A Note on Nominal Wage Rigidity and Real Wage Cyclicality

Marcello M. Estevão

Beth Anne Wilson*

Board of Governors of the Federal Reserve System

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Abstract: We discuss the ability of standard estimates of the correlation of wages and employment to measure the relative strength of aggregate demand and supply shocks, given that the choice of time period, deflator, and explanatory variables inherently biases the estimated cyclical coefficients toward identifying labor supply or demand. We determine that a closer look at the standard wage/labor correlation shows that it can neither provide information on the relative strength of supply and demand shocks, nor give an indication of the response of wages to aggregate demand shocks. Following this, we test the predictions of a neo-Keynesian model for the correlation of employment and wages using restrictions generated by the model to identify movements along or shifts in labor demand. Our results are consistent with the theory of nominal wage rigidity and we find no reason to reject the neo-Keynesian model based on the correlation of wages and employment.

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I. Introduction

Surprisingly, empirical studies of wage cyclicality are not derived from the models they are used to test. While most labor market models impose structure on the relationship between wages and cyclical variables, the common econometric strategy is to use the correlation of employment and real wages as a sufficient statistic for evaluating theory. A notable result of this strategy has been the strong rejection of theories of nominal wage rigidity because of the finding of slightly procyclical real wages.

Simply put, the Keynesian prediction that real wages move counter to the cycle begins with the assumption that aggregate demand shocks drive the business cycle. In this case, firms respond to the shocks by changing employment along their labor demand curve, given that nominal wages are rigid in the short run. Because the labor demand curve is negatively sloped, real wages will move countercyclically. Two questions arise in testing such an hypothesis: One, are aggregate demand shocks the driving force of the business cycle? And two, in response to aggregate demand shocks, will wages move countercyclically? By using the correlation of real wages and labor input, much of the empirical work on wage cyclicality has implicitly focused on the first question. But, the results are commonly viewed as answering the second.

This empirical approach is problematic, however, because it side steps the issue of specification. A closer look at the standard wage/labor correlation shows that it can neither provide information on the relative strength of supply and demand shocks, nor give an indication of the response of wages to aggregate demand shocks. To show this, we begin with an equation for the standard test of wage cyclicality:

$$(1) \quad w = \gamma n + \nu$$

where w is the real wage, n is the labor input, and ν is a stochastic error. The sign of estimates of γ is viewed as a test of the predictions of various models and as a summary statistic of the relative volatility of aggregate demand and supply shocks. If labor supply and labor demand are represented by equations (2):

$$(2) \quad (LS)\ w = \beta n + \mu \qquad (LD)\ w = -\alpha n + \epsilon$$

where μ represents shocks to labor supply (or aggregate demand shocks in a Keynesian framework) and ϵ captures shocks to labor demand (or aggregate supply shocks), then the probability limit of estimates of γ in equation (1) is,

$$(3) \quad plim(\hat{\gamma}) = \frac{\beta\sigma_\epsilon^2 - \alpha\sigma_\mu^2}{\sigma_\epsilon^2 + \sigma_\mu^2} .$$

The interpretation of the sign of estimates of γ as the strength of aggregate supply shocks (σ_ϵ^2) versus aggregate demand shocks (σ_μ^2) is now clear, but only if β and α are of equal magnitudes.

A more serious problem is evident when labor supply and demand are better specified. For example, an improved model of the labor market distinguishes between consumption real wages (w) and product real wage (w_p). If $w = w_p + \delta$, then the new labor demand equation would be:

$$(4)\quad (LD)\ w_p = -\alpha n + \epsilon \ \Rightarrow\ w = -\alpha n + \epsilon + \delta\ .$$

Assuming that ϵ and δ are independent, equation (3) becomes

$$(5)\quad plim(\hat{\gamma}) = \frac{\beta(\sigma_\epsilon^2 + \sigma_\delta^2) - \alpha\sigma_\mu^2}{\sigma_\epsilon^2 + \sigma_\delta^2 + \sigma_\mu^2}\ .$$

Notice that, if the difference between consumption and product wages is relevant, the resulting estimate of γ is positively biased. γ is now a bad summary statistic for the relative strength of demand and supply shocks, regardless of the elasticities of labor supply and demand. Additional improvements to the specification of labor demand and supply would just add further complexity to the interpretation of estimates of γ.

Practically, when estimating the average correlation between employment and real wages, a choice must be made as to time period, wage measure, and deflator. As suggested by equation (5), depending on the wage measure and the deflators used, one goes in the direction of identifying labor demand or labor supply rather than some unbiased measure of the relative strength of aggregate demand and supply shocks. By using the CPI or the GDP deflator, excluding the price of other inputs and technology, and by estimating over periods dominated by supply shocks, the results in much of the recent wage cyclicality literature are implicitly biased toward identifying labor supply.[1]

While a simple result, it shows the futility of using wage/labor correlations to evaluate the performance of macroeconomic models. Given the problems with the interpretation of the correlation, we outline a different test of nominal wage rigidity models, one that uses a simple structural model for the labor market to test whether in response to aggregate demand shocks, wages move countercyclically.

II. Model specification and the identification strategy

The model is a standard one.[2] Firms and workers meet at the beginning of each time period and set wages so that expected labor demand equals expected labor supply. Once nominal wages are determined, aggregate supply and demand shocks are revealed. Firms are then free to hire the amount of labor that maximizes profit while wages are locked in by the original contract.[3] We assumed that workers meet firms' demand for hours--putting them off their labor supply. This type of model has strong implications for the identification of both labor demand and labor supply. Labor demand can be identified by using unexpected aggregate demand shocks as instruments since firms will change hours according to their optimal plans, tracing out the labor demand curve. To identify labor supply, we need to distinguish between changes in labor input when workers are off the labor supply curve and movements along the labor supply curve. To do this we use variables, such as lagged productivity, that are correlated with workers' expectations of wage and price changes but, by definition, not correlated to <u>unexpected</u> aggregate demand shocks.

These identification hypotheses can be shown by a formal derivation of both curves. Assuming that firms and workers intertemporally maximize profit and utility, respectively, and face costs to adjust the level of hours demanded and supplied, we get the following equations:

$$(6) \quad \Delta h_t^d = c^d + \alpha_1 \Delta h_{t-1} + \alpha_2 \Delta w_t^p + \alpha_3 \Delta w_{t-1}^p + \alpha_4 \Delta b_t + \alpha_5 \Delta k_t + \alpha_6 \Delta p_{it} + \epsilon_t$$

and

$$(7) \quad \Delta h_t^s = c^s + \beta_1 \Delta h_{t-1} + \beta_2 \Delta w_t^{ce} + \beta_3 \Delta w_{t-1}^c + \beta_4 \Delta r_t^{ce}$$

where Δ represents first differences and lowercase letters represent the logarithm of the respective variable. Here, h_t is hours of work; w^p_t is wage deflated by producer prices; b_t is a proxy for total factor productivity; k_t is capital stock; p_{it} represents the real price of intermediate inputs; w^{ce}_t and r^{ce}_t are, respectively, the wage and the interest rates deflated by <u>expected</u> consumer prices. ϵ_t represents productivity shocks not captured by our proxy and is assumed to be i.i.d.. Expected prices are used in the labor supply specification because at the beginning of period t individuals do not observe actual prices.

Because workers' expected prices are not observed, equation (7) cannot be estimated directly. Substituting actual for expected prices in (7) where μ_t represents i.i.d. unexpected price changes, we get

$$(8) \quad \Delta h_t^s = c^s + \beta_1 \Delta h_{t-1} + \beta_2 \Delta w_t^c + \beta_3 \Delta w_{t-1}^c + \beta_4 \Delta r_t^c + \mu_t \,.$$

Now the identification strategy is clearer. Unexpected variations in aggregate demand (i.e. $\mu_t \neq 0$) trace the labor demand curve and are assumed independent of unobserved technological shocks, $\epsilon_{t.}$ Because technological shocks are correlated with capital, productivity and price of other inputs in equation (6) we also need instruments for these terms. Assuming ϵ_t is i.i.d., lagged values of these variables can be used as instruments.

To identify labor supply, note that by definition μ_t is independent of any variable in the information set of individuals at t-1. Therefore, lagged variables can be used as instruments for real wages at t because they are uncorrelated with the residual. We will use lagged consumer prices and productivity to identify the labor supply equation because they are not just uncorrelated to price expectation errors but also correlated to real consumption wages. Since our use of lagged variables as instruments for both curves depends on the assumption that the residuals are i.i.d., the presence of serial correlation in the residuals of our instrumental variables specification would imply a rejection of the identification hypotheses and, consequently, of our model.

III. Estimates of labor demand and labor supply elasticities

To test the predictions of the model and our identification strategy, we estimate the labor demand curve, equation (6), using quarterly manufacturing data from 1960:2 to 1996:2. We use manufacturing data because labor demand is not well defined at the very aggregate level due to technological and market structure differences across sectors. Total manufacturing hours from the Bureau of Labor Statistics' Productivity and Cost data are used as a measure of labor input. Total compensation per hour in manufacturing, which includes wages and salaries of employees and employer contribution to social insurance and private pension plans, captures compensation costs for firms in their profit maximization process. The real wage and price of intermediate inputs are obtained by deflating labor compensation costs and the producer price index for intermediate inputs by the manufacturing PPI. b_t is proxied by manufacturing labor productivity while changes in the stock of capital are assumed to be picked up by the constant term since we do not have reliable measures of capital at the quarterly frequency.

Because labor demand may not be well defined, even at the aggregate manufacturing level, the second set of estimates used pooled annual data for 446 four-digit manufacturing industries from the NBER productivity database.[4] We use hours of production workers as the measure of labor input. Real product wage is equal to total wage bill divided by production worker hours and deflated by the sectoral producer price. By moving from an aggregate framework to an industry one, we can also control for industry characteristics that may affect the aggregate results. Furthermore, this database provides information on capital and total factor productivity and contains a better measure of the real price of intermediate inputs. The use of annual data makes the lag explanatory variables irrelevant in this specification.

To capture unexpected aggregate demand shocks and, thus, identify labor demand, current and lagged unexpected changes in the real federal funds rate are used as instruments for wages. The unexpected real interest rate series is obtained by estimating a one-step-ahead forecast of the real interest rate using lags of itself and of total civilian unemployment as explanatory variables. We also included a political business cycle dummy which takes the value of one, two years prior to an election, and zero otherwise. Interest rate surprises were defined as the difference between actual and forecasted real interest rates.

Regression results are presented in table 1. The table reports the sum of the wage and lagged wage coefficients and the F-statistic for the test that this sum is zero. All other estimated coefficients have the expected signs. The OLS estimate of the labor demand elasticity reported in column (1) is negative, but measured imprecisely. The estimated elasticity is larger in absolute value once interest rate shocks are used as instruments, column (2). Columns (3) and (4) present results obtained when using alternative measures of unexpected demand shocks. We use shocks in interest rates and non-borrowed reserves constructed by Christiano et al (1996).[5] As it can be seen, the results are insensitive to these alternative measures of unexpected aggregate demand shocks.

Column (5) shows IV estimates obtained when production worker hours in manufacturing are used as dependent variable, as opposed to total hours of work in manufacturing. Production worker hours are more sensitive to wage changes than total hours of work because some of total worker hours are used as overhead input. We include the chi-square statistic of the Lagrange Multiplier test for the existence of serial correlation in the residuals of the IV specification.[6] We reject the existence of serial correlation in our results and, consequently, accept the restrictions imposed by the model. Tests of overidentifying restrictions do not reject the hypothesis of orthogonality between the instruments used here and the residuals.

As we discussed earlier, labor demand may not be well defined at the aggregate manufacturing level and to better estimate labor demand we also used data at the 4-digit industry level for manufacturing. Table 2 shows the results using pooled sectoral data. Note that even using OLS, the estimated coefficient is much larger than in table 1. Using IV, the estimated coefficient, -0.892, is larger in absolute terms than the OLS estimate, following the same pattern observed in aggregate results.[7] The point estimate for the wage elasticity is quite close to the one obtained in the specification using aggregated data and production worker hours as a regressor.

The estimated elasticities of labor supply are shown in table 3. Quarterly aggregate civilian hours 1960:2 to 1996:2 are used as a measure of labor supply. Average hourly earnings, which includes overtime, are used as the relevant nominal wage[8] and the federal funds rate is the nominal interest rate measure. We deflated wages and interest rates by the consumer price index for urban workers. Lagged producer prices, real consumption wages, and productivity growth are used as instruments for the contemporaneous real consumption wage in order to identify labor supply. The estimated labor supply elasticity is significantly positive and even larger once our instruments are used. The elasticity of labor supply with respect to the interest rate is positive and significant, although very small. As in the case of labor demand, the reported χ^2 statistic implies that there is no serial correlation in the IV residuals. Finally, the model passes the overidentifying restrictions test.[9]

IV. Conclusions

As a whole, the identification restrictions suggested by the model provide sensible results. Carefully specifying the labor demand curve yields a negative correlation between wages and hours and identifying labor demand using aggregate demand shocks generates a stronger negative relationship. These results are especially striking at the sectoral level. One clear prediction of our nominal wage rigidity model is that such an identification strategy should lead to the observed larger negative response, in contrast with other models such as countercyclical markup models. In these models, an aggregate demand shock would lead to a shift in labor demand and cause real product wages and labor input to be positively related.[10]

Our results are equally striking for labor supply. Careful specification leads to a positive correlation between wages and labor that becomes even stronger when the curve is more properly identified.

Given the results, the importance of specification brings us full circle to the initial point that raw correlations of wages and employment do not provide good tests of macroeconomic models. Furthermore, our results are consistent with the existence of nominal wage rigidities and we find no reason to reject the neo-Keynesian model based on the correlation of wages and labor input.

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Table 1 - Results using Aggregate Manufacturing Data from 1960:2 to 1996:2

Labor Demand Specification	(1) OLS	(2) IV^a	(3) IV^b	(4) IV^c	(5) IV^d
$\Sigma \Delta w^p$	-0.074	-0.389	-0.545	-0.321	-0.717
(F-stat)	(0.26)	(0.38)	(0.44)	(0.14)	(0.73)
Δh_{-1}	0.614**	0.881**	0.917**	0.875**	0.828**
(T-stat)	(9.01)	(6.43)	(5.22)	(5.86)	(5.92)
Δp_o	0.133	-0.662	-0.662	-0.491	-1.032
(T-stat)	(1.13)	(-1.09)	(-0.76)	(-0.77)	(-1.30)
b	0.414**	1.987**	2.549**	2.146**	2.644**
(T-stat)	(3.18)	(3.39)	(2.85)	(2.83)	(3.46)
constant	-0.002*	-0.012**	-0.015*	-0.013**	-0.015
(T-stat)	(-1.78)	(-2.55)	(2.06)	(-2.35)	(-2.46)
R^2	0.40	---	---	---	---
$\chi^2(3)^e$	---	6.00	3.61	4.68	6.46
$\chi^2(1)^f$	---	2.90	2.47	2.19	3.51
Deg. of Freedom	139	139	121	121	139

[a] Dependent variable: All employee hours in manufacturing sector. Instruments used: contemporaneous and lagged unexpected changes in the 6-month federal funds rate and lagged productivity and price of intermediate inputs.
[b] Instruments used: contemporaneous and lagged unexpected changes in the 6-month federal funds rate taken from Christiano et al (1996) and lagged productivity and price of intermediate inputs.
[c] Instruments used: contemporaneous and lagged unexpected changes in non-borrowed reserves taken from Christiano et al (1996) and lagged productivity and price of intermediate inputs.
[d] Dependent variable: manufacturing production worker hours. Instruments used: same as in a.
[e] χ^2-statistics for the overidentifying restrictions test.
[f] χ^2-statistics for the LM test of serial correlation of order one in the residuals.

Table 2- Results using Sectoral Manufacturing Data from 1960 to 1991

Labor Demand Specification	(4) OLS	(5) IV[a]
Δw^p (T-stat)	-.500** (-42.77)	-.892** (-4.67)
Δh-1	0.105**	0.053**
	(14.49)	(4.10)
Δk	0.443**	0.173**
	(23.20)	(2.61)
Δpo	-0.327**	-1.226**
	(-15.76)	(-5.28)
Δtfp	0.884**	0.176
	(74.62)	(1.55)
t	-0.000**	-0.002**
	(-4.47)	(-9.79)
constant	0.019**	0.139**
	(2.54)	(9.15)
R^2	.34	---
Avg. elasticity	-.500	-.892
Deg. of Freedom	13,818	13,489

[a] Instruments used: same as in Table 1.
** 1 percent significance level.

Table 3 - Results using Aggregate Manufacturing Data from 1960:2 to 1996:2

Labor Supply Specification	(1) OLS	(2) IV[a]
$\Sigma\,\Delta w^c$	0.706**	1.231**
(F-stat)	(22.87)	(16.92)
Δr^c	0.002**	0.003*
(T-stat)	(4.75)	(2.11)
Δh_{-1}	0.420**	0.407**
(T-stat)	(5.94)	(3.58)
trend	0.000**	0.000**
(T-stat)	(2.83)	(3.26)
constant	-0.004*	-0.009**
(T-stat)	(-1.82)	(-2.53)
R^2	.51	---
$\chi^2(4)^b$	---	1.92
$\chi^2(1)^c$	---	.06
Deg. of Freedom	122	122

[a] Dependent variable: Total civilian hours. Instrumental variables: lagged price growth, lagged labor productivity, and lagged real wages.
[b] χ^2-statistics for the overidentifying restrictions test.
[c] χ^2-statistics for the LM test of serial correlation of order one in the residuals.
* 5 percent significance level.
** 1 percent significance level.

Endnotes

1. Several papers have discussed the sensitivity of real wage cyclicality measures to the definition of variables and the time period used in the estimation procedure. For a recent survey on this literature see Abraham and Haltiwanger (1995).

2. The formal derivation of this model and of the estimated equations are laid out in Estevão and Wilson (1998).

3. Institutional arrangements which fix the pay scale once a year or every few years are examples of such contracts. Wilson (1997) finds evidence of nominal wage rigidity at firms that adjust wages annually.

4. See Bartelsman and Gray (1996) for a detailed description of this database. Using SIC codes to refer to sectors, sectors 2794, 3672, 3673, and 3292 were dropped from the database because they did not have observations for some key variables after 1987.

5. Christiano, Eichenbaum and Evans (1996) created series of shocks in interest rates and in non-borrowed reserves using a VAR framework. The variables included in their VAR are the GDP, the GDP deflator, an index of sensitive commodity prices, non-borrowed reserves, total reserves and the federal funds rate.

6. For a discussion of Lagrange Multiplier tests for two-stage least squares regressions, see Wooldridge (1990).

7. The direction of the sectoral results remains the same once we included multiplicative terms linking changes in real product wages and sectoral characteristics. Discussed at length in Estevão and Wilson (1997).

8. We use average hourly earnings instead of total labor compensation per hour because there

is some evidence that the former better captures workers' perceived earnings over the estimation period. B. Douglas Bernheim and John Karl Scholz (1993), for instance, found evidence that workers without college education do not incorporate their pension benefits into their estimates of total income. The IV results do not change significantly if average hourly earnings and total compensation per hour are used interchangeably.

9. As a further test of the robustness of the results we have used employment as the measure of labor input and the nature of the results do not change.

10. See, for instance, Rotemberg and Woodford (1991).