Rational Bias in Inflation Expectations[*]

Robert G. Murphy[†]
Boston College

Adam Rohde[‡]
Charles River Associates

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Abstract

This paper argues that individuals may rationally weight price increases for food and energy products differently from their expenditure shares when forming expectations about price inflation. We develop a simple dynamic model of the economy with gradual price adjustment in the core sector and flexible prices in the food and energy sectors. Serial correlation of supply shocks to food and energy allows individuals to gain an understanding about future shocks, possibly making it optimal for individuals to place more weight on the movement of prices in these sectors. We use survey data on expected inflation to show that the weights implied by the model differ from the expenditure shares of food and energy prices in the CPI for the United States. We find food price inflation is weighted more heavily and energy price inflation is weighted less heavily. But importantly, we cannot reject the hypothesis that these weights reflect rational behavior in forming expectations about inflation.

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[†] Department of Economics, Boston College, Chestnut Hill, MA 02467.
[‡] Charles River Associates, 200 Clarendon St., Boston, MA 02116.

INTRODUCTION

Expectations about price inflation play a central role in modern macroeconomic analysis. They are important for understanding how households and firms make saving, spending, and investing decisions, and are a key input into negotiations for labor contracts and the pricing of financial instruments. Central banks track them for comparison with internal forecasts and targets for inflation. The ability of monetary authorities to achieve price stability depends on an accurate understanding of inflation expectations.

A concern sometimes raised by policymakers is whether inflation in highly visible products such as food and energy might overly influence the public's perception of inflation. For example, discussion at the Federal Open Market Committee meeting in June 2008 clearly illustrates this concern:

> *"Participants had become more concerned about upside risks to the inflation outlook--including the possibility that persistent advances in energy and food prices could spur increases in long-run inflation expectations"*
>
> *"Some noted that the increase was greatest for short-term survey measures of households' inflation expectations, which may be influenced disproportionately by consumers' perceptions of changes in the prices of food and gasoline"*[1]

This concern is not a recent one, having featured prominently during policy discussions about supply shocks during the 1970s.[2]

In an interesting paper, Van Duyne [1982] considers policymakers' concerns that food price inflation may overly influence the public's expectations of inflation. He uses a simple model of the inflation process to illustrate how such "bias" can represent rational behavior.[3] Van Duyne is unable to reject the hypothesis that the weights implied by his model are equal to the actual expenditure shares of food and other items in the consumer price index. He concludes that "contrary to the conventional wisdom of policymakers, consumers appear not to bias their expectations toward food prices."[4]

Similar to Van Duyne, our paper explores whether prices of items that individuals frequently purchase and that often are quite volatile, such as food and energy products, play a larger role in the formation of inflation expectations than their expenditure shares would indicate. We show how it may be rational for individuals to assign relative weights to price increases in the food and energy sectors that are larger than those sectors' shares in consumer expenditure. To illustrate this potential "bias" in inflation expectations, we develop a simple three-sector dynamic aggregate demand-aggregate supply model of the economy with gradual price adjustment in the "core" (non-food, non-energy) sector and flexible prices in the food and energy sectors. Serial correlation of shocks to food and energy prices allows individuals to gain an understanding about future shocks, possibly making it optimal for individuals to place more weight on the movement of prices in these sectors, as past movements of these prices may help predict future inflation.[5]

Our framework extends Van Duyne's paper in three important ways. First, we model aggregate demand as a function of the real interest rate and incorporate a Taylor-type policy rule for the nominal interest rate, whereas Van Duyne expresses aggregate demand as a function of real money balances and assumes a money supply growth rule. Second, we allow for a differential optimal response by the monetary authority to inflation across sectors rather than assume a single response to overall inflation. Third, in our empirical analysis we test whether or not any observed bias in the formation of expectations about inflation is rational, whereas Van Duyne tests only for the presence of such bias but not whether it is rational.

We estimate the model using survey data on expected inflation from the Federal Reserve Bank of Philadelphia.[6] In contrast to Van Duyne, our results show the weights implied by the model for constructing expectations of inflation differ from the expenditure shares of food and energy prices in the Consumer Price Index (CPI) for the United States.[7] In particular, we find food price inflation is weighted more heavily and energy price inflation is weighted less heavily. But importantly, we cannot reject the hypothesis that these weights reflect rational behavior in forming expectations about inflation. Our analysis validates concerns raised by policymakers that expectations might not be well anchored with respect to some commodity price shocks, such as those to food prices. As a consequence, policy may need to be calibrated carefully to prevent such shocks from becoming embedded in expected inflation.

Several recent papers have considered the response of inflation expectations to commodity price movements and reach conflicting conclusions. Counter to our findings, work by Trehan [2011] suggests that households are more sensitive to both food *and* energy prices in forming inflation expectations than they are to core measures of inflation that exclude those items. He uses correlation analysis to show that survey measures of inflation expectations are more closely related to inflation in food and energy items than to core inflation. Experimental evidence presented by Georganas et al [2014] finds that perception of the economy-wide inflation rate is influenced by the frequency with which goods' prices are observed, consistent with our results for food prices but not energy. A recent paper by Arora et al [2013] shows that expected inflation responds strongly to (what they term) "explosive deviations" of overall inflation (often driven by energy prices) from core inflation. On the other hand, work by Verbrugge and Higgins [2015] finds energy price shocks are much less important in determining inflation expectations than are other macroeconomic variables, in line with our results and consistent with evidence in Bernanke [2007] that inflation expectations have become better anchored with respect to energy prices in recent decades. All of these papers use non-structural methods in their analyses and none explicitly test whether the observed response reflects rational behavior. [8] By contrast, we develop a structural model of the economy and use it to test directly whether inflation expectations respond rationally to food and energy price movements.

The paper proceeds as follows. We first develop a simple dynamic model of the economy to show how individuals may optimally overweight or underweight food and energy prices in forming expectations about overall inflation. We then present tests of the model's predictions using survey data on expected price inflation providing support for rational bias in inflation expectations. Finally, we summarize our findings and offer suggestions for further research.

THE MODEL

Our model assumes prices are flexible in the food and energy sectors but adjust sluggishly in the core (non-food and non-energy) sector, where firms with market power set price as a markup over marginal cost.[9] The model consists of a standard wage-price Phillips curve augmented to include supply shocks and a dynamic aggregate demand relationship incorporating a Taylor-type rule for monetary policy. Our approach builds on work by Van Duyne [1982], but differs from his by including a monetary policy rule for the nominal interest rate (instead of a money growth rule), expressing aggregate demand as a function of the real interest rate (instead of the real money supply), and allowing for differential response by the monetary authority to inflation across sectors.

Aggregate Supply

The composite price of goods and services in the core sector is given as a constant markup (μ) over marginal cost, which we proxy by unit labor costs:

$$P_t^c = \mu \frac{w_t l_t}{y_t} \tag{1}$$

where *w* is the wage, *l* is employment, and *y* is output.[10, 11] For simplicity, we assume a constant rate of labor productivity growth in the core sector so that equation (1) implies core inflation (π_t^c) equals wage inflation (ω_t) minus productivity growth (*g*):[12]

$$\pi_t^c = \omega_t - g\,. \tag{2}$$

The equilibrium wage is assumed to rise at the rate of expected inflation plus productivity growth, adjusted for the degree of slack in labor markets:

$$\omega_t^* = E_{t-1}\pi_t + g - a_1 u_t \tag{3}$$

where $E_{t-1}\pi_t$ is the expectation in period *t*-1 of inflation for period *t* and u_t is the gap between the actual rate of unemployment and its natural (full-employment) level. Actual wage inflation adjusts to its equilibrium rate gradually, either because overlapping wage contracts make nominal wages sticky or costs of acquiring information lead to lags in updating otherwise flexible wages. [13] We approximate this gradual adjustment of wage inflation with a simple relationship:

$$\omega_t - \omega_{t-1} = a_2(\omega_t^* - \omega_{t-1}) \qquad 0 < a_2 \leq 1 \tag{4}$$

where parameter a_2 determines the speed with which wage inflation adjusts to its equilibrium value.[14]

We ignore differences in productivity growth rates across sectors and assume that inflation rates in the food and energy sectors relative to the inflation rate in the core sector are driven by serially correlated supply shocks (ν_t and ε_t):

$$\begin{array}{ll} \pi_t^f = \pi_t^c + \nu_t & \pi_t^e = \pi_t^c + \varepsilon_t \\ \nu_t = \sigma \nu_{t-1} + \xi_t & \varepsilon_t = \delta \varepsilon_{t-1} + \eta_t \end{array} \tag{5}$$

where $|\sigma|$, $|\delta| < 1$, and ξ_t, η_t are mean-zero uncorrelated random shocks. In principle, the supply shocks could be either positively or negatively serially correlated and could be represented by more complicated time-series processes. As discussed later in the paper, we find that a first-order autoregressive process fits the data well and provides for a parsimonious representation of these shocks.

The overall rate of inflation for the economy is measured using a weighted average of price inflation in the food, energy, and core sectors of the economy:

$$\pi_t = A\pi_t^f + B\pi_t^e + (1 - A - B)\pi_t^c \tag{6}$$

where *A* and *B* are expenditure shares for food and energy items used to construct the price index for consumer expenditures.[15]

Using equations (2), (3), (4), (5), and (6), we can solve for a Phillips curve relating overall inflation to expected inflation and lagged values of inflation for the core, food, and energy sectors:

$$\pi_t = a_2 E_{t-1}\pi_t - a_1 a_2 u_t + (1-a_2)\pi_{t-1}^c + A\{\sigma(\pi_{t-1}^f - \pi_{t-1}^c) + \xi_t\} + B\{\delta(\pi_{t-1}^e - \pi_{t-1}^c) + \eta_t\} \quad (7)$$

where the last two terms are written as deviations of food and energy inflation from core inflation and can be interpreted as supply shocks. Equation (7) is similar to the expectations-augmented Phillips curve of Friedman [1968] as generalized by Gordon [1982] to incorporate supply shocks and inertia through lagged core inflation.[16]

Aggregate Demand

To complete the model, we specify an *IS*-type demand equation that relates the unemployment gap to the real interest rate:

$$u_t = a_3(i_t - E_t\pi_{t+1} - \rho) - \upsilon_t \quad (8)$$

where i_t is the nominal interest rate, $E_t\pi_{t+1}$ is the expectation of overall inflation in period t+1 as of period t, ρ is the natural or long-run value of the real interest rate at which the unemployment gap is zero, and υ_t is a mean-zero uncorrelated shock to demand.[17] The monetary authority is assumed to target the nominal interest rate so as to raise (lower) the *real* interest rate when inflation exceeds (falls short of) its target or when the unemployment rate is less than (greater than) its natural level.[18] We allow the monetary authority to respond differently to inflation in food, energy, and core sectors:

$$i_t = \pi_t + \rho + \theta_1(\lambda_f \pi_t^f + \lambda_e \pi_t^e + (1-\lambda_f - \lambda_e)\pi_t^c - \pi^*) - \theta_2 u_t \qquad 0 < \theta_1, \theta_2;\; 0 < \lambda_f, \lambda_e, \lambda_f + \lambda_e < 1 \tag{9}$$

where λ_f and λ_e are the relative weights the monetary authority places on food and energy inflation, θ_1 captures the response to deviations in overall inflation from its target, π^* is the monetary authority's target for inflation, θ_2 captures the response to deviations in unemployment from its natural rate, and ρ is the long-run real interest rate. Note that λ_f and λ_e need not equal the expenditure shares used in equation (6) to construct the price index for consumer expenditures. [19]

Substituting this Taylor-type rule into equation (8) and using equation (6) to express overall inflation in terms of its sectoral components yields the following dynamic aggregate demand expression:

$$u_t = \frac{a_3(A+\theta_1\lambda_f)}{(1+a_3\theta_2)}\pi_t^f + \frac{a_3(B+\theta_1\lambda_e)}{(1+a_3\theta_2)}\pi_t^e + \frac{a_3\{(1-A-B)+\theta_1(1-\lambda_e-\lambda_f)\}}{(1+a_3\theta_2)}\pi_t^c - \frac{a_3}{(1+a_3\theta_2)}E_t\pi_{t+1} - \frac{a_3\theta_1}{(1+a_3\theta_2)}\pi^* - \frac{1}{(1+a_3\theta_2)}\upsilon_t \tag{10}$$

relating unemployment to inflation in the food, energy, and core sectors. Equation (10) shows that when inflation increases, the unemployment gap also increases as the monetary authority raises the real interest rate to reduce aggregate demand and contain inflation. Depending on the values of λ_f and λ_e, the monetary authority may respond differently to inflation in the food, energy, and core sectors. The unemployment gap will respond more to inflation when the monetary authority places a larger weight, θ_1, on deviations from the inflation target and it will respond less to inflation when the monetary authority places a larger weight, θ_2, on stabilizing unemployment at its natural rate. An increase in expected inflation, given current and target inflation, lowers the real interest rate, raises demand and lowers the unemployment gap. Note that when inflation is constant and equal to its target level (and the demand shock is zero), equation (10) implies the unemployment gap is zero so that unemployment is equal to its natural rate.[20]

Equilibrium

To solve for the equilibrium value of inflation, we first substitute for period *t* sectoral inflation rates in equation (10) by using equations (2), (3), (4), and (5) to obtain:

$$\begin{aligned} u_t = \frac{a_3}{S}\pi_t + \frac{a_3\theta_1(1-a_2)}{S}\pi^c_{t-1} + \frac{a_3\theta_1\lambda_f}{S}\nu_t + \frac{a_3\theta_1\lambda_e}{S}\varepsilon_t \\ + \frac{a_2a_3\theta_1}{S}E_{t-1}\pi_t - \frac{a_3}{S}E_t\pi_{t+1} - \frac{a_3\theta_1}{S}\pi^* - \frac{1}{S}\upsilon_t \end{aligned} \qquad (11)$$

where $S = (1 + a_1a_2a_3\theta_1 + a_3\theta_2)$, and where we have used the definition of measured inflation given by equation (6) to combine sectoral inflation rates into overall inflation. Next, we use equation (11) to substitute for the unemployment gap in equation (7) and rearrange to obtain:

$$\begin{aligned} \pi_t = \frac{a_2(1+a_3\theta_2)}{X}E_{t-1}\pi_t + \frac{a_1a_2a_3}{X}E_t\pi_{t+1} + \frac{a_1a_2a_3\theta_1}{X}\pi^* + \\ \frac{\{(1-a_2)(1+a_3\theta_2) - S(\sigma A + \delta B)\}}{X}\pi^c_{t-1} + \frac{S\sigma A}{X}\pi^f_{t-1} + \\ \frac{S\delta B}{X}\pi^e_{t-1} + \frac{SA\xi_t}{X} + \frac{SB\eta_t}{X} - \frac{a_1a_2a_3\theta_1\lambda_f}{X}\nu_t - \frac{a_1a_2a_3\theta_1\lambda_e}{X}\varepsilon_t + \frac{a_1a_2}{X}\upsilon_t \end{aligned} \qquad (12)$$

where $X = \{1 + a_3\theta_2 + a_1a_2a_3(1+\theta_1)\}$ and, as before, $S = (1 + a_1a_2a_3\theta_1 + a_3\theta_2)$. Equation (12) shows how inflation in period *t* depends on inflation expected for period *t* and inflation expected for period t+1. An increase in expected inflation for period t as of period t-1 leads to higher wage inflation, which in turn is partly passed through into higher core inflation and, hence, overall inflation. An increase in expected inflation for period t+1 as of period t lowers the real interest rate and raises aggregate demand (i.e., reduces the unemployment gap), thereby increasing inflation. The equation exhibits a neutrality property: if expected inflation rates, target inflation, and lagged sectoral inflation rates all increase by the same proportion (and demand and supply shocks are zero), then overall inflation also will increase by the same proportion, and from equation (10) the unemployment gap will be unaffected.

To obtain a relationship describing equilibrium expected inflation, we take expectations of both sides of equation (12) as of time t-1, and rearrange to yield:

$$E_{t-1}\pi_t = \mu\pi^* + \psi E_{t-1}\pi_{t+1} + \zeta[\alpha\pi^f_{t-1} + \beta\pi^e_{t-1} + (1-\alpha-\beta)\pi^c_{t-1}] \tag{13}$$

where:

$$\alpha = \frac{\sigma(SA - a_1a_2a_3\theta_1\lambda_f)}{(1-a_2)(1+a_3\theta_2)}$$

$$\beta = \frac{\delta(SB - a_1a_2a_3\theta_1\lambda_e)}{(1-a_2)(1+a_3\theta_2)}$$

$$\zeta = \frac{(1-a_2)(1+a_3\theta_2)}{Z}$$

$$\mu = \frac{a_1a_2a_3\theta_1}{Z}$$

$$\psi = \frac{a_1a_2a_3}{Z}$$

$$S = (1 + a_1a_2a_3\theta_1 + a_3\theta_2)$$

$$Z = (1-a_2)(1+a_3\theta_2) + [a_1a_2a_3(1+\theta_1)].$$

Equation (13) relates inflation expected *one period* in the future to inflation expected *two periods* in the future, the monetary authority's inflation target, and a *weighted average* of lagged sectoral inflation rates. The monetary authority is assumed to use the same optimal relative weights that individuals use to form expectations about inflation. This implies that $\lambda_f = \alpha$ and $\lambda_e = \beta$. Applying these restrictions and solving gives the following expressions for λ_f and λ_e in terms of the parameters of the model:

$$\lambda_f = \frac{\sigma A(1 + a_1 a_2 a_3 \theta_1 + a_3 \theta_2)}{(1 - a_2)(1 + a_3\theta_2) + \sigma a_1 a_2 a_3 \theta_1}$$
$$\lambda_e = \frac{\delta B(1 + a_1 a_2 a_3 \theta_1 + a_3 \theta_2)}{(1 - a_2)(1 + a_3\theta_2) + \delta a_1 a_2 a_3 \theta_1}. \tag{14}$$

Substituting these expressions for λ_f and λ_e into equation (13) provides the complete solution for expected inflation:

$$E_{t-1}\pi_t = \mu\pi^* + \psi E_{t-1}\pi_{t+1} + \zeta[\alpha^*\pi_{t-1}^f + \beta^*\pi_{t-1}^e + (1 - \alpha^* - \beta^*)\pi_{t-1}^c] \tag{15}$$

where:

$$\alpha^* = \frac{\sigma A(1 + a_1 a_2 a_3 \theta_1 + a_3 \theta_2)}{\{(1 - a_2)(1 + a_3\theta_2) + \sigma a_1 a_2 a_3 \theta_1\}}$$
$$\beta^* = \frac{\delta B(1 + a_1 a_2 a_3 \theta_1 + a_3 \theta_2)}{\{(1 - a_2)(1 + a_3\theta_2) + \delta a_1 a_2 a_3 \theta_1\}}$$
$$\zeta = \frac{(1 - a_2)(1 + a_3\theta_2)}{Z}$$
$$\mu = \frac{a_1 a_2 a_3 \theta_1}{Z}$$
$$\psi = \frac{a_1 a_2 a_3}{Z}$$
$$Z = (1 - a_2)(1 + a_3\theta_2) + [a_1 a_2 a_3(1 + \theta_1)].$$

Similar to equation (13), equation (15) relates inflation expected one period in the future to inflation expected two periods in the future, the monetary authority's inflation target, and a weighted average of lagged sectoral inflation rates. But now the relative weights on sectoral inflation rates assume the monetary authority responds in a manner consistent with the underlying time series dynamics of sectoral inflation.

Note that the relative weights on lagged food, energy, and core inflation sum to one but in general are not equal to the expenditure shares used to compute the overall rate of inflation. In particular, the relative weights on food and energy inflation ($\alpha^*$and β^*) will exceed their respective expenditure shares (*A* and *B*) when $\sigma + a_2 > 1$ and $\delta + a_2 > 1$. These conditions are more likely to hold when the rate of inflation in the food and energy sectors is persistent (supply shocks to these sectors exhibit sufficient serial correlation so that σ and δ are large) and the speed of wage adjustment is not too sluggish (so that a_2 is large). Conversely, the relative weights will fall short of their respective expenditure shares when $\sigma + a_2 < 1$ and $\delta + a_2 < 1$. The intuition for these conditions is that serial correlation of shocks to food and energy sectors allows individuals to gain an understanding about future shocks. Higher serial correlation of shocks and the associated greater persistence in food and energy inflation, other things equal, leads individuals to optimally overweight food and energy inflation (and underweight core inflation) in forming expectations. But if the speed of wage adjustment is slow enough, core inflation, which depends directly on wage inflation, will exhibit sufficient persistence, leading individuals to overweight core inflation and underweight food and energy inflation in forming expectations.

Equation (15) imposes following restrictions on the relative weights individuals should optimally place on inflation in the food and energy sectors when forming expectations about overall inflation:

$$\begin{aligned}\alpha^* &= \frac{\sigma A(1+a_1a_2a_3\theta_1+a_3\theta_2)}{\{(1-a_2)(1+a_3\theta_2)+\sigma a_1a_2a_3\theta_1\}} \\ \beta^* &= \frac{\delta B(1+a_1a_2a_3\theta_1+a_3\theta_2)}{\{(1-a_2)(1+a_3\theta_2)+\delta a_1a_2a_3\theta_1\}}\end{aligned}. \qquad (16)$$

In the next section, we describe how these restrictions can be tested using survey data on inflation expectations to estimate the parameters of our model.

ESTIMATION RESULTS

We estimate relationships of the following form that match equation (15):

$$_{t-1}\pi_t^E = \gamma_0 + \gamma_1\,{}_{t-1}\pi_{t+1}^E + \gamma_2\pi_{t-1}^f + \gamma_3\pi_{t-1}^e + \gamma_4\pi_{t-1}^c \qquad (17)$$

where $_{t-1}\pi_t^E$ is expected CPI inflation for period t as of period t-1, $_{t-1}\pi_{t+1}^E$ is expected CPI inflation for period t+1 as of period t-1, and π^f, π^e, and π^c are CPI inflation rates for food, energy and core sectors. Because the monetary authority's target for inflation is assumed fixed (and equal to two percent), we include a constant term in the equation. To estimate equation (17), we need data for inflation expected one and two periods in the future. The Federal Reserve Bank of Philadelphia's Survey of Professional Forecasters (SPF) provides quarterly measures of CPI inflation in the United States expected for multiple time periods in the future, allowing direct estimation of equation (17).[21] Although the University of Michigan's Survey of Consumers is more representative of the population at large than the SPF, the Michigan survey reports monthly measures of inflation expected over the next year and the next five-to-ten years, not for one and two periods ahead.[22] In addition, the Michigan survey asks only about generic inflation, whereas the SPF asks about specific measures including the CPI. Because the SPF matches the timing of the expected inflation variables in our model and asks specifically about the CPI, we use those data in our analysis.[23]

The parameters $\alpha^*, \beta^*, \zeta, \mu,$ and ψ in equation (15) are related to the estimated coefficients of equation (17) by the following expressions:

$$\begin{aligned}
\alpha^* &\equiv \frac{\gamma_2}{\gamma_2+\gamma_3+\gamma_4} \\
\beta^* &\equiv \frac{\gamma_3}{\gamma_2+\gamma_3+\gamma_4} \\
\zeta &\equiv \gamma_2+\gamma_3+\gamma_4 \\
\mu &\equiv \gamma_0 / \pi^* \\
\psi &\equiv \gamma_1
\end{aligned} \tag{18}$$

where α^* and β^* represent the relative weights placed on food and energy prices in forming expectations about inflation. Under the null hypothesis that individuals form expectations about future inflation using our simple model, equations (16) and (18) imply the following restrictions:

$$\begin{aligned}
\frac{(1-a_2)\gamma_2\{\sigma\gamma_0+(\gamma_2+\gamma_3+\gamma_4)\pi^*\}}{\sigma(\gamma_2+\gamma_3+\gamma_4)\{(1-a_2)\gamma_0+(\gamma_2+\gamma_3+\gamma_4)\pi^*\}} &= A \\
\frac{(1-a_2)\gamma_3\{\delta\gamma_0+(\gamma_2+\gamma_3+\gamma_4)\pi^*\}}{\delta(\gamma_2+\gamma_3+\gamma_4)\{(1-a_2)\gamma_0+(\gamma_2+\gamma_3+\gamma_4)\pi^*\}} &= B
\end{aligned} \tag{19}$$

where we interpret *A* and *B* as the expenditure shares for food and energy used to compute the CPI. To test these restrictions, we need estimates of $a_2, \sigma, \delta,$ and π^* in addition to the parameters of equation (17). This requires estimation of equation (17) in combination with the wage adjustment equation and the autoregressive relationships for the supply shocks. To recover the wage adjustment parameter, a_2, we estimate a Phillips curve for wage inflation derived by substituting equation (3) into equation (4) and rearranging:

$$\omega_t = \phi_0 - \phi_1 u_t + \phi_2\, {}_{t-1}\pi_t^E + (1-\phi_2)\omega_{t-1} \tag{20}$$

where $\phi_2 \equiv a_2$. We impose the constraint that the coefficients on expected inflation and lagged wage inflation sum to one when estimating equation (20), as implied by equations (3) and (4).[24] To obtain estimates of the autoregressive parameters, σ and δ, we use equations (5) to derive the following relationships:

$$\pi_t^f - \pi_t^c = \vartheta_1(\pi_{t-1}^f - \pi_{t-1}^c) \qquad \pi_t^e - \pi_t^c = \vartheta_2(\pi_{t-1}^e - \pi_{t-1}^c) \tag{21}$$

where $\vartheta_1 \equiv \sigma$ and $\vartheta_2 \equiv \delta$. Finally, we assume that target inflation, π^*, equals 2 percent.[25] Using equations (20) and (21), the restrictions given by equation (19) can be written in terms of the estimated parameters:

$$\begin{aligned} \frac{(1-\phi_2)\gamma_2\{\vartheta_1\gamma_0 + (\gamma_2+\gamma_3+\gamma_4)\times 2\}}{\vartheta_1(\gamma_2+\gamma_3+\gamma_4)\{(1-\phi_2)\gamma_0 + (\gamma_2+\gamma_3+\gamma_4)\times 2\}} = A \\ \frac{(1-\phi_2)\gamma_3\{\vartheta_2\gamma_0 + (\gamma_2+\gamma_3+\gamma_4)\times 2\}}{\vartheta_2(\gamma_2+\gamma_3+\gamma_4)\{(1-\phi_2)\gamma_0 + (\gamma_2+\gamma_3+\gamma_4)\times 2\}} = B \end{aligned} \tag{22}$$

where, again, *A* and *B* are the expenditure shares of food and energy in the CPI.

We employ generalized method of moments (GMM) to jointly estimate equations (17), (20), and (21) using quarterly data for the United States.[26] For the inflation variables, we use the quarterly percentage change expressed at an annual rate for the food, energy, and core components of the CPI for All Urban Consumers (CPI-U). We measure the unemployment gap using the difference between the quarterly civilian unemployment rate for workers unemployed less than 27 weeks and the quarterly value of the natural rate estimated by the Congressional Budget Office [2015].[27] For wage inflation, we use the quarterly percentage change in average hourly earnings expressed at an annual rate. And as discussed earlier, we measure expected inflation using the SPF, which provides data for median expected inflation at an annual rate one and two quarters into the future. We start our sample period in 1982, the first full year that the SPF provides consistent data for multi-horizon expectations of inflation. In our estimation, we use as instruments four lags each of overall inflation, wage inflation, the unemployment gap, and inflation expected two quarters ahead.[28]

To test the hypotheses given by equation (22), we use the average relative importance weights of food and energy in the CPI-U as reported by the Bureau of Labor Statistics for values of *A* and *B*. Figure 1 plots these relative importance weights over our sample period. Except for an initial decline from 1982 through 1986, both shares are reasonably stable, fluctuating in a band of only a couple of percentage points around their average values. The food share gradually trends down after 1986 while the energy share moves up slightly during recent years.

<<Figure 1 Here>>

We report in Table 1 estimates for the coefficients of equations (17), (20), and (21) along with their standard errors.[29] For the period 1982 to 2014, all coefficients are of the correct positive sign and all are statistically different from zero at high levels of confidence. Hansen's J-statistic shows that we cannot reject at standard levels of confidence the set of overidentifying restrictions on the instruments. Our point estimate of the persistence of inflation in the food sector (ϑ_1) is higher than for the energy sector (ϑ_2), consistent the view that underlying shocks to raw energy prices feed through more rapidly into final-stage products and thus dissipate more quickly than do shocks to raw food prices.[30] Wage inflation adjusts to its equilibrium value at a rate that eliminates roughly 20 percent of the gap in one quarter, as captured by the point estimate of ϕ_2.

<<Table 1 Here>>

Table 1 also presents test results for the hypothesis that individuals form expectations rationally so that the parameters jointly satisfy the two restrictions given by equation (22).[31] The p-value of 0.41 indicates that we cannot reject the hypothesis that individuals form expectations rationally in accord with these restrictions. We can, however, reject the hypothesis that the estimated relative weights, given by equation (18) and reported in Table 1, are equal to the actual relative weights, as seen by the p-value of 0.00 for the test of relative weights. The estimated relative weight for food (0.275) is larger than its actual value (0.155) but the estimated relative weight for energy (0.047) is smaller than its actual value (0.082). This suggests rational overweighting for food but rational underweighting for energy in forming expectations about inflation.[32] The underweighting of energy inflation is consistent with evidence that monetary policy was tightened sharply in response to energy-related supply shocks during the 1970s and early

1980s so as to dampen inflation, leading expectations to become better anchored and less responsive to these shocks in subsequent decades.[33]

As shown in Figure 1, the relative weights of food and energy in the CPI were higher in the early 1980s before falling sharply and becoming more stable after 1985. To assess whether our findings are robust to excluding the early 1980s, Table 1 also provides results for the period from 1986 to 2014. The estimates and test results are similar to those for the full sample period, with the exception that the coefficient on the unemployment gap in equation (20) is significantly different from zero at only slightly above the ten-percent level, possibly reflecting greater importance for the shorter sample period of downward nominal wage rigidity during the prolonged episode of high unemployment associated with the Great Recession.[34] Once again, we cannot reject the hypothesis of rational bias in expectations formation.

We also consider a version of the model in which food and energy sectors are combined. Here we use data on prices in the food and energy sectors along with relative expenditure shares to compute a price index for the combined sectors.[35] We estimate a model of the same structure as before except that now only one non-core inflation rate enters the model:

$$ {}_{t-1}\pi_t^E = \gamma_0 + \gamma_1\, {}_{t-1}\pi_{t+1}^E + \gamma_2 \pi_{t-1}^{ef} + \gamma_3 \pi_{t-1}^c \tag{17a} $$

$$ \omega_t = \phi_0 - \phi_1 u_t + \phi_2\, {}_{t-1}\pi_t^E + (1-\phi_2)\omega_{t-1} \tag{20a} $$

$$ \pi_t^{ef} - \pi_t^c = \vartheta_1(\pi_{t-1}^{ef} - \pi_{t-1}^c) \tag{21a} $$

where π_t^{ef} is the composite rate of price inflation in the food and energy sectors. We use generalized method of moments to jointly estimate equations (17a), (20a), and (21a) and, as before, employ as instruments four lags each of overall inflation, wage inflation, the unemployment gap, and inflation expected two quarters ahead. The restriction in equation (22) now takes the form:

$$\frac{(1-\phi_2)\gamma_2\{\vartheta_1\gamma_0+(\gamma_2+\gamma_3)\times 2\}}{\vartheta_1(\gamma_2+\gamma_3)\{(1-\phi_2)\gamma_0+(\gamma_2+\gamma_3)\times 2\}}=C \qquad (22a)$$

where C is the combined expenditure share of food and energy in the CPI.

Table 2 provides results for the composite version of our model. All coefficients are of the correct positive sign and all are statistically significant at the one-percent level. For the period 1982 to 2014, we cannot reject the hypothesis that expectations are formed rationally according to the structure of our model, as indicated by the probability value of 0.87 for the test of the restriction given in equation (22a). We can, however, reject the hypothesis that the estimated relative weight for the food-energy composite sector is equal to its actual value, as shown by the p-value of 0.00. The estimated relative weight of 0.103 is smaller than its actual value of 0.237, indicating rational underweighting of composite food-energy inflation in the formation of expectations. Given the results of Table 1 showing underweighting of energy inflation and overweighting of food inflation, this underweighting of composite food-energy inflation suggests that the influence of energy price inflation dominates the influence of food price inflation in forming expectations of overall inflation. As discussed above, this underweighting may reflect better anchoring of inflation expectations with respect to energy price shocks since the early 1980s. We again provide a robustness check on our results by estimating the composite model over the period 1986 to 2014. The second column of Table 2 shows that estimates over this shorter sample period are similar to those for the full sample.[36]

<<Table 2 Here>>

SUMMARY

This paper has argued that individuals may *rationally* weight price increases in the food and energy sectors differently from the expenditure shares of these sectors in the CPI when forming expectations about overall price inflation. We developed a simple dynamic model of the economy to illustrate this finding. Serial correlation of shocks to food and energy prices allows individuals to gain an understanding about future shocks, possibly making it optimal for individuals to place more weight on the movement of prices in these sectors, as past movements of these prices may help predict future inflation. In particular, if the degree of persistence for shocks to food and energy inflation is high enough and the speed of wage adjustment is not too sluggish, the model predicts individuals will overweight price movements for food and energy compared with their expenditure shares in the CPI.

Using data on expected inflation from the Federal Reserve Bank of Philadelphia's Survey of Professional Forecasters, we show the weights implied by the model for constructing expectations of inflation differ from the expenditure shares of food and energy in the CPI. Specifically, we find food price inflation is weighted more heavily and energy price inflation is weighted less heavily. But we cannot reject the hypothesis that these weights reflect rational formation of expectations about inflation. These results indicate that expectations might not be well anchored with respect to some commodity price shocks, such as those to food prices. It follows that policymakers may need to tailor responses to such shocks to account for the disparity between expenditure shares and the weights individuals place on sectoral inflation in forming expectations. This may mean more forceful policy is necessary in response to some shocks to prevent them from becoming embedded in expected inflation.

Our goal in this paper was to develop a simple dynamic model of the macroeconomy to illustrate the possibility of rational bias in expectations formation and to provide some preliminary results using survey data on inflation expectations. The analysis showed how this bias depends on persistence in commodity price inflation and the degree of inertia in wage adjustment. Future research should extend our work by exploring the links between rational bias and models of rational inattentiveness, where differences in the cost of acquiring information across sectors (or differences in willingness to pay attention to news across sectors) could lead to over or underweighting of inflation across sectors.[37] Our approach could also be applied to countries other than the United States to ascertain similarities and differences across countries in the response of inflation expectations to movements in food and energy prices. Finally, our simple model could be modified to incorporate a greater degree of forward-looking behavior similar to New Keynesian sticky-price models.

APPENDIX

<<Table A-1 Here>>

<<Table A-2 Here>>

Acknowledgements

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Notes

[1] Federal Open Market Committee [2008], pp. 6-7.

[2] See Van Duyne [1982] for several examples.

[3] We adopt Van Duyne's terminology and use the word "bias" to denote rational overweighting or underweighting of price index components compared with their expenditure shares. This bias *does not* represent statistical bias in which consistently positive or negative forecast errors arise.

[4] Van Duyne [1982], p. 420.

[5] We study how expected inflation responds to movements in commodity prices and whether this response represents overweighting or underweighting compared to the expenditure shares of commodities in the consumer price index. A separate but related literature explores the question of whether survey measures of expected inflation represent rational forecasts of future inflation. See, for example, the volume by Sinclair [2010] and articles by Capistran and Timmermann [2009], Mankiw et al [2004], Ehrbeck and Waldmann [1996], Noble and Fields [1982], and Mullineaux [1978].

[6] As discussed later in the paper, we use data on expected CPI inflation from the Federal Reserve Bank of Philadelphia's Survey of Professional Forecasters (SPF) because it provides measures of expected inflation one-quarter and two-quarters ahead, which our methodology requires. Fuhrer [2012] and Mishkin [2007], among other authors, also use the Survey of Professional Forecasters to capture the public's expectation of inflation at different horizons. See Croushore [1993] for an overview of the SPF.

[7] One potential reason why our results differ from Van Duyne's is because we use a later sample period. Van Duyne estimates his model over the period 1966-1977, whereas we estimate our model over a sample period beginning in 1982 determined by the availability of the SPF data for expected inflation. Van Duyne uses data for expected inflation from the University of Michigan's Surveys of Consumers that is available for the earlier time period. His model requires data only for inflation expected one period in the future whereas our model requires data for inflation expected one and two periods in the future. Although the Michigan data also provide measures of inflation expected over

more than one horizon (one-year and five-year), these data do not provide measures of inflation expected over equal lengths of time one and two periods in the future, as needed for our analysis. Also, the Michigan five-year horizon is computed from a question that asks respondents about the *next five-to-ten years* and so is not very precise. By contrast, the SPF data exactly match our model's timing.

[8] Other authors who have analyzed the relationship between expected inflation and commodity price movements using non-structural methods include Wong [2014] and Celasun et al [2012].

[9] This difference in speed of price adjustment between commodity and core sectors draws on a distinction long emphasized in the literature between "flexprice" and "fixprice" markets. See, for example, Hicks [1974], Okun [1981], and the more recent discussions in De Cecco [2009] and Jespersen [2009]. These differences in price adjustment have been cited as a possible justification for government support programs aimed at limiting volatility of agricultural incomes, as discussed in Congressional Budget Office [1990], pp. 70-74.

[10] See Whelan [1997] for a derivation of a wage-price Phillips curve similar to the one we develop here.

[11] Profit-maximizing monopolistically competitive firms will set price as a markup over marginal cost, where the markup may vary with demand conditions. For example, Mazumder [2014] finds that the markup in the U.S. manufacturing sector is countercyclical. For simplicity, and following Whelan [1997], we treat the markup as constant.

[12] If real wages rise by less than productivity growth, we can replace g in equations (2) and (3) by zg where $0 < z < 1$, leaving our derivation of equation (7) unchanged. Feldstein [2008], Anderson [2007], and Sherk [2013] find evidence that real compensation has tracked productivity closely in line with equation (3).

[13] The equilibrium wage can be interpreted as the wage that would prevail under full information. When information is costly to acquire, firms and workers will update information with some lag, implying a gradual adjustment of wage inflation toward its equilibrium rate. See Mankiw and Reis [2002] for implications of "sticky information" in a model of price setting behavior.

[14] Many authors have shown that inflation is persistent. See, for example, Fuhrer and Moore [1995], Nelson [1998], Mankiw [2001], and Roberts [2006]. We assume gradual (or "sticky") adjustment of wage inflation to its equilibrium rate so that price inflation in the core sector exhibits persistence in our model. Equation (4) is consistent with sticky adjustment of the level of the wage when the adjustment equation for the level of the wage is $w_t / w_{t-1} = \left(w_t^* / w_{t-1}\right)^{a_2}$.

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[15] Equation (6) holds for Laspeyres fixed-weight indexes. The official CPI for the United States uses a Laspeyres formulation at its upper level for aggregate items such as food and energy. See Bureau of Labor Statistics [2007] for details.

[16] See also Gordon [1990], Fuhrer [1995], and Murphy [2000] who provide empirical support for standard Phillips curve models of inflation. Bernanke [2008] provides an overview of several important issues for Phillips curve analyses of inflation. Ball and Mazumder [2011] incorporate anchored expectations into an otherwise standard Phillips curve as a possible reason for why the United States did not experience deflation during and immediately after the Great Recession. Murphy [2014] finds that a Phillips curve modified to account for uncertainty about regional economic conditions can explain the behavior of inflation following the Great Recession.

[17] Romer [2012], Chapter 6, derives a New Keynesian *IS* curve relationship similar to equation (8) from the maximizing behavior of households.

[18] See Taylor [1993] and Bryant, Hooper, and Mann [1993] for a discussion of central bank interest-rate policy that appears to be well approximated by such rules.

[19] As shown later in the paper, our solution to the model imposes the condition that λ_f and λ_e equal the optimal weights on food and energy inflation used by individuals in forming expectations about overall inflation. This ensures that the monetary authority responds to food and energy inflation in a manner consistent with their underlying time series dynamics. We do not derive values for θ_1 and θ_2 in terms of other model parameters because this requires specifying the form of the monetary authority's preference structure and solving a complicated dynamic programming problem that is beyond the scope of this paper. Ball [1994, 1997] argues that solutions for Taylor-type rules are highly sensitive to particular specifications of preferences and model structure. Our empirical analysis accounts for the estimated values of these policy coefficients, ensuring our results incorporate policymakers' actual preferences while allowing differential response to sectoral inflation rates.

[20] We do not impose a zero lower bound on the nominal interest rate even though our model is estimated over the recent period when the federal funds rate was zero because the relevant interest rate in our model is more akin to long-term rates that have the most important effects on aggregate demand. Long-term interest rates remained above zero during and after the Great Recession. One also can view allowing a negative interest rate in our model as a simple way to capture alternative policy measures like quantitative easing.

[21] The SPF provides median inflation expected one, two, three, and four quarters ahead, along with an estimate for the next ten years. See Federal Reserve Bank of Philadelphia [2014] for details. The Philadelphia Fed also oversees the Livingston survey of forecasters, but that survey is conducted only every six months and provides forecasts for

inflation over the next 6 and 12 months. See Murphy [1986] for an analysis of the term structure of inflation forecasts using the Livingston expected inflation data.

[22] See Curtin [1996] for details about the Michigan expected inflation series.

[23] See Fuhrer [2012] and Mishkin [2007] who also use the SPF median to measure the public's inflation expectations at various horizons.

[24] This restriction ensures that wage inflation will approach its equilibrium value in the long run.

[25] Estimates of our model using a time-varying implicit inflation target from Leigh [2005] were similar to those we present below using a constant inflation target of 2 percent.

[26] The GMM estimation procedure allows for a generalized variance-covariance structure of regression error terms for these equations, which we use in our hypothesis tests. All data, except as noted, are from the U.S. Bureau of Labor Statistics.

[27] Gap measures using the short-term unemployment rate have been shown by Ball and Mazumder [2015] and Krueger et al [2014] to be a better indicator of economic slack in Phillips curve models than gap measures using the overall unemployment rate. In appendix Table A-1, we report results using the overall unemployment rate, which are very similar to those discussed here except that the coefficient on the gap term is smaller and not statistically significant at standard levels.

[28] Our instrument set uses lagged values of only two-quarter-ahead expected inflation, since the one-quarter-ahead and two-quarter-ahead series are highly correlated. Estimates when both series are included in the instrument set and when only the one-quarter-ahead series is included give results similar to those reported in the text.

[29] Estimates of the constant terms in equations (17) and (20) (not reported) were small in magnitude and generally not statistically significant.

[30] See Pedersen [2011] for analysis of the relative speed with which food and energy price shocks dissipate.

[31] The reported test statistic is distributed as χ^2 and is computed using the method described in Greene [2012], p. 528, for both linear and nonlinear hypotheses. We use this method when calculating test statistics for all hypothesis tests reported in our paper.

[32] Consistent with these results, we cannot reject the simple hypothesis that $\phi_2 + \vartheta_1 \geq 1$ (p-value = 0.35) but can reject the hypothesis that $\phi_2 + \vartheta_2 \geq 1$ (p-value = 0.00). Similar results also hold for the 1986 to 2014 sample period.

[33] Hooker [2002] finds that monetary policy has responded less forcefully to energy price shocks since around 1980 because expectations of inflation may have become less

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sensitive to such shocks. The underweighting of energy inflation in expectations formation is consistent with evidence discussed in Bernanke [2007] that inflation expectations have become better anchored with respect to energy price shocks in recent decades.

[34] Gali [2011] also obtains an insignificant coefficient on unemployment in wage Phillips curves and argues that the estimate is overly influenced by downward nominal wage rigidity during the period of prolonged high unemployment accompanying the Great Recession.

[35] See Bureau of Labor Statistics [2007], Ch. 17, pp. 34-38, for details on how to construct composite price indexes using relative expenditure shares and price indexes for sectors.

[36] In appendix Table A-2, we report estimates for the composite version of our model using the overall unemployment rate in the gap measure. These results are very similar to those reported in Table 2.

[37] See, for example, Mankiw and Reis [2002] and Carroll [2003] for models where information is updated only periodically.

References

Anderson, Richard G. 2007. How Well Do Wages Follow Productivity Growth? Federal Reserve Bank of St. Louis *Economic Synopses,* 2007(7).

Arora, Vipin, Pedro Gomis-Porqueras, and Shuping Shi. 2013. The Divergence Between Core and Headline Inflation: Implications for Consumers' Inflation Expectations. *Journal of Macroeconomics*, 38, Part B(December): 497-504.

Ball, Laurence M. 1994. Discussion, in *Goals, Guidelines, and Constraints Facing Monetary Policymakers*, edited by Jeffrey C. Fuhrer. Conference Series No. 38. Boston: Federal Reserve Bank of Boston, pp. 39-42.

____________. 1997. Efficient Rules for Monetary Policy. NBER Working Paper No. 5952, March, Cambridge: National Bureau of Economic Research.

Ball, Laurence M., and Sandeep Mazumder. 2011. Inflation Dynamics and the Great Recession. *Brookings Papers on Economic Activity*, 2011(Spring): 337–381.

____________. 2015. A Phillips Curve with Anchored Expectations and Short-Term Unemployment. IMF Working Paper WP/15/39, Washington: International Monetary Fund.

Bernanke, Ben S. 2007. Inflation Expectations and Inflation Forecasting. Speech at the Monetary Economics Workshop of the National Bureau of Economic Research Summer Institute, Cambridge, MA, July 10, 2007.

____________. 2008. Outstanding Issues in the Analysis of Inflation, in *Understanding Inflation and the Implications for Monetary Policy*, edited by Jeff Fuhrer, Yolanda K. Kodrzycki, Jane Sneddon Little, and Giovanni P. Olivei. Cambridge: MIT Press, pp. 447–456.

Bryant, Ralph C., Peter Hooper, and Catherine L. Mann. 1993. *Evaluating Policy Regimes: New Research in Empirical Macroeconomics*. Washington: Brookings Institution Press.

Bureau of Labor Statistics. 2007. *Handbook of Methods*, *Chapter 17: The Consumer Price Index*. Washington: U.S. Department of Labor.

Capistran, Carlos, and Allen Timmermann. 2009. Disagreement and Biases in Inflation Expectations. *Journal of Money, Credit and Banking*, 41(2-3)(March-April): 365-396.

Carroll, Christopher D. 2003. Macroeconomic Expectations of Households and Professional Forecasters. *Quarterly Journal of Economics*, 118(1)(February): 269-298.

Celasun, Oya, Roxana Mihet, and Lev Ratnovski. 2012. Commodity Prices and Inflation Expectations in the United States. IMF Working Paper WP/12/89, March, Washington: International Monetary Fund.

Croushore, Dean. 1993. Introducing: The Survey of Professional Forecasters. Federal Reserve Bank of Philadelphia *Business Review*, November/December, 3-15.

Congressional Budget Office. 2015. *The Budget and Economic Outlook: 2015 to 2025*. January. Washington, DC: Congressional Budget Office.

____________. 1990. *The Outlook for Farm and Commodity Program Spending: Fiscal Years 1990 to 1995*. April. Washington, DC: Congressional Budget Office.

Curtin, Richard T. 1996. Procedure to Estimate Price Expectations. Manuscript, Ann Arbor: University of Michigan Survey Research Center.

De Cecco, Marcello. 2009. Hicks's Notion and Use of the Concepts of Fix-Price and Flex-Price, in *Markets, Money and Capital: Hicksian Economics for the Twenty First Century*, edited by Roberto Scazzieri, Amartya Sen, and Stefano Zamagni. Cambridge: Cambridge University Press, pp. 157-163.

Ehrbeck, Tilman, and Robert Waldmann. 1996. Why are Professional Forecasters Biased? Agency Versus Behavioral Explanations. *Quarterly Journal of Economics*, 111(1)(February): 21-40.

Federal Open Market Committee. 2008. Minutes of the Meeting of June 24-25, 2008, Board of Governors of the Federal Reserve System, Washington, DC.

Federal Reserve Bank of Philadelphia. 2014. *Survey of Professional Forecasters Documentation*. February. Philadelphia, PA: Federal Reserve Bank of Philadelphia.

Feldstein, Martin. 2008. Did Wages Reflect Growth in Productivity? *Journal of Policy Modeling*, 30(4): 591–594.

Friedman, Milton. 1968. The Role of Monetary Policy. *American Economic Review*, 58(1)(March): 1–17.

Fuhrer, Jeffery C. 1995. The Phillips Curve is Alive and Well. *New England Economic Review*, 1995(March/April): 41-56.

____________. 2012. The Role of Expectations in Inflation Dynamics. *International Journal of Central Banking*, 8, Supplement 1(January): 137-165.

Fuhrer, Jeffery C., and George Moore. 1995. Inflation Persistence. *Quarterly Journal of Economics* 110(1)(February): 127-159.

Gali, Jordi. 2011. The Return of the Wage Phillips Curve. *Journal of the European Economic Association*, 9(3)(June): 436-461.

Georganas, Sotiris, Paul J. Healy, and Nan Li. 2014. Frequency Bias in Consumers′ Perceptions of Inflation: An Experimental Study. *European Economic Review*, 67(April): 144-158.

Gordon, Robert J. 1982. Inflation, Flexible Exchange Rates, and the Natural Rate of Unemployment, in *Workers, Jobs, and Inflation*, edited by Martin Baily. Washington: The Brookings Institution, 89–158.

____________. 1990. U.S. Inflation, Labor's Share, and the Natural Rate of Unemployment, in *Economics of Wage Determination*, edited by Heinz Koenig. Berlin: Springer-Verlag.

Greene, William H. 2012. *Econometric Analysis*, 7th edn. Upper Saddle River, NJ: Prentice Hall.

Hicks, John. 1974. *The Crisis in Keynesian Economics*. New York: Basic Books.

Hooker, Mark A. 2002. Are Oil Shocks Inflationary? *Journal of Money, Credit and Banking*, 34(2)(May): 540-561.

Jespersen, Jesper. 2009. *Macroeconomic Methodology: A Post-Keynesian Perspective*. Cheltenham, UK: Edward Elgar Publishing Limited.

Krueger, Alan B., Judd Cramer, and David Cho. 2014. Are the Long-Term Unemployed on the Margins of the Labor Market? *Brookings Papers on Economic Activity*, 2014(Spring): 229-280.

Leigh, Daniel. 2005. Estimating the Implicit Inflation Target: An Application to U.S. Monetary Policy. IMF Working Paper WP/05/77, Washington: International Monetary Fund.

Mankiw, N. Gregory. 2001. The Inexorable And Mysterious Tradeoff Between Inflation And Unemployment. *Economic Journal*, vol. 111(471)(April): 45-61.

Mankiw, N. Gregory, and Ricardo Reis. 2002. Sticky Information Versus Sticky Price: A Proposal to Replace the New Keynesian Phillips Curve. *Quarterly Journal of Economics*, 117(4)(November): 1295-1328.

Mankiw, N. Gregory, Ricardo Reis, and Justin Wolfers. 2004. Disagreement about Inflation Expectations. *NBER Macroeconomics Annual 2003*, 18: 209-248.

Mazumder, Sandeep. 2014. The Price-Marginal Cost Markup and its Determinants in U.S. Manufacturing. *Macroeconomic Dynamics*, 18(4)(June): 783-811.

Mishkin, Frederic S. 2007. Inflation Dynamics. NBER Working Paper No. 13147, June, Cambridge: National Bureau of Economic Research.

Mullineaux, Donald J. 1978. On Testing for Rationality: Another Look at the Livingston Price Expectations Data. *Journal of Political Economy*, 86(2)(April) Part 1: 329-336.

Murphy, Robert. 1986. The Expectations Theory of the Term Structure: Evidence from Inflation Forecasts. *Journal of Macroeconomics*, 8(4): 423-434.

____________. 2000. What's Behind the Decline in the NAIRU? in *The Economic Outlook For 2000*, edited by Saul Hymans, Ann Arbor: University of Michigan.

____________. 2014. Explaining Inflation in the Aftermath of the Great Recession. *Journal of Macroeconomics*, 40(June): 228-244.

Nelson, Edward. 1998. Sluggish Inflation and Optimizing Models of the Business Cycle. *Journal of Monetary Economics*, 42(2): 303-322.

Noble, Nicholas R., and T. Windsor Fields. 1982. Testing the Rationality of Inflation Expectations Derived from Survey Data: A Structure-Based Approach. *Southern Economic Journal*, 49: 361-373.

Okun, Arthur M. 1981. *Prices and Quantities: A Macroeconomic Analysis*. Washington, DC: The Brookings Institution.

Pedersen, Michael. 2011. Propagation of Shocks to Food and Energy Prices: An International Comparison. *Seminarios de Macroeconomía y Finanzas del Banco Central año 2011*, Central Bank of Chile.

Roberts, John M. 2006. Monetary Policy and Inflation Dynamics. *International Journal of Central Banking*, 2(3): 193-230.

Romer, David. 2012. *Advanced Macroeconomics,* 4th edn. New York: McGraw-Hill Irvin.

Sherk, James. 2013. Productivity and Compensation: Growing Together. Heritage Foundation Center for Data Analysis *Backgrounder.* No. 2825, July.

Sinclair, Peter, ed. 2010. *Inflation Expectations*. Routledge International Studies in Money and Banking. New York: Routledge.

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

Trehan, Bharat. 2011. Household Inflation Expectations and the Price of Oil: It's Déjà Vu All Over Again. *FRBSF Economic Letter*, 2011-16. San Francisco: Federal Reserve Bank of San Francisco.

Van Duyne, Carl. 1982. Food Prices, Expectations, and Inflation. *American Journal of Agricultural Economics*, 64(3)(August): 419-430.

Verbrugge, Randal, and Amy Higgins. 2015. Do Energy Prices Drive the Long-Term Inflation Expectations of Households? *Economic Trends*, 03-24-2015. Cleveland: Federal Reserve Bank of Cleveland.

Whelan, Karl. 1997. Wage Curve vs. Phillips Curve: Are There Macroeconomic Implications? Finance and Economics Discussion Series, 1997-51. Washington, DC: Board of Governors of the Federal Reserve System.

Wong, Benjamin. 2014. Inflation Expectations and How it Explains the Inflationary Impact of Oil Price Shocks: Evidence from the Michigan Survey. Centre for Applied

Macroeconomic Analysis Working Paper 45/2014, June. Canberra: Crawford School of Public Policy, The Australian National University.

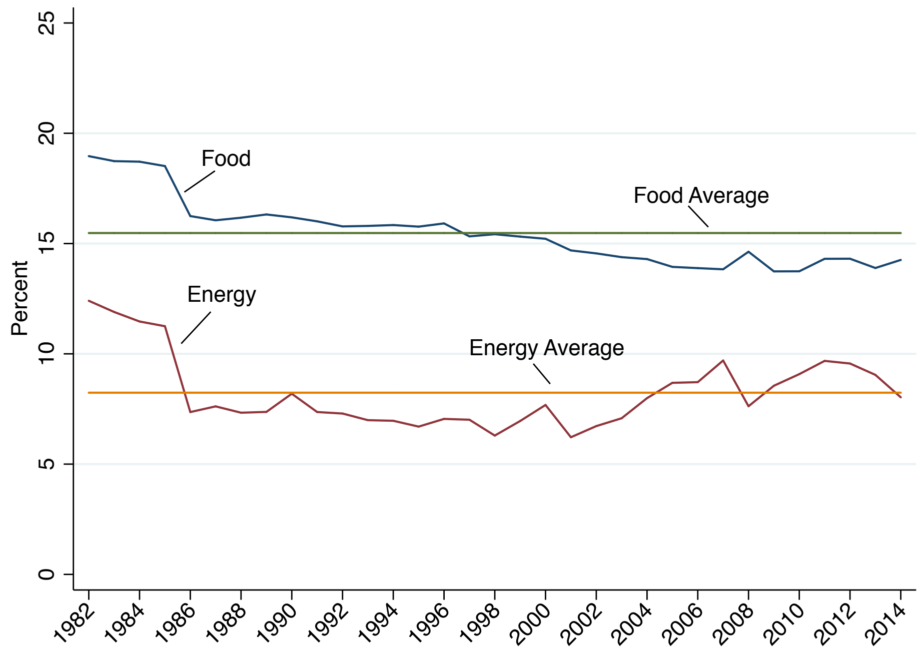

Figure 1. Relative Importance of Food and Energy in the CPI, 1982 to 2014

Source: Bureau of Labor Statistics and authors' calculations. Data are for the Consumer Price Index for All Urban Consumers (CPI-U) and represent the relative importance in percent of food and energy products in the overall price index.

Table 1 Estimation Results for Food and Energy Model[a]

Sample Period	1982:1-2014:4	1986:1-2014:4
γ_1	0.779** (0.080)	0.795** (0.085)
γ_2	0. 068** (0.011)	0.064** (0.012)
γ_3	0.012** (0.002)	0.013** (0.002)
γ_4	0.168* (0.075)	0.169* (0.077)
ϕ_1	0.125* (0.063)	0.107 (0.065)
ϕ_2	0.201** (0.044)	0.167** (0.038)
ϑ_1	0.700** (0.095)	0. 852** (0.109)
ϑ_2	0. 310** (0.071)	0.364** (0.069)
Number of Observations	130	116
J-Statistic: $\chi^2(58)$ p-value	68.97 (0.15)	70.00 (0.13)
Rationality: $\chi^2(2)^b$ p-value	1.80 (0.41)	1.30 (0.52)
Relative Weights: $\chi^2(2)^c$ p-value	39.96 (0.00)	15.68 (0.00)
Relative Weights	Estimated Actual	Estimated Actual
Food	0.275 0.155	0.261 0.150
Energy	0.047 0.082	0.053 0.078

Notes:

a. Coefficient estimates are for equations (17), (20), and (21) using GMM. Robust standard errors are in parentheses under these estimates with * and ** indicating coefficient is statistically different from zero at five-percent and one-percent levels, respectively.

b. Test of null hypothesis that estimated relative weights satisfy restrictions given by equation (22).

c. Test of null hypothesis that estimated relative weights equal actual relative weights.

Table 2 Estimation Results for Food-Energy Composite Model[a]

Sample Period	1982:1-2014:4	1986:1-2014:4
γ_1	0.639** (0.102)	0.672** (0.110)
γ_2	0.035** (0.007)	0.048** (0.006)
γ_3	0.309** (0.093)	0.298** (0.095)
ϕ_1	0.211** (0.069)	0.215** (0.079)
ϕ_2	0.180** (0.048)	0.181** (0.052)
ϑ_1	0.328** (0.084)	0.338** (0.090)
Number of Observations	130	116
J-Statistic: $\chi^2(43)$ p-value	55.19 (0.10)	46.86 (0.32)
Rationality: $\chi^2(1)$[b] p-value	0.03 (0.87)	1.03 (0.31)
Relative Weights: $\chi^2(1)$[c] p-value	13.49 (0.00)	5.61 (0.02)
Relative Weights Food-Energy	Estimated Actual 0.103 0.237	Estimated Actual 0.139 0.228

Notes:

a. Coefficient estimates are for equations (17a), (20a), and (21a) using GMM. Robust standard errors are in parentheses under these estimates with ** indicating coefficient is statistically different from zero at one-percent level.

b. Test of null hypothesis that estimated relative weights satisfy restrictions given by equation (22a).

c. Test of null hypothesis that estimated relative weights equal actual relative weights.

Table A-1 Estimation Results for Food and Energy Model
Using Overall Unemployment Rate for Gap Variable[a]

Sample Period	1982:1-2014:4	1986:1-2014:4
γ_1	0.832** (0.064)	0.810** (0.078)
γ_2	0. 063** (0.010)	0.059** (0.011)
γ_3	0.010** (0.002)	0.009** (0.002)
γ_4	0.115 (0.063)	0.142* (0.068)
ϕ_1	0.031 (0.028)	0.037 (0.026)
ϕ_2	0.176** (0.042)	0.163** (0.037)
ϑ_1	0.757** (0.089)	0. 876** (0.117)
ϑ_2	0. 352** (0.064)	0.399** (0.072)
Number of Observations	130	116
J-Statistic: $\chi^2(58)$ p-value	76.10 (0.06)	70.38 (0.13)
Rationality: $\chi^2(2)$[b] p-value	1.84 (0.40)	1.10 (0.58)
Relative Weights: $\chi^2(2)$[c] p-value	37.58 (0.00)	22.61 (0.00)
Relative Weights Food Energy	Estimated Actual 0.335 0.155 0.052 0.082	Estimated Actual 0.281 0.150 0.045 0.078

Notes:

a. Coefficient estimates are for equations (17), (20), and (21) using GMM. Robust standard errors are in parentheses under these estimates with * and ** indicating coefficient is statistically different from zero at five-percent and one-percent levels, respectively.

b. Test of null hypothesis that estimated relative weights satisfy restrictions given by equation (22).

c. Test of null hypothesis that estimated relative weights equal actual relative weights.

Table A-2 Estimation Results for Food-Energy Composite Model Using Overall Unemployment Rate for Gap Variable[a]

Sample Period	1982:1-2014:4	1986:1-2014:4
γ_1	0.588** (0.109)	0.670** (0.109)
γ_2	0.037** (0.008)	0.045** (0.006)
γ_3	0.333** (0.095)	0.288** (0.093)
ϕ_1	0.072* (0.034)	0.084** (0.031)
ϕ_2	0.142** (0.046)	0.171** (0.051)
ϑ_1	0.332** (0.081)	0.334** (0.081)
Number of Observations	130	116
J-Statistic: $\chi^2(43)$ p-value	58.83 (0.05)	52.44 (0.15)
Rationality: $\chi^2(1)^b$ p-value	0.01 (0.93)	0.79 (0.37)
Relative Weights: $\chi^2(1)^c$ p-value	13.39 (0.00)	5.49 (0.02)
Relative Weights Food-Energy	Estimated 0.100 Actual 0.237	Estimated 0.136 Actual 0.228

Notes:

a. Coefficient estimates are for equations (17a), (20a), and (21a) using GMM. Robust standard errors are in parentheses under these estimates with * and ** indicating coefficient is statistically different from zero at five-percent and one-percent levels, respectively.

b. Test of null hypothesis that estimated relative weights satisfy restrictions given by equation (22a).

c. Test of null hypothesis that estimated relative weights equal actual relative weights.