The Formation of Wage Expectations in the Effort and Quit Decisions of Workers

Carl M. Campbell III
Department of Economics
Northern Illinois University
DeKalb, IL 60115
Phone: 815-753-6974
e-mail: carlcamp@niu.edu

October 2009

Abstract

While much work in macroeconomics considers the formation of price expectations, there has been relatively little work analyzing wage expectations. This study develops models in which workers form expectations of average wages in choosing levels of effort and on-the-job search, under the assumption that information on lagged average wages is free but other information is costly. Under reasonable conditions, workers' expectations are likely to be at least partly adaptive. It is argued that wage expectations may be more important than price expectations in explaining unemployment fluctuations.

I would like to thank Qiang Chen and John Conlisk for valuable comments on earlier versions of this paper.

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I. Introduction

In recent years economists have done a good deal of research on the issue of price expectations. One line of inquiry involves testing whether survey measures of expected inflation satisfy the criteria for rational expectations. In a second line of research, Mankiw and Reis (2002) assume that some firms operate with out-of-date information about optimal prices, and they demonstrate that this "sticky information" model can explain output and inflation dynamics better than a model with sticky prices. However, while price expectations have received much attention, a related issue that has been overlooked is workers' expectations about average wages.

This study models the formation of workers' wage expectations and argues that expectations of average wages may be at least as important as expectations of the price level in explaining unemployment fluctuations. Workers' wage expectations are analyzed in the context of their effort and on-the-job search decisions, since these decisions depend on the relationship between a worker's current wage and his or her expectations of the mean of the aggregate wage distribution. Under reasonable conditions, it is demonstrated that expectations may not be completely rational.

The motivation for this work is that systematic errors in workers' wage expectations may have significant macroeconomic consequences. If workers' expectations about average wages are not completely rational, they may appear to exhibit money illusion in their effort and quit decisions. In Section II it is argued that the wage expectations of workers may be more important than the price expectations of either firms or workers in explaining business cycle fluctuations.

Section III develops a model of information acquisition for the effort decision of workers. It is assumed that workers can form expectations of average wages both by using a free adaptive expectations calculation and by acquiring costly information that yields a more accurate estimate. A worker seeks to minimize the sum of information acquisition costs and the utility loss that results from making decisions with imperfect information (since the effort exerted by a worker who forms incorrect wage expectations will be suboptimal). Two methods for acquiring information about average wages are considered: sampling wages at a subset of firms and gathering and analyzing macroeconomic data. In both cases it is demonstrated that workers' expectations do not necessarily satisfy the criteria for rational expectations and that their expectations are likely to be at least partly adaptive. The model is modified in Section IV to analyze the job search decision, which affects workers' quit behavior. Section V concludes and discusses implications of the model.

The main contributions of this study lie in identifying the benefits of information to workers and demonstrating why utility-maximizing workers may make systematic errors in their wage expectations.[1] In doing so, it provides theoretical justification for efficiency wage modeling in which effort and quits depend partly on lagged average wages. In addition, this study shows how microeconomic parameters affect the degree to which expectations are rational vs. adaptive.

II. Why Wage Expectations Matter

There is an extensive literature that involves testing the rationality of price expectations, and much of this work uses the survey of economists conducted by Joseph Livingston and/or the household survey conducted by the Michigan Institute of Social Research. Taken together, these studies suggest that expectations are neither completely rational nor completely adaptive. On one hand, Evans and Gulamani (1984), Batchelor and Dua (1989), Roberts (1997), Thomas (1999), and Mankiw, Reis, and Wolfers (2003) find that expectations do not satisfy the criteria for rational expectations, as they show that forecast errors can be predicted by information available at the time of the forecast (e.g., money supply growth, unemployment, the budget deficit, interest rates, the output gap, and lagged inflation). On the other hand, the findings of Mullineaux (1980), Gramlich (1983), and Baghestani and Noori (1988) indicate that expectations are not purely adaptive.[2] In addition, Fuhrer (1997) and Roberts (1998) demonstrate that expectations can be described as a mixture of rational and adaptive expectations.[3]

The assumption that expectations are not purely rational is made by Mankiw and Reis (2002) in their sticky information model. They assume that some firms (chosen randomly) operate with current information about optimal prices, while the remaining firms operate with out-of-date information, and they demonstrate that their model outperforms the sticky price model in explaining output and inflation dynamics.

In the studies that test the rationality of inflationary expectations and in the sticky information model, the variable of interest is price expectations. In contrast, the present study assumes that individuals have imperfect information about average wages. While this study differs from the rest of the literature by considering wage expectations rather than price expectations, the macroeconomic consequences of imperfect information may be more important for wage expectations than for price expectations.

Labor market outcomes are determined from the interaction between firms and workers. From the point of view of firms, it is difficult to see why imperfect information about the price level would significantly affect unemployment. Information on the price level is readily available from the Bureau of Labor Statistics on a monthly basis, both for the aggregate economy and for many specific goods and services. Given the ease of accessing these statistics through the internet, it is not obvious why some firms would operate with information that is out of date.

Even if firms lack perfect information about the price level, the mechanism through which imperfect information would translate into large changes in unemployment is not clear. Mankiw and Reis consider firms' pricing and output decisions but do not consider their wage and employment decisions, and there is no reason why firms in their model would not continually set wages at their market-clearing level.

The behavior of workers is likely to be influenced more by their expectations about average wages than by their expectations about the price level. Workers make several decisions that may affect the wages set by firms: how much labor to supply, at what value to set their reservation wage, how hard to work, and how hard to look for another job. These decisions probably depend more on workers' relative wages than on their real wages, as evidenced by the fact that real wages have increased dramatically over the past 60 years, yet we have not observed a significant decline in the quit rate or significant increases in labor supply or effort.

Theoretical considerations suggest that workers' labor market decisions are likely to depend more on relative wages than on real wages. The decisions concerning reservation wages (controlling for labor supply) and quits should depend on relative wages rather than on real wages, since these decisions are made by comparing wages at a given firm with opportunities elsewhere. In terms of workers' effort, the relative wage is the relevant variable in the shirking model. In the gift-exchange model, effort could depend on either relative or real wages, depending on whether workers' loyalty is affected by the relationship between their pay and the market wage or by the relationship between their pay and the prices of goods and services. The one decision that unambiguously depends on real wages is labor supply. However, empirical work suggests that the elasticity of labor supply with respect to the real wage is small.[4] Thus, it is reasonable to believe that workers' behavior is affected more by their expectations of average wages than by their expectations of the price level.

In addition, errors in wage expectations are probably larger than errors in price expectations. As previously discussed, price expectation errors are likely to be small since the Consumer Price Index is published monthly and is readily available. On the other hand, what matters for workers' effort and quit decisions are their wages relative to average wages for workers in the same occupation who have similar qualifications (e.g., experience and education), and this information is not easily obtainable. In fact, employers in Bewley's (1999) survey believed that their workers did not have a very precise idea about the wages at other firms.

If firms pay efficiency wages, workers' imperfect information about average wages can have significant macroeconomic consequences, since firms take into account the reaction of workers in setting wages. For example, a firm that knows its workers' expectations are partly adaptive has an incentive to adjust wages slowly in response to contractionary shocks, out of concern that adjusting wages too quickly would adversely affect its workers' effort and quit behavior. This sluggish adjustment of nominal wages would likely cause unemployment to rise. In contrast to conventional efficiency wage models, in which efficiency depends on the actual real or relative wage of workers, an efficiency wage model with imperfect information about average wages is able explain nominal wage rigidity.[5] In addition, as discussed in Campbell (2008), a short-run Phillips curve can be derived from a model with efficiency wages and imperfect information about average wages.

III. Expectation Formation in Choosing Optimal Effort

One explanation for a positive relationship between wages and effort is the shirking model of Shapiro and Stiglitz (1984), in which a higher wage raises the cost of job loss and induces workers to exert more effort. The cost of job loss depends negatively on the wages offered by other firms, which means that workers' effort depends on the relationship between their current wages and average wages in the rest of the economy.[6]

In the shirking model, it is generally assumed that all firms pay the same wage, which means that workers know with certainty the average wage offered by other firms. In reality, however, this is not a reasonable assumption. Wages vary across employers, even for jobs that are similar, and workers generally do not have perfect information concerning the wages offered by other firms. Lacking perfect information, workers need to form expectations about wages elsewhere in order to choose the optimal effort level.

A worker who forms incorrect expectations of the average wage will provide a suboptimal level of effort and suffer a utility loss. A worker overestimating average wages will provide less than optimal effort, so that, on average, the loss of future earnings resulting from the increased probability of dismissal will exceed the utility gain from lower effort. A worker who underestimates average wages will suffer the opposite type of utility loss.

This section develops a model of information acquisition on the part of workers, who incur costs from acquiring information and from making decisions with imperfect information. It is assumed that wages vary across firms and that the average wage, $\overline{W}_t$, is unobserved. While the mean of the wage distribution is unknown, workers have two tools at their disposal to estimate this mean. First, they can observe past average wages at no cost and can predict the mean of the wage distribution from this out-of-date information. Second, they can obtain information about current average wages through activities such as sampling wages at other firms and gathering and analyzing macroeconomic data. Workers face the tradeoff that acquiring more information is costly, but it enables them to form more accurate estimates of the mean of the wage distribution, resulting in effort that is closer to its optimal level.

Let $\hat{W}_{t-1}^{L}$ represent workers' expectations of the mean of the aggregate wage distribution based on their knowledge of past average wages. While this study does not make specific assumptions about how $\hat{W}_{t-1}^{L}$ is determined, there are several ways workers may form their estimates. In an economy in which wages have shown no upward or downward trend, the best predictor of current wages may be a weighted average of lagged wages, while in an economy that has historically experienced positive wage growth, the best predictor of current wages may be last period's wage plus a weighted average of wage inflation in previous periods.[7]

Workers can also form expectations of the mean of the wage distribution by acquiring other relevant information, which is assumed to be costly. There has been little previous work on the methods used by workers to estimate average wages, so it is not clear how they form their estimates. Possible ways to estimate average wages include obtaining information on wages at a subsample of firms (e.g., by contacting firms, talking to friends, and reading help-wanted ads) and gathering and analyzing macroeconomic data (e.g., the growth rate of money, fiscal policy, and unemployment). Let I represent the amount of information acquired and c represent the cost of each unit of information.

It is assumed that the amount of information acquired by workers is determined by the following tradeoff. Let $V(W_t, \overline{W}_t^T, e_t)$ represent the present value of a worker's expected utility, where W_t is the worker's current wage, $\overline{W}_t^T$ is the true mean of the wage distribution, and e_t is effort.[8] This expression for V takes into account the disutility of effort and the utility of consumption, which depends on income in the current and future periods.

Effort has two opposing effects on lifetime utility. An increase in effort reduces current utility, but it also reduces the probability of dismissal, which increases expected lifetime consumption (by raising expected future income). Optimal effort is determined from the condition dV/de_t=0. Let $e(\overline{W}_t^T)$ represent effort when a worker knows that the mean of the wage distribution is $\overline{W}_t^T$ and $e(\overline{W}_t^E)$ represent effort when the worker estimates that the mean is $\overline{W}_t^E$. Then the utility loss resulting from incorrect expectations of average wages can be expressed as

(1) $$VL(\overline{W}_t^E - \overline{W}_t^T) = V(W_t, \overline{W}_t^T, e(\overline{W}_t^T)) - V(W_t, \overline{W}_t^T, e(\overline{W}_t^E)),$$

with $VL(0) = 0$ and $VL'' > 0$.

The assumption that $VL'' > 0$ means that the utility loss rises at an increasing rate as the difference between $\overline{W}_t^E$ and $\overline{W}_t^T$ increases.[9]

The total expected utility loss (*TEL*) equals the cost of acquiring information plus the expected utility loss from incorrect information, and this loss can be expressed as

(2) $$TEL = cI + E[VL(\overline{W}_t^E - \overline{W}_t^T)].$$

If equation (2) is approximated with a second-order Taylor expansion around the point where $\overline{W}_t^E = \overline{W}_t^T$, the following equation is obtained:

$$TEL \approx cI + E[VL(0)] + E[VL'(0)(\overline{W}_t^E - \overline{W}_t^T)] + \frac{1}{2}E[VL''(0)(\overline{W}_t^E - \overline{W}_t^T)^2].$$

This expression can be simplified by making the substitutions $VL(0)$=0 and $VL'(0) = 0$ and by noting that $VL''(0)$ is a constant,[10] yielding

(3) $$TEL \approx cI + \frac{1}{2}VL''(0)E[(\overline{W}_t^{\,E} - \overline{W}_t^{\,T})^2],$$

where $E[(\overline{W}_t^{\,E} - \overline{W}_t^{\,T})^2]$ depends negatively on the amount of information acquired. A worker acquires the amount of information (I) that minimizes this expected utility loss. As previously discussed, two ways that workers may acquire information about current average wages are sampling wages at other firms and collecting and analyzing macroeconomic data. The implications of both types of processes are now considered.

Sampling wages at other firms

To the extent that workers estimate average wages by sampling wages at other firms, it will be assumed that they sample wages randomly. Let I represent the number of wages sampled, σ_{WD}^2 represent the variance of the wage distribution, and $\overline{W}_t^{\,I}$ represent the average of the wages sampled. The accuracy of adaptive expectations is measured by the standard deviation of the forecast error. If workers observe the relationship between $\overline{W}_t$ and $\hat{W}_{t-1}^L$ over M periods, this standard deviation can be expressed as

$$\sigma_L = \sqrt{\frac{\sum_{i=1}^{M}(\overline{W}_{t-i} - \hat{W}_{t-i-1}^L)^2}{M-1}}.$$

Assuming that workers use a Baysesian process to form their expectations, with $\hat{W}_{t-1}^L$ and σ_L^2 as their priors, the mean and standard deviation of the posterior distribution will be

(5) $$\overline{W}_t^{\,E} = \frac{\sigma_{WD}^2 \hat{W}_{t-1}^L + \sigma_L^2 I \overline{W}_t^{\,I}}{\sigma_{WD}^2 + I\sigma_L^2},$$ and

(6) $$\sigma_E = \sqrt{\frac{\sigma_{WD}^2 \sigma_L^2}{\sigma_{WD}^2 + I\sigma_L^2}}\,.$$

Since $E[(\overline{W}_t^{\,e} - \overline{W}_t^{\,T})^2] = \sigma_E^2$, *TEL* can be expressed as

(7) $$TEL \approx cI + \frac{1}{2} VL''(0) \frac{\sigma_{WD}^2 \sigma_L^2}{\sigma_{WD}^2 + I\sigma_L^2}\,,$$

and the condition for cost minimization is

(8) $$\frac{dTEL}{dI} = 0 = c - \frac{1}{2} VL''(0) \frac{\sigma_{WD}^2 \sigma_L^4}{[\sigma_{WD}^2 + I\sigma_L^2]^2}\,.$$

Solving this equation for *I* yields

(9) $$I = \sqrt{\frac{\sigma_{WD}^2 VL''(0)}{2c}} - \frac{\sigma_{WD}^2}{\sigma_L^2}\,,$$ with the boundary condition that $I \geq 0$.

Equation (5) can be expressed as

(10) $$\overline{W}_t^{\,E} = \omega \overline{W}_t^{\,I} + (1-\omega)\hat{W}_{t-1}^{\,L}\,,$$ where

(11) $$\omega = \frac{\sigma_L^2 I}{\sigma_{WD}^2 + I\sigma_L^2}\,.$$

Substituting (9) into (11) yields

(12) $$\omega = 1 - \frac{\sqrt{2\sigma_{WD}^2 c}}{\sigma_L^2 \sqrt{VL''(0)}}\,,$$ with the boundary condition that $\omega \geq 0$.

Thus, ω depends negatively on the cost of information and depends positively on σ_L, which means that it depends negatively on the historical accuracy of adaptive expectations.[11]

If workers sample wages at other firms, their estimates should be unbiased predictors of the true mean, and differences between $\overline{W}_t^I$ and $\overline{W}_t^T$ should be serially uncorrelated and unpredictable to other agents. Thus, $\overline{W}_t^I$ can be expressed as

$$(12) \qquad \overline{W}_t^I = \overline{W}_t^T + \varepsilon_t ,$$

where ε_t is a random error term. Substituting (12) into (10) yields

$$(13) \qquad \overline{W}_t^E = (1-\omega)\hat{W}_{t-1}^L + \omega\overline{W}_t^T + \omega\varepsilon_t ,$$

which means that expectations are a weighted average of adaptive and rational expectations.

Unless c is so low that workers sample every wage, ω is less than 1, which means expectations will be at least partly adaptive. On the other hand, ω may equal 0 under reasonable conditions. If $2c\sigma_{WD}^2 > \sigma_L^4 VL''(0)$, cost minimization is characterized by a corner solution in which workers acquire no information and expectations are completely adaptive.

Gathering and Analyzing Macroeconomic Data

A second way that workers can form expectations about the mean of the aggregate wage distribution is by collecting and analyzing published macroeconomic data on variables such as unemployment, fiscal policy, and money growth.

It is likely that most workers will use fairly unsophisticated methods to predict average wages from macroeconomic data, since relatively few workers have a strong background in economics. For example, Siegfried (2000) estimates that approximately 1,363,000 student took an introductory economics course in 2000, which is about 34% of the population of 18 year-olds in 2000.[12] In addition, Vascellaro (2005) reports figures obtained from John Siegfried indicating that there were 16,141 degrees awarded to economics majors at 272 colleges and universities that he tracked during the 2003-2004 academic year. If the number of economics degrees outside these 272 schools amounted to 50% of the number awarded at these institutions, the number of economics degrees would approximately equal 0.6% of the population of 22 year-olds in 2004 (based on the number of 18-year olds four years earlier). Since college attendance rates have increased significantly over the past 50 years, it is likely that exposure to economics in the adult population as a whole is lower than among individuals in their early 20's.

Given the population's limited knowledge about economics, it seems likely that most people do not use sophisticated econometric techniques to form expectations of average wages. Rather, to the extent that individuals use macroeconomic variables other than lagged average wages to predict current average wages, it is likely that most consider one or two variables (such as unemployment and GDP growth), observe the effect of these variables on wages in recent memory, and do a simple mental calculation (rather than run a formal regression). For example, while few individuals collect data on unemployment and wages and run a Phillips curve regression, they may note that wage inflation fell by x% when the unemployment rate rose by y% in a previous recession.

In modeling the way that individuals form expectations of current wages from lagged wages and macroeconomic variables, it is assumed that wages are determined by the equation,

$$W_t = \gamma M_t + (1-\gamma)W_t^e + \varepsilon_t, \tag{14}$$

where M_t represents demand, W_t^e represents workers' expectations of average wages, and ε_t is a white-noise error term with a variance of ν^2. Nominal demand is assumed to be determined from the relationship

(15) $$M_t = \beta_1 x_{1,t} + \beta_2 x_{2,t} + \cdots + \beta_N x_{N,t},$$

where $x_1, x_2, \ldots, x_N$ represent the variables that determine demand. For simplicity, it is assumed that the cost of obtaining each variable is the same and that x_1 through x_N are ordered according to their predictive power. (Thus, x_1 has the most predictive power, and x_N has the least.) In addition, it is assumed that the variables x_1 through x_N are orthogonal to one another, so that x_2 represents information that is not predicable from x_1, x_3 represents information that is not predictable from x_1 and x_2, etc. These variables are assumed to follow a first-order autoregressive process, so that

(16) $$x_{i,t} = \rho_i x_{i,t-1} + e_{i,t} = \sum_{j=0}^{\infty} \rho_i^j e_{i,t-j} .$$

Suppose a worker uses I variables (where $I \leq N$) to predict current average wages. Suppose also that the worker uses information contained in lagged average wages. Then

(17) $$W_t^e = \alpha W_{t-1} + \hat{\beta}_1 \rho_1 x_{1,t-1} + \hat{\beta}_2 \rho_2 x_{2,t-1} + \cdots + \hat{\beta}_I \rho_{I1} x_{I,t-1},$$

where $\hat{\beta}_1, \hat{\beta}_2, \ldots, \hat{\beta}_I$ represent workers' best estimates of $\beta_1, \beta_2, \ldots, \beta_I$. If (15) and (17) are substituted into (14), the following expression for current wages is obtained:

$$(18)\qquad \begin{aligned} W_t &= (1-\gamma)\alpha W_{t-1} + \gamma[\beta_1 x_{1,t} + \beta_2 x_{2,t} + \cdots + \beta_N x_{N,t}] \\ &\quad + (1-\gamma)[\hat{\beta}_1 \rho_1 x_{1,t-1} + \hat{\beta}_2 \rho_2 x_{2,t-1} + \cdots + \hat{\beta}_I \rho_I x_{I,t-1}] + \varepsilon_t . \end{aligned}$$

The Appendix demonstrates that expressing wages in period t as a function of current and lagged values of the stochastic shocks yields

$$(19)\qquad W_t = \sum_{i=1}^{I}\sum_{j=0}^{\infty}\left[\gamma\beta_i\rho_i^j \frac{1-A_i^{j+1}}{1-A_i} + (1-\gamma)\hat{\beta}_i\rho_i^j \frac{1-A_i^j}{1-A_i}\right]e_{i,t-j} + \gamma\sum_{i=I+1}^{N}\beta_i\sum_{j=0}^{\infty}\rho_i^j \frac{1-A_i^{j+1}}{1-A_i} e_{i,t-j} + \varepsilon_t ,$$

where $A_i = \dfrac{(1-\gamma)\alpha}{\rho_i}$.

From (16) and (19), expressions can be derived for the variance of W_{t-1}, the variance of the macroeconomic variables, the covariance between W_{t-1} and W_t, the covariance between W_t and the macroeconomic variables, and the covariance between W_{t-1} and the macroeconomic variables. If a worker uses I of the N macroeconomic variables to predict average wages, the estimated coefficients on lagged average wages and on the macroeconomic variables are determined from the regression equation, $\hat{\mathbf{b}} = (\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\mathbf{W}$, where $\hat{\mathbf{b}}$ is a vector with I+1 rows whose first row is the coefficient on lagged wages (α) and whose remaining I rows are the estimated coefficients on the included macroeconomic variables ($\hat{\beta}_1$ through $\hat{\beta}_I$), $\mathbf{X}'\mathbf{X}$ is the variance-covariance matrix,[13] and $\mathbf{X}'\mathbf{W}$ is a vector whose first row is the covariance between current wages and lagged wages and whose remaining rows are the covariances between current wages and the included macroeconomic variables.[14]

The coefficients in $\hat{\mathbf{b}}$ depend on the behavior of wages, which, in turn, depend on the coefficients in $\hat{\mathbf{b}}$. A closed-form solution for these coefficients is not tractable, so the model is simulated. In these simulations it is assumed that demand is determined by three macroeconomic variables (x_1, x_2, and x_3), and that workers may use lagged wages plus zero, one, two, or all three of the macroeconomic variables to form their expectations of current average wages.

The expressions for $\mathbf{X'X}$ and $\mathbf{X'W}$ depend on the estimated value of α and the estimated values of the $\hat{\beta}_i$'s for the included macroeconomic variables. In equilibrium, the first row of $\hat{\mathbf{b}}$ must equal the estimated value of α for the typical worker. In addition, rows two through I+1 of $\hat{\mathbf{b}}$ must equal the corresponding value of $\hat{\beta}_i$ for the typical worker. Given values for the model's parameters (γ, ν^2, the ρ_i's, the β_i's, and the σ_i^2's), these equilibrium conditions uniquely determine values for α and for the $\hat{\beta}_i$'s for the included macroeconomic variables.

Estimated coefficients on lagged wages and on the macroeconomic variables are calculated for different values of the model's parameters, and the results are reported in Table 1. For each set of parameters, values for α and the $\hat{\beta}_i$'s are calculated for cases when workers use three, two (x_1 and x_2), one (x_1), and zero macroeconomic variables to form their wage expectations.

When workers use all of the macroeconomic variables, $\hat{\beta}_i = \beta_i$ for all three variables and the coefficient on lagged wages is zero, implying that their expectations are unbiased. However, when workers do not use all the available information (i.e., I<3), their expectations are partly adaptive (since α>0) and their expectations are no longer unbiased (since $\hat{\beta}_i < \beta_i$ for the included variables).[15] Also, $\hat{\beta}_i \approx \beta_i/(1-\alpha)$ when 0<I<3, implying that expectations are approximately a weighted average of unbiased and adaptive expectations, with weights of α and 1- α. (This approximation is more exact when ρ_i is close to 1.) When I=0, workers' wage expectations are characterized by an autoregressive process in which the coefficient on lagged average wages is less than 1.

It is assumed that the mental process that workers use to infer average wages from macroeconomic data can be viewed as OLS estimation, so that the typical worker does not correct for serial correlation. As previously discussed, only a small percentage of workers have majored in economics, and it is likely that very few workers would even notice serial correlation, let alone correct for it in estimating average wages. The benefit of correcting for serial correlation is likely to be very small; the value of information lies in enabling workers to more accurately predict the mean of the wage distribution to make a more optimal choice of effort, and correcting for serial correlation would generally not result in effort levels that are significantly closer to their optimal levels. It could be assumed that workers have the ability to correct for serial correlation, but that this correction is costly, so that few workers take serial correlation into account in estimating average wages.

Table 2 reports how the sum of squared errors (from the regressions reported in Table 1) varies depending on the number of variables used. Within each cell E_3, E_2, E_1, and E_0 represent the sum of squared errors when workers use three, two, one, or zero macroeconomic variables. A comparison of the second and fifth columns shows that when ν^2 and the σ^2's both rise by a factor of 3.33, the sum of squared errors also rises by a factor of 3.33.

The sum of squared forecast errors can be expressed as $f(I, \sigma_1^2, \sigma_2^2, \sigma_3^2, \nu^2)$. Table 2 shows that $f_I < 0$, since the sum of squared errors falls as I increases. In addition, f_{II} is generally positive in Table 2 (i.e. adding more variables usually reduces the sum of squared errors at a decreasing rate), but it is not always positive.

It is likely that v^2 will be high in economies in which the σ^2's are high (and will be low in economies in which the σ^2's are low) since in economies in which the macroeconomic variables are more volatile, the other factors that affect wages are likely to be more volatile. Let ζ represent a shift variable that affects the σ^2's and v^2 equiproportionately. Then the sum of squared errors can be written as $f(I, \zeta)$. Since $f_I < 0$ and the sum of squared errors is proportional to ζ, it follows that $f_{I\zeta}$<0. Letting c represent the cost of acquiring each variable, the total expected utility loss is

$$TEL \approx cI + \frac{1}{2} VL''(0) f(I, \zeta) .$$

Workers choose the value of I that minimizes TEL. Since the sign of f_{II} is ambiguous, an interior solution does not necessarily exist. However, it can be demonstrated that I falls or remains constant as c rises and that I rises or remains constant as ζ rises. Let I^* represent the optimal value of I in an initial equilibrium and let $TEL(I^*)$ represent the expected utility loss when I is chosen to minimize TEL. Suppose that c rises, raising TEL at each value of I. Then $TEL(I)$ rises more than $TEL(I^*)$ for $I>I^*$ and $TEL(I)$ rises less than $TEL(I^*)$ for $I<I^*$. Thus, a rise in c may lower the optimal value of I, but it cannot raise it. Suppose that ζ rises, raising TEL at each value of I. Since $f_{I\zeta}<0$, $TEL(I)$ rises more than $TEL(I^*)$ for $I<I^*$ and $TEL(I)$ rises less than $TEL(I^*)$ for $I>I^*$. Thus, a rise in ζ may raise the optimal value of I, but it cannot lower it. These results imply that expectations tend to become less rational as the cost of acquiring information increases and tend to become more rational as wage inflation becomes less predictable from lagged variables.

IV. Expectations Formation in Choosing Optimal Job Search Intensity

Section III develops a model in which workers acquire information about average wages in choosing their level of effort. Another decision made by workers is how much time to spend looking for a different job, and this decision also depends on the ratio of their own wages to average wages elsewhere. Thus, workers need to estimate the mean of the wage distribution to determine how much time to devote to job search, and their process of information acquisition can be modeled in the same way as in Section III. In fact, the job search decision is probably more important for macroeconomic outcomes than the effort decision described in Section III (based on the shirking model), since survey evidence suggests that theories involving turnover are much more relevant than theories involving shirking in explaining the rigidity of wages.[16]

In deciding how much job search to undertake, workers face the tradeoff that job search is costly, but it may enable them to find a job that will yield higher income in the future. The present value of a worker's expected lifetime utility can be denoted $V(W_t, \overline{W}_t^T, s_t)$, where W_t and $\overline{W}_t^T$ are defined as in Section III, and s_t measures the worker's job search intensity. The optimal level of search is determined from the condition that $dV/ds_t=0$. If $s(\overline{W}_t^T)$ represents the optimal level of search when a worker knows that the mean of the wage distribution is $\overline{W}_t^T$ and $s(\overline{W}_t^E)$ represents the optimal level of search when the worker estimates that the mean is $\overline{W}_t^E$, the utility loss resulting from imperfect expectations of average wages is

$$VL(\overline{W}_t^E - \overline{W}_t^T) = V(W_t, \overline{W}_t^T, s(\overline{W}_t^T)) - V(W_t, \overline{W}_t^T, s(\overline{W}_t^E)).$$

Using a model similar to the one developed in Section III, it can be demonstrated that, in deciding how much time to devote to job search, workers' expectations of average wages will be likely to be at least partly adaptive.

Workers will quit their present jobs if they find a more attractive job at a different firm. The probability that a worker quits can be viewed as depending on two factors: 1) the difference between the worker's current wage and the actual mean of the wage distribution, and 2) the worker's search intensity (because, controlling for the first factor, the probability of finding one of the jobs that offers a higher wage depends on how hard he or she searches). Accordingly, the probability of a worker quitting can be expressed as

$$q = f(W_t - \overline{W}_t^T, s(\overline{W}_t^E)).$$

Since the probability of quitting depends on job search intensity, and since job search intensity depends on $\overline{W}_t^E$, workers' quit propensities are affected by their expectations of average wages, as well as by the actual average wage. Thus, the probability that a worker quits may be partly a function of lagged average wages.

Campbell (1995) finds support for the hypothesis that quits depend partly on lagged average wages. In this study, quit rates in 2-digit SIC manufacturing industries are regressed on current and lagged industry wages and on current and lagged values of average manufacturing wages. The hypothesis that industry wages and average manufacturing wages have the same long-run effect on industry quits cannot be rejected. However, it is found that industry quit rates respond almost immediately to industry wages, but respond with a relatively long lag to average manufacturing wages, suggesting that expectations of average wages are partly adaptive.

V. Conclusion

This study develops a model in which workers can obtain costly information that enables them to more accurately predict the mean of the aggregate wage distribution; they then use this information to choose their levels of effort and job search. It is demonstrated that the workers' expectations do not necessarily satisfy the criteria for rational expectations and that expectations are likely to be at least partly adaptive. The degree to which expectations are rational vs. adaptive depends on the cost of acquiring information and on accuracy with which wages can be predicted from lagged information.

The main contributions of this work lie in highlighting the importance of workers' wage expectations and in identifying the benefits of information about average wages. This information is valuable to workers because it enables them to make better decisions about their effort and job search intensity.

This study limits its analysis to workers' effort and job search decisions, since these choices are related to efficiency wage theory. Another labor market decision that could be modeled in a similar framework is the behavior of unemployed workers as they acquire information to choose the optimal reservation wage. If unemployed individuals have imperfect information about average wages, they may use a process similar to that described in Sections III and IV to estimate the mean of the wage distribution. In this case, their reservation wages will depend partly on lagged average wages, which means that they may exhibit money illusion in deciding whether to accept a given job offer.

The theory developed in this study may provide an explanation for Lucas's (1973) finding that countries with greater variability in inflation experience smaller increases in output in response to nominal demand shocks. In countries with greater inflation variability, it is likely that average wages are less predictable from lagged information, relative to countries with lower inflation variability. Accordingly, the values of σ_L and ζ are likely to be higher in countries with greater inflation variability, inducing workers to acquire more information and resulting in a higher value of ω. Thus, expectations will look more like rational expectations in these countries, so a given nominal demand shock should have a smaller effect on real output.[17]

One implication of this study is that more work should be done on the issue of how workers estimate wages elsewhere. While there has been a great deal of research on the formation of price expectations, there has been relatively little (if any) research on the formation of wage expectations. This study discusses several methods that workers may use in estimating average wages, such as sampling wages at other firms and analyzing macroeconomic variables. In addition, workers may employ other methods not discussed in this study to estimate average wages. Investigating the methods used by workers to predict average wages and estimating the relative importance of these different methods would yield insights into the ways that effort and quits respond to macroeconomic shocks. Since firms take the response of workers into account in setting wages, such research may help economists understand the reasons for sluggish nominal wage adjustment.

Appendix

From (18), wages can be expressed as

$$W_t = (1-\gamma)\alpha W_{t-1} + \gamma[\beta_1 x_{1,t} + \beta_2 x_{2,t} + \cdots + \beta_N x_{N,t}]$$
$$+ (1-\gamma)[\hat{\beta}_1 \rho_1 x_{1,t-1} + \hat{\beta}_2 \rho_2 x_{2,t-1} + \cdots + \hat{\beta}_I \rho_I x_{I,t-1}] + \varepsilon_t .$$

By using repeated substitution, wages can be expressed as

$$W_t = \gamma \sum_{j=0}^{\infty} (1-\gamma)^j \alpha^j [\beta_1 x_{1,t-j} + \beta_2 x_{2,t-j} + \cdots + \beta_N x_{N,t-j}]$$
$$+ (1-\gamma) \sum_{j=0}^{\infty} (1-\gamma)^j \alpha^j [\hat{\beta}_1 \rho_1 x_{1,t-j-1} + \hat{\beta}_2 \rho_2 x_{2,t-j-1} + \cdots + \hat{\beta}_I \rho_I x_{I,t-j-1}].$$

Solving this equation for W_t as a function of the underlying shocks yields

$$W_t = \sum_{i=1}^{I} \sum_{j=0}^{\infty} \left[\gamma \beta_i \rho_i^j \frac{1-A_i^{j+1}}{1-A_i} + (1-\gamma) \hat{\beta}_i \rho_i^j \frac{1-A_i^j}{1-A_i} \right] e_{i,t-j}$$
$$+ \gamma \sum_{i=I+1}^{N} \beta_i \sum_{j=0}^{\infty} \rho_i^j \frac{1-A_i^{j+1}}{1-A_i} e_{i,t-j} + \varepsilon_t .$$

where $A_i = \dfrac{(1-\gamma)\alpha}{\rho_i}$.

$$\text{Var}[x_{i,t-1}] = \frac{\sigma_i^2}{1-\rho_i^2}$$

$$\text{Cov}[W_t x_{i,t-1}] = \sigma_i^2 \sum_{j=1}^{\infty} \left[\gamma \beta_i \rho_i^{2j-1} \frac{1-A_i^{j+1}}{1-A_i} + (1-\gamma) \hat{\beta}_i \rho_i^{2j-1} \frac{1-A_i^j}{1-A_i} \right]$$

$$\text{Cov}[W_{t-1} x_{i,t-1}] = \sigma_i^2 \sum_{j=0}^{\infty} \left[\gamma \beta_i \rho_i^{2j} \frac{1-A_i^{j+1}}{1-A_i} + (1-\gamma) \hat{\beta}_i \rho_i^{2j} \frac{1-A_i^j}{1-A_i} \right]$$

Variables not included:

$$\text{Cov}[W_t x_{i,t-1}] = \gamma\beta_i\sigma_i^2 \sum_{j=1}^{\infty} \rho_i^{2j-1} \frac{1-A_i^{j+1}}{1-A_i}$$

$$\text{Cov}[W_{t-1} x_{i,t-1}] = \gamma\beta_i\sigma_i^2 \sum_{j=0}^{\infty} \rho_i^{2j} \frac{1-A_i^{j+1}}{1-A_i}$$

$$\begin{aligned}\text{Var}[W_{t-1}] = &\sum_{i=1}^{I} \sigma_i^2 \sum_{j=0}^{\infty} \left[\gamma^2\beta_i^2\rho_i^{2j} \frac{1-2A_i^{j+1}+A_i^{2j+2}}{1-2A_i+A_i^2} + 2\gamma(1-\gamma)\beta_i\hat{\beta}_i\rho_i^{2j} \frac{1-A_i^{j}-A_i^{j+1}+A_i^{2j+1}}{1-2A_i+A_i^2} \right. \\ &\left. + (1-\gamma)^2\hat{\beta}_i^2\rho_i^{2j} \frac{1-2A_i^{j}+A_i^{2j}}{1-2A_i+A_i^2} \right] \\ &+ \gamma^2 \sum_{i=I+1}^{N} \beta_i^2\sigma_i^2 \sum_{j=0}^{\infty} \left[\rho_i^{2j} \frac{1-2A_i^{j+1}+A_i^{2j+2}}{1-2A_i+A_i^2} \right] + \nu^2 .\end{aligned}$$

$$\begin{aligned}\text{Cov}[W_t W_{t-1}] = &\sum_{i=1}^{I} \sigma_i^2 \left[\sum_{j=1}^{\infty} \gamma^2\beta_i^2\rho_i^{2j-1} \frac{1-A_i^{j}-A_i^{j+1}+A_i^{2j+1}}{1-2A_i+A_i^2} + \gamma(1-\gamma)\beta_i\hat{\beta}_i\rho_i^{2j-1} \frac{1-A_i^{j-1}-A_i^{j+1}+A_i^{2j}}{1-2A_i+A_i^2} \right. \\ &\left. + \gamma(1-\gamma)\beta_i\hat{\beta}_i\rho_i^{2j-1} \frac{1-2A_i^{j}+A_i^{2j}}{1-2A_i+A_i^2} + (1-\gamma)^2\hat{\beta}_i^2\rho_i^{2j-1} \frac{1-A_i^{j-1}-A_i^{j}+A_i^{2j-1}}{1-2A_i+A_i^2} \right] \\ &+ \gamma^2 \sum_{i=I+1}^{N} \beta_i^2\sigma_i^2 \sum_{j=1}^{\infty} \left[\rho_i^{2j-1} \frac{1-A_i^{j}-A_i^{j+1}+A_i^{2j+1}}{1-2A_i+A_i^2} \right].\end{aligned}$$

$$W_t - W_t^e = W_t - \alpha W_{t-1} - \sum_{i=1}^{I*} \hat{\beta}_i^* \rho_i x_{i,t-1}$$

$$\begin{aligned}W_t - W_t^e = &\sum_{i=1}^{I} \sum_{j=0}^{\infty} \left[\gamma\beta_i\rho_i^{j} \frac{1-A_i^{j+1}}{1-A_i} + (1-\gamma)\hat{\beta}_i\rho_i^{j} \frac{1-A_i^{j}}{1-A_i} \right] e_{i,t-j} \\ &+ \gamma \sum_{i=I+1}^{N} \beta_i \sum_{j=0}^{\infty} \rho_i^{j} \frac{1-A_i^{j+1}}{1-A_i} e_{i,t-j} + \varepsilon_t \\ &- \alpha \sum_{i=1}^{I} \sum_{j=1}^{\infty} \left[\gamma\beta_i\rho_i^{j-1} \frac{1-A_i^{j}}{1-A_i} + (1-\gamma)\hat{\beta}_i\rho_i^{j-1} \frac{1-A_i^{j-1}}{1-A_i} \right] e_{i,t-j} \\ &- \alpha\gamma \sum_{i=I+1}^{N} \beta_i \sum_{j=1}^{\infty} \rho_i^{j-1} \frac{1-A_i^{j}}{1-A_i} e_{i,t-j} - \alpha\varepsilon_{t-1} - \sum_{i=1}^{I*} \hat{\beta}_i^* \rho_i \sum_{j=1}^{\infty} \rho_i^{j-1} e_{i,t-j}\end{aligned}$$

$$W_t - W_t^e = \gamma \sum_{i=1}^{N} \beta_i e_{i,t} + \sum_{i=1}^{I} \sum_{j=1}^{\infty} \left[\gamma \beta_i \rho_i^j \frac{1-A_i^{j+1}}{1-A_i} + (1-\gamma)\hat{\beta}_i \rho_i^j \frac{1-A_i^j}{1-A_i} \right] e_{i,t-j}$$
$$+ \gamma \sum_{i=I+1}^{N} \beta_i \sum_{j=1}^{\infty} \rho_i^j \frac{1-A_i^{j+1}}{1-A_i} e_{i,t-j} + \varepsilon_t$$
$$- \alpha \sum_{i=1}^{I} \sum_{j=1}^{\infty} \left[\gamma \beta_i \rho_i^{j-1} \frac{1-A_i^j}{1-A_i} + (1-\gamma)\hat{\beta}_i \rho_i^{j-1} \frac{1-A_i^{j-1}}{1-A_i} \right] e_{i,t-j}$$
$$- \alpha\gamma \sum_{i=I+1}^{N} \beta_i \sum_{j=1}^{\infty} \rho_i^{j-1} \frac{1-A_i^j}{1-A_i} e_{i,t-j} - \alpha \varepsilon_{t-1} - \sum_{i=1}^{I^*} \hat{\beta}_i^* \rho_i \sum_{j=1}^{\infty} \rho_i^{j-1} e_{i,t-j}$$

$$W_t - W_t^e = \gamma \sum_{i=1}^{N} \beta_i e_{i,t} + \sum_{i=1}^{I} \sum_{j=1}^{\infty} \left[\gamma \beta_i \rho_i^{j-1} \frac{\rho_i - \alpha + \alpha\gamma A_i^j}{1-A_i} + (1-\gamma)\hat{\beta}_i \rho_i^{j-1} \frac{\rho_i - \alpha + \alpha\gamma A_i^{j-1}}{1-A_i} - \hat{\beta}_i^* \rho_i^j \right] e_{i,t-j}$$
$$+ \gamma \sum_{i=I+1}^{N} \beta_i \sum_{j=1}^{\infty} \rho_i^{j-1} \frac{\rho_i - \alpha + \alpha\gamma A_i^j}{1-A_i} e_{i,t-j} + \varepsilon_t - \alpha \varepsilon_{t-1}$$

If $I^*=I$,

$$W_t - W_t^e = \gamma \sum_{i=1}^{N} \beta_i e_{i,t}$$
$$+ \sum_{i=1}^{I} \frac{1}{1-A_i} \sum_{j=1}^{\infty} \rho_i^{j-1} \left[\gamma \beta_i (\rho_i - \alpha + \alpha\gamma A_i^j) + (1-\gamma)\hat{\beta}_i (\rho_i - \alpha + \alpha\gamma A_i^{j-1}) - \hat{\beta}_i \rho_i (1-A_i) \right] e_{i,t-j}$$
$$+ \gamma \sum_{i=I+1}^{N} \beta_i \sum_{j=1}^{\infty} \rho_i^{j-1} \frac{\rho_i - \alpha + \alpha\gamma A_i^j}{1-A_i} e_{i,t-j} + \varepsilon_t - \alpha \varepsilon_{t-1}$$

$$W_t - W_t^e = \gamma \sum_{i=1}^{N} \beta_i e_{i,t}$$
$$+ \sum_{i=1}^{I} \frac{1}{1-A_i} \sum_{j=1}^{\infty} \gamma \rho_i^{j-1} \left[\beta_i (\rho_i - \alpha + \alpha\gamma A_i^j) + (1-\gamma)\hat{\beta}_i \alpha A_i^{j-1} - \hat{\beta}_i \rho_i \right] e_{i,t-j}$$
$$+ \gamma \sum_{i=I+1}^{N} \beta_i \sum_{j=1}^{\infty} \rho_i^{j-1} \frac{\rho_i - \alpha + \alpha\gamma A_i^j}{1-A_i} e_{i,t-j} + \varepsilon_t - \alpha \varepsilon_{t-1}$$

$$E[W_t - W_t^e]^2 = \gamma^2 \sum_{i=1}^{N} \beta_i^2 \sigma_i^2 + \sum_{i=1}^{I} \Bigg(\frac{\sigma_i^2}{(1-A_i)^2} \sum_{j=1}^{\infty} \gamma^2 \rho_i^{2j-2} \Big[\beta_i^2 (\rho_i - \alpha)^2 + 2\beta_i^2 (\rho_i - \alpha)\alpha\gamma A_i^j + \beta_i^2 \alpha^2 \gamma^2 A_i^{2j}$$

$$+ (1-\gamma)^2 \hat{\beta}_i^2 \alpha^2 A_i^{2j-2} + \hat{\beta}_i^2 \rho_i^2 + 2\beta_i \hat{\beta}_i (1-\gamma)\alpha(\rho_i A_i^{j-1} - \alpha A_i^{j-1} + \alpha\gamma A_i^{2j-1})$$

$$- 2\beta_i \hat{\beta}_i \rho_i (\rho_i - \alpha + \alpha\gamma A_i^j) - 2\hat{\beta}_i^2 (1-\gamma)\alpha\rho_i A_i^{j-1} \Big] \Bigg)$$

$$+ \gamma^2 \sum_{i=I+1}^{N} \frac{\beta_i^2 \sigma_i^2}{(1-A_i)^2} \sum_{j=1}^{\infty} \rho_i^{2j-2} \Big[(\rho_i - \alpha)^2 + 2(\rho_i - \alpha)\alpha\gamma A_i^j + \alpha^2 \gamma^2 A_i^{2j} \Big] + \nu^2 + \alpha^2 \nu^2 .$$

If $I^* < I$,

$$W_t - W_t^e = \gamma \sum_{i=1}^{N} \beta_i e_{i,t} + \sum_{i=1}^{I} \sum_{j=1}^{\infty} \left[\gamma \beta_i \rho_i^j \frac{1-A_i^{j+1}}{1-A_i} + (1-\gamma)\hat{\beta}_i \rho_i^j \frac{1-A_i^j}{1-A_i} \right] e_{i,t-j}$$

$$+ \gamma \sum_{i=I+1}^{N} \beta_i \sum_{j=1}^{\infty} \rho_i^j \frac{1-A_i^{j+1}}{1-A_i} e_{i,t-j} + \varepsilon_t$$

$$- \alpha^* \sum_{i=1}^{I} \sum_{j=1}^{\infty} \left[\gamma \beta_i \rho_i^{j-1} \frac{1-A_i^j}{1-A_i} + (1-\gamma)\hat{\beta}_i \rho_i^{j-1} \frac{1-A_i^{j-1}}{1-A_i} \right] e_{i,t-j}$$

$$- \alpha^* \gamma \sum_{i=I+1}^{N} \beta_i \sum_{j=1}^{\infty} \rho_i^{j-1} \frac{1-A_i^j}{1-A_i} e_{i,t-j} - \sum_{i=1}^{I^*} \hat{\beta}_i^* \rho_i \sum_{j=1}^{\infty} \rho_i^{j-1} e_{i,t-j}$$

$$W_t - W_t^e = \gamma \sum_{i=1}^{N} \beta_i e_{i,t}$$

$$+ \sum_{i=1}^{I^*} \frac{1}{1-A_i} \sum_{j=1}^{\infty} \Big[\gamma \beta_i \rho_i^{j-1} [\rho_i - \alpha^* + (\alpha^* - \rho_i A_i) A_i^j]$$

$$+ (1-\gamma)\hat{\beta}_i \rho_i^{j-1} [\rho_i - \alpha^* + (\alpha^* - \rho_i A_i) A_i^{j-1}] - \hat{\beta}_i^* \rho_i^j (1-A_i) \Big] e_{i,t-j}$$

$$+ \sum_{i=I^*+1}^{I} \frac{1}{1-A_i} \sum_{j=1}^{\infty} \Big[\gamma \beta_i \rho_i^{j-1} [\rho_i - \alpha^* + (\alpha^* - \rho_i A_i) A_i^j]$$

$$+ (1-\gamma)\hat{\beta}_i \rho_i^{j-1} [\rho_i - \alpha^* + (\alpha^* - \rho_i A_i) A_i^{j-1}] \Big] e_{i,t-j}$$

$$+ \gamma \sum_{i=I+1}^{N} \frac{\beta_i}{1-A_i} \sum_{j=1}^{\infty} \rho_i^{j-1} [\rho_i - \alpha^* + (\alpha^* - \rho_i A_i) A_i^j] e_{i,t-j} + \varepsilon_t$$

If *I*>I*,

$$
\begin{aligned}
W_t - W_t^e &= \gamma \sum_{i=1}^{N} \beta_i e_{i,t} + \sum_{i=1}^{I} \sum_{j=1}^{\infty} \left[\gamma \beta_i \rho_i^j \frac{1-A_i^{j+1}}{1-A_i} + (1-\gamma)\hat{\beta}_i \rho_i^j \frac{1-A_i^j}{1-A_i} \right] e_{i,t-j} \\
&\quad + \gamma \sum_{i=I+1}^{N} \beta_i \sum_{j=1}^{\infty} \rho_i^j \frac{1-A_i^{j+1}}{1-A_i} e_{i,t-j} + \varepsilon_t \\
&\quad - \alpha^* \sum_{i=1}^{I} \sum_{j=1}^{\infty} \left[\gamma \beta_i \rho_i^{j-1} \frac{1-A_i^j}{1-A_i} + (1-\gamma)\hat{\beta}_i \rho_i^{j-1} \frac{1-A_i^{j-1}}{1-A_i} \right] e_{i,t-j} \\
&\quad - \alpha^* \gamma \sum_{i=I+1}^{N} \beta_i \sum_{j=1}^{\infty} \rho_i^{j-1} \frac{1-A_i^j}{1-A_i} e_{i,t-j} - \sum_{i=1}^{I^*} \hat{\beta}_i^* \rho_i \sum_{j=1}^{\infty} \rho_i^{j-1} e_{i,t-j}
\end{aligned}
$$

$$
\begin{aligned}
W_t - W_t^e &= \gamma \sum_{i=1}^{N} \beta_i e_{i,t} \\
&\quad + \sum_{i=1}^{I} \frac{1}{1-A_i} \sum_{j=1}^{\infty} \Big[\gamma \beta_i \rho_i^{j-1} [\rho_i - \alpha^* + (\alpha^* - \rho_i A_i) A_i^j] \\
&\qquad\qquad + (1-\gamma)\hat{\beta}_i \rho_i^{j-1} [\rho_i - \alpha^* + (\alpha^* - \rho_i A_i) A_i^{j-1}] - \hat{\beta}_i^* \rho_i^j (1-A_i) \Big] e_{i,t-j} \\
&\quad + \sum_{i=I+1}^{I^*} \frac{1}{1-A_i} \sum_{j=1}^{\infty} \Big[\gamma \beta_i \rho_i^{j-1} [\rho_i - \alpha^* + (\alpha^* - \rho_i A_i) A_i^j] - \hat{\beta}_i^* \rho_i^j (1-A_i) \Big] e_{i,t-j} \\
&\quad + \gamma \sum_{i=I^*+1}^{N} \frac{\beta_i}{1-A_i} \sum_{j=1}^{\infty} \rho_i^{j-1} [\rho_i - \alpha^* + (\alpha^* - \rho_i A_i) A_i^j] e_{i,t-j} + \varepsilon_t
\end{aligned}
$$

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Table 1
Estimated Coefficients on Lagged Average Wages and Macroeconomic Variables

	$\beta_1 = 0.45$, $\beta_2 = 0.33$, $\beta_3 = 0.22$, γ=0.5 $\sigma_1^2 = .03$, $\sigma_2^2 = .03$, $\sigma_3^2 = .03$, $\nu^2 = .03$				$\beta_1 = 0.45$, $\beta_2 = 0.33$, $\beta_3 = 0.22$, γ=0.5 $\sigma_1^2 = .10$, $\sigma_2^2 = .10$, $\sigma_3^2 = .10$, $\nu^2 = .03$			
	# of included variables, rep. worker				# of included variables, rep. worker			
	3	2	1	0	3	2	1	0
ρ_1=0.95 ρ_2=0.95 ρ_3=0.95	α=0 β_1=0.45 β_2=0.33 β_3=0.22	α=0.113 β_1=0.399 β_2=0.293	α=0.350 β_1=0.292	α=0.642	α=0 β_1=0.45 β_2=0.33 β_3=0.22	α=0.330 β_1=0.301 β_2=0.221	α=0.728 β_1=0.122	α=0.886
ρ_1=0.95 ρ_2=0.95 ρ_3=0.50	α=0 β_1=0.45 β_2=0.33 β_3=0.22	α=0.008 β_1=0.447 β_2=0.327	α=0.256 β_1=0.335	α=0.594	α=0 β_1=0.45 β_2=0.33 β_3=0.22	α=0.024 β_1=0.439 β_2=0.322	α=0.621 β_1=0.170	α=0.869
ρ_1=0.95 ρ_2=0.50 ρ_3=0.95	α=0 β_1=0.45 β_2=0.33 β_3=0.22	α=0.114 β_1=0.399 β_2=0.283	α=0.130 β_1=0.392	α=0.522	α=0 β_1=0.45 β_2=0.33 β_3=0.22	α=0.338 β_1=0.298 β_2=0.191	α=0.373 β_1=0.282	α=0.838
ρ_1=0.50 ρ_2=0.95 ρ_3=0.95	α=0 β_1=0.45 β_2=0.33 β_3=0.22	α=0.115 β_1=0.386 β_2=0.292	α=0.355 β_1=0.250	α=0.375	α=0 β_1=0.45 β_2=0.33 β_3=0.22	α=0.345 β_1=0.256 β_2=0.216	α=0.743 β_1=0.032	α=0.748
ρ_1=0.50 ρ_2=0.50 ρ_3=0.50	α=0 β_1=0.45 β_2=0.33 β_3=0.22	α=0.008 β_1=0.446 β_2=0.327	α=0.026 β_1=0.436	α=0.057	α=0 β_1=0.45 β_2=0.33 β_3=0.22	α=0.026 β_1=0.436 β_2=0.319	α=0.080 β_1=0.405	α=0.171
	$\beta_1 = 1/3$, $\beta_2 = 1/3$, $\beta_3 = 1/3$, γ=0.5 $\sigma_1^2 = .03$, $\sigma_2^2 = .03$, $\sigma_3^2 = .03$, $\nu^2 = .03$				$\beta_1 = 1/3$, $\beta_2 = 1/3$, $\beta_3 = 1/3$, γ=0.5 $\sigma_1^2 = .10$, $\sigma_2^2 = .10$, $\sigma_3^2 = .10$, $\nu^2 = .03$			
ρ_1=0.95 ρ_2=0.95 ρ_3=0.95	α=0 β_1=0.333 β_2=0.333 β_3=0.333	α=0.254 β_1=0.248 β_2=0.248	α=0.468 β_1=0.177	α=0.616	α=0 β_1=0.333 β_2=0.333 β_3=0.333	α=0.622 β_1=0.126 β_2=0.126	α=0.812 β_1=0.062	α=0.878

Table 1
Estimated Coefficients on Lagged Average Wages and Macroeconomic Variables
(con't)

	$\beta_1 = 0.45$, $\beta_2 = 0.33$, $\beta_3 = 0.22$, γ=0.5 $\sigma_1^2 = .03$, $\sigma_2^2 = .03$, $\sigma_3^2 = .03$, $\nu^2 = .10$				$\beta_1 = 0.45$, $\beta_2 = 0.33$, $\beta_3 = 0.22$, γ=0.5 $\sigma_1^2 = .10$, $\sigma_2^2 = .10$, $\sigma_3^2 = .10$, $\nu^2 = .10$			
	# of included variables, rep. worker				# of included variables, rep. worker			
	3	2	1	0	3	2	1	0
ρ_1=0.95 ρ_2=0.95 ρ_3=0.95	α=0 β_1=0.45 β_2=0.33 β_3=0.22	α=0.035 β_1=0.434 β_2=0.318	α=0.113 β_1=0.399	α=0.254	α=0 β_1=0.45 β_2=0.33 β_3=0.22	α=0.113 β_1=0.399 β_2=0.293	α=0.350 β_1=0.292	α=0.642
ρ_1=0.95 ρ_2=0.95 ρ_3=0.50	α=0 β_1=0.45 β_2=0.33 β_3=0.22	α=0.002 β_1=0.449 β_2=0.329	α=0.081 β_1=0.414	α=0.223	α=0 β_1=0.45 β_2=0.33 β_3=0.22	α=0.008 β_1=0.447 β_2=0.327	α=0.256 β_1=0.335	α=0.594
ρ_1=0.95 ρ_2=0.50 ρ_3=0.95	α=0 β_1=0.45 β_2=0.33 β_3=0.22	α=0.035 β_1=0.434 β_2=0.316	α=0.040 β_1=0.432	α=0.184	α=0 β_1=0.45 β_2=0.33 β_3=0.22	α=0.114 β_1=0.399 β_2=0.283	α=0.130 β_1=0.392	α=0.522
ρ_1=0.50 ρ_2=0.95 ρ_3=0.95	α=0 β_1=0.45 β_2=0.33 β_3=0.22	α=0.035 β_1=0.430 β_2=0.318	α=0.114 β_1=0.386	α=0.123	α=0 β_1=0.45 β_2=0.33 β_3=0.22	α=0.115 β_1=0.386 β_2=0.292	α=0.355 β_1=0.250	α=0.375
ρ_1=0.50 ρ_2=0.50 ρ_3=0.50	α=0 β_1=0.45 β_2=0.33 β_3=0.22	α=0.002 β_1=0.449 β_2=0.329	α=0.008 β_1=0.446	α=0.018	α=0 β_1=0.45 β_2=0.33 β_3=0.22	α=0.008 β_1=0.446 β_2=0.327	α=0.026 β_1=0.436	α=0.057
	$\beta_1 = 1/3$, $\beta_2 = 1/3$, $\beta_3 = 1/3$, γ=0.5 $\sigma_1^2 = .03$, $\sigma_2^2 = .03$, $\sigma_3^2 = .03$, $\nu^2 = .10$				$\beta_1 = 1/3$, $\beta_2 = 1/3$, $\beta_3 = 1/3$, γ=0.5 $\sigma_1^2 = .10$, $\sigma_2^2 = .10$, $\sigma_3^2 = .10$, $\nu^2 = .10$			
ρ_1=0.95 ρ_2=0.95 ρ_3=0.95	α=0 β_1=0.333 β_2=0.333 β_3=0.333	α=0.080 β_1=0.307 β_2=0.307	α=0.159 β_1=0.280	α=0.236	α=0 β_1=0.333 β_2=0.333 β_3=0.333	α=0.254 β_1=0.248 β_2=0.248	α=0.468 β_1=0.177	α=0.616

Table 2
Sum of Squared Errors

	$\beta_1 = 0.45$, $\beta_2 = 0.33$, $\beta_3 = 0.22$, γ=0.5			
	$\sigma_1^2 = \sigma_2^2 = \sigma_3^2 = .03$ $\nu^2 = .03$	$\sigma_1^2 = \sigma_2^2 = \sigma_3^2 = .10$ $\nu^2 = .03$	$\sigma_1^2 = \sigma_2^2 = \sigma_3^2 = .03$ $\nu^2 = .10$	$\sigma_1^2 = \sigma_2^2 = \sigma_3^2 = .10$ $\nu^2 = .10$
ρ_1=0.95 ρ_2=0.95 ρ_3=0.95	E_3=0.03270 E_2=0.03604 E_1=0.04304 E_0=0.05172	E_3=0.03900 E_2=0.04952 E_1=0.06203 E_0=0.06699	E_3=0.10270 E_2=0.10606 E_1=0.11357 E_0=0.12710	E_3=0.10900 E_2=0.12013 E_1=0.14348 E_0=0.17240
ρ_1=0.95 ρ_2=0.95 ρ_3=0.50	E_3=0.03270 E_2=0.03282 E_1=0.04017 E_0=0.05023	E_3=0.03900 E_2=0.03940 E_1=0.05840 E_0=0.06625	E_3=0.10270 E_2=0.10282 E_1=0.11036 E_0=0.12406	E_3=0.10900 E_2=0.10940 E_1=0.13390 E_0=0.16743
ρ_1=0.95 ρ_2=0.50 ρ_3=0.95	E_3=0.03270 E_2=0.03604 E_1=0.03630 E_0=0.04795	E_3=0.03900 E_2=0.04954 E_1=0.05014 E_0=0.06502	E_3=0.10270 E_2=0.10606 E_1=0.10633 E_0=0.12018	E_3=0.10900 E_2=0.12013 E_1=0.12101 E_0=0.15983
ρ_1=0.50 ρ_2=0.95 ρ_3=0.95	E_3=0.03270 E_2=0.03604 E_1=0.04305 E_0=0.04340	E_3=0.03900 E_2=0.04955 E_1=0.06167 E_0=0.06170	E_3=0.10270 E_2=0.10606 E_1=0.11357 E_0=0.11407	E_3=0.10900 E_2=0.12014 E_1=0.14351 E_0=0.14468
ρ_1=0.50 ρ_2=0.50 ρ_3=0.50	E_3=0.03270 E_2=0.03282 E_1=0.03309 E_0=0.03360	E_3=0.03900 E_2=0.03940 E_1=0.04030 E_0=0.04190	E_3=0.10270 E_2=0.10282 E_1=0.10309 E_0=0.10360	E_3=0.10900 E_2=0.10940 E_1=0.11031 E_0=0.11198
	$\beta_1 = 1/3$, $\beta_2 = 1/3$, $\beta_3 = 1/3$, γ=0.5			
ρ_1=0.95 ρ_2=0.95 ρ_3=0.95	E_3=0.03250 E_2=0.04001 E_1=0.04633 E_0=0.05073	E_3=0.03833 E_2=0.05790 E_1=0.06385 E_0=0.06590	E_3=0.10250 E_2=0.11020 E_1=0.11780 E_0=0.12519	E_3=0.10833 E_2=0.13337 E_1=0.15442 E_0=0.16909

Footnotes

[1] Conlisk (1988) discusses theoretical reasons for why rational behavior may result in expectations that are not unbiased. Under the assumption that it is costly to form accurate expectations of next period's price, he demonstrates that optimal forecasts may be a weighted average of an unbiased estimate obtained from agents' costly optimization activities and a "free estimator," which may be determined from an adaptive expectations process. However, Conlisk does not identify the benefits of information.

[2] Mullineaux (1980) and Gramlich (1983) find that, controlling for lagged inflation, other macroeconomic variables have significant effects on expectations, which suggests that economists and households use more than just past inflation to predict future inflation. Additional evidence that expectations are not purely adaptive comes from Baghestani and Noori (1988), who find that survey respondents predict inflation more accurately than an ARIMA model, implying that their expectations depend on more than just lagged inflation.

[3] Fuhrer (1997) estimates Phillips curves in which expected inflation depends on a weighted average of lagged inflation and actual future inflation. He can reject the hypothesis that expectations are completely rational, but cannot reject the hypothesis that they are completely adaptive. However, he demonstrates that inflation dynamics are predicted more accurately by a model with mixed rational and adaptive expectations than by a model with completely adaptive expectations. Roberts (1998) shows that survey forecasts of inflation can be explained by a model in which part of the population has rational expectations and the rest has adaptive expectations.

[4] Blundell and MaCurdy (1999) report on previous estimates of labor supply elasticities in Tables 1 and 2 of their study. The average uncompensated labor supply elasticity reported in these tables is 0.086 for men and 0.689 for married women. In addition, Card (1991, p. 22) reviews several previous studies of labor supply and concludes, "Taken together, the literature suggests that the elasticity of intertemporal substitution is surely no higher than 0.5, and probably no higher than 0.20."

[5] As discussed in Yellen (1984) and Ball and Romer (1990), efficiency wage models in which efficiency depends on real wages explain real wage rigidity.

[6] Effort may depend on the variance of the wage distribution as well as its mean. However, workers are probably more concerned with the mean than with the variance, so this study does not consider the effect of the variance.

[7] In addition, if price inflation data are more highly publicized than wage inflation data and if wage inflation and price inflation are highly correlated, it could be assumed that workers observe lagged price inflation at no cost and form their expectations of average wages from data on lagged price inflation.

[8] If workers expect their own wages and average wages to grow at different rates, then W_t and $\overline{W}_t^T$ should be viewed as the present value of wages.)

[9] For example, if the utility loss is represented by the quadratic equation, $VL = \theta(\overline{W}_t^E - \overline{W}_t^T)^2$, then $VL''(0) = 2\theta$. In the analysis in Section III, $VL(\overline{W}_t^E - \overline{W}_t^T)$ is treated as a general functional form. However, an equation representing this loss can be obtained if specific assumptions are made about the utility function of workers. In an unpublished appendix, the effort model of Campbell (2006) is used to derive a specific expression for $VL(\overline{W}_t^E - \overline{W}_t^T)$. (This appendix is available from the author upon request.)

[10] The equation $VL'(0) = 0$ is obtained from the relationship $VL' = dVL / d\overline{W}^E = (\partial VL / \partial e)(\partial e / \partial \overline{W}^E)$, where $\partial VL / \partial e = 0$ at the point $\overline{W}^E = \overline{W}^T$.

[11] Consistent with these results, Sethi and Franke (1995) develop a model in which agents can choose whether to use a costless adaptive expectations procedure or pay to acquire information that allows them to predict the true outcome with certainty. They find that agents are more likely to acquire this information when optimization costs are low or when the economy is characterized by a "high degree of exogenous variability."

[12] According to the U.S. Census Bureau (2000), there were 4,051,598 18 year-olds in 2000.

[13] The upper right-hand element of $\mathbf{X'X}$ is the variance of W_{t-1}, the other diagonal elements are the variances of the macroeconomic variables, the elements on the first row and on the first column (except the upper right) are the covariances between W_{t-1} and the macroeconomic variables, and the other elements of the matrix are 0.

[14] If workers use all three macroeconomic variables, $\hat{\mathbf{b}}$ and $\mathbf{X'W}$ will be 4x1 vectors and $\mathbf{X'X}$ will be a 4x4 matrix; if they use two of the macroeconomic variables, $\hat{\mathbf{b}}$ and $\mathbf{X'W}$ will be 3x1 vectors and $\mathbf{X'X}$ will be a 3x3 matrix; etc.

[15] Since the macroeconomic variables are constructed to be orthogonal to one another, unbiased expectations when $0<I<3$ would mean that $\hat{\beta}_i = \beta_i$ for each of the included macroeconomic variables.

[16] In Campbell and Kamlani's (1997) and Bewley's (1999) surveys of employers, respondents indicated that they viewed labor turnover as being much more important than shirking in explaining wage rigidity.
[17] Ball, Mankiw, and Romer (1988) perform a similar cross-country analysis in which they estimate the degree to which nominal shocks raise real output for 43 countries, and they find that the tradeoff parameter depends negatively on the average inflation rate. They attribute the effect of inflation on the tradeoff parameter to the fact that prices may be changed more frequently in economies characterized by high inflation. Another interpretation for this finding, which is more in line with the present study, is that high rates of inflation may affect the frequency with which workers receive wage increases.