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pg. 1

The Effect of Marginal Tax Rate Uncertainty on the Union Wage Premium

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Abstract

We test the impact of unexpected changes of marginal tax rates on the union wage premium. Extending a model of monopolistic competition used by Ball (1987, 1988), we find that the optimal response to an increase in marginal tax rate uncertainty is a reduction in the progressivity of the marginal tax rate. In the context of the model, this leads to a decrease in the degree of wage indexation. A reduction in the extent of indexation reduces the value of the nominal wage and narrows the gap between union and non-union wages. The Panel Survey of Income Dynamics data on males was used for the empirical analysis. The estimates support the hypothesis that marginal tax rate uncertainty decreases the union wage premium.[1]

INTRODUCTION

The issue of the union/non-union wage differential has received significant attention, and the results are rich with insights about factors responsible for this differential (Lewis 1963, 1986; Parsley 1980; Freeman and Medoff 1984; Hirsch and Addison 1986). Concurrently, research on the issue of tax rate uncertainty has provided interesting insights into the behavior of economic agents in the context of such contingencies (Alm 1988; Skinner 1988; Chang and Wildasin 1986, and McGratten 1994). However, the impact of marginal tax rate uncertainty on the union/non-union wage differential has not been addressed. In this paper, we evaluate the impact of marginal wage tax rate uncertainty on the union/non-union wage differential.

A strong case can be made that marginal wage tax rates in the U.S. are uncertain. There have been frequent and significant changes in the personal income taxes over the last three decades: twelve between 1960-1980, and a major change in every year during the 1980s.[2] Further, Skinner (1988) estimates that tax rate uncertainty might have been responsible for efficiency losses to the extent of $15 billion in 1986. Changes in tax laws have created a situation where individuals are unsure of how exemptions, deductions, and exclusions apply to them, and the degree to which they apply – a situation which makes economic agents uncertain about the marginal wage tax rate applicable to their labor income.[3]

Our empirical results support the contention that tax rate[4] uncertainty reduces the union/non-union wage differential. A brief description of the theoretical framework is presented below. We provide a diagrammatic exposition of the intuition of the results.

1

We then give a description of the empirical analysis, which is followed by concluding remarks.

The Analytical Framework

Our analysis is similar to Ball's (1987, 1988), where the product market is monopolistically competitive and the labor market is one in which nominal wage contracts are signed. We extend this framework to include uncertain marginal wage taxes into the labor supply decisions.[5] Workers are immobile once they sign one-period contracts. There are a large number of firms, each indexed by i, distributed evenly between $i = 0$ and $i = 1$.

The production technology of firm i is well described by

(1) $y_{it} = \alpha\, l_{it} + \theta_t,\ 0 < \alpha \leq 1,$

where y_i is the log of output and l_i is the log of employment. θ_t is a random variable representing a productivity shock which is distributed normally with a zero mean and a known variance. The subscript t refers to the value of a variable in time t.

The stock of money is determined exogenously and we assume that it follows a Wiener process with a zero mean and a known variance. The demand for money is

(2) $m_t - p_t = (1/\vartheta)y_t,\ \vartheta > 0,$

where $m_t = \overline{m} + \eta_t$; m_t is the log of the money stock; η_t is an aggregate velocity shock with zero mean and a known variance; p_t is the log of the aggregate price level; and ϑ is the elasticity of real aggregate demand with respect to real balances. The aggregate price level and the aggregate output level are obtained by integrating over individual prices and output over the continuum of firms distributed evenly over the interval $i=0$ and $i=1$.[6]

We follow Rotemberg (1983) and Ball (1988) in specifying the demand for firm i's product, as a share of aggregate demand, as depending on its relative price:

(3) $y_{it} - y_t = -\varepsilon(p_{it} - p_t),\ \varepsilon > 1,$

where ε is determined by the substitutability of products of different firms. Note that our description of the product market is different from Gray's (1976) and Fischer's (1977). We choose this alternative characterization because most unionized firms sell their output in markets that are not perfectly competitive.[7] Using equation (2) and (3) the demand for firm i's product is

(4) $y_{it} = \mu(m_t - p_t) - \varepsilon(p_{it} - p_t).$

The demand for firm i's product depends positively on real balances and negatively on its relative price.

The production function (1) and the product demand equation (4), along with the profit maximization condition, gives us the labor demand function which can be written as

(5) $l^d_{it} = [1/(\alpha + \varepsilon - \alpha\varepsilon)][\mu(m_t - p_t) - \varepsilon(w_{it} - p_t) + (\varepsilon - 1)\theta]$.

In this description, labor demand depends positively on productivity shocks, as well as real balances, and negatively on the real wage. The supply of labor, from the pool of immobile workers available during the contract period, is

(6) $l^s_{it} = \delta(w_{it} - p_t - \tau_{it})$, $\delta \geq 0$,

where τ_i is the marginal tax rate applicable to labor income, and δ is the elasticity of labor supply. In this description, labor supply depends positively on net-of-tax real wage. Workers and firms sign one-period wage contracts that are identical to Gray's (1976) formulation. These contracts, which are signed in period $t-1$, take the form

(7) $w_{it} = E_{t-1}w^*_{it} + \gamma\,[\,p_t - E_{t-1}p_t]$,

where E_{t-1}, is the expectation formed in period $t-1$, γ is the indexation parameter, [8] and w^*_{it} is the market clearing nominal wage in period t.

The marginal tax rate [9] is

(8) $\tau_{it} = \tau_0 + \tau_1 y_{it} + e_t$,

where e_t is a random variable with a zero mean and a known variance and represents the uncertainty concerning the marginal tax rate, and τ_1 represents the progressivity parameter. This approximation was proposed by McCallum and Whitaker (1979) and used by Waller and VanHoose (1985), and the difference here is the inclusion of uncertainty in the marginal wage tax rate. It is useful to conceptualize this marginal tax rate as applicable to the "local" market i, and it is useful to think of this as the *average* marginal wage tax rate applicable to the local market.[10] The marginal tax rate is proportional if $\tau_i = 0$, regressive if $\tau_i < 0$, and progressive if $\tau_i > 0$. The government in this context collects revenues to finance its consumption, which provides no utility to consumers or producers. We assume a balanced budget.

The two parties, the government and wage setters, choose to minimize social welfare loss as measured by expected value of quadratic deviations of employment from the full information level. The interaction between the wage setting process is characterized as a Stackelberg game, with the government as the leader choosing the magnitude of the progressivity parameter, and the indexation parameter is chosen as an outcome of the wage setting process.

In what follows we first report the value of the optimal setting of the progressivity parameter, which is followed by the optimal value of the indexation parameter.[11] The optimal value of the progressivity parameter is:

$$(9) \quad \tau_1^* = \rho_1 + \left\{ -\rho_2 VA \operatorname{Re}_1 [\rho_3 VAR \theta_t + \rho_4 VAR \eta_t] / (\rho_5 VAR \eta_t VAR \theta_t) \right\},$$

where

$$\rho_1 = \left\{ [(1/(\alpha + \varepsilon - \alpha \varepsilon))(1 + \delta(1 - \alpha)) - \delta(1 - \alpha)] / [\delta^2 (1 - \alpha)^2 (1/(\alpha + \varepsilon - \alpha \varepsilon))\delta^2 \alpha(1 - \alpha)] \right\},$$

$$\rho_2 = \delta^2 \mu^2 \alpha,$$

$$\rho_3 = \left\{ (1 - \alpha) + \alpha (1/(\alpha + \varepsilon - \alpha \varepsilon))^2 \right\},$$

$$\rho_4 = \sigma^2 (1 - \alpha)^2, \text{ and}$$

$$\rho_5 = \left[\delta(1 - \alpha) + (1/(\alpha + \varepsilon - \alpha \varepsilon))^2 \delta \alpha \right] \sigma^2 (1 + \delta).$$

Substituting the value of the optimal progressivity parameter into the social welfare function and solving for the optimal indexation parameter provides

$$(9') \quad \gamma^* = 1 - \frac{\phi_1 (\sigma_{\theta_t}^2)(\sigma_{e_t}^2)}{\phi_2 (\sigma_{\theta_t}^2)(\sigma_{\eta_t}^2) + \phi_3 [\phi_4 (\sigma_{\theta_t}^2) - \phi_5 (\sigma_{\eta_t}^2)]}$$
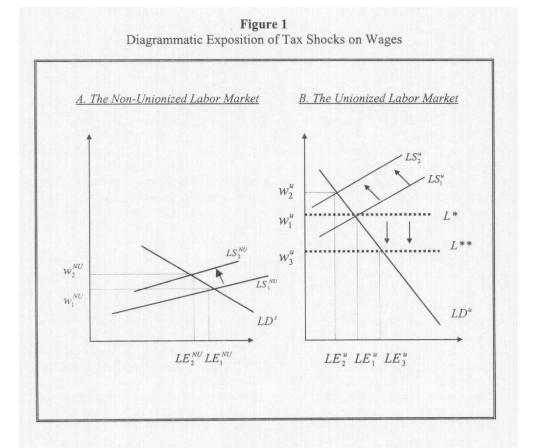
where ϕ_i, i=1,...,5 are the structural parameters, [12] and $(\sigma_{\theta_t}^2)$, $(\sigma_{e_t}^2)$, and $(\sigma_{\eta_t}^2)$ are the variances of productivity, tax, and velocity shocks. The interesting feature of this result is that $(\partial \gamma^* / \partial \sigma_\cdot^2) < 0$, which indicates that there is a decrease in the socially optimal degree of indexation with an increase in the variance of tax shocks.

The random variable e_t, in the specification of the marginal wage tax rate in (8), now plays a central role in the optimal value of the indexation parameter. The magnitude of its variance $\sigma_{e_t}^2$ has a direct influence on the indexation parameter and consequently the contracted nominal wage. Additionally, a distinct result emerges regarding the optimal value of the indexation parameter: increases in the variances of tax shocks reduce the degree of indexation, and, consequently, the contracted nominal wage.

Diagrammatic Exposition of Tax Shocks on Wages

To more clearly understand the intuition of the result consider for example the case of a positive tax shock, which would move the labor supply schedule inward. Start with the fact that at any point in time there is a positive difference between the wages paid to union workers and non-union workers (Lewis 1963, 1986; Parsley 1980; Freeman and Medoff 1984; Hirsch and Addison 1986), implying that the wage in a spot labor market is lower than the unionized counterpart. A positive tax shock shifts the labor supply

schedule inward from LS_1^{NU} to LS_2^{NU}, (panel A of Figure 1), and raises wages in the spot market from w^s to w_2^s. In the unionized labor market, the negotiated wage is identical to the market clearing wage w_1^u. At w_1^u, the full information labor supply schedule is LS_1^u. The union contract leaves it to the discretion of the employer to determine the level of employment (implying an absolutely elastic labor schedule $L*$), which, prior to the arrival of information on demand and supply shocks, is LE_1^u (depicted in panel B of Figure 1). As the tax shock impinges on the unionized labor market, the full-information labor supply function moves from LS_1^u to LS_2^u, just as it does in the case of the spot labor market.

Figure 1
Diagrammatic Exposition of Tax Shocks on Wages

A. The Non-Unionized Labor Market   *B. The Unionized Labor Market*

The optimal response to this tax shock in the unionized labor market is two-fold. To minimize loss,[13] there is first a decrease in the optimal progressivity parameter τ_1 of the

marginal tax rate described in (8). This has the effect of flattening the full-information labor supply schedule. For a shock of identical magnitude, we find that a flatter labor supply schedule while moving leftward by the same horizontal distance, has a smaller impact on the equilibrium level of employment. This flattened labor supply schedule, which occurs as a result of the reduction of the optimal setting of the progressivity parameter (in response to a positive tax shock), reduces the undesirable impact on full-information employment and output.

Second, the reduction in the optimal progressivity parameter of the marginal tax rate also has the effect of reducing the contracted nominal wage down from w_1^u to w_3^u (moving the perfectly elastic labor supply schedule down from $L*$ to $L**$) and raising employment from LE_1^u to LE_3^u. In this way the reductions in the optimal progressivity parameter, and the optimal indexation parameter, have the effect of minimizing loss and reducing the negative impact of the tax shocks on employment and output.

In effect the tax shock drives down the indexation parameter γ^* and nominal wages, thereby narrowing the gap between spot (non-union) and contracted (union) wages.[14]

Empirical Analysis

The University of Michigan's Panel Survey of Income Dynamics (PSID) data for 1984 on male heads of households are used for the empirical analysis.[15] The choice of 1984 as the year of interest is based on a simple idea. The 1980s were a decade characterized by a major tax change in every year. Some of these changes were of greater magnitude such as the Reagan tax cuts of 1981-1982 and the Tax Reform Act of 1986. This places 1984 as a convenient mid-point between these two major tax policy events. By 1984, the impact of the 1981-1982 tax cut had been absorbed by the economy and there was no reason for agents to have formed expectations of the Tax Reform Act of 1986. Choosing 1984 provides a convenient mid-point when the impact of an unanticipated tax change would have been discernible.

The main thrust of the current research is to quantify the effect of marginal tax rate uncertainty on the union/non-union wage gap. We propose an instrumental variable approach for the dual purpose of accounting for any possible feedback effects between the marginal tax rates and wages, and to generate the uncertain component of the marginal wage tax rates. Specifically, we use a modified version of a two-step framework originally proposed by Barro (1977, 1978). In our context, this entails regressing the reported actual marginal tax rate [MARTX][16] of the individuals in the sample on a set of instruments (viz., number of exemptions [EXMPS], filing status dummies [SINGLE=1, 0 otherwise, and MARRIED filing jointly =1, 0 otherwise -- i.e., omitted filing status category being married filing individually], percent of wages contributed to a pension plan [PENSPAY], and home mortgage status dummy [MORTGAGE = 1 if the individual carries a home mortgage, 0 otherwise]) to generate a residual (e) in the first stage. The square of this residual (e) from the first stage, defined as R, is used in the second stage[17] as a proxy for the uncertain component of the marginal tax rate variable.

To empirically test the main hypothesis that increasing marginal tax rate uncertainty leads to a reduction in the union/non-union wage gap, the following earnings function is proposed:

(10)   ln Wage = β_0 + $\beta_1(EXP)$ + $\beta_2(EXP2)$ + $\beta_3(TENURE)$ + $\beta_4(TEN2)$ +
[*vector of controls for level of education, region, race, marital status, occupation, and industry*] + $\alpha_1(UNION)$ + $\alpha_2(R)$ + $\alpha_3(UNION*R)$ + error

Along with the standard human capital, demographic, occupation/industry controls, and union status (*UNION*) -- two other related variables, i.e., a proxy for marginal tax uncertainty (*R*), and an interaction between the union status and uncertain tax variable (*UNION*R*) are also added to the above specification. Two points become apparent if the theoretical reasoning underlying the result on optimal indexation (equation 9´) holds true. First, with a positive tax shock, there is an increase in the full-information wage, implying a positive relationship between the tax rate and wages. Second, the underlying reason is that variability in the tax rate leads to a decrease in the optimal degree of indexation and the indexed nominal wage. This implies a decrease in the union/non-union wage differential. Accordingly, one would empirically expect a positive sign for the uncertain tax variable (**R**) and a negative sign for the interaction term (*UNION*R*). For comparative purposes the above model was also estimated without the interaction term (*UNION*R*). The regression results[18] along with the variable descriptions are presented in Table 1.

The standard human capital variables are significant and have the correct sign. As far as the included demographic variables are concerned, Southerners in general earn about 8 percent less and whites enjoy a premium of 7.5 percent. The validity of the proposed hypothesis that marginal tax uncertainty dampens the union wage premium can be tested by examining the coefficients of the uncertain tax variable (**R**) as well as the interaction term (*UNION*R*). As predicted by the theoretical model, both variables have the correct sign (positive and negative, respectively) and are statistically significant.

CONCLUSION

This paper measures the impact of marginal tax rate uncertainty on the union wage premium. This was accomplished in two stages. In the first phase, a theoretical model was used to establish the implications of increasing marginal wage tax rate uncertainty on the union/non-union wage premium. This theoretical result conclusively indicated a decrease in the contracted nominal wage as the market clearing wage was rising providing a convincing basis for the claim that increasing tax rate uncertainty reduced the union wage premium.

The second part of the exercise involved testing the hypothesis using a variation of a commonly used earnings function. An instrumental variables appproach was used to measure tax rate uncertainty, which was used as an explanatory variable in the earnings function. The Panel Survey on Income Dynamics micro data were used for empirical

analysis. The estimates provide strong empirical support for the maintained hypothesis. Arguably, the instrumental variable approach to measuring marginal tax rate uncertainty is not without shortcomings. Nevertheless, the results provide a convincing channel through which uncertain tax policy might erode the union wage premium.

Table 1
Regression Results - Dependent Variable: ln Wage (= natural log of wage rate)

VARIABLE	MODEL 1		MODEL 2	
	Parameter Estimate	t-value	Parameter Estimate	t-value
INTERCEPT	5.947803	77.385	5.940720	77.522
Schooling Dummies (omitted HS dropouts)				
High School	0.100647	2.871	0.100236	2.869
Some College	0.230270	6.951	0.230501	6.981
College	0.451821	9.808	0.448733	9.772
Advanced	0.593035	10.183	0.586368	10.097
EXP (= actual full-time experience)	0.027143	7.156	0.027506	7.273
EXP2 = EXP^2	-0.000527	-7.612	-0.000536	-7.752
TENURE (= # of months with present employer)	0.002043	6.795	0.002039	6.801
TEN2 (=$TENURE^2$)	-0.000002926	-3.668	-0.00000292	-3.672
SOUTH (=1; 0 otherwise)	-0.079161	-3.320	-0.077231	-3.249
WHITE (=1; 0 otherwise)	0.076390	2.951	0.078173	3.029
MARRIED (=1; 0 otherwise)	0.018686	0.536	0.012487	0.359
OCCUPATION DUMMIES	Included		Included	
INDUSTRY DUMMIES	Included		Included	
UNION (=1 if union member; 0 otherwise)	.211567	7.675	0.263822	8.403
R (= a proxy for the uncertain marginal tax rate)	.000517	5.880	0.000622	6.700
UNION*R	-	-	-0.000934	-3.440
R-sq*	.4442		.4482	
Sample	1660		1660	

*Computed between the observed and predicted values of the dependent variable.

A concluding observation is in order. Bell (1989 p.57) points out that "the preponderance of evidence suggests that economic factors by themselves do not fully explain the upward trend in union concessions in industries in the 1980s." If concessions by unions in the 1980s were responsible for the erosion in the union/non-union wage premium, and concessions by themselves are not fully explained by economic factors, it is very likely that one factor is missing in the explanation. It is that unions, when they have employment stability as their objective function, will cede wage concessions when shocks impinge--especially marginal tax rate shocks. Taking tax shocks into account provides a more complete rendition of the extent of concessions offered by unions in the 1980s.

APPENDIX

Derivation of the Social Welfare Function: The Optimal Indexation and Progressivity Parameter

A. Derivation of Employment Under Full Information

Equating (5) and (6) in the text, and solving for the equilibrium wage, and substituting it into the labor demand function (5), gives us the equilibrium level of employment, which can be described as:

(A-1-1) $\quad l_{it} = [1/((\alpha + \varepsilon - \alpha\varepsilon)\delta + \varepsilon)][-\sigma\delta p_t + \sigma\delta m_t + \delta(\varepsilon - 1)\theta_t - \delta\varepsilon\tau_t]$.

Using this equilibrium level of employment and the tax function (8) in the production function (1) gives us the output schedule for the individual firm which is:

(A-1-2)
$$y_{it} = [1/[\delta(\alpha + \varepsilon - \alpha\varepsilon) + \varepsilon + \varepsilon\delta\alpha\tau_1)]]$$
$$X[-\alpha\sigma\delta(\alpha + \varepsilon - \alpha\varepsilon)p_t + \sigma\delta\alpha m_t - \varepsilon\delta\alpha\tau_0 - \alpha\varepsilon\delta\mu e_t + ((\alpha + \varepsilon - \alpha\varepsilon)\delta + \varepsilon)\theta_t].$$

Using the output schedule of the individual firm above, and the product demand equation (4), gives us the price level. Using this price level once again in the firm's product demand equation and aggregating gives us the reduced form equation for output, which is:

(A-1-3) $\quad y_t^* = [1/(\varepsilon\delta\alpha\tau_1 + \varepsilon[1 + \delta(1 - \alpha)])][-\alpha\varepsilon\delta\mu e_t - \alpha\varepsilon\delta\tau_0 + (\delta + 1)\varepsilon\theta_t]$.

Using the value of (A-2-3) in the tax function (8) and the price level in the labor demand equation (5) gives us the full information level of employment:

(A-1-4) $l_{it}* = [\delta/[\delta\alpha\tau_0 - +[1+\delta(1-\alpha)]]][\varepsilon+\delta(\alpha+\varepsilon-\alpha\varepsilon)]$

$$X\left[\begin{array}{l}\{-\varepsilon(1+\delta)\tau_1 + (\varepsilon-1)[\alpha\delta\tau_1[1+\delta(1-\alpha)]] + (1+\delta)\}\theta_t - [\varepsilon\mu[1+\delta(1-\alpha)] + \alpha\delta\mu]e_t \\ -[\varepsilon[1+\delta(1-\alpha)] + \alpha\delta]\tau_0 \end{array}\right]$$

B. Derivation of Employment Under Wage Indexation

Substituting the contracted nominal wage (7) in labor demand (5) gives us the level of employment under indexation, which is:

(A-1-5) $l_{it} = (\alpha+\varepsilon-\alpha\varepsilon)\left[-\varepsilon E_{t-1}w^*_{it} + [\varepsilon(1-\gamma)+\sigma]p_t + \varepsilon\gamma E_{t-1}p_t + \sigma m_t + (\varepsilon-1)\theta_t\right].$

Using this level of employment in the production function gives us the output of the representative firm under indexation. Using the resulting value of output under indexation along with the product demand equation (4) in the text, gives us the individuals firm's price. Substituting for the market clearing wage in the firm's price and aggregating gives us the aggregate price level:

(A-1-6) $p_t = [1/\{\sigma - (\alpha(\alpha+\varepsilon-\alpha\varepsilon)(\sigma+\varepsilon(\gamma-1)))\}((\alpha+\varepsilon-\alpha\varepsilon)\varepsilon+\delta)]$

$$X\ [((\alpha+\varepsilon-\alpha\varepsilon)\varepsilon+\delta)\sigma(\alpha+\varepsilon-\alpha\varepsilon)m_t + \varepsilon\alpha(\alpha+\varepsilon-\alpha\varepsilon)\delta\tau_0$$

$$+ \varepsilon\alpha(\alpha+\varepsilon-\alpha\varepsilon)\delta\tau_1 E_{t-1}y_t - \varepsilon((\alpha+\varepsilon-\alpha\varepsilon)\varepsilon+\delta)$$

$$X[1+\alpha(\varepsilon-1)(\alpha+\varepsilon-\alpha\varepsilon)]\theta_t + \alpha\varepsilon(\alpha+\varepsilon-\alpha\varepsilon)$$

$$X\{(1-\gamma)((\alpha+\varepsilon-\alpha\varepsilon)\varepsilon+\delta)-\sigma(\alpha+\varepsilon-\alpha\varepsilon)\}E_{t-1}p_t]$$

There are two steps involved in solving for the level of employment under indexation. First taking expectations of the price level above to obtain the expected value at *t-1* and then using both the price level and its expected value in the equation of exchange (2) provides an expression for output. Next, taking the expected value of output, the equilibrium wages, as well as the price level along with the expected wage in the labor demand function provides us with the level of employment under indexation:

(A-1-7) $l^d_{it} = \lambda\{\xi_t + \chi\eta_, + \psi\tau_\circ\},$

where:

$$\lambda = [1/[\sigma((\alpha + \varepsilon - \alpha\varepsilon)\alpha - 1) + (\alpha + \varepsilon - \alpha\varepsilon)\alpha\varepsilon(\gamma - 1)],$$
$$\xi = [((\alpha + \varepsilon - \alpha\varepsilon)\alpha - 1)\sigma(\alpha + \varepsilon - \alpha\varepsilon)(\varepsilon - 1) - (\alpha + \varepsilon - \alpha\varepsilon)\varepsilon((\alpha + \varepsilon - \alpha\varepsilon)\sigma + (\gamma - 1))],$$
$$\chi = (\alpha + \varepsilon - \alpha\varepsilon)\varepsilon\sigma(\gamma - 1), \quad and$$

$$\psi = \frac{\begin{array}{l}[(\alpha + \varepsilon - \alpha\varepsilon)\varepsilon\delta][\sigma\{\delta((\alpha + \varepsilon - \alpha\varepsilon)\alpha - 1) - (\alpha + \varepsilon - \alpha\varepsilon)\varepsilon]X \\ \left[\begin{array}{l}(\alpha + \varepsilon + \alpha\varepsilon)\varepsilon\delta[\sigma\{\delta((\alpha + \varepsilon - \alpha\varepsilon)\alpha - 1) - (\alpha + \varepsilon - \alpha\varepsilon)\varepsilon\} \\ +(\alpha + \varepsilon - \alpha\varepsilon)\alpha\varepsilon\{\{\{\alpha + \varepsilon - \alpha\varepsilon)\varepsilon + \delta)(\gamma - 1) + \sigma(\alpha + \varepsilon - \alpha\varepsilon)\}\}]\end{array}\right]\end{array}}{\begin{array}{l}(\alpha + \varepsilon - \alpha\varepsilon)\varepsilon + \delta)\{\delta(\alpha(\alpha + \varepsilon - \alpha\varepsilon) - 1) - \varepsilon(\alpha + \varepsilon - \alpha\varepsilon)\} \\ X[\delta + (\alpha + \varepsilon - \alpha\varepsilon)\varepsilon(1 + \delta\alpha\tau_1) - \delta\alpha(\alpha + \varepsilon - \alpha\varepsilon)]\end{array}}.$$

The social welfare function used in the analysis is described as:

(A-1-8) $\qquad LOSS = E[l_{it}^d - l_{it}^*]^2,$

and substituting for employment under indexation and employment under full information in the expression above, we get:

(A-1-8´) $\qquad LOSS = \phi_1^2 VAR\eta_t + \phi_2^2 VA\,Re_t + [\phi_3 - \phi_4]^2 VAR\theta_t,$

where:

$$\phi_1 = \{[\sigma(\gamma - 1)]/[\alpha(\gamma - 1) - \sigma(1 - \alpha)]\},$$
$$\phi_2 = \{\delta\mu/[\delta\alpha\tau_1 + [1 + \delta(1 - \alpha)]]\},$$
$$\phi_3 = -\{[\alpha + \varepsilon - \alpha\varepsilon]\{\sigma[\alpha + \varepsilon - \alpha\varepsilon] - \sigma(\varepsilon - 1) - \varepsilon(\gamma - 1)\}/[\alpha(\gamma - 1) - \sigma(1 - \alpha)]\}, and$$
$$\phi_4 = [\delta\{(\alpha\delta\tau_1 + [1 + \delta(1 - \alpha)] - \delta(1 + \delta\tau_1))\}[1 + \delta(1 - \alpha)][\delta\alpha\tau_1 + 1 + \delta(1 - \alpha)]].$$

The individuals who are involved in the wage setting process, who are followers in this Stackelberg game, begin by choosing the optimal value of the indexation parameter. The tax-setting authority, in the role of the leader, then chooses the value of the progressivity parameter of the marginal wage tax rate. The loss function is first differentiated with respect to the indexation parameter and the first order condition is solved for its optimal value. It is this value that is reported in equation (9). The solution process requires that this optimal value is substituted back into the loss function, and differentiated with regard to the progressivity parameter. The first order condition is then solved for the optimal value of the progressivity parameter which is:

$$\tau_1^* = \rho_1 + \left\{ -\rho_2 VA\,\text{Re}_t \left[\rho_3 VAR\theta_t + \rho_4 VAR\eta_t \right] / \left(\rho_5 VAR\eta_t VAR\theta_t \right) \right\},$$

$$\rho_1 = \left\{ \left[(1/(\alpha + \varepsilon - \alpha\varepsilon))(1 + \delta(1 - \alpha)) - \delta(1 - \alpha) \right] / \left[\delta^2(1 - \alpha)^2 + (1/(\alpha + \varepsilon - \alpha\varepsilon))\delta^2\alpha(1 - \alpha) \right] \right\},$$

$$\rho_2 = \delta^2\mu^2\alpha,$$

$$\rho_3 = \left\{ (1 - \alpha) + \alpha(1/(\alpha + \varepsilon - \alpha\varepsilon))^2 \right\},$$

$$\rho_4 = \sigma^2(1 - \alpha)^2, \text{ and}$$

$$\rho_5 = \left[\delta(1 - \alpha) + (1/(\alpha + \varepsilon - \alpha\varepsilon))^2\delta\alpha \right]\sigma^2(1 + \delta).$$

ENDNOTES

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[2] Alm (1988) identifies three different sources of uncertainty. First, frequent and unpredictable changes infuse uncertainty into economic decision-making. Second, difficulties arise in interpreting the existing tax laws. Third, even the mention of tax law changes introduces uncertainty into plans that individuals make.

[3] Figure 1, Barro and Sahasakul (1983), p. 436, demonstrates the variability of the average marginal tax rate.

[4] Our analysis considers tax *rate* uncertainty and not tax *base* uncertainty.

[5] Skinner (1988) provides an analysis of the extent and the impact of marginal wage tax rate uncertainty in the U.S. context.

[6] See Ball (1987, 1988) for a derivation of the aggregate price level and the aggregate output level.

[7] See Hirsch and Connolly (1987).

[8] Workers sign contracts at the beginning of the period, prior to the arrival of shocks to the system. At this point, they form expectations about the market-clearing wage. To this market-clearing wage, they index their wages to unanticipated inflation. However, this does not provide a clear picture about the degree of indexation and its role. To do this, it is necessary to explicitly recognize that once the contract is signed, the ex-post labor supply becomes absolutely elastic and it is the firm that determines the quantity of labor that will be used in every period. It stands to reason that at this stage, workers would be worried about employment stability. To protect themselves against high variability of employment they index their wages optimally to unanticipated inflation with the presumption that the indexation parameter, which is determined

endogenously, will protect against employment variability. This is the theoretical reason for thinking of labor contracts embodying wage indexation. The empirical issues of indexation of labor contracts have been studied by Hendricks and Kahn (1985) and have been considered as recently as Ghosal and Loungani (1996). Finally, between 55% and 60% of labor contracts have some form of indexation to the CPI. These reasons motivate our consideration of labor contracts with embedded indexation.

[9] This marginal tax rate specification plays a central role in our empirical analysis. The random variable in this specification of the marginal tax rate, e_t, is the variable **R** in the empirical analysis. The reader is requested to look at footnotes 14 and 15 for a complete description of the role of the random variable e_t.

[10] The aggregate marginal wage tax rate is obtained in the same way as aggregate price level and output level.

[11] See the appendix for a detailed derivation of the social welfare function, and optimal value of the indexation and progressivity parameter.

[12] The parameter values reported below have been identified in equations 1-8, and the values of ϕ_i, i=1,..., 5 are:

$$\phi_1 = \mu\alpha\delta^2\mu^2[(1-\alpha) + \alpha(1/(\alpha+\varepsilon-\alpha\varepsilon))^2][\delta(1-\alpha) + (1/(\alpha+\varepsilon-\alpha\varepsilon))^2],$$

$$\phi_2 = \mu^2\delta(1+\delta)^2,$$

$$\phi_3 = \alpha\delta^2,$$

$$\phi_4 = [(1-\alpha) + \alpha(1/(\alpha+\varepsilon-\alpha\varepsilon))^2](1-\alpha\delta),$$

$$\phi_5 = \mu^2(1-\alpha).$$

[13] Loss is measured by the criterion of quadratic deviations of output from the full-information level.

[14] The pre-tax shock wage premium was $(w_1^U - w_1^{NU})$, and subsequent to the tax shock was $(w_3^U - w_2^{NU})$.

[15] Previous studies that have addressed the impact of unions on wages have used cross-sectional data. In a life-cycle framework, a cross-sectional analysis assumes that a researcher is following an individual over his/her lifetime--which implies that all individual differences (heterogeneity) can be accounted for by exogenous variables. Since workers in a cross-section framework are likely to be at various stages of their life-cycle, the marginal tax rate uncertainty derived over individuals should indeed be a good approximation for tax rate uncertainty over time. To avoid any gender related complications only data on males were used.

[16] The marginal tax variable is reported in the PSID survey and is defined as: "The values for this variable represent the actual marginal tax rate based on Head and Wife's taxable income, number of exemptions, and tax table used."

[17] Barro's methodology suggests using the residual from the first stage as the uncertain component of the marginal tax rate variable. Instead, we utilize the square of the residual. The motivation for doing so is that e^2 (=R in the present context) is a consistent estimator of $\sigma^2(e)$. We would like to thank the referee for this suggestion.

Briefly, following is the first-stage-estimated equation with t-values in parentheses:

$$\hat{MARTX} = \underset{(23.724)}{17.69} \; \underset{(7.76)}{-1.299} \, EXMP + \underset{(4.185)}{3.227} \; SINGLE + \underset{(12.76)}{8.009} \; MARRIED + \underset{(3.41)}{.511} \; PENSPAY + \underset{(13.457)}{5.436}$$

and the $R^2 = .1822$, $\bar{R}^2 = .1803$, and F - value $= 93.55$.

[18] Model 1 is without the (*UNION*R*) interaction term and model 2 is with the interaction term.

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