Rational Bias In Inflation Expectations

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RATIONAL BIAS IN INFLATION EXPECTATIONS

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Abstract. We empirically examine the Biased Expectations Hypothesis, which states that recent price movements in certain sectors play special roles in the formation of individuals inflation expectations. Specifically we analyze whether economists rationally bias their expectations and whether economists and consumers naively bias their expectations with respect to recent inflation in the food and energy sectors. We develop theoretical models for both rationally formed and naively formed inflation expectations. We find that economists do not bias their rationally formed expectations and that consumers and economists do not naively form inflation expectations. Our results do not support the Biased Expectations Hypothesis; rather, they reinforce the use of core measures of inflation in policy making.

1. Introduction

Inflation expectations are used by households and firms in decisions concerning saving, spending, investing, and long-term labor and financial contracts. Through these various decisions inflation expectations help determine actual inflation by affecting aggregate demand and price-setting behavior in labor and financial markets. Accordingly, a central banks ability to achieve price stability depends on the proper understanding of such expectations and their implications. Central banks track survey measures of inflation expectations for comparison with internal forecasts of inflation and with long run inflation targets. As such, understanding the ways in which inflation expectations are formed is crucial in the implementation of monetary policy.

Factors influencing the formation of inflation expectations include, among other things, the way in which monetary authorities conduct policy, how well that policy is

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communicated to the public, and the recent history of price movements. A common view among some policymakers concerning how inflation expectations are formed is that households place extra emphasis on recent price movements in certain highly visible sectors. The view is called the Biased Expectation Hypothesis (BEH). This hypothesis states that recent movements in certain sectoral prices play a special role in the formation of consumers inflation expectations. Put another way with respect to the food sector,

> "the BEH says that economic agents, when forming expectations about future inflation, place relatively more weight on recent behavior of food prices than expenditure shares indicate." [1]

Analyzing whether observed inflation expectations are determined in this way is an important issue for monetary policymakers.

There are at least two ways of understanding this over emphasis of inflation in certain sectors. The first is a simplistic view of the BEH. Consider the frequency with which individuals purchase different goods. The goods that an individual purchases more often might weigh more heavily in the individuals assessment of the movement of overall prices recently, as the individual readily recognizes changes in the prices of these goods. Therefore, price movements in the sectors producing these goods might disproportionately influence the formation of the individuals expectations for overall inflation. Food and energy are natural choices for sectors that fit this description of highly visible goods prices. [2]

The second, more sophisticated, interpretation of the BEH has its roots in Van Duynes 1982 paper: Food Prices, Expectations, and Inflation. He shows how a disproportionate influence of price movements in certain sectors can be consistent with rationality. Specifically, he develops a simple macroeconomic model in which it is rational to place weights on sectoral inflation rates that differ from the sectors shares in

[1] Van Duyne, 1982, p. 419

[2] Another determinant of the differing frequency with which an individual assesses prices of different goods could be differences in information costs related to learning about prices in different sectors. However, given that the Consumer Price Index (CPI) and its components are readily available to the public, cost differentials for price information across sectors seems unlikely to be very large.

consumer expenditure. The notion of rational expectations used is that from John Muths 1961 paper, Rational Expectations and the Theory of Price Movements, which posits that price expectations are essentially the same as the predictions of relevant economic theory. Rational bias, in the context of Van Duynes model and the rest of this paper, is defined as the use of weights for sectoral inflation other than those reflecting consumer expenditure shares, when forming inflation expectations rationally; this notion will also be referred to as rational weighting.

Van Duyne develops a two-sector model of the economy in which the processes for determination of food supply shocks are serially correlated. Serial correlation means past shocks help to predict future shocks. Stated differently, serial correlation, resulting from distributed lags in the adjustments of food prices to changes in raw commodity prices, allows for individuals to gain understanding of the future of food price shocks.Therefore, in forming expectations, it is rational for such individuals to place more weight on the movement of prices in the food sector, as past movements of prices in this sector predict actual current inflation, while price movements in other sectors are not predictive in this way. Given that the model holds overall inflation equal to inflation in the manufacturing sector plus temporary disturbances to the rate of inflation in the food sector, serial correlation of food price shocks emphasizes the role that changes in inflation in this sector plays in what can be expected for headline inflation. Thus, it is rational for economic agents to put more weight on past inflation in the food sector when forming expectations about current headline inflation. Van Duynes theoretical model produces an equation for inflation expectations with weights for sectoral inflation different from the sectors respective shares in consumer expenditure. Since sectoral shares in consumer expenditure are the weights used to calculate the CPI, the weights in the model would be biased away from those that are used in calculating actual inflation.

Using the conclusions of this theoretical framework, Van Duyne employs regression analysis to evaluate the BEH for food price movements during the period from 1966 through 1977. Here, he addresses whether consumers actually bias their inflation expectations. He looks specifically at expectations for inflation from the University of Michigans survey of consumer expectations. His empirical findings indicate that consumers do not bias their expectations for inflation in the basket of goods used to calculate the CPI away from the expenditure shares of the sectors. Van Duyne was unable to reject the hypothesis that consumers use weights for food price movements that are the same as food sectors share in expenditure.

Other authors have studied the relationship between inflation, expectations, and the movement of prices in particular sectors or of certain commodities. In a recent working paper, Celasun, Mihet, and Ratnovski (2012), look at the effects of commodity price movements, specifically oil prices, on both market-based and survey-based measures of inflation expectations. The market-based measure is implied by the difference between regular Treasury note and bond yields and Treasury Inflation- Protected Security (TIPS) yields. The survey-based measure was, again, the University of Michigans survey of consumer inflation expectations. The authors found that oil and food price movements had statistically significant impact on short-term TIPS-based inflation expectations; they also found that oil prices had an economically significant impact. The conclusion that sectoral price movements do drive inflation expectations is an important start toward understanding how inflation expectations are determined and their role in the determination of actual inflation; however, the paper does not consider whether the weights placed on such price movements are different from their respective expenditure shares. This additional subtlety is vital for monetary authorities to make responsible policy decisions when interpreting price movements and the importance they give to price movements across different sectors. Specifically, the fact that policy makers now tend to focus on core inflation measures over headline measures could be a mistake, if the highly variable movements in food and energy prices play emphasized roles in the determination of inflation expectations that then help determine future actual inflation.

2. Research Questions and Analytical Approach

The analysis we conduct in this paper is twofold. We look at the more sophisticated manifestation of the BEH that uses the serial correlation of price shocks within a generalization of Van Duyne′s algebraic framework, and we investigate directly whether the weights, used by consumers, to determine inflation expectations differ from the sectoral shares in consumer expenditure, over the period from 1983 to 2012.

As data about consumer expectations for inflation that satisfies the needs of our theoretical framework, which we develop in the following sections, (i.e. inflation expectations data for two periods in the future) is unavailable from the University of Michigan survey of consumers, we substitute for the data collected by the Philadelphia Federal Reserve Bank about the multi period inflation expectations of professional economists. We recognize that it is likely that the expectations of professional economists are more Muth rational than those of consumers, as understanding economic theory is their profession. However, it is reasonable to think that consumers are not ignorant of basic economic thinking and that their expectations for inflation would not be drastically different than those of the economists, when presented with price movements. In particular, the vital assumption of serial correlation of price shocks to the food and energy sectors, in the theory to be developed, is fairly intuitive and could be reasonably assumed to factor into consumers′ formation of inflation expectations.

First we determine if rationally formed inflation expectations of economists are biased (taking into account serial correlation of food and energy price shocks). Second we determine if typical consumers bias their expectations in a simplistic way, that is they naively use the sectoral shares in consumer expenditure to weight price movements in the food and energy sectors when forming inflation expectations.

To specify our empirical analysis:

[1] We address whether the expectations formed by economists for inflation in the food and energy sectors are biased during the period of 1980 through 2012 in accord with the BEH. Specifically, we examine whether the professional economists surveyed by the

Philadelphia Federal Reserve Bank bias the relative weights they assign to the food and energy sectors in their expectations for movements in the CPI away from the sectors' respective shares in consumer expenditure. This analysis is done within a context of rationally formed inflation expectations.

[2] Further, we address whether the expectations for inflation in the food and energy sectors formed by typical consumers are biased during the period of 1980 through 2012. Specifically, we examine whether the consumers surveyed by the University of Michigan bias the relative weights they assign to the food and energy sectors in their expectations for movements in the CPI away from the sectors' respective shares in consumer expenditure. We do this analysis to see if individuals naively use consumer expenditure shares to form inflation expectations.

In order to address the first relationship, we developed modified versions of Van Duyne's theoretical and empirical models, which allow for analysis of the BEH with respect to food and energy price fluctuations for the period from 1980 through 2012.

For the analysis of naive weighting in individuals′ inflation expectations, there is little theoretical or algebraic development necessary. A simple algebraic relationship is arrived at intuitively and an analogous equation is estimated empirically.

For the analysis rational weighting portion of the analysis, we augment the theoretical model Van Duyne develops in *Food Prices, Expectations, and Inflation* so that simultaneous analysis of expectations for price movements in both the food and the energy sector is possible. We create a three sector update to Van Duyne's two sector simple stochastic model of the inflation process, which allows for analysis of the links between food price shocks, expectations, and the overall rate of inflation. Finally, we alter the demand equation and monetary policy rule described in Van Duyne's model. His monetary policy rule, which focuses on how the monetary authority of the modeled economy sets the rate of growth of the nominal money supply, does not capture how contemporary monetary policy is conducted. While, during the late 1960s and the 1970s, it was the practice of many monetary authorities to use the growth rate of the money supply directly as a primary tool of monetary policy, over the past three decades it has been common practice for interest rates to be the main tools of monetary policy. As such, we designed a monetary policy rule that reflects this. Consequently, the demand equation we use is also changed to close our model containing interest rates.

With this new theoretical framework as a basis, we conduct empirical analysis. We estimate equations for inflation expectations one quarter in the future, reflecting their theoretical analogues, using regression analysis. The regressions, as stated above, analyze the period from the 1980s through the most recent recession. We then use the coefficients we estimate through the regressions to test for bias of sectoral inflation in forming expectations for overall inflation in both the rational weighting context and the naive weighting context.

3. Rational Weighting Theoretical Model

3.1. **Overview.** The augmented Van Duyne theoretical model contains three goods: a fixed-price good, called the manufactured good, and two flex-price goods, called the food and the energy goods. We emphasize the structure of the fixed-price sector, while we ignore some significant aspects of flex-price sectors.[3] However, we retain the vital aspect of fixprice-flexprice models: there are quick price adjustments in flex-price markets and sluggish price adjustments in the fixed-price markets. Thus, prices across the differing sectors are determined in fundamentally different ways. Specifically, food and energy prices are subject to serially correlated supply shocks whereas manufacturing price movements are only dependent on wage inflation. It is this difference in how prices are determined that allows for the conclusion that placing disproportionate relative weight on recent food and energy price behavior may be Muth rational. Our overall theoretical approach will follow Van Duyne's approach.

3.2. **Elements from Van Duyne Model.** We assume the price of the manufactured good reflects constant markup on production costs. We use cost of labor as a proxy.

[3]Explicitly, we do not address the role of commodity stocks in the determination of prices in the flex-price markets, as Van Duyne does in his model.

Thus,

$$[1] P_t^m = w_t,$$

where P_t^m is the rate of change in the price of the manufactured good and w_t is the economy wide rate of wage inflation. Here, prices in the manufacturing sector change at the same rate as nominal wages.[4]

Now the model must address how wage inflation. With wage agreements renegotiated frequently, nominal wages rise at rate of expected inflation, adjusted for aggregate demand:

$$[2] w_t^* = -a_0 U_t + E_{t-1} P_t$$

where w_t^* is the rate of wage inflation during period t in the absence of multi-period contracts, U_t is the deviation of the actual unemployment rate from the natural rate of unemployment, which is a measure of demand pressure in labor markets, and $E_{t-1}P_t$ is the expected rate of inflation in period $t-1$ for period t; a_0 and all parameters of the model are positive. Given multi-period wage contracts, actual wage inflation adjusts to w_t^* slowly. Therefore,

$$[3] w_t - w_{t-1} = a_2(w_t^* - w_{t-1})$$

where $0 < a_2 < 1$ is a parameter summarizing the degree of inertia in the wage formation process. Here a smaller value for the parameter a_2 implies more sluggish adjustments of wage inflation to changes in expectations or changes in demand. If we combine the equations [2] and [3], we get

$$[4] w_t = -a_1 U_t + a_2 E_{t-1} P_t + [1 - a_2] w_{t-1}, a_1 = a_0 a_2.$$

Since, in reality, wage contracts span several periods, $E_{t-1}P_t$ should be interpreted as expectations of inflation several periods into the future. These equations, taken directly from Van Duyne's theoretical model, summarize the way in which wage inflation is

[4] In order to keep the model manageable, we ignore adjustment lags and other costs of production. Such costs include those for capital and raw materials. Further, we assume productivity growth is zero in this model, paralleling Van Duyne's paper.

determined within the model. Hence, the rate of inflation in the manufacturing sector is also determined.

3.3. **Alterations to Van Duyne Model.** Let us first address how we determine headline inflation in the model with three sectors. We can write overall rate of inflation in the economy as a weighted average of the inflation observed in the three sectors of the economy:

$$[6] P_t = AP_t^x + BP_t^f + (1 - A - B)P_t^m$$

where $0 < A, B < 1$, $A + B \neq 1$. P_t is the overall rate of inflation in the economy. A, B, and $(1-A-B)$ are fixed weights reflecting the shares of energy, food, and manufacturing in consumer expenditures. P_t^x is the rate of inflation in the energy sector and P_t^f is the rate of inflation in the food sector. This method of modeling headline inflation is similar to the way in which the CPI is calculated. Note, as shown below, we assume that shocks to inflation in the food and energy sectors affect inflation in wages only through expectations.

Now, consider the two flex-price sectors of the model economy. Here augmentations to Van Duyne's model must be made to adapt it to generalize to three sectors instead of two. In a stationary economy, barring unequal long term rates of technological progress across sectors, rates of inflation should be equal in the different sectors in the long term. However, as this paper focuses on the short run, inflation in the energy and food sectors can deviate from inflation in the manufacturing sector due to exogenous supply shocks. Thus,

$$[7.1] P_t^x = P_t^m + \gamma_t, [7.2] P_t^f = P_t^m + \epsilon_t$$

where γ_t represents a temporary disturbance in the rate of change of energy prices and ϵ_t represents a temporary disturbances in the rate of change of food prices. These supply shocks may be serially correlated giving

$$[8.1] \gamma_t = \sigma\gamma_{t-1} + \nu_t, [8.2] \epsilon_t = \delta\epsilon_{t-1} + \tau_t$$

where $|\sigma|, |\delta| < 1$, ν_t is a white noise process for the energy sector, and τ_t is a white noise process for the food sector. Such shocks could be serially correlated if prices adjust with distributed lags to changes in raw commodity prices. Serial correlation allows for past shocks to help predict current price movements. Since past movements of prices in these sectors predict current inflation, it is rational for economic agents to place more weight on the movement of prices in the food sector when forming expectations about inflation.

Combining [6], [7.1], and [7.2] produces

$$[9] P_t = P_t^m + A\gamma_t + B\epsilon_t.$$

This states that, apart for temporary disturbances in the prices of food and energy, the current rate of overall inflation is determined by manufacturing price trends. Serial correlation of food and energy price shocks emphasize the role that price movements in these sectors play in what can be expected for headline inflation. Through equations [8.1],[8.2], and [9], we see the unexpected conclusion that rational economic agents will put more weight on past inflation in the food and energy sectors, when forming expectations about current headline inflation.

3.4. **Closing the Model.** Two equations describing the demand side of the economy are still required. The first summarizes demand and states that the gap between observed unemployment and the natural rate of unemployment is a function of the nominal interest rate minus expectations for inflation one period in the future minus the natural rate of interest. Hence,

$$[10] U_t = a_3[i_t - E_t P_{t+1} - \rho]$$

where $a_3 > 0$, i_t is the nominal interest rate, and ρ is the natural rate of interest, which is similar to the world interest rate.Observe that

$$r_t = i_t - E_t P_{t+1},$$

where r_t is the real interest rate, is the Fisher Equation. Therefore, this demand equation essentially states that the unemployment gap is a function of the real interest rate gap. The second equation is a monetary policy rule modeled as a version of a Taylor Rule:

$$[11] i_t = P_t + \rho + \theta_1[P_t - P^*] - \theta_2 U_t,$$

where P^* is the monetary authority's target for inflation, θ_1 measures the degree to which the monetary authority accommodates inflationary shocks, and θ_2 measures the degree to which the monetary authority accommodates demand shocks. This equation states that the nominal interest rate is a function of the overall rate of inflation, the natural rate of interest, the deviation of inflation from the monetary authority's target for inflation, and the unemployment gap. This monetary policy rule reflects the way most contemporary monetary authorities conduct monetary policy, namely through interest rates. Both of these equations are adapted versions of equations from N. Gregory Mankiw's text *Macroeconomics*. Our augmented version of Van Duyne's theoretical model, generalized to a three sector economy, is now complete.

3.5. **Algebraic Progression and Results of Model.** We need an equation for inflation expectations in period t for period $t+1$ is needed to see how expectations in period t can be biased by the weights assigned to sectoral inflation. This section will illustrate

> "the paradoxical result that rational expectations in this model are biased, not in the statistical sense, but in the sense that the optimum weights used to combine sectoral inflation rates are not proportional to expenditure shares." (Van Duyne 423)

This relation can be found through the algebraic interactions of the equations of the theoretical model. Again, economic actors are Muth rational when they know the structure of the economy described in the model, know all endogenous variables realized in period t, waste none of this information, and assume all other actors do the same.

Substituting [11] into [10] yields

$$[12] U_t = \frac{a_3 + a_3\theta_1}{1 + a_3\theta_2} P_t - \frac{a_3\theta_1}{1 + a_3\theta_2} P^* - \frac{a_3}{1 + a_3\theta_2} E_t P_{t+1},$$

an equation for the unemployment gap including inflation, target inflation, and inflation expectations.

Combining [4], [9], and [12] gives

$$[13] P_t = \frac{a_1 a_3\theta_1}{Z} P^* + \frac{a_1 a_3}{Z} E_t P_{t+1} + \frac{(1 - a_2)(1 + a_3\theta_2)}{Z} w_{t-1} + \frac{A(1 + a_3\theta_2)}{Z} \gamma_t + \frac{B(1 + a_3\theta_2)}{Z} \epsilon_t,$$

where $Z = (1 - a_2)(1 + a_3\theta_2) + [a_1 a_3(1 + \theta_1)]$. Here, inflation is a function of target inflation, expectations, wage inflation, and temporary disturbances in inflation in the food and energy sectors.

Taking expectations in period t for period $t + 1$ of equation [13] produces

$$[14] E_t P_{t+1} =$$

$$\frac{a_1 a_3\theta_1}{Z} P^* + \frac{a_1 a_3}{Z} E_t P_{t+2} + \frac{(1 - a_2)(1 + a_3\theta_2)}{Z} w_t + \frac{A(1 + a_3\theta_2)}{Z} E_t \gamma_{t+1} + \frac{B(1 + a_3\theta_2)}{Z} E_t \epsilon_{t+1},$$

an equation for inflation expectations. However, this is not the equation that is needed, as it does not yet show expectations as a function of past sectoral inflation rates.

Given the mathematical results

$$[a] w_t = P_t^m, [b] E_t \gamma_{t+1} = \sigma\gamma_t = \sigma[P_t^x - P_t^m],$$

and

$$[c] E_t \epsilon_{t+1} = \delta\epsilon_t = \delta[P_t^f - P_t^m],$$

we see that

$$[15] E_t P_{t+1} = \frac{a_1 a_3\theta_1}{Z} P^* + \frac{a_1 a_3}{Z} E_t P_{t+2} +$$

$$\frac{\sigma A(1 + a_3\theta_2)}{Z} P_t^x + \frac{\delta B(1 + a_3\theta_2)}{Z} P_t^f + \frac{(1 - a_2 - \sigma A - \delta B)(1 + a_3\theta_2)}{Z} P_t^m.$$

Rational expectations for inflation one period in the future are a function of a weighted sum of sectoral inflation rates with weights that, generally, differ from sectoral expenditure shares. These weights do not sum to one. The serial correlation of the shocks to the food and energy sectors allow for expectations of inflation to be expressed as such a function of past sectoral inflation rates. We now see the intuition for weights on sectoral inflation unequal to expenditure shares borne out algebraically. Expectations one period in the future are also a function of expectations two periods in the future and the monetary authority's target for inflation.

To make this equation clearer, let

$$\alpha^* = \frac{\sigma A}{1-a_2}, \beta^* = \frac{\delta B}{1-a_2}, \zeta = \frac{(1-a_2)(1-a_3\theta_2)}{Z}.$$

In combination with [15] these give

$$[16] E_t P_t = \frac{a_1 a_3 \theta_1}{Z} P^* + \frac{a_1 a_3}{Z} E_t P_{t+2} + \zeta[\alpha^* P_t^x + \beta^* P_t^f + (1-\alpha^*-\beta^*) P_t^m].$$

The weights assigned to sectoral inflation in the relation describing inflation expectations are now more easily interpreted.

If it were to be assumed that expectations simply reflect past inflation, calculated using expenditure shares, then

$$[5] E_t P_{t+1} = P_t$$

and

$$[6] P_t = A P_t^x + B P_t^f + (1-A-B) P_t^m.$$

[5] and [6] show that

$$[6.1] E_t P_{t+1} = A P_t^x + B P_t^f + (1-A-B) P_t^m.$$

Although [5] is not used in the model, this very simplistic assumption allows comparison between the sectoral weights used in the calculation of inflation expectations arrived at through our model and those that are based simply on expenditure share. The relative weights assigned to inflation in the three sectors, found within our model, are not typically equal to the sectors share in expenditure. To see this compare

$$AP_t^x + BP_t^f + (1 - A - B)P_t^m$$

from [6.1] and

$$\alpha^* P_t^x + \beta^* P_t^f + (1 - \alpha^* - \beta^*)P_t^m,$$

from [16] where

$$\alpha^* = \frac{\sigma A}{1 - a_2}, \beta^* = \frac{\delta B}{1 - a_2}.$$

The weights α^* and β^* are the relative weights that economic agents ought to place on the sectoral rates of inflation in the food and energy sectors in order to form optimum and rational expectations of future inflation. ζ can be thought of as the actual inflation elasticity of expectations, which is less than one "because agents do not expect a fully accommodating monetary policy."[5] The direction and magnitude of the bias in weights is dependent on the values of the parameters of the model.[6]

In conclusion, the relative weights placed on the recent behavior of food and energy prices, in general, are not equal to the expenditure shares for the energy and food sectors. More specifically, if energy (food) prices and manufacturing prices are determined in fundamentally different ways, and if these sectoral inflation rates differ, then

> "rational agents should form their expectations by combining sectoral inflation rates using relative weights that generally differ from expenditure shares."[7]

[5]Van Duyne, 1982, p. 423

[6]The special case in which $\alpha^* = A$ or $\beta^* = B$ occurs when $\sigma + a_2 = 1$ or $\delta + a_2 = 1$. Recall that a_2 represents the degree of inertia in the wage formation process and that $0 < a_2 < 1$. A smaller value for the parameter a_2 implies more sluggish adjustments of wage inflation to changes in expectations or changes in demand. σ and δ represent the degree to which price movements in the energy and food sectors are serially correlated, respectively. Higher values of σ and δ indicate that future temporary disturbances in the energy and food sectors are determined more by pervious temporary disturbances in the energy and food sectors. This case is not generally the case, and the case where $\alpha^* = A$ and $\beta^* = B$ requires $\sigma = \delta$.

[7]Van Duyne, 1982, p. 424

Thus, it has been illustrated that, in contrast to the simplistic frequency of interaction view of the BEH, it is Muth rational for expectations of inflation to be biased away from the sectoral shares in expenditure, used to calculate actual inflation. The issue of actual bias realized in inflation expectations will next be assessed.

4. Rational Weighting Empirical Analysis

4.1. **Overview.** This section addresses the question of whether, when forming expectations of inflation, individuals, in practice, bias the weights they rationally arrive at for inflation in the food and energy sectors away from the sectors respective shares in consumer expenditure. This section outlines the empirical analysis we have done along with the econometric obstacles we encountered. Analysis here specifically addresses whether the professional economists surveyed by the Philadelphia Federal Reserve Bank bias the relative weights assigned to sectoral inflation, for the food and energy sectors, in the formation of their expectations for movements in the CPI.

Our empirical analysis includes estimation of actual weights placed on sectoral inflation through regression analysis and testing for bias in these weights, above or below those weights reflecting expenditure share.

4.2. **Regression Analysis.** Given the algebraic result of the theoretical model for inflation expectations one period in the future,

$$[15] E_tP_{t+1} = \frac{a_1a_3\theta_1}{Z}P^* + \frac{a_1a_3}{Z}E_tP_{t+2} +$$

$$\frac{\sigma A(1+a_3\theta_2)}{Z}P_t^x + \frac{\delta B(1+a_3\theta_2)}{Z}P_t^f + \frac{(1-a_2-\sigma A-\delta B)(1+a_3\theta_2)}{Z}P_t^m,$$

we estimate analogous equations to see if expectations are in fact rationally weighted. Hence, we estimate equations of the form

$$[17] E_tP_{t+1} = \alpha_0 + \alpha_1P^* + \alpha_2E_tP_{t+2} + \alpha_3PX_t + \alpha_4PF_t + \alpha_5PO_t + u_t.$$

In [17], E_tP_{t+1} represents expectations of inflation in period t for period $t+1$, P^* represents the monetary authority's long term target for inflation (assumed to be 2%), E_tP_{t+2} represents expectations of inflation in period t for period $t+2$, PX_t represents inflation in the energy sector, PF_t represents inflation in the food sector, PO_t represents core inflation, and u_t is an error term. Here we use core inflation (headline inflation less inflation in the food and energy sectors) in place of inflation in the manufacturing sector because in the theoretical model sectoral inflation in the manufacturing sector should be interpreted as inflation in the economy outside that in the food and energy sectors. Both inflation in the manufacturing sector in the theoretical model and core inflation in the empirical model are rates of inflation for all consumer expenditures other than food and energy. Also, the target for inflation reflects the implicit target for inflation used by the Federal Reserve System, 2%. All other variables we use in the estimation of equations of form similar to [17] should be interpreted in the same manner as above.

4.3. **Relating Theory and Empirics.** To see the relationship between the theoretical model and the empirical model, which allows for testing for bias in the weights assigned to sectoral inflation rates, recall the following equations:

$$[17] E_tP_{t+1} = \alpha_0 + \alpha_1 P^* + \alpha_2 E_tP_{t+2} + \alpha_3 PX_t + \alpha_4 PF_t + \alpha_5 PO_t + u_t,$$

$$[16] E_tP_{t+1} = \frac{a_1 a_3 \theta_1}{Z} P^* + \frac{a_1 a_3}{Z} E_tP_{t+2} + \zeta[\alpha^* P_t^x + \beta^* P_t^f + (1-\alpha^*-\beta^*)P_t^m].$$

[17] is the general equation to be estimated empirically and [16] is the final algebraic result of the theoretical model that allows for easy interpretation of sectoral weights. Comparison of these equations shows that

$$\alpha_3 \equiv \zeta\alpha^*, \alpha_4 \equiv \zeta\beta^*, \alpha_5 \equiv \zeta(1-\alpha^*-\beta^*).$$

Thus,

$$\zeta \equiv \alpha_3 + \alpha_4 + \alpha_5 \implies \alpha^* \equiv \frac{\alpha_3}{\alpha_3+\alpha_4+\alpha_5}, \beta^* \equiv \frac{\alpha_4}{\alpha_3+\alpha_4+\alpha_5}.$$

The relation between weights in theory and empirics is now clear: the coefficients in the estimated equation can be combined to estimate the optimal weights assigned to the sectoral rates of inflation from the theoretical model. Further, we now see explicitly how ζ can be interpreted as an elasticity: $\zeta \equiv \alpha_3 + \alpha_4 + \alpha_5$ represents the effect of a one percentage point increase in actual inflation on expected inflation.

4.4. **Testing for Bias.** The results of the regression analysis are tested to see whether the relative weights placed on food, energy, and core inflation differ from the respective shares in consumer expenditures in a statistically and/or economically significant way. This is testing of the BEH. For such testing, the following null hypotheses are used.

Energy Sector:

$$[18] H_0 : \alpha^* \equiv \frac{\alpha_3}{\alpha_3 + \alpha_4 + \alpha_5} = A.$$

Food Sector:

$$[19] H_0 : \beta^* \equiv \frac{\alpha_4}{\alpha_3 + \alpha_4 + \alpha_5} = B.$$

Again, α^* is the relative weight agents place on inflation in the energy sector and β^* is the relative weight agents place on inflation in the food sector; A is a fixed weight taking its value from the energy sector's share of consumer expenditure and B is a fixed weight taking its value from the food sector's share of consumer expenditure. Further, equations [18] and [19] allow for the following equations:

$$[20] (1 - A)\alpha_3 - A\alpha_4 - A\alpha_5 = 0, [21] (1 - B)\alpha_4 - B\alpha_3 - B\alpha_5 = 0.$$

These linear combinations of estimated coefficients are what is actually tested statistically. Thus, the empirical methodology for testing the BEH for both the food and energy sectors has been described.

4.5. **Econometric Issues.** A few econometric issues are necessary to confront in the estimation of these equations. First, coefficients will only be estimated for equations with a one period lag. This mirrors Van Duyne's analysis, as all coefficients he estimated for equations using data with lags of two or more periods were found to be small and insignificant. Second, there is a strong possibility that expectations for inflation two periods in the future, E_tP_{t+2}, (an independent explanatory variable) are correlated with the error term, u_t. One could write an equation for E_tP_{t+2} similar to [17] that includes, as an explanatory variable, inflation expectations for three periods in the future, E_tP_{t+3}. This would mean that the coefficients to be estimated would suffer from omitted variable bias since E_tP_{t+3} is missing from [17]. As such, the technique of instrumental variables is necessary to correct for this potential bias. The instruments that were chosen include the lagged unemployment gap, lagged overall inflation, lagged employment cost index, and lagged average hourly wage. Each of these is likely to be correlated with E_tP_{t+2} but not with u_t from [17], if lagged two or more periods. Thus, these are useful instrumental variables. With these instruments lagged two periods, Instrumental Variable Two Stage Least Squares estimation is performed in place of Ordinary Least Squares estimation.

4.6. **Data.** We analyze data from the period of 1980 through 2012. Analysis involves estimation of equations of the form [17] using data from multiple time intervals. This is necessary as the food and energy sectors' shares in consumer expenditure change over the three decade interval. Thus, to pickup any periods with potentially larger biases we calculate the average expenditure shares over different periods of time and test the estimated coefficients for those periods against these. data used is quarterly observations; therefore, one period is equivalent to one quarter.

As stated above, the expectations of inflation used in the regression analysis is quarterly inflation expectations for headline CPI from the Philadelphia Federal Reserve Bank's survey of professional economists. This data is available for one to four quarters in the future. The analysis uses expectations for one and two quarters in the future.

Observed price data is taken in quarterly form from the Bureau of Labor Statistics. The headline (overall) Consumer Price Index is used to calculate overall inflation, Core CPI is used to calculate core inflation, CPI Energy is used to calculate inflation in the energy sector, and CPI Food is used to calculate inflation in the food sector.

Coefficients estimated for each time interval are tested against the average of expenditure shares for the appropriate sector, energy or food, during that interval as reported by the Bureau of Labor Statistics. When looking at the entire period, both the most recent expenditure share data, mirroring Van Duynes paper, and overall averages are used.

Finally, the data used for instrumental variables includes be lagged overall CPI, lagged Employment Cost Index, both from the BLS, average hourly wages, and the lagged difference between the Unemployment Rate and the Natural Rate of Unemployment, NROU (an estimate of the natural rate from the Congressional Budget Office).

The results of this analysis are discussed below.

5. Naive Weighting Theoretical and Empirical Analysis

The naive weighting view of biased expectations analyzes whether the weights that individuals place on sectoral inflation rates for the food and energy sectors, when forming inflation expectations, are simply taken as the same sectors′ share in consumer expenditure. If it were to be assumed that expectations simply reflect past inflation, calculated using expenditure shares, then (as described previously)

$$[5] E_t P_{t+1} = P_t$$

and

$$[6] P_t = AP_t^x + BP_t^f + (1 - A - B)P_t^m.$$

[5] and [6] show that

$$[6.1] E_t P_{t+1} = AP_t^x + BP_t^f + (1 - A - B)P_t^m.$$

This very simplistic assumption allows sectoral weights used in the formation of expectations for inflation to be based simply on expenditure shares. This view does not incorporate any economic theory outside general intuition. As such, we empirically model inflation expectations as,

$$[21] E_t P_{t+1} = h + iPX_t + jPF_t + kPO_t + u_t,$$

where $E_t P_{t+1}$ is expectations in period t for inflation in period $t+1$, PX_t is inflation in the energy sector in period t, PF_t is inflation in the food sector in period t, PO_t is inflation other than in the food and energy sectors in period t, and i and j are less than 1 and are the shares individuals actually assign to sectoral inflation. This equation gives inflation expectations one period in the future as a function of inflation in the energy sector, the food sector, and the rest of the economy. Therefore, estimation of i and j through regression analysis allows us to test the hypotheses (the linear combinations that follow are actually tested):

Energy Sector:

$$[22] H_0 : i = A$$

$$[22.1] A - i = 0$$

Food Sector:

$$[23] H_0 : j = B$$

$$[23.1] B - j = 0$$

where A and B are the energy and food sectors$'$ share in consumer expenditure, respectively. In this way we determine whether consumers bias their expectations for inflation with respect to the food and energy sectors in the simplistic way. The data used for inflation expectations comes from the University of Michigan's survey of consumers' expectations for inflation one quarter in the future. The data for sectoral inflation and core inflation is the same BLS data for the CPI as above.

We also use the expectations data from the Philadelphia Federal Reserve Bank of economists$'$ inflation expectations to check that the economists do not naively weight sectoral inflation rates when forming their expectations.

6. Results

6.1. **Rational Weighting Empirical Results.** Here we test whether individuals bias the rational weights given by our theoretical model for sectoral inflation rates as they play into the formation of inflation expectations. As outlined above, we estimate equations of the form [17] by using Instrumental Variables in a Two Stage Least Squares regression context. The elements of the set of regressions we run vary, as mentioned above, by the time interval of the data we use to regress expectations for inflation one period in the future on the explanatory variables and instruments. This allows us to capture changes in the expenditure shares of the food and energy sectors in the CPI while maintaining a large enough number of observations to get meaningful results from regression analysis. The expenditure share averages we used are listed in Table 1; the shares for the food and energy sectors in consumer expenditure vary roughly from 12% to 15% and from 6% to 9%, respectively.

Table 1. Expenditure Share Averages

Time Period	Average Food Share	Average Energy Share
2011	0.129926567	0.09365255
1984 – 2011	0.137648059	0.076796152
1984 – 1989	0.147723517	0.082601995
1990 – 2000	0.140413309	0.069559561
2001 – 2011	0.129387103	0.08086592
1984 – 1997	0.144568597	0.076087921
1998 – 2011	0.13072752	0.077504383

The specific time periods were 1983-1989 tested against expenditure share averages for 1984-1989, 1990-2000 tested against expenditure share averages for 1990-2000, 2001-2012 tested against expenditure share averages for 2001-2011, 1983-1997 tested against expenditure share averages for 1984-1997, 1998-2012 tested against expenditure share averages for 1998-2011, 1983-2012 tested against expenditure share averages for 1984-2011, and 1983-2012 tested against expenditure shares for 2011. Restrictions in the data required the slight mismatch of regression data from expenditure share averages.[8] The time periods break the overall period into rough thirds, halves, and a single whole. We test the coefficients we get from instrumental variables regression analysis against these expenditure share averages according to hypotheses [18] and [19]. The linear combinations we use to approximate α^* and β^*, the rational weights implied through our model for inflation in the energy and food sectors, are derived above. The actual equations tested were of the forms [20] and [21]. The p-values resulting from the tests of these hypotheses are included in Table 2. The test that is run is a one tailed χ^2 test. The results we present in Table 2 are the probabilities of getting a statistic at least as extreme, in the χ^2 distribution with the appropriate degrees of freedom, as the one observed from the data.

TABLE 2. Rational Weighting χ^2 Test Results (Philadelphia Fed Expectations Data)

Time Period	Energy Test P-Value	Food Test P-Value	Joint Test P-Value
2011	0.9412	0.1376	0.2954
1983 – 2012	0.6840	0.1310	0.2240
1983 – 1989	0.9673	0.7361	0.9433
1990 – 2000	0.8920	0.5687	0.7824
2001 – 2012	0.1920	0.1867	0.0725
1983 – 1997	0.6412	0.6707	0.8205
1998 – 2012	0.1373	0.2339	0.0489

We find that we are not able to reject all hypotheses, tested separately, at the 10% level. We then investigate whether the hypotheses occur at the same time by running joint hypothesis tests for both the energy and food hypotheses for all time periods. We find that we are not able to reject all joint hypotheses at the 10% level, except for 2001 to 2012 and 1998 to 2012. Still we cannot reject the joint hypothesis at the 5% level for 2001 to 2012. It may be that in the latter portion of the period there was a particularly stable inflation overall and therefore more naive weighting of sectoral inflation rates in the format of overall inflation expectations was passable. These

[8]Expenditure share data was available from the BLS only back until 1984 and up to 2011; while the dataset used in our regression analysis spanned 1983 to 2012.

results indicate that the weights used to form inflation expectations by the economists surveyed by the Philadelphia Federal Reserve Bank are rational; however, they do not differ from the sectoral shares in consumer expenditure in a statistically significant way. The weights are rational in that they are arrived at through our model that incorporates serial correlation of sectoral price shocks. We discuss these implications further in the concluding section.

6.2. **Naive Weighting Empirical Results.** Here we investigate whether economists and typical consumers simply take a simple weighted average of sectoral expenditure shares to form their inflation expectations, call this naive weighting. As the naive weighting model we develop does not include the term for expectations two periods in the future, this model requires only Ordinary Least Squares regression analysis to estimate equations of the form [21]. Similarly to the rational empirical analysis, we use run a set of regressions for different time periods. These are the same time periods as in the rational weighting case; thus the average shares in consumer expenditure for the food and energy sectors are again those from Table 1. As mentioned above, we run these simple regressions using both consumer inflation expectation data from the University of Michigan (to see if consumers naively weight inflation in different sectors when forming inflation expectations) and inflation expectation data from the Philadelphia Federal reserve Bank (to see if economists naively weight inflation in different sectors when forming inflation expectations). We test the coefficients we get from OLS regression analysis against the expenditure share averages according to hypotheses [22] and [23]. The actual tests conducted were of the forms [22.1] and [23.1]. The p-values resulting from the tests of these hypotheses are described in Table 3 for the University of Michigan consumer expectations data and in Table 4 for the Philadelphia Federal Reserve Bank economist expectations data. The test that is run for both sets of regression results is a F test. The results we present in Table 3 and Table 4 are the probabilities of getting a statistic at least as extreme, in the F distribution, as the one observed from the data.

TABLE 3. Naive Weighting F Test Results (University of Michigan Expectations Data)

Time Period	Energy Test P-Value	Food Test P-Value	Joint Test P-Value
2011	0.0000	0.0326	0.0000
1983 – 2012	0.0000	0.0139	0.0000
1983 – 1989	0.0000	0.0659	0.0000
1990 – 2000	0.0000	0.0010	0.0000
2001 – 2012	0.0000	0.4203	0.0000
1983 – 1997	0.0000	0.0010	0.0000
1998 – 2012	0.0000	0.4945	0.0000

For the University of Michigan consumer inflation expectation data, we find that we reject all hypotheses for the energy sector at any level of significance; however, we can only reject the food hypotheses for 2011, 1983-2012, 1990-2000, and 1983-1997 at the 5% level. We are able to reject 1983-1989 at the 10% level, but are not able to reject the hypotheses for 2001-2012 nor 1998-2012 at all. We again run tests of the hypotheses for the food and energy jointly to see if we are able to reject the hypotheses that individuals naively weight inflation expectations with respect to both the food and energy sectors at the same time. We are able to reject all joint hypotheses. These results suggest that consumers do not weight sectoral inflation in a naive way when forming inflation expectations.

TABLE 4. Naive Weighting F Test Results (Philadelphia Fed Expectations Data)

Time Period	Energy Test P-Value	Food Test P-Value	Joint Test P-Value
2011	0.0000	0.0057	0.0000
1983 – 2012	0.0000	0.0038	0.0000
1983 – 1989	0.0044	0.5922	0.0100
1990 – 2000	0.0000	0.0921	0.0000
2001 – 2012	0.0000	0.0243	0.0000
1983 – 1997	0.0000	0.2385	0.0000
1998 – 2012	0.0000	0.0115	0.0000

For the Philadelphia Federal Reserve inflation expectation data, we find that we reject all hypotheses for the energy sector at any level of significance; however, we can only reject the food hypotheses for 2011, 1983-2012, 2001-2012, and 1998-2012 at the 5% level. We are able to reject 1990-2000 at the 10% level, but are not able to reject the hypotheses for 1983-1989 nor 1983-1997 at all. We again run joint tests and are able to reject all joint hypotheses. These results suggest that economists do not weight sectoral inflation in a naive way when forming inflation expectations. We analyze these results in combination with the results of the rational weighting analysis further in the following section.

7. Conclusion

The project of this paper was to analyze whether individuals′ inflation expectations were biased during the period from 1983 to 2012. That is, we sought to test whether it is the case that individuals use relative weights for sectoral inflation rates that differ from the sectors′ respective shares in consumer expenditure, when forming expectations for headline inflation. This, as stated above, is the crux of the Biased Expectations Hypothesis, that is held to be true by many policy makers. The BEH states that recent price movements in certain sectors play special or emphasized roles in individuals inflation expectations. We focus on analysis of the BEH within a theoretical framework that produces rational weighting for individuals′ inflation expectations. Further, this framework allows the possibility for these weights to be biased while being rationally formed.

Because data about consumer expectations for inflation that satisfies the needs of the theoretical framework developed in the previous sections (i.e. expectations data for two periods in the future) is unavailable from the University of Michigan survey of consumers, we use data collected by the Philadelphia Federal Reserve Bank about the multi period inflation expectations of professional economists. We recognize that it is likely that the expectations of professional economists are more Muth rational than those of consumers, as understanding economic theory is their profession. However, it is reasonable to think that consumers are not ignorant of basic economic thinking and that their expectations for inflation would not be drastically different than those of the economists, when presented with price movements. In particular, the serial correlation of price shocks to the food and energy sectors is fairly intuitive and could be reasonably assumed to factor into consumers′ formation of inflation expectations. Further, the focus of our empirical analysis is on whether the expectations that economists form are biased, in the way we have outlined. Understanding this and recognizing that typical consumers are, again, not oblivious to economic theory and general macroeconomic intuition, we can understand how it is that consumers do weight their inflations, assuming they are somewhat Muth rational.

We conducted empirical analysis to investigate whether individuals do bias their expectations, given rational formation of expectations. Using data from the period from 1983 to 2012, we looked at whether economists surveyed by the Philadelphia Federal Reserve Bank biased their headline inflation expectations and whether these same economists and consumers naively biased their inflation expectations. Combining pieces of analysis, we may be able to say something about whether consumers bias the weights they assign to sectoral inflation rates in their formation of headline inflation expectations.

The rationally weighted results suggest that when economists form inflation expectations rationally they do not form them with a statistically significant bias with respect to inflation in both the food and the energy sectors. Our theoretical model implies that the weights used to form inflation expectations by the economists surveyed by the Philadelphia Federal Reserve Bank are rational; however, our results indicate that these weights do not differ from the sectoral shares in consumer expenditure. Further as conventional wisdom suggests, the results of the naive weighting analysis indicate that economists and typical consumers do not simply use a weighted average of sectoral expenditure shares to form their inflation expectations. [9] This result suggests that both groups do something more sophisticated to form their inflation expectations, though this is difficult to test directly. If it is the case that typical consumers are forming inflation

[9]The coefficients on sectoral inflation rates from the naive weighting analysis are typically smaller than the sectoral expenditure shares.

expectations in a manner similar to that described by our model, then we could reasonably conclude that consumers, like the economists we were able to analyze more fully, do not bias their inflation expectations.

This result has important consequences for policy makers. If the BEH is not credible then policy makers should not emphasize recent movements of prices in the food and energy sectors when making policy decisions. Instead, as many policy makers already do, measures of inflation that exclude these highly variable sectoral inflation rates ought to be emphasized.

8. References

Bruine, de Bruin, der Klaauw van, and Giorgio Topa. "Expectations of Inflation: The Biasing Effect of Thoughts about Specific Prices." Journal of Economic Psychology 32.5 (2011): 834-45.

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

Mankiw, N. Gregory. "A Dynamic Model of Aggregate Demand and Aggregate Supply." Macroeconomics. 7th ed. New York: Worth, 2010. 409-42. Print.

Mankiw, N. G., Ricardo Reis, and Justin Wolfers. Disagreement about Inflation Expectations., 2003.

Muth, J. F. "Rational Expectations and the Theory of Price Movements." Econometrica 29 (1961): 315-35.

Simmons, Peter, and Daniel Weiserbs. "Consumer Price Perceptions and Expectations." Oxford Economic Papers 44.1 (1992): 35-50.

Van Duyne, Carl. "Food Prices, Expectations, and Inflation." American Journal of Agricultural Economics 64.3 (1982): 419-30.

Wooldridge, Jeffery M. "Instrumental Variables Estimation and Two Stage Least Squares." Introductory Econometrics. 4th ed. Mason, OH: South-Western Cengage Learning, 2009. 506-45. Print.