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Is inflation sticky?

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Abstract

New Keynesian sticky-price models predict that monetary policy can affect real variables. However, they also predict that inflation can be reduced without depressing output or employment. In fact, bringing down inflation is costly, presenting a challenge to the New Keynesian model. Two departures from the New Keynesian model predict costly disinflation. One assumes sticky inflation rather than sticky prices, while the other assumes less-than-perfectly rational expectations. Taking into account information from surveys of inflation expectations, I find the evidence suggests that inflation is not sticky and that inflation expectations are less than perfectly rational.

Keywords: New Keynesian Economics; Price rigidity; Inflation
JEL classification: E31; E52

1. Introduction

New Keynesian models with sticky prices have the virtue of explaining how purely monetary shocks can affect real variables such as output or employment. However, a number of authors have pointed out that these models do not predict at *inflation* will be sticky (Phelps, 1978: Taylor, 1983: Ball, 1991: Fuhrer and Moore, 1992, 1995). Rather, in New Keynesian models, it is possible for inflation to change with no effect on output or employment, so that a central

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bank can reduce inflation without cost – even though prices are sticky – as long as expectations of inflation change at the same time as inflation itself.

But reducing inflation appears to entail costs. Conventional estimates for the United States put the cost of a 1 percentage point reduction in inflation at about 2 percentage points of higher unemployment for a period of 1 year (Blinder, 1987, pp. 38–39). The employment and output losses associated with reducing inflation appear to be widespread across countries and over time. Ball (1993), for example has documented costly disinflation in 19 countries over a 30 year period.

Inflation may be costly to reduce for a number of reasons. One requirement for costless disinflation is that a central bank is believed when it announces that it intends to reduce inflation. If the formulation of expectations is less than perfectly rational, then expectations may not adjust in a way that is consistent with costless disinflation. Evidence from the literature on the rationality of survey measures of inflation expectations, which I review below, is supportive of less-than-perfectly rational expectations.

Another explanation for the costly disinflation is the sticky-inflation model, first propose by Buiter and Jewitt (1981) and recently emphasized by Fuhrer and Moore (1992, 1995). The sticky-inflation model and the sticky-price model share assumptions about the source of nominal rigidity in the economy. The models part company in their specification of the supply curve. The sticky-price model can be interpreted as building on standard supply curves that relate the level of a quantity variable to the expected level of relative prices. But the sticky-inflation model replaces this conventional supply curve with a relationship between the levels of quantities and changes in relative prices.

Fuhrer and Moore (1995) have estimated both the sticky-price and sticky-inflation models with recent US data, under the assumption of rational expectations. They find that the sticky-inflation model fits the data much better than the sticky-price model. However, I show that the model Fuhrer and Moore estimate is observationally equivalent to a model with sticky prices and expectations that are imperfectly rational. In particular, the model they estimate is equivalent to a model in which expectations are an average of rational expectations and a simple extrapolation of last period's inflation rate. Hence, Fuhrer and Moore's results do not allow us to determine whether sticky inflation or imperfectly rational expectations is responsible for costly disinflation.

In the empirical work of the paper, I use direct measures of inflation expectations from surveys of consumers and economists in order to distinguish between the competing hypotheses. When I use survey measures of expectations, I do not need to maintain the assumption of rational expectations. Hence, I can formulate a direct test of the sticky-inflation hypothesis. I examine a variety of specifications and find that, in most cases, the results favor the hypothesis of sticky prices over sticky inflation. Combined with the results on the rationality of survey expectations, the direct tests of the sticky-inflation hypothesis suggest that the reason inflation is costly to reduce is not it is inherently sticky, but rather that inflation expectations are less than perfectly rational.

2. Microfoundations of the sticky-price and sticky-inflation models

I adopt Taylor's (1979, 1980) staggered contracts framework as the model of nominal rigidity that underlies both the sticky-price and sticky-inflation models. As Fuhrer and Moore (1992) have shown, the sticky-inflation model can also be derived using Calvo's (1983) model of staggered contracts as the model of nominal rigidity.[1]

In Taylor's staggered contracts model, wages are assumed to be set for two periods, so the average wage the firm pays is

$$w_t = (x_t + x_{t-1})/2. \tag{1}$$

where x_t is the 'contract' wage set in period t, which the firm will pay in periods t and $t + 1$, and w is the observable wage, which is an average of the current and previous contract wages; w and x refer to logarithms.

Workers are assumed to be concerned about unemployment and about real wages over the life of the contract. The labor supply curve is, therefore,

$$x_t - (p_t + \mathrm{E}_t p_{t+1})/2 = b_0 - \beta RU_t + \varepsilon_t. \tag{2}$$

where p is the log of price, RU is unemployment, ε is a white-noise error term, and b_0 and β are constants, $\beta > 0$, so that higher unemployment is associated with lower expected real wages.

The firm sets prices as a constant markup over wages. Normalizing the markup to zero,

$$p_t = w_t. \tag{3}$$

Eqs. (1)–(3) can be combined to form:

$$\Delta p_t - \mathrm{E}_t \Delta p_{t+1} = b_0 - 2\beta(RU_t + RU_{t-1}) + 2(\varepsilon_t + \varepsilon_{t-1}) + \eta_t, \tag{4}$$

where $\eta_t = (\mathrm{E}_{t-1} p_t - p_t)$, an expectational error term. Eq. (4) is essentially an expectations-augmented Phillips curve such as that proposed by Friedman and Phelps: It says that inflation will move with expected inflation, and that, conditional on expectations, inflation will be high when output is high.

The model is also similar to the Lucas (1973) supply curve. An important difference is that expectations of future inflation enter the equation. The reason future inflation matters, of course, is that prices are sticky.

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[1] The menu cost model of Mankiw (1985) and Akerlof and Yellen (1985) is another popular model of price rigidity. However, Caplin and Spulber (1987) have shown that menu costs can be compatible with aggregate nominal neutrality. More generally, the implications of these models for the effects of monetary policy on real economic activity are not as clear as for the staggered contracts model.

As noted in the introduction, inflation can be reduced costlessly under certain circumstances in this model, which can be seen by inspection of Eq. (4): If the disinflation is announced sufficiently in advance, inflation expectations can change by the same amount as inflation and output need not change to effect a change in inflation.

To rule out sudden changes in the inflation rate. Fuhrer and Moore (1992, 1995) have modified the preceding model. They replace Eq. (2) with

$$(x_t - p_t) = \mathrm{E}_t[(x_{t-1} - p_{t-1}) + (x_{t+1} - p_{t+1})]/2 \\ + b_0' - \beta' RU_t + \varepsilon_t'. \tag{5}$$

where $\beta' > 0$. They characterize their model as a real contracting model because the real contract wage is set relative to past and expected future real contract wages. However, Eq. (5) can be rewritten as

$$\Delta x_t - (\Delta p_t + \mathrm{E}_t \Delta p_{t+1})/2 = b_0' - \beta' RU_t + \varepsilon_t'. \tag{6}$$

Rewritten this way, the 'real' contracting model can be viewed as a 'slipped derivative' version of the labor supply curve in the original sticky-price model, Eq. (2). That is, Eq. (6) says that the *change* in wages is set relative to the expected *change* in aggregate prices and the expected *level* of aggregate economic activity. So instead of the expected level of relative wages moving with the level of economic activity as in Eq. (2), Eq. (6) says that the change in wages moves with overall economic activity.

Eq. (6) can be combined with Eqs. (1) and (3) to yield:

$$\Delta^2 p_t - \mathrm{E}_t \Delta^2 p_{t+1} = b_0' - \beta'(RU_t + RU_{t-1}) + 2(\varepsilon_t' + \varepsilon_{t-1}') + \eta_t', \tag{7}$$

which is simply Eq. (4) with the price level replaced by inflation. Hence, while Eq. (4) is a model of sticky prices. Eq. (7) is a model of sticky *inflation.* As Fuhrer and Moore have emphasized, costless disinflation is impossible in such a model.

Fuhrer and Moore (1995) have estimated Eq. (7) conditional on rational expectations and found that it fit the data better than Eq. (4). They concluded from this result that inflation is sticky. However, there is an alternative interpretation of their result. Eq. (7) can be rewritten as

$$\Delta p_t - (\Delta p_{t-1} + \mathrm{E}_t \Delta p_{t+1})/2 = b_0'/2 - \beta'(RU_t + RU_{t-1})/2 \\ + (\varepsilon_t' + \varepsilon_{t-1}') + \eta_t'/2. \tag{8}$$

Comparing Eq. (8) with Eq. (4) suggests the following interpretation: Suppose that purely rational expectations were replaced by expectations that were halfway between rational expectations and an extrapolation of last period's inflation. Then, Eq. (8) would be consistent with a model with sticky prices, but with expectations that were an average of perfectly rational and purely adaptive. Because Eq. (8) is identical to Eq. (7), a model with sticky prices with 'not-quite-rational expectations' is observationally equivalent to a model with sticky inflation and rational expectations.

In Section 5, I use direct observations of inflation expectations to distinguish between the two competing interpretations of Fuhrer and Moore's results. The direct evidence comes in the form of surveys of inflation expectations. Because part of the distinction between the competing hypotheses is the degree of rationality of inflation expectations, I first review the evidence on this subject before moving on to direct tests of whether sticky inflation or sticky prices are important.

3. Properties of surveys of inflation expectations

3.1. Survey expectations are not purely adaptive

There is a large literature on surveys of inflation expectations. One result from this literature is that survey measures of inflation expectations are not purely adaptive – that is, they reflect more information than what is imbedded in lagged inflation. Mullineaux (1980) and Gramlich (1983), for example, both found that the money supply helps explain movements in survey expectations.

3.2. But survey expectations are not purely rational, either

Most papers that have examined survey expectations have concluded that they are not perfectly rational. For example, Bryan and Gavin (1986) and Batchelor and Dua (1989) find that the Livingston survey of economists' predictions is a biased forecast of inflation, while Pesaran (1987) finds that a survey of British manufacturers does not make efficient use of available information.[2] However, papers that have examined the Michigan survey of household inflation expectations have come mixed conclusions. In this section, I review these papers and try to reconcile the competing claims. The evidence suggests that while there is some indication that the Michigan survey is an unbiased predictor of inflation, the survey does not pass a stricter test of rationality, that a forecast make efficient use of all available information.

[2] These results are for expectations of inflation 1 year ahead. Studies that have examined short-term expectations – of a month to a quarter ahead – have found that expectations are rational (Pearce, 1987; Keane and Runkle, 1990). Rationality 1 year ahead is obviously a higher hurdle to clear, but a failure of rationality over a 1-year period is relevant in the staggered-contracts models, since the contracts may last a year or more.

The standard test for unbiasedness is the regression:

$$(p_t - p_{t-4}) = a_0 + a_1 S_{t-4}(p_t - p_{t-4}) + \varepsilon_t, \tag{9}$$

where $(p_t - p_{t-4})$ is the actual outcome for inflation over a four-quarter period and $S_{t-4}(p_t - p_{t-4})$ is the survey's average response for expected inflation over the period from $t-4$ to t. If the survey is an unbiased forecast of inflation, then a_0 is zero and a_1 is one.

Researchers who have examined the unbiasedness of the Michigan survey over long periods of time – extending form at least the late 1960s to the mid-1980s – find that it is an unbiased forecast of inflation: This is the conclusion of Bryan and Gavin (1986) and Rich (1989). Looking over a more-recent period (post-1978), however, both Baghestani (1992) and Englander and Stone (1989) find that the Michigan survey is biased.

Even if we accept the results from the longer sample and conclude that the Michigan survey is unbiased, we have not addressed the stricter criterion that rational forecasts make efficient use of all available information. Studies of the efficiency of the Michigan survey have reached mixed conclusions. Examining the period 1968–1987, Rich (1989) concludes that forecast errors from the Michigan survey were not related to lagged forecast errors or to lagged inflation, and hence that the Michigan survey made efficient use of this information. But Batchelor and Dua (1989), looking at the period 1956–1983 (as well as subperiods), report that the Michigan survey did not make efficient use of information that included a broad range of economic variables, including the money supply, the unemployment rate, and capacity utilization. Similarly, Bahestani (1992) found that, over the period 1978 through 1985, the forecast from a model of inflation that included lagged inflation, the unemployment rate, and the exchange rate contained important information that the Michigan survey did not incorporate, a finding that constitutes a rejection of rationality.

Batchelor and Dua report only summary results, and Baghestani looks for efficiency only for a period where unbiasedness is rejected. To confirm and extend these earlier results on efficiency, I conducted some further tests, reported in the appendix. To summarize, I find that the Michigan survey of inflation expectations did not make econometrically efficient use of information that was available at the time the forecast were made. Hence, the results for the Michigan survey are in accord with those for other surveys, namely, that inflation expectations are not perfectly rational.[3]

[3] Of course, survey evidence is subject to the usual caveats – notably, that survey respondents may not have incentives to provide accurate information. Some evidence that may boost confidence in the usefulness of surveys of inflation expectations is that they are helpful in modeling inflation (Roberts, 1995) and in predicting wages and interest rates (Englander and Stone, 1989).

4. Empirical specification

4.1. Deriving the empirical model

The imperfect rationality of inflation expectations is a necessary condition for the sticky-prices-plus-not-quite-rational-expectations hypothesis to hold, but it is not sufficient: Inflation can be sticky even if inflation expectations are imperfectly rational. In this section, I conduct direct tests of the hypotheses of sticky inflation versus sticky prices under the assumption that the surveys are correct measures of inflation expectations. To do this, I derive a nested version of the two models.

First, rewrite Eq. (4) – the sticky-price model – as:

$$\Delta p_t - \mathrm{E}_t \Delta p_{t+1} = b_0 - 2\beta(RU_t + RU_{t-1}) + 2(\varepsilon_t + \varepsilon_{t-1}) - (\mathrm{E}_{t-1}\Delta p_t - \Delta p_t). \quad (10)$$

To take full advantage of observations on inflation expectations, rewrite Eq. (10) as:

$$\Delta p_t - (\mathrm{E}_t \Delta p_{t+1} + \mathrm{E}_{t-1}\Delta p_t)/2 = b_0/2 - \beta(RU_t + RU_{t-1}) + (\varepsilon_t + \varepsilon_{t-1}). \quad (11)$$

The sticky-inflation model (Eq. (8)) is

$$\Delta p_t - (\Delta p_{t-1} + \mathrm{E}_t \Delta p_{t+1})/2 = b_0/2 - \beta'(RU_t + RU_{t-1})/2 + (\varepsilon'_t + \varepsilon'_{t-1}) + (\mathrm{E}_{t-1}\Delta p_t - \Delta p_t)/2. \quad (12)$$

To rewrite Eq. (12) so that it nests easily with Eq. (11), it needs to have the same left-hand-side variable as Eq. (11). One possibility is

$$\Delta p_t - (\mathrm{E}_{t-1}\Delta p_t + \mathrm{E}_t \Delta p_{t+1})/2 = b'_0/2 - \beta'(RU_t + RU_{t-1})/2 + (\Delta p_{t-1} - \Delta p_t)/2 + (\varepsilon'_t + \varepsilon'_{t-1}). \quad (13)$$

This specification is a generalization of Eq. (11) with the addition of the term $(\Delta p_{t-1} - \Delta p_t)/2$. Hence, a way of testing which specification is correct would be to estimate the equation:

$$\Delta p_t - (\mathrm{E}_{t-1}\Delta p_t + \mathrm{E}_t \Delta p_{t+1})/2 = c_0 - \gamma(RU_t + RU_{t-1})/2 + \lambda(\Delta p_{t-1} - \Delta p_t) + (\varepsilon_t + \varepsilon_{t-1}) \quad (14)$$

and test whether λ is closer to zero or one-half.

Alternatively, we can rewrite Eq. (13) as

$$\Delta p_t - (\mathrm{E}_{t-1}\Delta p_t + \mathrm{E}_t \Delta p_{t+1})/2 = b'_3/3 - \beta'(RU_t + RU_{t-1})/3 + [\Delta p_{t-1} - (\mathrm{E}_{t-1}\Delta p_t + \mathrm{E}_t \Delta p_{t+1})/2]/3 + (2/3)(\varepsilon'_t + \varepsilon'_{t-1}). \quad (15)$$

Eq. (15) suggests the test equation:

$$\Delta p_t - (\mathrm{E}_{t-1}\Delta p_t + \mathrm{E}_t\Delta p_{t+1})/2 = c_0' - \gamma'(RU_t + RU_{t-1})/2 + \lambda'[\Delta p_{t-1} - (\mathrm{E}_{t-1}\Delta p_t + \mathrm{E}_t\Delta p_{t+1})/2] + (\varepsilon_t' + \varepsilon_{t-1}'). \tag{16}$$

A value of λ' from Eq. (16) close to one-third would be evidence in favor of the sticky-inflation hypothesis, whereas λ' near zero would be more consistent with sticky prices.

Eq. (16) is also of interest because it nests another hypothesis about how inflation expectations are formed, that inflation expectations are purely adaptive. If λ' is one, then forward-looking measures of inflation expectations do not matter. Such a result would mean that lagged inflation fully accounts for expectations.

4.2. Data issues

I use semiannual data for most of the estimation I present. Although semiannual estimation is unusual, it is useful in this context for two reasons. First, one of the two measures of inflation expectations that I examine – the Livingston survey – is available only semiannually. Second, the theory sends itself to esitmation with semiannual data because the wage contracts that underlie the straggered contracts model are likely set for one year at a time, which, in a model of two-period contracts, implies that semiannual data would be the most convenient. While using quarterly data also would have allowed me to use year-long contracts, it also would have increased the number of parameters I would need to estimate, reducing econometric power.

The expectations surveys ask about inflation over the coming 12 months, whereas with semiannual data, it would be more convenient to have data on expectations over the coming six months. In the estimation, I have used the 12-month expectations as proxies for the 6-month expectations. Hence, I have implicitly assumed that individual's expectations are the same for each of the two upcoming 6-month periods.

To conform with the inquiries in the Michigan and Livingston surveys, I used the consumer price index as my measure of inflation. I measured inflation between the final months of each 6-month period – that is, from June to December and from December to June. (When I present annual results, I use the December surveys and December-over-December percent changes in prices.)

I present estimates with all three of the major measures of economic activity: The unemployment rate, GDP, and capacity utilization in the manufacturing sector. I also explored sensitivity to detrending. Capacity utilization is stationary according to the usual tests, but GDP clearly is not, and unemployment gives ambiguous results. As a consequence, I present results both for detrended and 'raw' unemployment, whereas for GDP, I only present results for detrended series. I used the Hodrick–Prescott filter, which is available as part of the Rats econometric package (Doan, 1992), to estimate the trends, using two values of the filter's smoothness parameter: 1600, the value suggested by Hodrick and Prescott, and 16,000, which may do a better job of preventing cyclical variation from being confused with the trend.[4]

In addition, I report results using stochastic detrending for output. I use the model Watson (1986) proposed, which assumes that the log of GDP is the sum of two components, trend and cycle, that have orthogonal innovations. The trend is assumed to follow a random walk with drift, while the cycle is assumed to follow an autoregressive process of order two. I estimate the model with the EM algorithm and use the resulting cyclical component as my estimate of detrended GDP (see Hamilton, 1994, Chapter 13, for a description of the EM algorithm).

Because changes in real oil prices are an important and readily identifiable source of ε variation, I made a slight modification to the model. In place of Eq. (14), I estimated:

$$\begin{aligned}\Delta p_t - (\mathrm{E}_{t-1}\Delta p_t + \mathrm{E}_t\Delta p_{t+1})/2 &= c_0 - \gamma(RU_t + RU_{t-1})/2 \\ &\quad + \lambda(\Delta p_{t-1} - \Delta p_t) + c_1\Delta rpo_t + (\varepsilon_t + \varepsilon_{t-1}). \end{aligned} \tag{17}$$

and in place of Eq. (16).

$$\begin{aligned}\Delta p_t - (\mathrm{E}_{t-1}\Delta p_t + \mathrm{E}_t\Delta p_{t+1})/2 &= c_0' - \gamma'(RU_t + RU_{t-1})/2 \\ &\quad + \lambda'[\Delta p_{t-1} - (\mathrm{E}_{t-1}\Delta p_t + \mathrm{E}_t\Delta p_{t+1})/2] + c_1'\Delta rpo_t \\ &\quad + (\varepsilon_t' + \varepsilon_{t-1}'), \end{aligned} \tag{18}$$

where Δrpo is the percentage change in the real price of crude oil. I use the producer price index for crude petroleum divided by the GDP deflator to measure real crude oil prices.

OLS estimates of Eqs. (17) and (18) may have two potential source of bias. First, it is possible that current-period economic activity is correlated with the ε shocks. Second, the terms including lagged inflation are likely correlated with the error term, since the errors may be serially correlated, and so will be correlated with Δp_{t-1}. Also, these terms contain elements that appear on the left-hand side of the equations and so are likely to be correlated with the error terms.

The estimation assumes that economic activity is not correlated with the error term. I make this assumption for two reasons. First, King and Watson (1994)

[4] I also experimented with detrending output by regressing its log on a time trend and its square. The results were very similar to those obtained with the Hodrick–Prescott filter with the smoothness parameter equal to 16,000, and so I do not report these results.

argue persuasively that, in practice, aggregate economic activity is little affected by shocks to inflation, at least over the period of a year or so that concerns us here. Second, in results not reported here, I estimated the equations using current and lagged values of more justifiably exogenous instruments (real government purchases of goods and services and a dummy variable equal to one when a Democrat was president) and found that the results were similar to those reported, but noisier. These results confirmed King and Watson's – that there is little correlation between ε and aggregate economic activity – and so I restrict my presentation to the more precise estimates.

By contrast, using instrumental variables for the terms containing lagged inflation is crucial because these terms are clearly correlated with the ε shocks. Since I am assuming that unemployment and other economic activity variables are not correlated with ε, these variables will be appropriate instruments for the terms involving lagged inflation. In my estimation, I use three lags of the economic activity variable as instruments.

Under the staggered contracts model, the error terms in Eqs. (17) and (18) may be serially correlated. I therefore estimated the equations using the Newey–West covariance-matrix adjustment, allowing for up to eighth-order serial correlation.

5. Nesting sticky prices and sticky inflation: Results

Table 1 shows estimates of Eqs. (17) and (18), using the level of the unemployment rate as the measure of economic activity. As expected, the unemployment rate is statistically significant, with a negative coefficient. Real crude oil prices are also significant.

The first three columns in Table 1 show estimates of Eq. (17). In the first two columns, the Michigan survey is the measure of inflation expectations. Most of the estimation I present extends back to 1961 (a date chosen because GDP data are currently available only from 1959 onward). As I noted above, the Michigan survey asked only qualitative questions about inflation expectations before 1967. To allow for the possibility that the estimates may be affected by the inclusion of this earlier period, I also present results for the Michigan survey excluding this earlier period; the results are little affected.

In none of the estimates of Eqs. (17) and (18) in Table 1 is the key test coefficient on the variable involving lagged unemployment (λ or λ') significantly different from zero, the value it is predicted to take under the hypothesis of sticky prices. The λ estimates are not insignificant because they are imprecisely estimated, since λ is significantly different from the value it would have under the sticky-inflation hypothesis – one-half in the first three columns of Table 1 and one-third in the last two columns. Rather, the coefficients are simply quite small. These results are consistent with those I reported in Roberts (1995),

Table 1
Tests for sticky-inflation, using the unemployment rate
[Semi-annual data. Two-stage least squares: Newey-West correction with eight lags. Dependent variable: $\Delta p_t - (E_t \Delta p_{t+1} + E_{t-1} \Delta p_t)$]

	1961:1–1995:2	1967:1–1995:2	1961:1 to 1995:2		
Expectations survey:	Michigan	Michigan	Livingston	Michigan	Livingston
Constant	0.96	1.44	4.04	0.96	3.76
	(0.63)	(0.63)	(0.62)	(0.65)	(0.56)
Unemployment[1]	− 0.225	− 0.281	− 0.612	− 0.222	− 0.569
	(0.091)	(0.087)	(0.095)	(0.097)	(0.082)
Real oil price	0.017	0.016	0.017	0.018	0.017
	(0.007)	(0.007)	(0.007)	(0.007)	(0.006)
$\Delta p_{t-1} - \Delta p_t$	− 0.014	− 0.032	0.057	–	
	(0.123)	(0.132)	(0.103)		
$\Delta p_{t-1} - (E\Delta p_{t+1} + E\Delta p_t)/2$	–	–	–	0.009	0.079
				(0.122)	(0.086)
$\bar{R}^2$	0.19	0.21	0.29	0.18	0.37
SER	1.60	1.70	1.67	1.60	1.57
Autocorr. 1	0.39	0.38	0.39	0.36	0.36
2	0.39	0.38	0.41	0.38	0.40
3	0.37	0.34	0.29	0.36	0.28
4	0.20	0.19	0.12	0.19	0.11
P-value, overid.	0.66	0.63	0.60	0.70	0.66
$\bar{R}^2$, first-stage	0.03	0.04	0.03	0.02	0.19

Notes: Numbers in parentheses are standard errors.
[1] Average of current and previous period.

where I found that the sticky-price model performed well when estimated with survey measures of inflation expectations.[5]

The results in the first four columns of Table 1 would be more convincing if the $\bar{R}^2$ values in the first-stage regression of the instrumental variables estimator – shown in the bottom line of the table – were larger. That is, the lagged unemployment rate is often a poor instrument for the terms including lagged inflation. Nonetheless, the $\bar{R}^2$ is strongly significant in the final column, and the test coefficient is also small and insignificant, suggesting that the negative conclusions for the sticky-inflation hypothesis in this table are not entirely the result of poor instruments. Among the goals of the sensitivity analysis that follows will be to boost the explanatory power in the first-stage regressions.

[5] A corollary of the rejection of sticky inflation in the estimates of Eq. (18) is that the hypothesis of purely adaptive expectations – which corresponds to a value of $\lambda' = 1$ – is also rejected.

While the staggered contracts model predicts positive first-order serial correlation of the residuals, the serial correlation lasts for a longer period than the model predicts. One possible explanation for the excessive serial correlation is that wage contracts are longer than 1 year. I return to this possibility later on.

Table 2 presents results using detrended unemployment. Here, I show results only for Eq. (18), since the first-stage $\bar{R}^2$ values were higher for the test variable in this equation. And in fact, all of the first-stage $\bar{R}^2$ values are statistically significant in Table 2. The results for the coefficient λ', on the difference between lagged inflation and inflation expectations, are similar to those in Table 1: Again, λ' is small, not significantly different from zero, but significantly different from one-third.

Table 3 repeats the estimation shown in Table 1, using detrended log GDP (times 100, to create units similar to the unemployment rate) as the measure of economic activity. As with detrended unemployment, the first-stage $\bar{R}^2$ values are statistically significant, indicating that lagged detrended GDP is a good instrument for the test variables. As in Table 1, economic activity is statistically significant and has the correct sign; the estimates of the effects of real oil prices are similar to those in Table 1.

Table 2
Sensitivity analysis of tests for sticky inflation, using detrended unemployment
[Semi-annual data. 1961:1 to 1995:2. Two-stage least squares: Newey-West correction with eight lags. Dependent variable: $\Delta p_t - (E_t\Delta p_{t+1} + E_{t-1}\Delta p_t)$]

	HP filter, σ = 16,000		HP filter, σ = 1,600	
Expectations survey:	Michigan	Livingston	Michigan	Livingston
Constant	– 0.38	0.30	– 0.29	0.39
	(0.24)	(0.21)	(0.31)	(0.27)
Unemployment[1]	– 0.361	– 0.768	– 0.679	– 1.053
	(0.099)	(0.130)	(0.185)	(0.247)
Real oil price	0.018	0.015	0.016	0.013
	(0.007)	(0.006)	(0.007)	(0.005)
$\Delta p_{t-1} - (E\Delta p_{t+1} + E\Delta p_t)/2$	– 0.028	0.014	– 0.008	– 0.050
	(0.135)	(0.098)	(0.156)	(0.101)
$\bar{R}^2$	0.19	0.34	0.22	0.33
SER	1.60	1.61	1.57	1.62
Autocorr. 1	0.39	0.45	0.42	0.50
2	0.40	0.46	0.43	0.50
3	0.40	0.35	0.45	0.40
4	0.23	0.20	0.30	0.26
P-value, overid.	0.76	0.64	0.82	0.58
$\bar{R}^2$, first-stage	0.07	0.23	0.13	0.29

Notes: Numbers in parentheses are standard errors.
[1] Average of current and previous period.

Table 3
Tests for sticky-inflation, using detrended output Hodrick–prescott trend, $\sigma = 16{,}000$
[Semi-annual data. Two-stage least squares: Newey-West correction with eight lags. Dependent variable: $\Delta p_t - (E_t \Delta p_{t+1} + E_{t-1}\Delta p_t)$]

	1961:1–1995:2	1967:1–1995:2	1961:1 to 1995:2		
Expectations survey:	Michigan	Michigan	Livingston	Michigan	Livingston
Constant	−0.27	−0.28	0.38	−0.23	0.28
	(0.25)	(0.28)	(0.24)	(0.23)	(0.19)
Detrended GDP[1]	0.265	0.312	0.439	0.228	0.326
	(0.082)	(0.099)	(0.125)	(0.065)	(0.074)
Real oil price	0.019	0.017	0.021	0.016	0.015
	(0.009)	(0.008)	(0.010)	(0.006)	(0.006)
$\Delta p_{t-1} - \Delta p_t$	0.164	0.132	0.348	–	–
	(0.149)	(0.157)	(0.187)		
$\Delta p_{t-1} - (E\Delta_{t+1} + E\Delta p_t)/2$	–	–	–	0.142	0.261
				(0.110)	(0.103)
$\bar{R}^2$	0.13	0.16	0.04	0.36	0.47
SER	1.66	1.75	1.94	1.43	1.44
Autocorr. 1	0.18	0.18	0.15	0.17	0.14
2	0.32	0.32	0.31	0.31	0.31
3	0.30	0.30	0.20	0.30	0.20
4	0.13	0.16	0.04	0.13	0.03
P-value, overid.	0.93	0.85	0.91	0.92	0.91
$\bar{R}^2$, first-stage	0.10	0.12	0.10	0.15	0.31

Notes: Numbers in parentheses are standard errors.
[1] Average of current and previous period.

The coefficients on the variables involving lagged inflation in Table 3 are all larger than those in Table 1. However, the estimates using the Michigan survey are again not statistically different from zero. Although the estimate of λ from Eq. (17) using the Michigan survey (the first column) is significantly different from one half, in the estimate of Eq. (18) in the fourth column of Table 3, λ' is not significantly different from one-third. The results in this column suggest that while the hypothesis of sticky prices is not rejected, neither is the hypothesis of sticky inflation.

The results using the Livingston survey are still more favorable for the hypothesis of sticky inflation. The coefficients on both λ and λ' are not significantly different from the values associated with sticky inflation, and, in the final column, the estimate is also significantly different from zero. The results in Table 3 present a mixed picture, with the coefficients in two of four cases not significantly different from either sticky prices or sticky inflation, while the results in the first and last columns provide support respectively for sticky prices and sticky inflation.

Table 4
Sensivity analysis of tests for sticky inflation, using detrended output
[Semi-annual data, 1961:1 to 1995:2. Two-stage least squares: Newey-West correction with eight lags. Dependent variable: $\Delta p_t - (E_t \Delta p_{t+1} + E_{t-1} \Delta p_t)$]

	HP filter			Stochastic trend	
	$\sigma = 1600$		$\sigma = 16{,}000$		
Expectations survey:	Michigan	Livingston	Livingston	Michigan	Livingston
Constant	− 0.21	0.34	0.35	− 0.18	0.35
	(0.26)	(0.22)	(0.20)	(0.23)	(0.34)
Detrended GDP[1]	0.264	0.396	0.361	0.247	0.247
	(0.089)	(0.087)	(0.103)	(0.103)	(0.121)
Real oil price	0.016	0.015	0.013	0.016	0.016
	(0.007)	(0.006)	(0.004)	(0.007)	(0.006)
$\Delta p_{t-1} - (E\Delta p_{t+1}$	0.119	0.302	0.278	0.183	0.089
$+ E\Delta p_t)/2$	(0.127)	(0.103)	(0.221)	(0.159)	(0.219)
$MA(1)$ coefficient	–	–	0.290	–	–
			(0.122)		
$\bar{R}^2$	0.34	0.46	0.45	0.34	0.31
SER	1.45	1.46	1.47	1.44	1.64
Autcorr. 1	0.22	0.13	0.09	0.10	0.39
2	0.35	0.33	0.37	0.23	0.38
3	0.35	0.24	0.21	0.21	0.24
4	0.18	0.09	0.08	0.03	0.07
P-value, overid.	0.89	0.98	–	0.52	0.34
$\bar{R}^2$, first-stage	0.12	0.28	0.31	0.18	0.18

Notes: Numbers in parentheses are standard errors.
[1] Average of current and previous period.

Table 4 presents some sensitivity analysis. In the first two columns, I repeat the estimates of the last two columns of Table 3, but with the GDP trend calculated using a smoothness parameter of 1600. The results are little different, with the Michigan index results again not significantly different from either sticky inflation or sticky prices, while the results with the Livingston reject sticky prices but not sticky inflation.

One feature of the results in Table 3, in contrast to those in table 1 and 2, is that the first autocorrelation of the residuals is notably smaller. This result is perhaps not surprising, since the estimates in Table 3 put a larger weight on a term that includes elements that appear with a lag on the left-hand side of the equation, and so could account for some of the serial correlation of the residuals. But the staggered-contracts model predicts substantial first-order serial correlation. Because the estimates that suggest the stickiest inflation also have the least first-order serial correlation, the terms involving lagged inflation may be picking up the serial correlation of the residuals, despite the use of instrumental variables.[6]

To evaluate that possibility, I re-estimated the specification in the final column of Table 3 – which had the largest value of the test statistic – allowing for an MA(1) error term.[7] While the moving average parameter is statistically significant, the coefficient on the difference between lagged inflation and inflation expectations is little different than in Table 3. However, the standard error is now big enough that the hypotheses of sticky prices cannot be rejected. The increase in the standard error suggests that there may be a relationship between the moving average error and the difference between lagged and expected inflation, but the evidence is weak.

The last two columns of Table 4 show results using the stochastic detrending method described in Section 4. GDP detrended in this way is a good instrument for the difference between lagged and expected inflation. Nonetheless, λ' is not estimated precisely using either measure of inflation expectations, and we can reject neither sticky inflation nor sticky prices. The other aspects of the estimate are in line with results using other detrending methods.

Table 5 presents results using capacity utilization in the manufacturing sector as the measure of economic activity. Although the coefficients on economic activity again have the correct signs, they are no longer always statistically significant. Nonetheless, lagged capacity utilization is a better instrument for the test variables than was the unemployment rate. The results with capacity utilization are mostly favorable for the hypothesis of sticky prices: Estimates of λ are small, not significantly different from zero, and significantly different from one-half for both the Michigan and Livingston survey estimates of Eq. (17). The estimates of Eq. (18) (the last two columns) are mixed: The estimate using the Michigan survey favors the sticky-price model, while the equation that uses the Livingston survey rejects the sticky-price model but not the sticky-inflation model.

As I noted earlier, the amount of serial correlation in the residuals from the semiannual equations is greater than would be consistent with a literal interpretation of the staggered-contracts model with annual contracts. One explanation is that the implicit duration of the wage contracts underlying the

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[6] While in theory lagged GDP ought to be as valid an instrument as unemployment or capacity utilization, in practice, GDP is, to a large extent, constructed by deflating nominal spending figures by prices. Measurement error in prices could lead to correlation between GDP and the residual error term, making lagged GDP an inappropriate instrument.

[7] I first regressed the difference between lagged inflation and inflation expectations on the instruments. I included the fitted value from this regression as a regressor in a least-squares estimate of Eq. (18) with an MA(1) error term. This procedure will give consistent parameter estimates but incorrect standard errors. To obtain the correct standard errors, I used the MA(1) parameter from the first-stage estimation to filter the data and then estimated Eq. (18) with the filtered data, using two-stage least squares.

Table 5
Tests for sticky-inflation, using capacity utilization
[Semi-annual data. Two-stage least squares: Newey-West correction with eight lags. Dependent variable: $\Delta p_t - (E_t \Delta p_{t+1} + E_{t-1} \Delta p_t)$]

	1961:1–1995:2	1967:1–1995:2	1961:1 to 1995:2		
Expectations survey:	Michigan	Michigan	Livingston	Michigan	Livingston
Constant	−9.70	−13.04	−19.00	−10.13	−17.06
	(5.03)	(5.51)	(5.11)	(4.42)	(3.75)
Capacity util.[1]	0.113	0.156	0.235	0.119	0.211
	(0.063)	(0.069)	(0.064)	(0.056)	(0.047)
Real oil price	0.016	0.014	0.018	0.016	0.016
	(0.006)	(0.005)	(0.006)	(0.005)	(0.005)
$\Delta p_{t-1} - \Delta p_t$	−0.025	−0.132	0.095	–	–
	(0.164)	(0.166)	(0.133)		
$\Delta p_{t-1} - (E\Delta p_{t+1} + E\Delta p_t)/2$	–	–	–	0.058	0.193
				(0.138)	(0.080)
$\bar{R}^2$	0.24	0.34	0.32	0.26	0.47
SER	1.55	1.55	1.63	1.53	1.44
Autocorr. 1	0.38	0.42	0.30	0.29	0.17
2	0.41	0.40	0.39	0.38	0.34
3	0.42	0.41	0.30	0.39	0.27
4	0.25	0.26	0.13	0.22	0.10
P-value, overid.	0.40	0.38	0.31	0.52	0.42
$\bar{R}^2$, first-stage	0.09	0.12	0.09	0.07	0.30

Notes: Numbers in parentheses are standard errors.
[1] Average of current and previous period.

model is greater than one year. To explore this possibility, I re-estimated the model with annual data, implicitly assuming that the contracts were two years long. The results are presented in Table 6, for Eq. (18) only. Positive serial correlation of the residual now stops at the first lag, a result consistent with the staggered contracts model. However, for the Michigan survey results, large negative correlation now appears at the second lag. And in all cases, there is large serial correlation at the fourth lag. These results suggest that while annual estimation solves the problem of excessive positive serial correlation in the semiannual results, they present other serial correlation problems. Still, it is of interest to determine if the results are sensitive to the change in frequency.

As with the semiannual estimates, the coefficients on economic activity generally have the correct sign, although they are statistically significant in only four of six cases. The estimates of λ', the key test parameter, are uniformly small, not significantly different from zero, but significantly different from one-third, the value they would take under the hypothesis of sticky inflation. So while some

Table 6
Tests for sticky Inflation. Using Annual Data, 1962 to 1995.
[Two-stage least squares. Newey-West correction with eight lags Dependent variable: $\Delta p_t - (E_t \Delta p_{t+1} + E_{t-1} \Delta p_t)$]

Expectation survey:	Unemployment[1]		Detrended GDP[1]		Capacity until.	
	Mich.	Liv.	Mich.	Liv.	Mich.	Liv.
Constant	− 0.26	0.37	− 0.24	0.24	− 9.11	− 22.60
	(0.16)	(0.25)	(0.12)	(0.31)	(4.53)	(4.17)
Economic activity[2]	− 0.130	− 0.602	0.227	0.282	0.110	0.281
	(0.083)	(0.141)	(0.055)	(0.102)	(0.057)	(0.052)
Real oil price	0.044	0.041	0.040	0.029	0.044	0.038
	(0.011)	(0.012)	(0.013)	(0.010)	(0.011)	(0.008)
$\Delta p_{t-1} - (E\Delta p_{t+1} + E\Delta p_t)/2$	− 0.043	− 0.045	− 0.125	− 0.120	− 0.096	0.034
	(0.101)	(0.068)	(0.081)	(0.125)	(0.118)	(0.053)
$\bar{R}^2$	0.39	0.45	0.54	0.48	0.44	0.62
SER	1.29	1.50	1.13	1.46	1.24	1.25
Autocorr. 1	0.29	0.51	0.24	0.49	0.35	0.48
2	− 0.24	0.06	− 0.30	− 0.07	− 0.08	− 0.05
3	0.01	0.10	− 0.05	− 0.05	0.11	0.08
4	0.28	0.32	0.16	0.26	0.24	0.22
P-value, overid.	0.32	0.52	0.24	0.36	0.31	0.76
$\bar{R}^2$, first-stage	0.08	0.19	0.32	0.31	0.14	0.34

Notes: Numbers in parentheses are standard errors.
[1] Using HP filter, $\sigma = 16{,}000$.
[2] Average of current and previous period.

of the semiannual estimates (notably, those using detrended GDP) were favorable to the sticky-inflation hypothesis, the results using annual data are uniformly favorable to the hypothesis of sticky-prices.

6. Is there a simple model of survey expectations?

The results from the previous section suggest that, when estimation is done with survey expectations, we get the standard sticky-price results, such as in Eq. (4):

$$\Delta p_t - S_t \Delta p_{t+1} = b_0 - \beta(RU_t + RU_{t-1}) + 2(\varepsilon_t + \varepsilon_{t-1}) + \eta_t. \tag{19}$$

On the other hand, Fuhrer and Moore (1995) found that when they estimate assuming rational expectations, they obtain results consistent with the sticky-inflation model, Eq. (8):

$$\Delta p_t - (\Delta p_{t-1} + M_t \Delta p_{t+1})/2 = b'_0/2 - \beta'(RU_t + RU_{t-1})/2 + (\varepsilon'_t + \varepsilon'_{t-1}) + \eta'_t/2, \tag{20}$$

where $M_t\Delta p_{t+1}$ indicates the 'mathematical', or purely rational, expectation. One ready way to reconcile these results would be if

$$S_t\Delta p_{t+1} = (\Delta p_{t-1} + M_t\Delta p_{t+1})/2. \tag{21}$$

that is, if the survey expectations were well represented as the average of rational expectations and 'adaptive' expectations, as captured by lagged inflation. Such a finding would be a particular model of the departure of the survey expectations from perfect rationality documented in Section 3.

A somewhat more general test would estimate:

$$S_t(p_{t+4} - p_t) = \alpha(L)\Delta p_{t-1} + (1 - \alpha(1)M_t(p_{t+4} - p_t), \tag{22}$$

where $S_t(p_{t+4} - p_t)$ indicates the 1-year-head survey measure of inflation expectations and $M_t(p_{t+4} - p_t)$ is the purely rational expectation over that period. The notation $\alpha(L)$ indicates a lag polynomial, while $\alpha(1)$ indicates the sum of the coefficients in the lag polynomial. The discussion in the previous paragraph suggested that $\alpha(1) = \frac{1}{2}$ but, more generally, if $0 < \alpha(1)$, then expectations are less than rational.

Eq. (22) can be rewritten as

$$M_t(p_{t+4} - p_t) = [1/(1 - \alpha(1)][S_t(p_{t+4} - p_t) - \alpha(L)\Delta p_{t-1}]. \tag{23}$$

Substitute realized inflation for the expectation, which introduces an error term:

$$p_{t+4} - p_t = [1/(1 - \alpha(1)][S_t(p_{t+4} - p_t) - \alpha(L)\Delta p_{t-1}] + \eta_t. \tag{24}$$

If $M_t(p_{t+4} - p_t)$ in Eq. (23) is truly rational, then the error term η will be uncorrelated with lagged inflation, the survey expectation formed at time t, and any other information from period t or earlier. So, Eq. (24) can be estimated by ordinary least squares. For estimation, it is convenient to further rewrite Eq. (24) as

$$\begin{aligned} &p_{t+4} - p_t - S_t(p_{t+4} - p_t) \\ &\quad = -[1/(1 - \alpha(1)][\alpha(L)\Delta p_{t-1} - \alpha(1)S_t(p_{t+4} - p_t)] + \eta_t. \end{aligned} \tag{25}$$

The top panel of Table 7 shows results of estimating Eq. (25) with the Michigan survey of inflation expectations using eight lags of inflation (results using four lags were similar). Because the residuals from this regression may be serially correlated, I have applied the Newey-West correction, allowing for up to MA(8) errors.

Unfortunately, the results in Table 7 indicate that the departure of survey expectations from rationality is not adequately captured by the simple weighted-average model. The sum of coefficients on lagged inflation is positive, whereas if inflation expectations were well represented as a weighted average of lagged and 'rational' expectations, this sum should be negative. The sum of coefficients is insignificant, as predicted under perfectly rational expectations. However, the exclusion test indicates that inflation is nonetheless an important factor explaining the deviation of survey expectations from rationality. This

Table 7
Are survey expectations a weighted average of rational and adaptive expectations?

Michigan Survey. Estimation period: 1967:Q1 to 1995:Q4. Uses eight lags of inflation.

Z $\quad p_{t+4} - p_t - S_t(p_{t+4} - p_t) = -[1/(1 - \alpha(1)][\alpha(L)\Delta p_{t-1} - \alpha(1)S_t(p_{t+4} - p_t)] + \eta_t.$

Estimation technique	$-[\alpha(1)/(1 - \alpha(1)]$	$\alpha(1)$	Exclusion test[1]
1. OLS	0.08 (0.10)	−0.09	0.00003
2. IV[2]	0.10 (0.12)	−0.11	0.0003

Livingston Survey. Estimation period: 1967:H1 to 1995:H2. Uses four lags of inflation.

$$p_{t+2} - p_t - S_t(p_{t+2} - p_2) = -[1/(1 - \alpha(1)][\alpha(L)\Delta p_{t-1} - \alpha(1)S_t(p_{t+2} - p_t)] + \eta_t.$$

Estimation technique	$-[\alpha(1)/(1 - \alpha(1)]$	$\alpha(1)$	Exclusion test[1]
1. OLS	−0.09 (0.15)	0.08	0.03
2. IV[3]	0.12 (0.24)	−0.13	0.013

Notes: Numbers in parentheses are standard errors.
[1] Probability level.
[2] Lagged Michigan survey used as instrument for Michigan survey.
[3] Lagged Livingston survey used as instrument for Livingston survey.

result suggests that some other model of the deviation of the surveys from rationality should be preferred. The results for the Livingston survey, in the bottom panel of Table 7, are similar.[8]

Combining these results with those on the rationality of survey expectations discussed in Section 2 suggests that while inflation expectations are neither purely rational nor purely adaptive, they are not readily represented as being a weighted average of these two extremes.

7. Conclusions

The new Keynesian framework, in which simple models of nominal rigidity are imposed on standard models with rational expectations and conventional supply curves, has difficulty explaining why inflation is costly to reduce. Fuhrer

[8] To allow for the possibility of sampling error in the Michigan survey. I have repeated the estimation, using the lagged Michigan survey as an instrument. The results are no better.

and Moore (1995), however, find that the US experience is consistent with a modified version of the basic New Keynesian model. The modification can be interpreted as requiring us either to drop the standard model of the supply curve adopted in the new Keynesian model in favor of the more elaborate models that lead to sticky inflation, or to accept inflation expectations that are less than perfectly rational. The evidence that I have presented above suggests that some form of not-quite-rational-expectations is the preferred explanation.

Is the distinction between sticky inflation and not-quite-rational expectations important? For some purposes, it is not. For example, Buiter and Miller (1985) show that with sticky inflation, the output cost of disinflationary policies is smaller when inflation is reduced slowly. This result also holds under not-quite-rational expectations and sticky prices.

However, in other settings, the distinction between the models can be important. For example, in models where labor demand is fully developed, the sticky-price model implies a well-determined equilibrium real wage that will be a function of determinants of the positions of the labor supply and labor demand curves, such as technology, the capital stock, and the size of the labor force. But under the sticky-inflation model, in addition to being a function of these factors, the real wage will also be a function of the history of real wages and of inflation and so is not as well tied down. This property may make the sticky-inflation model less well suited for long-run policy analysis.

One advantage of models with perfectly rational expectations is that policy analysis is rather simple: To determine the implications of a change in policy regime, the analyst estimates the underlying behavioral model under the existing policy regime and then simulates the model under the new policy rule. But when expectation formation is imperfectly rational, the policy analyst must be more humble. The analyst cannot use the experience under the old regime by itself to predict how the economy will respond. If the prospective policy regime is similar to one used in the past, the analyst could draw on that experience. But if the proposed policy is entirely original, it is possible that only experience with the new policy can determine how the economy will respond.

Appendix. Evidence on the efficiency of the Michigan survey

As I noted in the text, earlier studies of the efficiency of the Michigan survey (Batchelor and Dua, 1989; Rich, 1989; Baghestani, 1992) are incomplete. To confirm and extend these earlier results on efficiency, I present some further tests here. Because the evidence for unbiasedness was strongest for the sample that extended back to 1966, I used this sample for the stronger test of efficiency. (While the Institute for Social Research at the University of Michigan has included questions on inflation in its consumer survey program since its instigation in 1948, questions about quantitative expectations have only been asked since May 1966.) Imposing unbiasedness, the efficiency test involves regressing forecast errors on information that was available at the time of the survey:

$$(p_t - p_{t-4}) - S_{t-4}(p_t - p_{t-4}) = \beta X_{t-4} + \varepsilon_t, \tag{A.1}$$

where X is a vector of information available at the time the expectation was formed.

For the period from 1966 to 1978, the inflation expectations question in the Michigan survey was asked only quarterly. As a consequence, I use quarterly data. Prior to 1978, the question was asked in the middle month of the quarter, and so I use only the observation from the middle month of the quarter in the post-1978 data as well. To match the expectations data, I also measured the outcome for inflation from the middle month of the quarter to the middle month of the quarter a year later.

In addition to a constant term, I included several macroeconomic variables in the vector X: inflation, the unemployment rate, changes in the Federal funds rate, and lagged forecast errors. Inflation and lagged forecast errors are obvious variables that might be useful in explaining inflation or its forecast errors; Rich (1989) also examined these variables. The Federal funds rate is the interest rate on loans of bank reserves. As such, it is closely linked to the main policy instrument of the Federal Reserve System, and so may be a good indicator of monetary policy. To render it stationary, I differenced it. The unemployment rate is highly correlated with aggregate economic activity. It has the advantage over GDP that it is not revised, and so the currently available data are the same as those available at the time that the expectations were formed. In my basic test, I included eight lags of each variable. I then looked at eight lags of each variable individually. I lagged the forecast error four quarters, since the forecasts are overlapping. To allow for publication lags, I lagged the other three variables one period.

Because the forecasts are overlapping, the error term ε will be serially correlated – in particular, it will follow a moving average error process of order three. Also, the one-quarter publication lag may introduce additional serial correlation. In order to draw correct statistical inferences, I adjusted the residual covariance matrix to allow for up to fourth-order serial correlation; I used the Newey-West procedure to ensure that the adjustment matrix was invertible.

I examined two measures of consumer price inflation: the consumer price index and the Fisher-type chain-weighted personal consumption expenditures price index. Each of these indexes has advantages and disadvantages. The consumer price index has the advantage of being the most prominent measure of consumer price inflation, and so the measure that will be foremost in the public's mind. It also is not revised, and so the currently available data are the same as what was available at the time that the expectations were formed. However, until 1983, the CPI used a conceptually flawed measure of homeownership costs that may have made it a distorted measure of inflation before 1983. Also, the

Table 8
Is the Michigan survey of inflation expectations econometrically efficient?
Probability levels of exclusion tests, Estimation period: 1966:Q1 to 1994:Q3

Included explanatory variable (eight lags)				Inflation measures	
Errors	Inflation	Unemployment	ΔFF	CPI	Fisher-type chain-index
√	√	√	√	0.000000[1]	0.000000[2]
√				0.005	0.07
	√			0.0007	0.24
		√		0.007	0.004
			√	0.11	0.08

Notes: (1) $\chi^2 = 170$; (2) $\chi^2 = 103$

CPI updates its market basket only infrequently, and the basket is always at least three, and sometimes as many as 13, years out of date.

By contrast, the Fisher-type chain index is designed to keep the market basket up to date, and it uses a conceptually superior measure of homeownership costs. It is therefore a better approximation of the true cost of living the CPI. But, precisely because it differs from the CPI, it is not the 'headline' number. And indeed, it was not even published until 1992, so that the public could not have known about it for most of the sample.[9]

Table 8 summarizes the results. For both measures of consumer prices, the test that uses all of the macro variables leads to an overwhelming rejection of the efficiency hypothesis. For the CPI, lagged forecast errors, inflation, and unemployment all helped explain the forecast error, with rejections at least at the 1% level. The Federal funds rate had the least explanatory power, with a rejection at only the 11% level. Using the Fisher-type chain index, only the unemployment rate causes rejection at more than the 5% level.

These results suggest that the Michigan survey of inflation expectations is not econometrically efficient: Information that was available at the time the forcasts were made was not used in the most efficient manner possible. These results are consistent with Baghestani (1992) and Batchelor and Dua (1989), who also rejected the hypothesis that the Michigan survey was econometrically efficient.

[9]Both measures will suffer from a number of other well-known difficulties with price measurement, such as difficulties in measuring quality improvements. See Lebow et al. (1994) for a review of some of the issues.

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