REAL WAGES OVER THE BUSINESS CYCLE

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This paper investigates the sources of fluctuations in aggregate hours and the economy-wide average real wage. Of particular interest is the weak correlation between real wages and aggregate hours over the business cycle. This correlation, which is essentially zero, has been the source of much debate since the early works of Dunlop [1938] and Tarshis [1939]. Models driven solely by productivity shocks such as Kydland and Prescott [1982] predict a strong positive correlation between real wages and aggregate hours. Models which assume sticky wages and are driven solely by aggregate demand shocks such as Fischer [1977] predict a strong negative correlation between real wages and aggregate hours.[1] Thus, establishing the cyclical pattern in real wages may tell us something about the source of business cycle fluctuations as well as the transmission mechanism.

Two types of conclusions can be drawn from the failure of these models to predict the weak correlation between real wages and aggregate hours. First, it is possible that the models themselves are flawed; that is, there is some other type of transmission mechanism that explains the relationship between the shocks and the business cycle. This is the approach taken by Ball, Mankiw and Romer [1988] who present a model with sticky prices rather than sticky wages. Their model predicts an acyclical real wage in the face of aggregate demand shocks.

The second possible conclusion that can be drawn from the failure of these early models is that there is some truth to each of the models and the fact that real wages are acyclical is evidence that business cycles are driven by several different types of shocks, some with opposing effects on the real wage. This is the approach taken recently in empirical studies by Sumner and Silver [1989], and Gamber and Joutz [1993].

This paper further explores the possibility that the weak correlation between real wages and aggregate hours is due to the fact that business cycles are generated by several different types of shocks. In particular, we investigate the impact of four different types of structural shocks on aggregate labor market fluctuations: labor supply, labor demand (productivity), aggregate demand and oil prices.

Our empirical methodology follows the spirit of Blanchard and Quah [1989] and Shapiro and Watson [1988] *and* the traditional approach to estimating the cyclical behavior of real wages. First, we estimate and report results from a structural vector autoregression (VAR) with long run restrictions. Spencer [1993] and Fleischman [1994] have studied labor market dynamics using similar techniques. Second, we regress real wage growth on hours growth using data from subsets of the shocks identified in the structural vector autoregression.

Our motivation for considering oil price shocks is that real business cycle theorists have recently postulated that oil prices may account for the acyclical nature of real wages. In particular, Kim and Loungani [1992] incorporate exogenous oil price shocks into a real business cycle model in an effort to reduce the simulated correlation between real wages and hours. Since oil price shocks shift both labor supply and labor demand, the correlation between hours and wages is reduced. Our aim is to measure the contribution of oil shocks to determine whether they do in fact account for the acyclical nature of real wages.

The traditional approach to measuring the cyclical behavior of real wages is to regress real wage growth on some measure of the cycle such as unemployment or aggregate hours growth. To facilitate the comparison of our structural VAR results with the results of this traditional approach we regress real wage growth on aggregate hours growth where the data on wages and hours are constructed from a subset of the structural shocks estimated from our VAR. For example, we construct hours and wages due to labor demand shocks by setting the other three structural shocks equal to zero and recreating these series using the coefficients estimated from the VAR. We repeat this exercise for various combinations of the structural shocks.

Using data generated from labor demand shocks only, we find a highly procyclical real wage. When data from either labor supply or aggregate demand only are used, we find a countercyclical real wage. Using data from oil price shocks we find the real wage to be countercyclical. The more important question that we investigate is which combination of shocks is necessary to generate an acyclical real wage. We find that when labor demand shocks are combined with labor supply shocks the positive correlation between wages and hours is reduced only slightly and is still significantly positive. In contrast, when labor demand shocks are combined with aggregate demand shocks the positive correlation is substantially reduced. When labor demand shocks are combined with oil price shocks the positive correlation between real wages and hours is reduced only slightly. Thus, our results indicate that aggregate demand, not labor supply or oil price shocks, is more important in contributing to the acyclical nature of real wages.

AN EMPIRICAL MODEL OF THE AGGREGATE LABOR MARKET

We assume that aggregate hours worked (h) and the economy-wide average real wage (w) are each functions of four independent shocks: labor supply (ϵ^{LS}), labor demand (ϵ^{LD}), aggregate demand (ϵ^{AD}) and oil prices (ϵ^{O}).

$$w = w(\epsilon^{LS}, \epsilon^{LD}, \epsilon^{AD}, \epsilon^{O}). \quad (1)$$

$$h = h(\epsilon^{LS}, \epsilon^{LD}, \epsilon^{AD}, \epsilon^{O}). \quad (2)$$

These shocks are assumed to be mutually and serially uncorrelated demand and supply shifters. For example, an increase in female labor force participation (that was not predicted from past observations) could represent a realization of ϵ^{LS}. Similarly, a surprise monetary tightening by the Federal Reserve could represent a negative realization of ϵ^{AD}.[2]

In principle, if the labor market is well described by a simple demand and supply model, we should be able to look at the correlation between aggregate hours and wages and discover the type of shock driving the business cycle. A positive labor supply shock (ϵ^{LS}) shifts the labor supply curve down and to the right, decreasing the real wage and increasing hours. Thus, if business cycles are primarily driven by labor supply shocks we should observe a countercyclical real wage. A positive labor demand shock (ϵ^{LD}) shifts the labor demand curve up and to the right producing a procyclical real wage movement. A positive aggregate demand shock (ϵ^{AD}) operating through a sticky wage mechanism such as Fischer [1977] produces a countercyclical real wage movement. A positive oil price shock (ϵ^{O}) operating through the Kim and Loungani [1992] mechanism produces an acyclical real wage.[3]

Figure 1 shows a scatter plot of the differenced logs of hours and wages. A regression line estimated from these data yields a small and statistically insignificant negative relationship. One of the following conclusions can be drawn from this diagram:

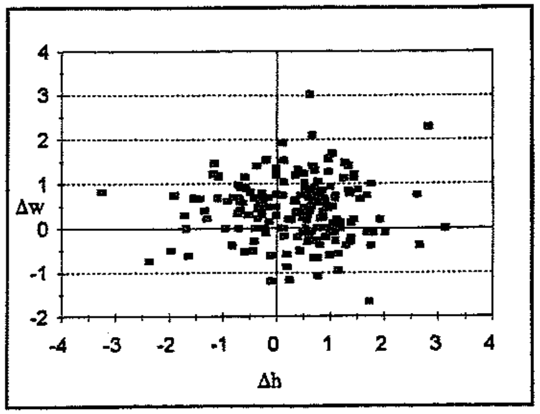
- If one type of shock is primarily responsible for generating business cycle fluctuations, then the simple demand and supply model described above is incorrect.

- Several types of shocks, some with opposing effects on the real wage, are responsible for generating business cycle fluctuations.

To a non-time-series, non-macroeconomist Figure 1 represents a classic identification problem in econometrics. The widely scattered points suggest that shifts in demand and supply are equally responsible for generating movements in the real wage and hours worked. To a time-series macroeconomist, however, it represents a puzzle because the tradition has been to assume that a single type of shock (either aggregate demand or supply) is responsible for generating business cycle fluctuations.

Our approach is inspired by the classic identification problem in econometrics. In particular, we estimate a vector autoregression model of the aggregate labor market, impose identifying restrictions and then use the identified labor demand and supply curves to explain real wage movements over the business cycle. Our thesis is that the acyclical real wage is not evidence against traditional models but rather evidence

Figure 1
Scatter Plot of Real Wage Growth Vs Aggregate Hours Growth
Actual Data



that business cycles are driven by multiple shocks working through multiple transmission mechanisms.

We begin by estimating the following vector autoregressive model of the aggregate labor market.

(3) $$Z_t = B(L)Z_{t-1} + \mu_t,$$

where $Z_t = (\Delta h_t, \Delta w_t, \Delta u_t, \Delta o_t)$ and μ_t, is a vector of residuals with variance Ω, h is the log of aggregate hours for the non-farm business sector, w is the log of average hourly compensation for the non-farm business sector deflated by the consumer price index,[4] u is the unemployment rate for males age 20 and above and o is the log of the producer price index for crude petroleum deflated by the consumer price index.[5] For notational ease we have included oil in the vector even though it is assumed to be exogenous. In the estimation to follow, the (4,1), (4,2) and (4,3) elements of the $B(L)$ matrix are therefore constrained to be zero.

The system of equations represented by equation (3) takes the standard VAR form. Each variable in the **Z** vector is regressed on 6 lags of itself and 6 lags of the other variables in **Z**. Series that were found to be nonstationary were differenced to produce quarterly growth rates.[6] Since oil prices are assumed to be exogenous they are regressed on only six own lags.

Since all of the series in equation (3) are stationary it may be inverted to yield the moving average representation

(4) $$Z_t = C(L)\mu_t.$$

The elements of $C(L)$ are the unrestricted impulse responses. For example, $C_{11}(L)$ shows the response of aggregate hours worked to a change in the first element of μ_t. Although the elements of $C(L)$ are easy to compute — by simulating the response of each equation to a one unit increase in each shock — they are meaningless because in the sample of data the estimated μ_t's are not uncorrelated. So as one element of μ_t changes so do the others. The real question is which element of μ_t is causing the others to move? Which is primitive or exogenous to the others? The system of equations described by equations (3) and (4) cannot be used to resolve this issue since they simply summarize correlations among the data. In a simple demand and supply diagram this is analogous to observing a correlation of prices and quantities and trying to infer the supply and demand shifts that caused them.

The problem we face is to use economic theory to identify the structural labor demand and supply shifters from (3) and (4). This is essentially the analogue of the problem of trying to identify a demand equation by estimating a reduced form relationship between price and quantity where the correlation between the residual and the independent variable clouds the estimate. Thus, we seek an alternative representation of the form:

(5) $$Z_t = A(L)\epsilon_t.$$

where $\epsilon = (\epsilon^{LS}, \epsilon^{LD}, \epsilon^{AD}, \epsilon^{O})'$ are orthogonal shocks and the $A(j) = C(j)A(0), j = 0,...$ are the structural impulse responses. To construct equations (5) from equations (4) we must impose several identifying restrictions. First we note that there is a straightforward relationship between the residuals in (4) and (5):

(6) $$\mu_t = A(0)\epsilon_t.$$

Thus to identify the model we must impose restrictions on the 16 elements of A(0). First we impose the normalization restriction $A(0)A(0)' = \Omega$. While it is possible to normalize the variance of the shocks to any number it is most convenient to normalize it to one so that a one standard deviation shock is also a one unit shock. This restriction identifies 10 elements of the $A(0)$ matrix. Second, we assume that oil prices are exogenous which restricts the (4,1), (4,2), (4,3) elements of $A(0)$ to be zero. In other words, the only element in the bottom row of $A(0)$ that is not zero is the first element which means that the price of oil is a function of only its own lags. Third, we assume that aggregate demand has no long-run impact on the real variables of the system which implies that the (1,3) and (2,3) elements of $C(1)A(0)$ are zero. Since the third shock in ϵ is the aggregate demand shock (ϵ^{AD}) this restriction implies that the effects of this shock on real wages and hours worked die out over time. This assumption implies that the natural rate hypothesis holds in the long run.

So far there are a total of 15 restrictions on the $A(0)$ matrix. The final restriction follows Shapiro and Watson by assuming that the labor supply curve is vertical in the long-run. Pencavel [1987] presents empirical evidence that the labor supply curve is vertical in the long run. Thus, a shock to labor demand has no long-run impact on aggregate hours worked. This restriction is imposed by setting the (1,2) element of $C(1)A(0)$ to zero.

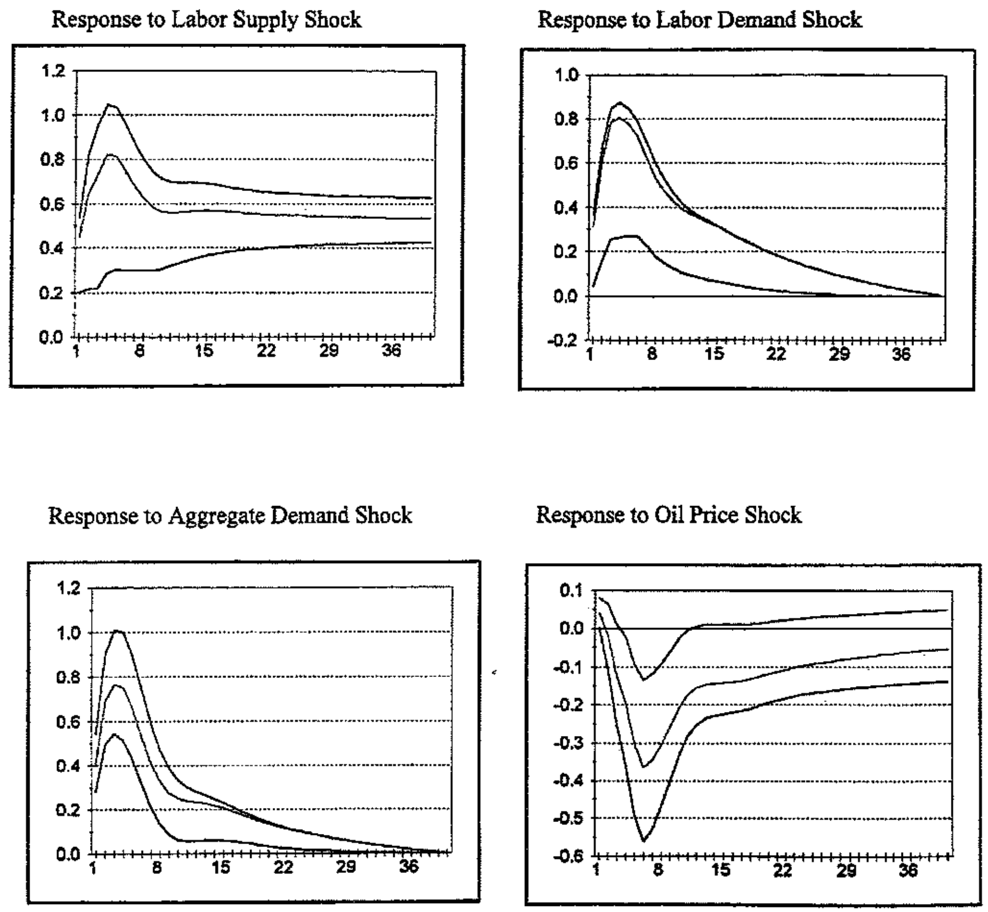
Structural VAR Results

Figures 2 and 3 present the impulse response functions from our structural VAR estimated over the 1948 - 1995:2 period. The responses, along with one-standard error confidence intervals based on 1000 bootstrap simulations are provided as recommended by Runkle [1987]. The bootstrap simulations are conducted by reshuffling the estimated errors from equation (3) and then using the reshuffled errors and the original estimated coefficients (the elements of B(L) to construct new series on wages, hours, oil prices, and unemployment. This process is repeated 1,000 times. The sample of estimated parameters is then used to compute the standard error bands.[7]

The impulse response functions all have the expected shapes. The hours responses to labor supply, labor demand and aggregate demand shocks are all positive. The response to oil prices is negative. The real wage responses to labor supply, aggregate demand and oil prices are negative. The response to labor demand is positive. The fact that real wages respond negatively to aggregate demand is consistent with a sticky-wage story for the aggregate demand transmission mechanism [Fischer, 1977]. The fact that both wages and hours worked fall in response to an oil price shock is inconsistent with the Kim and Loungani hypothesis that oil price shocks have an ambiguous effect on hours worked. Both real wages and hours worked decline in response to an oil price shock suggesting that the negative impact on labor demand dominates any positive impact on labor supply.

Tables 1 and 2 show the variance decompositions derived from the structural VAR. These numbers show the percent of the forecast error variance attributed to particular shocks at various horizons. Variance decompositions provide one form of evidence on the importance of each of the structural shocks in explaining the movements in wages and hours (the regression results reported in Table 4 provide another form of evidence). At the one quarter horizon the forecast error variance of hours worked is mainly a function of labor supply (43.48 percent). As the horizon lengthens, the contribution of labor supply to the variance of hours worked decreases while the contributions of labor demand increases. The error variance for the real wage is dominated by labor demand shocks at all horizons. Oil price shocks account for very little of the error variance of either wages or hours worked. These variance decompositions show that the business cycle (proxied by aggregate hours worked) is driven by a variety of shocks. Neither the Keynesian view which would suggest a dominance of aggregate demand shocks or the real business cycle view which would suggest a dominance of labor demand shocks is completely correct. The results for real wages suggest that labor demand or productivity is the main determinant of wages and that aggregate demand plays a secondary role. These results also partly explain why the real wage is acyclical — the business cycle is driven by equal contributions from labor supply, labor demand and aggregate demand while real wages are mainly driven by labor demand. Thus, shocks other than labor demand that generate business cycle movements do not move the real wage and therefore reduce the correlation between wages and the cycle. In other words, wages appear sticky or rigid by standard mea-

FIGURE 2
Impulse Response Functions for Aggregate Hours Worked

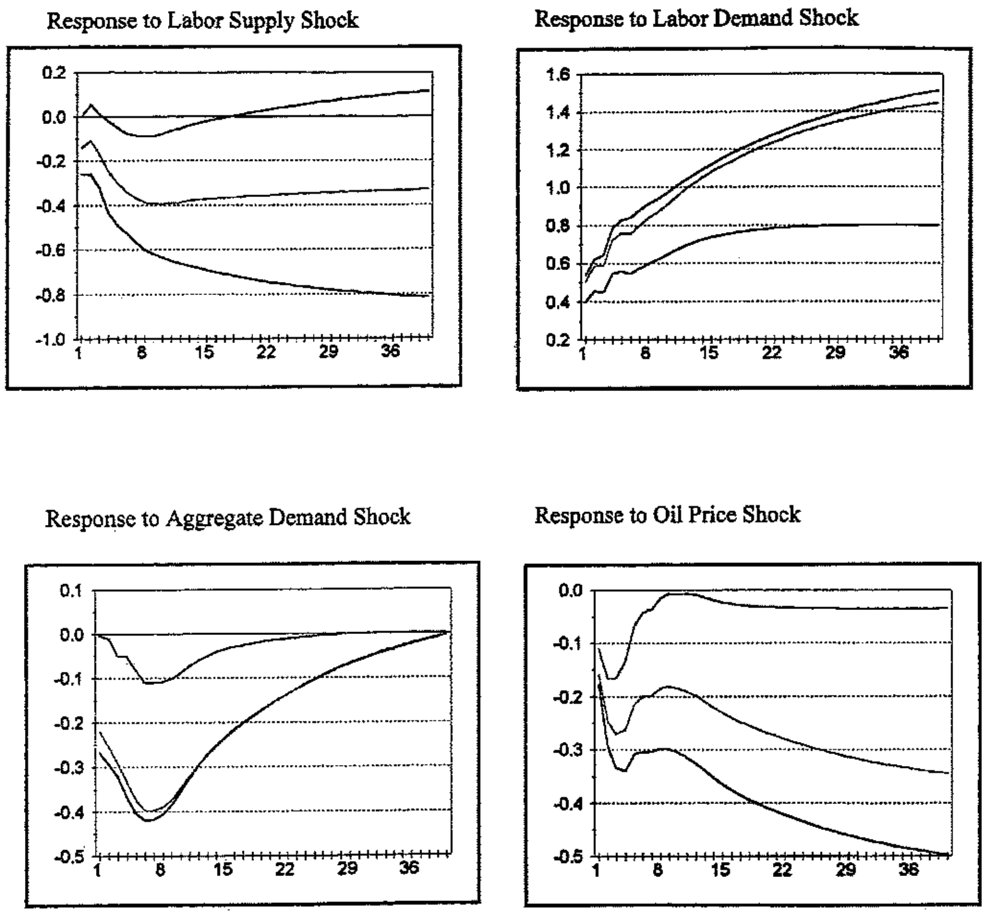


sures. In the following section we relate the standard method of measuring the cyclical behavior of real wages with our VAR method in order to isolate the causes of this apparent wage rigidity.

THE TRADITIONAL APPROACH TO MEASURING THE CYCLICAL BEHAVIOR OF REAL WAGES

The traditional approach to measuring the cyclical pattern in real wages is to regress real wage growth on either employment growth or real output growth. (See, for example Sumner and Silver [1989] and their survey of this literature.) Regressing our measures of real wage growth on hours growth yields the following estimated equation:

FIGURE 3
Impulse Response Functions for the Real Wage



(7) $$\Delta w_t = .41 - .004\Delta h_t, \quad DW = 2.06, \quad adj(R^2) = 0.07,$$
$$(.07) \quad (0.06)$$

where standard errors are in parentheses below the parameter estimates.

The real wage is clearly acyclical. What is equally clear from the impulse responses, however, is that the coefficient on hours in this regression is a mongrel coefficient; that is, it captures the effects of labor demand shocks (which tend to generate a positive correlation), aggregate demand and labor supply (which tend to generate negative correlations), and oil price shocks (which generate a positive correlation). What the above regression and impulse responses do not indicate is whether the acyclical real wage is the result of the effect of labor demand shocks being offset by the effects of a single shock such as aggregate demand shocks or some combination of

TABLE 1
Variance Decomposition for Aggregate Hours Worked

The Percent of the Forecast Error Variance in Aggregate Hours Due To:

Horizon (qtrs)	Labor Supply	Labor Demand	Aggregate Demand	Oil
1	43.48	20.90	35.25	0.37
	(12.1,65.1)	(0.3,20.9)	(20.4,68.4)	(0.0,1.7)
2	35.61	27.64	25.93	0.81
	(8.8,57.5)	(3.1,37.26)	(22.0,68.0)	(2.6,3.1)
3	34.01	29.65	34.25	2.09
	(8.6,55.2)	(4.8,38.5)	(20.9,65.0)	(0.8,6.3)
4	34.46	29.14	33.64	2.76
	(9.6,54.7)	(5.0,37.7)	(20.6,63.1)	(1.1,8.2)
8	31.91	28.30	35.22	4.57
	(8.5,51.0)	(5.0,36.6)	(21.6,63.2)	(2.5,11.5)
12	31.45	28.52	34.85	5.17
	(8.2,50.4)	(5.3,36.8)	(21.4,62.2)	(2.8,12.9)
40	31.16	28.90	34.77	5.18
	(8.2,50.1)	(5.5,39.0)	(21.4,62.0)	(2.8,13.0)

The numbers in parentheses below the estimated variances are the one standard error bands computed from the bootstrap simulations.

TABLE 2
Variance Decomposition for the Real Wage

The Percent of the Forecast Error Variance in the Real Wage Due To:

Horizon (qtrs)	Labor Supply	Labor Demand	Aggregate Demand	Oil
1	5.84	73.04	13.98	7.14
	(0.0,22.2)	(54.2,87.0)	(0.0,23.4)	(3.9,10.17)
2	5.89	71.44	13.68	8.99
	(0.6,21.5)	(52.9,83.5)	(0.2,22.6)	(5.3,13.5)
3	6.7	70.44	13.8	9.01
	(1.9,22.1)	(51.7,81.1)	(1.2,22.6)	(5.7,13.8)
4	8.06	70.30	13.29	8.40
	(2.7,23.7)	(51.0,80.1)	(1.4,21.9)	(5.8,13.4)
8	9.00	68.86	13.38	8.75
	(3.7,24.1)	(49.5,7.3)	(2.3,21.6)	(6.8,14.6)
12	8.65	68.85	13.67	8.62
	(3.9,24.1)	(49.7,76.7)	(2.8,21.5)	(6.8,14.5)
40	8.61	68.75	14.08	8.56
	(4.1,23.9)	(50.1,76.2)	(3.3,21.04)	(6.9,14.5)

The numbers in parentheses below the estimated variances are the one standard error bands computed from the bootstrap simulations.

TABLE 3
Bivariate Wage Regression Results
Single Shock

$$\Delta w_t = \alpha + \beta \Delta h_t$$

Shock Used to Construct Wage and Hours Series	β
Actual Series (ϵ^{LD}, ϵ^{LS}, ϵ^{AD}, ϵ^{O})	-0.004
	(0.06)
Labor Demand (ϵ^{LD})	0.57[a]
	(0.05)
Labor Supply (ϵ^{LS})	-0.51[a]
	(0.03)
Aggregate Demand (ϵ^{AD})	-0.33[a]
	(0.02)
Oil Price (ϵ^{O})	-0.19[a]
	(0.07)

Standard errors are in parentheses below the parameter estimates.
a. Significant at the 0.01 level. All regressions were corrected for first order serial correlation.

TABLE 4
Bivariate Wage Regression Results
Multiple Shocks

$$\Delta w_t = \alpha + \beta \Delta h_t$$

Shock Used to Construct Wage and Hours Series	β
Actual Series (ϵ^{LD}, ϵ^{LS}, ϵ^{AD}, ϵ^{O})	-0.004
	(0.06)
Labor Demand (ϵ^{LD})	0.57[a]
	(0.05)
Labor Demand and Labor Supply (ϵ^{LD}, ϵ^{LS})	0.25[a]
	(0.06)
Labor Demand and Aggregate Demand (ϵ^{LD}, ϵ^{AD})	0.08[b]
	(0.05)
Labor Demand and Oil Price (ϵ^{LD}, ϵ^{O})	0.48[a]
	(0.06)
Labor Demand, Labor Supply and Aggregate Demand (ϵ^{LD}, ϵ^{LS}, ϵ^{AD})	-0.002
	(0.05)
Labor Demand, Labor Supply and Oil Price (ϵ^{LD}, ϵ^{LS}, ϵ^{O})	0.21[a]
	(0.06)

Notes: Standard errors are in parentheses below the parameter estimates.
a. Significant at the 0.01 level.
b. Significant at the .10 level. All regressions were corrected for first order serial correlation.

FIGURE 4
Scatter Plot of Real Wage Growth Vs Aggregate Hours Growth
Demand Shocks Only

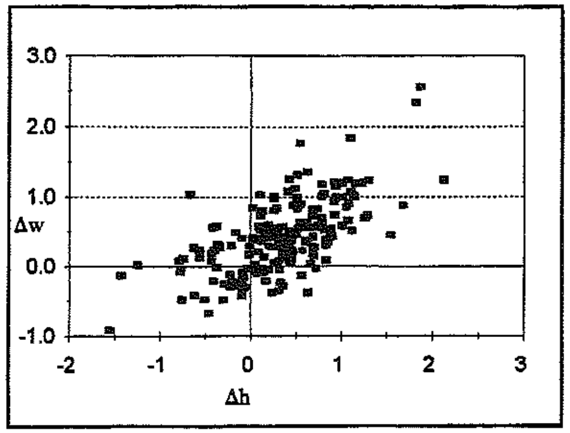
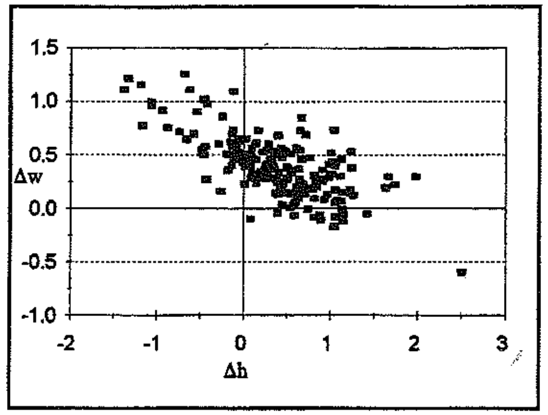


FIGURE 5
Scatter Plot of Real Wage Growth Vs Aggregate Hours Growth
Labor Supply Shocks Only



the shocks which tend to produce negative (or no) correlations between wages and hours. In other words, if the only shock that existed in the world was labor demand then according to our VAR estimates the real wage would be highly procyclical which would be very supportive of real business cycle theory. But the observed real wage is not highly procyclical so we would like to know which of the other shocks is (or are) mainly responsible for muddying the estimated cyclical behavior of real wages.

FIGURE 6
Scatter Plot of Real Wage Growth Vs Aggregate Hours Growth
Aggregate Demand Shocks Only

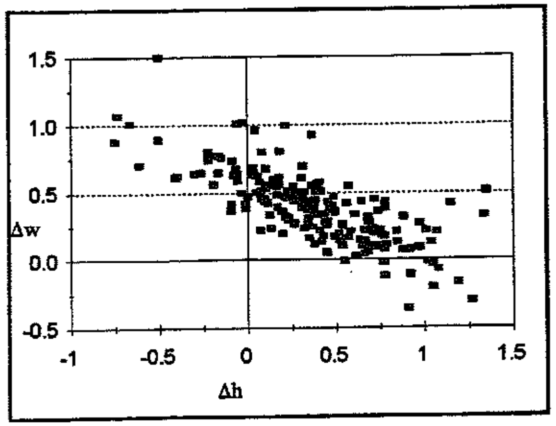
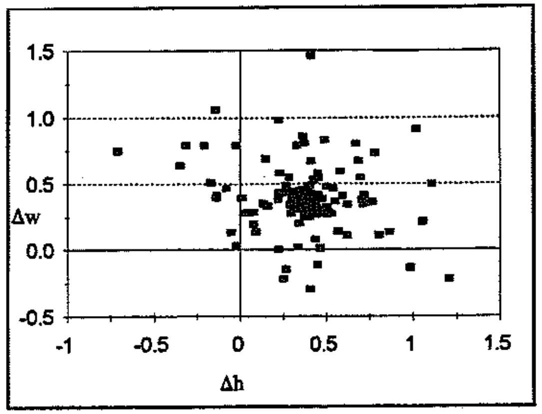


FIGURE 7
Scatter Plot of Real Wage Growth Vs Aggregate Hours Growth
Oil Price Shocks Only



To answer this question we constructed several new wage and hours series from our structural VAR using various combinations of the structural shocks. To begin, we constructed wage and hours series using the structural moving average coefficients estimated from equation (6) but zeroing out all structural shocks except for labor demand shocks. This exercise essentially recreates historical series for wages and

hours assuming that only labor demand shocks had occurred.[8] We then repeated this exercise assuming that only labor supply shocks had occurred, and then only aggregate demand shocks, and then only oil price shocks. Following the construction of these series we estimated regressions of the form (7) using the data generated with single shocks. The results of these regressions are reported in Table 3.

As expected from the impulse response functions, the real wage is highly procyclical in response to labor demand shocks. Labor supply shocks produce a highly countercyclical real wage. Aggregate demand produces a significant negative correlation between hours and wages and oil price shocks produce a negative correlation between hours and real wages.

Figures 4 through 7 show the scatter diagrams which correspond to the regression results reported in Table 3. Figure 4 shows the scatter plot generated from the labor demand shocks only. Figure 5 shows the scatter plot generated from the labor supply shocks only. Both labor demand and supply curves look reasonable. Figure 6 shows the negative correlation between real wages and hours in the face of aggregate demand shocks. Finally, Figure 7 shows the countercyclical real wage response to oil price shocks.

Our next goal was to try various combination of shocks to see if a particular shock is mainly responsible for offsetting the positive correlation between hours and wages produced by labor demand shocks. We constructed several new data series as described above but this time the wage and hours series all contained labor demand shocks plus one or two of the other shocks. The results from these regressions are presented in Table 4.

Our benchmark for this analysis is the real wage cyclicality measure when only labor demand shocks are present. This is the real business cycle world where both wages and hours are driven only by labor demand. Reconstructing hours and wages using only the labor demand shocks and then estimating equation (7) with these constructed series yields a coefficient on differenced hours of 0.57 (which is statistically significant at the one percent level). Adding labor supply and aggregate demand should mitigate the procyclical response of real wages to hours when only labor demand shocks are present. The third line of Table 4 shows that adding labor supply shocks reduces the coefficient on hours worked by more than half but it still shows a statistically significant procyclical real wage. The next line of Table 4 shows that by adding the aggregate demand shocks to the system (in place of labor supply) the real wage cyclicality is reduced by seven fold. As the fifth line shows, adding oil price shocks to the system only slightly reduces the cyclicality of the real wage. It appears that the main offsetting effects come from aggregate demand and labor supply. To test this proposition from a different angle we estimate the bivariate regression with labor demand, labor supply and aggregate demand shocks. This regression, which omits the effect of oil prices on wages and hours, shows an acyclical real wage that differs very little from the results using the actual series. Finally, a regression with labor demand, labor supply and oil — omitting aggregate demand — shows a significantly pro-cyclical real wage.

CONCLUSION

This paper presents empirical evidence on the sources of aggregate labor market fluctuations in the context of a structural vector autoregression. We estimate the contribution of labor supply, labor demand, aggregate demand and oil price shocks under the assumption of a long-run vertical labor supply curve. We find that real wages are mainly driven by labor demand shocks and aggregate hours worked are driven by labor supply, labor demand and aggregate demand. This evidence is consistent with the eclectic view that business cycles are a function of various shocks rather than being driven solely by either aggregate demand shocks or aggregate supply shocks.

In addition to identifying the sources of aggregate labor market fluctuations we also identified the reasons why the real wage is acyclical. The departure from a procyclical real wage is due to the presence of labor supply and aggregate demand shocks. Our results indicate that increases in oil prices reduce hours and have no significant impact on the real wage. Furthermore, the contribution of oil price shocks to hours and wage variation is quite small. This lack of explanatory power on the part of oil prices is consistent with the results of Shapiro and Watson [1988] and Bohi [1989].

NOTES

The authors wish to thank Nathan Balke, Peter Ferderer, Dennis Jansen, Joseph Haslag and the editor of this *Journal* for helpful comments. The majority of this paper was written while Gamber was at Lafayette College. The views expressed are those of the authors and do not necessarily reflect those of the Congressional Budget Office. All remaining errors are solely the authors' responsibility.

1. Real business cycle models such as Kydland and Prescott [1982] generate a procyclical real wage because they assume that business cycles are driven solely by productivity shocks. The productivity shocks move the labor demand curve along a fixed labor supply curve. The sticky wage model of Fischer [1977] generates a countercylical real wage because increases (decreases) in aggregate demand increase (decrease) the price level and with a fixed nominal wage decrease (increase) the real wage.
2. Gamber [1996] looks further into the issue of how the shocks identified with a structural VAR are related to actual historical events.
3. According to Kim and Loungani an increase in the price of oil causes the labor demand curve to fall (as productivity falls) and the labor supply to increase (as wealth falls). If these shifts are approximately equal the real wage will appear acyclical.
4. Similar results were obtained using the average real hourly wage in manufacturing.
5. All series are taken from CITIBASE [1978]. The CITIBASE mnemonics are LBMNU (aggregate hours), LBCPU7 (nominal average hourly compensation), LHMUR (prime age male unemployment rate), GDPD (GDP implicit price deflator) and PW561 (price of crude oil). The data on oil prices and aggregate hours are the same as those employed by Shapiro and Watson [1988].
6. The logs of hours, wages and oil prices all contain unit roots but are stationary in first differences. The prime age male unemployment rate is trend stationary. None of these variables are cointegrated. The time series properties imply that the system contains three permanent and two temporary shocks. We label the permanent shocks labor demand, labor supply and oil prices. The remaining temporary shock is labeled aggregate demand.
7. Note that the estimated impulse responses and variance decompositions do not fall in the middle of the simulated standard error bands. The reason is that the standard error bands are computed relative to the mean of the 1,000 bootstrap simulations. In most cases, the mean of the simulations differs from the estimates.

8. Once the structural shocks (ϵ_t) and structural moving average coefficients ($A(L)$) are identified the original series (Z_t) can be reconstructed as follows:

$$Z_{T+j} = \sum_{s=0}^{j-1} A_s \varepsilon_{T+j-2} + \hat{z}_{T+j}$$

where is the forecast of Z_{T+j} based on information at time T (the first observation of the sample) generated from the estimated VAR. The summation term shows that the gap between the forecast and the actual is due to the structural shocks. To create the series described in the text various combinations of the ϵ_t vector were set to zero. For example, to create the Z_t due to labor demand only, ϵ^{LS}, ϵ^{AD}, and ϵ^{O} were set to zero.

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