the aggregate price level, and y is aggregate output (all variables are in logs). Equation (1) can be derived from profit-maximization when firms have isoelastic cost and demand functions. Intuitively, a rise in aggregate spending shifts out each firm's demand curve, raising its desired relative price.

The model is set in discrete time; in the empirical work, I interpret a period as a year. A fraction w of all firms have sticky prices and the rest have flexible prices. Flexible-price firms set their nominal prices at the desired level p^* after observing the current p and y. Sticky-price firms choose prices one period in advance, and set them equal to expected optimal prices. Thus

$$(2) \qquad p^f = p + vy ;$$

$$p^s = p^e + vy^e ,$$

where p^f and p^s are the prices of flexible- and sticky-price firms, and e denotes an expectation as of the previous period. The terms p^e and y^e may or may not equal mathematical expectations, depending on whether we assume rational expectations.

The aggregate price level is the average of p^s and p^f with weights w and 1-w. Using this fact and equation (2), one derives

$$(3) \qquad p = p^e + vy^e + [(1-w)v/w]y .$$

Subtracting the lagged price level from each side yields

$$(4) \qquad \pi = \pi^e + vy^e + [(1-w)v/w]y ,$$

where $\pi=p-p_{-1}$ is inflation and $\pi^e=p^e-p_{-1}$ is expected inflation.

Equation (4) is an expectations-augmented Phillips curve. Inflation depends on expected inflation and two output terms: expected output, which affects prices set in advance, and actual output, which affects flexible prices.

As discussed above, much recent research uses a more sophisticated model of price setting, the Taylor-Calvo model of staggering. I depart from this work for two reasons. First, I use annual data, because higher-frequency output data are not available for the pre-1914 period. It is standard to assume that each firm adjusts its price once a year, based on evidence that this is a realistic frequency (Blinder et al., 1998). Previous authors assume that prices are set for four periods when they use quarterly data (e.g. Fuhrer-Moore) and two periods with semi-annual data (Roberts). In my case, adjustment once a year means adjustment every period, which precludes staggering across firms. If all prices were set in advance, my model would also preclude any response of inflation to output within a year. I introduce a flexible-price sector to allow some contemporaneous response.

The second reason for omitting staggered adjustment is that, contrary to the conventional wisdom, it may not be important for fitting the facts. As discussed in Section II, the failures of the forward-looking Taylor-Calvo model show that staggering is not sufficient to explain inflation dynamics; some other imperfection must be introduced. And once we allow deviations from rational expectations, it is not clear that staggering is even necessary. As shown below, deviations from rationality explain broad features of the data even with synchronized adjustment. Future research can examine whether re-introducing staggering produces even better results, perhaps using quarterly postwar data.

V. EXPECTATIONS UNDER TWO MONETARY REGIMES

A. The Two Periods

I test my model with data from two periods in U.S. monetary history. The first is the current regime of highly persistent inflation, which I date from 1960 through the present (my data end in 1997). Some authors consider the entire period since World War II, but Barsky (1987) finds that strong inflation persistence emerged only around 1960. For the post-1960 period, Barsky and others find that the process for inflation has a unit root. A common interpretation is that policy has accomodated shocks to inflation, leading the shocks to have permanent effects.

For annual data on the GDP deflator, the augmented Dickey-Fuller test confirms the finding of a unit root in inflation over 1960-1997. Therefore, to construct univariate inflation forecasts, I use a stationary model for the change in inflation ($\Delta\pi$). I assume that the behavior of annual $\Delta\pi$ can be approximated by an AR-2 process. Table I reports OLS estimates of the parameters of this process. Both AR coefficients are statistically significant but modest in size. The small coefficients confirm that inflation is not too far from a pure random walk.[1]

The other period I examine is the gold-standard era from 1879 through 1914. Friedman and Schwartz (1963) argue that there were important regime shifts in 1879, when the U.S. returned to the gold standard, and in 1914, when the Federal Reserve was established. As discussed above, previous work finds that inflation was close to white noise during this period -- the price level was close to a random walk. Shocks such as gold discoveries and shifts in money demand produced one-time changes in the price level.

I reexamine the inflation process for 1879-1914 using the two leading series for the output deflator, those of Balke and Gordon (1989) and Romer (1989). For each series, Table I reports estimates of AR-2 models for the level of inflation. All the

[1] I do not include a constant in the univariate model for $\Delta\pi$. This means I assume no deterministic drift in the level of inflation.

coefficients are small and statistically insignificant, confirming that inflation was close to white noise. The constant in the equation is also close to zero, implying that the univariate forecast of inflation is close to zero in all years.

I assume that each of the periods 1879-1914 and 1960-97 is a stable regime. In each regime, agents understand the univariate behavior of inflation starting from the beginning of the period. That is, I ignore issues of learning and transitions between regimes. The assumption of a stable regime is a strong one, but it is an assumption made implicitly in most studies of the current period.[2]

B. What Expectations Are Near-Rational?

I argue above that optimal univariate forecasts are a near-rational form of expectations in many monetary regimes. In contrast, backward-looking expectations are near-rational only if inflation is highly persistent. Here I confirm these ideas by computing forecast errors for various kinds of expectations.

As a benchmark, I first compute errors based on optimal multivariate forecasts. I forecast inflation based on lags of inflation, output, and a short-term interest rate. Output is defined as detrended real GNP (for the early period) or GDP (for the later period); the trend is measured by the Hodrick-Prescott filter with smoothing parameter 1000. Inflation is the percentage

[2] The need to assume a stable regime is the reason I do not consider data between World War I and World War II. The interwar period was relatively short, and it was punctuated by one-of-a-kind shocks such as the deflation of the 1930s. The behavior of the economy was too erratic to treat the period as a well-understood regime.

change in the GDP deflator. For the early period, output and inflation data are taken from both Romer and Balke-Gordon. The interest rate for both periods is the commercial paper rate.

As discussed above, inflation appears to be non-stationary for the post-1960 period. I also find, as does Roberts (1998), that the interest rate is non-stationary, and that the real interest, $r = i-\pi$, is stationary. (Equivalently, i and π are cointegrated). Therefore, for the post-1960 period, I forecast inflation by regressing the change in inflation on lags of the stationary variables y, $\Delta\pi$, and r. For the pre-1914 period, I regress inflation on y, π, and i. For each period, I include two lags of all variables.

Table II presents the standard errors of these multivariate forecasting equations. For the post-1960 period, the standard error is 0.86. For the pre-1914 period, the standard error is 2.10 for the Balke-Gordon data and 3.26 for the Romer data, reflecting greater inflation variability in the earlier period.

Table II also presents the standard errors of optimal univariate forecasts from Table I. These errors are only modestly larger than those of multivariate forecasts: ignoring output and interest rates raises the standard errors by 27 percent in the later period and by 14 or 5 percent in the early period. Finally, the Table presents standard errors based on backward-looking expectations, $\pi^e=\pi_{-1}$. As discussed in Section II, these errors are not much larger than multivariate forecast errors for the post-1960 period. But in the pre-1914 period, backward-looking expectations produce errors that are 48 or 41 percent larger. This finding confirms that backward-looking expectations are far from rational in the early period.

VI. TESTS OF THE MODEL UNDER ALTERNATIVE EXPECTATIONS

This section compares my model of price setting to the data under alternative assumptions about expectations. The main methodology follows Fuhrer-Moore and Roberts: I compare unrestricted impulse response functions for inflation to IRFs arising from the model.

A. Unconstrained Impulse Response Functions

Following the recent literature, I summarize the facts to be explained with a vector autogression for output, inflation, and the interest rate. For the post-1960 period, I estimate a VAR for the stationary system (y, $\Delta\pi$, r) and then transform the results to obtain a system for (y, π, i); for the pre-1914 period, I estimate a VAR for (y, π, i). To obtain impulse response functions, I order the variables as suggested by Roberts and by Christiano et al. (1996): i does not affect y or π contemporaneously, and π does not affect y contemporaneously.[3]

Figure 1A presents impulse response functions for the post-1960 period with two-standard-error bands. The IRFs are similar to those obtained by previous authors using quarterly data, and they

[3] Note I assume that certain contemporaneous effects are zero in annual data. Thus my assumptions are stronger than the assumptions when impulse responses are computed with quarterly data. This fact does not appear important for my results, however. For the post-1960 period, impulse responses based on quarterly and annual data are similar.

are consistent with textbook macro models. An output shock, usually interpreted as an aggregate-demand shock, has a transitory effect on output and permanently raises inflation and the interest rate. An inflation shock causes permanent increases in inflation and the interest rate, and has little effect on output. An interest-rate shock, usually interpreted as a Federal Reserve tightening, reduces output temporarily and inflation permanently. The nominal interest rate rises initially and then falls below its original level.

The phenomenon of inflation persistence is captured by the three responses of inflation -- the middle row of graphs in Figure 1A. Each of the shocks has a permanent effect on inflation.

Figures 1B and 1C show impulse response functions for the pre-1914 period based on the Romer and Balke-Gordon data. Here, an interest-rate shock cannot be interpreted as a Fed tightening, because there was no Fed. Presumably, interest-rate innovations arise from shifts in the money stock and the demand for money.

In most ways, the impulse responses in the pre-1914 period are similar to the responses in the post-1960 period. But there is an important exception: there is no inflation persistence. For a period or two, each shock moves inflation in the same direction as before, but then the effects die out. The effects on the nominal interest rate are also transitory. A central challenge for models of inflation is to explain this shift in behavior.

<u>B. The Model with Rational Expectations</u>

The rest of this section asks whether my model of price setting is consistent with the facts. I examine the model under alternative assumptions about expectations, starting with rational expectations.

In my simple model, it is obvious that rational expectations has counterfactual implications. Rational expectations means that π^e and y^e in equation (4) can be interpreted as mathematical expectations:

$$(5) \qquad \pi = E\pi + vEy + [(1-w)v/w]y ,$$

where E is a mathematical expectation as of the previous period. If one takes expectations of both sides, $E\pi$ terms cancel and one obtains

$$(6) \qquad Ey = 0 .$$

Thus next period's expected output gap is zero, regardless of the history of the economy. This means that the average output effect of any shock must disappear after the period of the shock. This prediction is contradicted by the impulse responses in Figure 1, which show that y and i shocks have output effects lasting beyond the initial period.[4]

Of course the strong result in equation (6) arises from the simplicity of my model. In price-setting models with staggered adjustment, shocks can have non-zero effects on future output. If my result is viewed in isolation, a natural response is to introduce staggering. However, as discussed in Section II, other

[4] Suppose one assumes that the real interest rate has a non-zero effect on future output. With this additional assumption, the result that expected output is always zero implies that the real interest rate is a constant. This in turn implies that all impulse responses of the nominal interest rate and inflation are the same, which is also rejected by the data.

papers show that rational-expectations models with staggering do not fit the facts: they do not generate equation (6), but they have other counterfactual implications. Therefore, rather than modify my price-setting model, I try to fit the facts by relaxing the assumption of rational expectations.

C. The Model with Univariate Forecasts

I now consider the model with optimal univariate expectations. In this case, inflation is given by equation (4) with π^e determined by the models estimated in Table I. Since equation (4) includes y^e, I also need a model for output expectations. I assume that these expectations, like inflation expectations, are given by optimal univariate forecasts; specifically, y is modelled as an AR-2 process without a constant. Table III presents estimates of the AR coefficients for output in the two regimes.

In this version of the model, y^e and π^e cannot be interpreted as mathematical expectations. Thus one cannot perform the manipulations in equations (5) and (6) and derive a restriction on output alone. But the model implies testable restrictions on the behavior of inflation.

Consider first the gold-standard period, when inflation is stationary. For this period, substituting univariate forecasts of inflation and output into equation (4) yields

$$(7) \quad \pi = b_0 + b_1\pi_{-1} + b_2\pi_{-2} + [(1-w)v/w]y + vd_1y_{-1} + vd_2y_{-2} ,$$

where b_0, b_1, and b_2 are the constant and AR coefficients for inflation and d_1 and d_2 are the AR coefficients for output (see Tables I and III). This equation is a restricted version of the inflation equation in the VAR, which (given the ordering of the variables) includes contemporaneous output and two lags of output, inflation, and the interest rate. There are six restrictions: the constant and coefficients on the lagged π's are given by b_0, b_1, and b_2; the coefficients on the two lagged interest rates are zero; and the ratio of the coefficients on y_{-1} and y_{-2} is d_1/d_2. Since w and v are free parameters, the model does not determine the coefficient on y or the absolute sizes of the coefficients on y_{-1} and y_{-2}.

For the post-1960 period, π^e is formed by adding the univariate forecast of $\Delta\pi$ to π_{-1}. Substituting forecasts of y and π into (4) leads to

$$(8)\quad \Delta\pi = b_1(\Delta\pi)_{-1} + b_2(\Delta\pi)_{-2} + [(1-w)v/w]y + vd_1y_{-1} + vd_2y_{-2}\ ,$$

where b_1 and b_2 are the AR coefficients for $\Delta\pi$. This equation places six restrictions on the $\Delta\pi$ equation in the VAR for (y, $\Delta\pi$, r).

For both 1879-1914 and 1960-97, I perform F-tests of the model's restrictions. The restrictions are never rejected at the 10% level. Thus the model appears consistent with the data for both monetary regimes.[5]

To gain intuition about the model's goodness of fit, I follow Fuhrer-Moore and Roberts and construct restricted impulse response functions. Starting with the unrestricted VARs, I replace the inflation equations for the two periods with (7) and (8). I leave

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[5] These tests assume that the b's and d's in the restricted equations are given by the point estimates in Tables I and III. Thus I ignore sampling error in the estimated b's and d's. This appears to bias my tests toward rejection of the restrictions.

the output and interest-rate equations unchanged, and compute IRFs for the new systems.

This exercise requires values for the two parameters of the restricted inflation equation, the coefficients on y and y^e. Initially, I estimate these parameters by OLS for each time period. For the pre-1914 period, the point estimate of the y^e coefficient is negative, which contradicts the theory, but the coefficient is far from significant. (The estimates are imprecise because of the limited number of observations and the collinearity of y and y^e.) For this period I set the coefficient on y^e to zero and reestimate the coefficient on y. I have experimented with other choices of coefficients, and it appears the qualitative results are robust for reasonable ranges of values.

Figure 2 presents the restricted IRFs. The impulse responses of output and interest rates (not shown) are very close to the responses for the unrestricted system, because the restrictions do not affect these variables directly. More important, the responses of inflation are also close to the unrestricted responses. For both periods, the restricted IRFs lie within the confidence intervals for the unrestricted IRFs. In the restricted as well as unrestricted systems, shocks have permanent effects on inflation in the later period and transitory effects in the earlier period. In the restricted case, these results reflect the difference in univariate forecasting models across regimes. Lagged inflation has a strong effect on expected inflation, and hence on actual inflation, in the post-1960 period but not the pre-1914 period.

D. The Model with Backward-Looking Expectations

As discussed in Section II, a number of authors propose a simple backward-looking model of expectations, $\pi^e = \pi_{-1}$. Here I investigate the performance of this model using a methodology that parallels the previous section. In equation (4), I replace π^e with π_{-1}; to isolate the role of inflation expectations, I continue to assume that y^e is an optimal univariate forecast. This approach yields another restricted version of the inflation equation in the VAR. For each period, I test the restrictions and construct restricted impulse response functions.

For the post-1960 period, the restrictions on the inflation equation are rejected at the 10% level but not the 5% level. Thus the model with backward-looking behavior is not strongly at odds with the data. As shown in Figure 3, the restricted impulse response functions for 1960-97 are fairly close to the unrestricted IRFs. The success of the backward-looking model is not surprising, since backward-looking expectations are close to optimal univariate forecasts for the post-1960 period.

For the pre-1914 period, the results are very different. For both the Balke-Gordon and Romer data sets, the model's restrictions under backward-looking expectations are easily rejected at the 1% level. In Figure 3, the restricted responses of inflation to y and π shocks lie far outside the confidence intervals for the unrestricted responses. The main problem is that shocks have permanent effects on inflation in the restricted case, while the unrestricted effects die out. The model's assumption of backward-looking expectations creates inflation persistence that does not exist in the pre-1914 data.

VII. CONCLUSION

This paper proposes a near-rational model of expectations: agents make optimal univariate forecasts of inflation and output. This assumption helps to explain the behavior of U.S. inflation in two different periods, 1960-97 and 1879-1914. In contrast, neither fully rational expectations nor backward-looking expectations fits both periods.

My model of expectations meets Lucas's (1976) criterion for reliable policy analysis: it holds across different monetary regimes. In future work, I will apply my model to normative questions about monetary policy, such as the choice of an instrument or target rule. I hope my approach yields more credible results than policy analyses based on rational expectations (e.g. McCallum and Nelson, 1999) or backward-looking expectations (e.g. Ball, 1999).

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Table 1. Univariate Models of Inflation

1960-1997 Dependent Vbl: $\Delta\pi$			1879-1914 (Balke-Gordon) Dependent Vbl: π	1879-1914 (Romer) Dependent Vbl: π
		constant	0.235 (0.400)	0.497 (0.572)
$(\Delta\pi)_{-1}$	0.342 (0.156)	π_{-1}	0.194 (0.160)	0.070 (0.162)
$(\Delta\pi)_{-2}$	-0.359 (0.154)	π_{-2}	-0.043 (0.160)	0.145 (0.159)
S.E.E.	1.087	S.E.E.	2.398	3.413

(Standard errors are in parentheses.)

Table 2. Standard Errors of Inflation Forecasts

	1960-1997	1879-1914 Balke-Gordon	1879-1914 Romer
Multivariate	0.856	2.097	3.261
Univariate	1.087	2.398	3.413
Backward-Looking	1.173	3.112	4.623

Table 3. Univariate Models of Output
(Dependent Vbl: y)

	1960-1997	1879-1914 Balke-Gordon	1879-1914 Romer
y_{-1}	0.879	0.525	0.748
	(0.159)	(0.187)	(0.181)
y_{-2}	-0.300	0.095	-0.073
	(0.150)	(0.183)	(0.181)
S.E.E.	1.845	4.252	2.691

(Standard errors are in parentheses.)

Figure 1a. Unrestricted Impulse Responses, 1960-1997

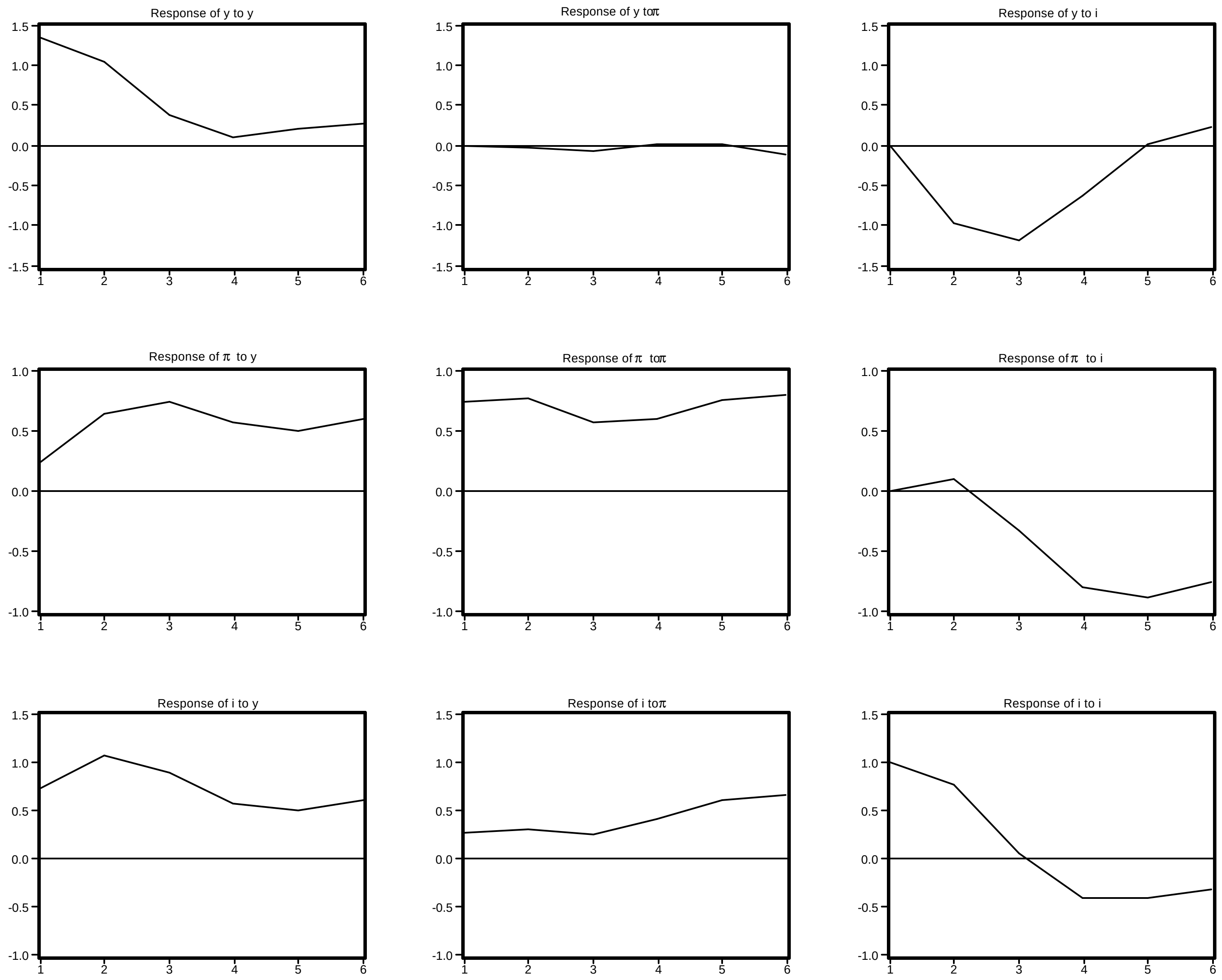

Figure 1b. Unrestricted Impulse Responses, 1879-1914 (Romer)

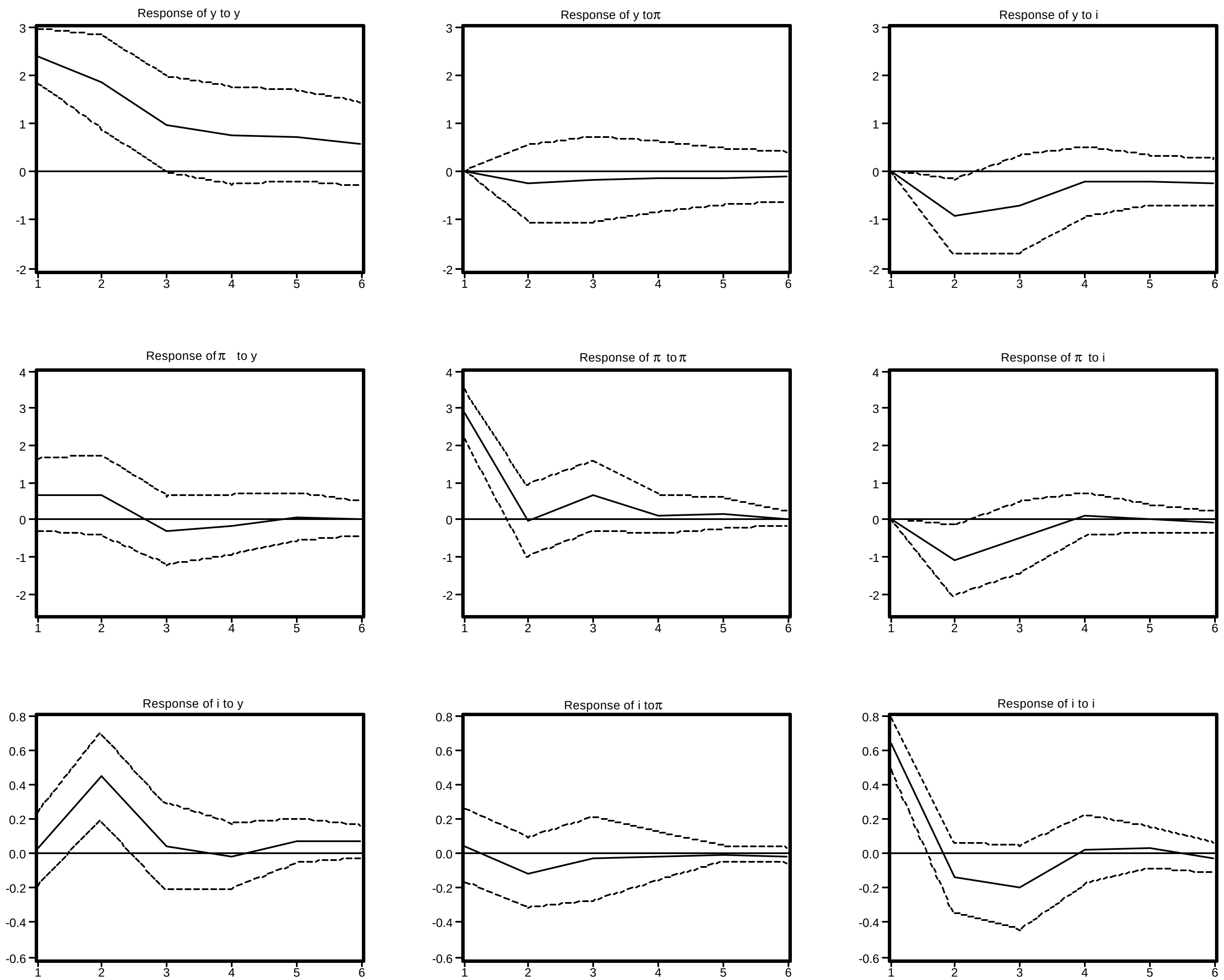

Figure 1c. Unrestricted Impulse Responses, 1879-1914 (Balke-Gordon)

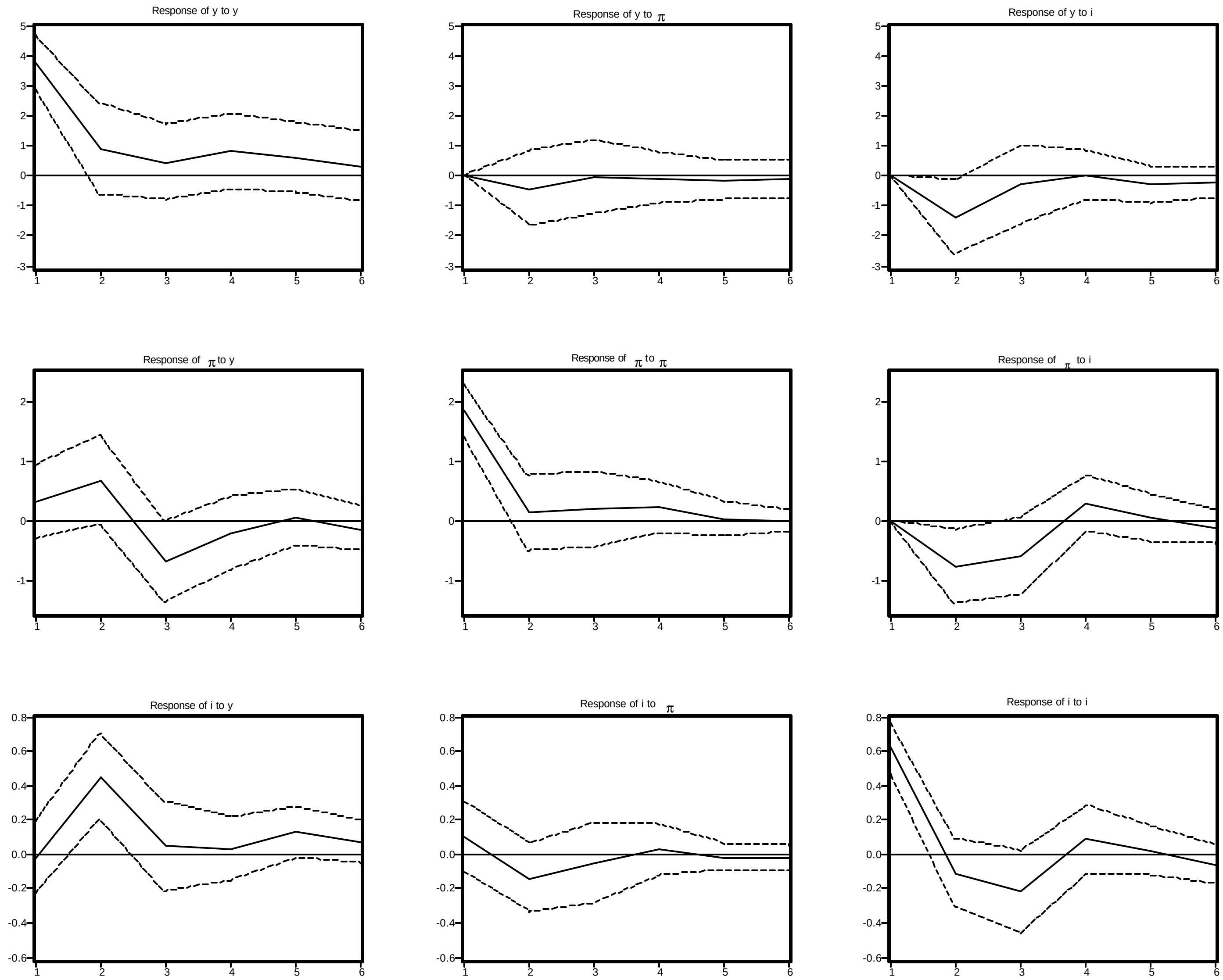

Figure 2. Inflation Responses with Optimal Univariate Forecasts

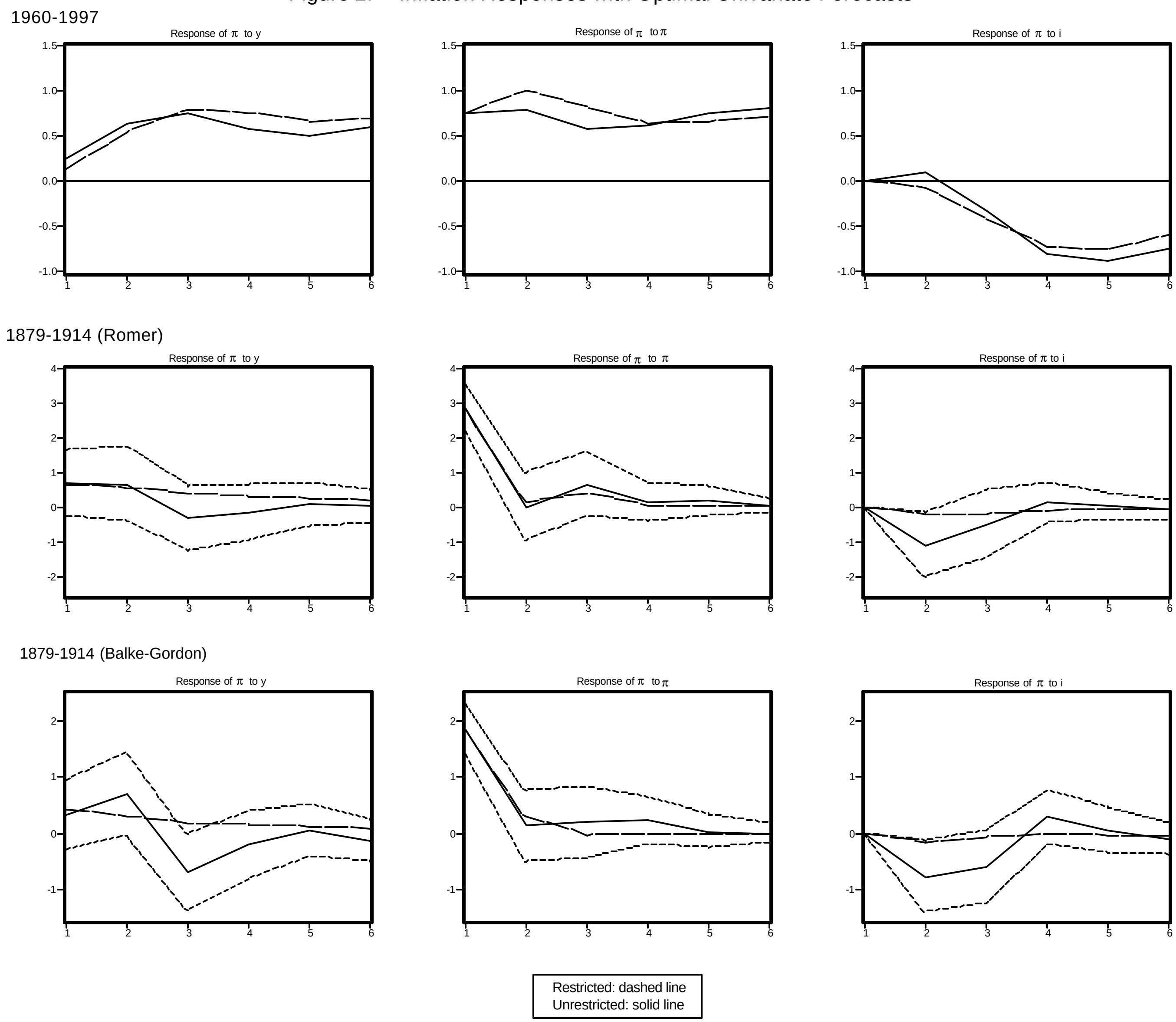

Figure 3. Inflation Responses with Backward-Looking Expectations