WAGE CONTRACTS, STICKY PRICES AND EXCHANGE RATE VOLATILITY: EVIDENCE FROM NINE INDUSTRIAL COUNTRIES

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ABSTRACT

In this paper, I investigate the link between real wage rigidities, nominal wage and price rigidities, and nominal exchange rate volatility. Using a model of overlapping wage contracts and monopolistic price-setting, where prices are costly to change, I find sticky nominal prices and wages to be a feature of all the major industrialised countries. However, I also find real wage rigidities to be absent for most of these countries. In the face of rigidities to nominal wages and prices, flexibility in the real product wage comes about through the dynamics of prices, wages and exchange rates, and the indexation of wages to consumer prices.

TABLE OF CONTENTS

WAGE CONTRACTS, STICKY PRICES AND EXCHANGE RATE VOLATILITY: EVIDENCE FROM NINE INDUSTRIAL COUNTRIES

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1. INTRODUCTION

This paper examines the relationship between real and nominal wage flexibility, the stickiness of goods' prices, and the volatility of nominal exchange rates. The motivation for this study is to find a link between two of the most striking global macroeconomic developments since the early 1970's - the secular rise in unemployment rates[1] and the apparently inexplicable volatility of real exchange rates.[2]

These phenomena can both be viewed as *prima facie* empirical falsifications of the notion that the world consists of continuously clearing competitive markets. However, an important distinction needs to be made between these two events. The increase in unemployment has been attributed largely to a real rigidity,

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[1] Bruno and Sachs (1986) provide an extensive analysis of unemployment in the major industrial countries over this period. For a recent analysis of European unemployment, see Dreze and Bean (1990).

[2] Inexplicable that is, in terms of an equilibrium response to changes in fundamental economic conditions (Mussa, 1986). Branson (1986) considers the large real appreciation of the $US in the early 1980's to have been an equilibrium response to a permanently more expansionary fiscal policy. However, many puzzles remain e.g. Germany and Japan have had stable policies but the DEM/Yen real exchange rate has nevertheless been very volatile.

namely, the inability of real wages to adjust in the face of adverse shocks, such as an oil shock. On the other hand, the volatility in real exchange rates i.e. the failure of purchasing power parity (PPP) to hold, has been attributed primarily to the stickiness of goods' prices, which is a nominal rigidity.

In this paper I construct a model of overlapping wage contracts and nominal price determination which examines the effects on aggregate supply of the nominal and real rigidities discussed above. The model permits a test of two related hypotheses. The first is that an excessive degree of wage indexation in the major industrial countries resulted in real wages being set above the levels that would have cleared the labour market in the period 1973-1988. The second is that the greater is the degree of nominal wage and price rigidities, the greater will be the variance of nominal exchange rate innovations and hence in the short term, real exchange rate innovations. The countries examined are Australia, Austria, Canada, France, Germany, Italy, Japan, the United Kingdom and the United States.

The model is outlined in Section 2; optimal wage contracts are derived in Section 3 with empirical questions addressed in Sections 4 and 5. Section 6 contains a summary and conclusions.

Anticipating the conclusions, I find support for the real wage rigidity hypothesis for only two countries, Germany and the United Kingdom. However, I find compelling evidence that nominal wage and price rigidities are a cause of volatile real exchange rates for all the countries examined. In those countries where it exists, the requisite flexibility of real product wages in the face of sticky nominal wages and prices is brought about through the dynamics of prices, wages and exchange rates, and the indexation of wages to consumer prices.

2. THE MODEL

(i) The Labour Market

The labour force consists of n cohorts of workers, each of which has a wage contract which lasts for n periods. I assume that all workers in the economy are represented by a single union. Each cohort-specific worker receives the same wage, but differences in wages can arise between workers of different cohorts. Without loss of generality, let the wage contract of the first cohort be in effect from period t through period t+n-1. It is negotiated at the end of period t-1, and so is contingent on information known at that time. The contract is

$$w^1_t = {}_{t-1}w^1_t = w^{1o}_t = {}_{t-1}w^{1o}_t \tag{1a}$$

$${}_{t-1}w^1_{t+1} = {}_{t-1}w^1_t + \pi({}_{t-1}p^c_{t+1} - {}_{t-1}p^c_t) \tag{1b}$$

$$w^1_{t+1} = {}_{t-1}w^1_{t+1} + \theta(p^c_t - {}_{t-1}p^c_t) \tag{1c}$$

$$\vdots$$

$${}_{t-1}w^1_{t+n-1} = {}_{t-1}w^1_{t+n-2} + \pi({}_{t-1}p^c_{t+n-1} - {}_{t-1}p^c_t) \tag{1d}$$

$$w^1_{t+n-1} = {}_{t-1}w^1_{t+n-1} + \theta(p^c_{t+n-2} - {}_{t-1}p^c_{t+n-2}) \tag{1e}$$

where π is the "escalator" coefficient and θ is the "catch-up". w is (the natural logarithm of) the nominal wage, ${}_{t-1}w^1_t$ is the nominal wage for period t expected at the end of period t-1 and w^{1o}_t is the nominal wage that clears the market for workers in cohort 1.

p^c_t is the log of consumer prices, defined as

$$p^c_t = \sigma p_t + (1 - \sigma)(e_t + pf_t) \qquad (2)$$

where p is the log of domestic producer prices, e is the log of the nominal exchange rate (the domestic price of foreign currency), pf is the log of foreign producer prices and $(1 - \sigma)$ is the share of imports in consumption.

By assumption, the price level p_t is not known until the end of period t. Employment decisions by firms (which are made at the beginning of each period) are thus made on the basis of the expected real wage for that period - the known nominal wage relative to the expected level of producer prices. The nominal wage for period t, w^1_t, is set equal to the market-clearing wage for that period. The expected nominal wage for period t+1 is the expected wage for period t, ${}_{t-1}w^1_t$, plus a fraction π of the expected inflation in consumer prices over that period, ${}_{t-1}p^c_{t+1} - {}_{t-1}p^c_t$. In addition, the contract allows for a fraction θ of the price surprise in the previous period $p^c_t - {}_{t-1}p^c_t$, to augment wages in t+1. Of course, with rational expectations, this amount has an expected value of zero in t-1, the time of contract negotiation. To keep the model simple I assume that $\pi = 1 - \theta$, i.e., price changes are assumed to be fully passed onto wages.[3] However, the extent to which wage inflation reflects anticipated and unanticipated price inflation (the value of θ) is left open to estimation.

Nominal wages for periods t+2...t+n-1 are set in an analogous manner. w^1_{t+n-1}, for instance, is the wage expected at t-1 for the previous period, ${}_{t-1}w^1_{t+n-2}$, plus a fraction $(1 - \theta)$ of the expected price inflation from t+n-2 to t+n-1, plus a fraction θ of the difference between the price level in t+n-2 and the price level expected at t-1 for t+n-2. In short, the contract sets a sequence of

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[3] This assumption is tested and found to be generally supported by the data; see Section 5 below.

n *ex-ante* nominal wages ${}_{t-1}w^1_t \ldots {}_{t-1}w^1_{t+n-1}$, the last n-1 of which are based on expected future inflation. *Ex-post* nominal wages $w^1_t \ldots w^1_{t+n-1}$ differ from *ex-ante* wages because of mistakes in forecasting prices, some fraction of which is passed on to wages. A new contract is signed at the end of period t+n-1, which determines wages in periods t+n through t+2n-1.

Wages for cohort 2 are set in precisely the same way, except that they are negotiated at the end of period t, and take effect from periods t+1 through t+n. The crucial difference between the wages set for cohorts 1 and 2 (apart from the one period overlap) is the latter are based on information known (and hence expectations formed) at the end of period t. The contracts for cohorts 3...n are set in periods t+1...t+n-2 respectively. They start in periods t+2...t+n-1 and expire in periods t+n+1...t+2n-2.

Aggregate wages at time t+n-1 are given by[4]

$$w_{t+n-1} = (1/n)(w^1_{t+n-1} + w^2_{t+n-1} + \ldots w^n_{t+n-1}) \tag{3a}$$

where

$$\begin{aligned} w^1_{t+n-1} = w^1_t &+ (1-\theta)({}_{t-1}p^c_{t+n-1} - {}_{t-1}p^c_t) \\ &+ \theta(p^c_{t+n-2} - {}_{t-1}p^c_{t+n-2}) \\ &+ \theta(p^c_{t+n-3} - {}_{t-1}p^c_{t+n-3}) \\ &\;\cdot \\ &\;\cdot \end{aligned} \tag{3b}$$

[4] In making this aggregation, I assume that, at any given point in time, all agents in the economy have access to the same information set, and that they use the same expectations-generating mechanism to forecast future prices and wages. I also assume that all n cohorts choose the same θ. This assumption is usually made in the literature on overlapping wage contracts.

$$
\begin{aligned}
&\quad \cdot \\
&\quad + \theta(p^c_t - {}_{t-1}p^c_t)
\end{aligned}
$$

$$
\begin{aligned}
w^2_{t+n-1} = w^2_t &+ (1-\theta)({}_tp^c_{t+n-1} - {}_tp^c_t) \\
&+ \theta(p^c_{t+n-2} - {}_tp^c_{t+n-2}) \\
&+ \theta(p^c_{t+n-3} - {}_tp^c_{t+n-3}) \\
&\cdot \\
&\cdot \\
&\cdot \\
&+ \theta(p^c_{t+1} - {}_tp^c_{t+1})
\end{aligned}
\tag{3c}
$$

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$$
w^n_{t+n-1} = {}_{t+n-2}w^n_{t+n-1} = {}_{t+n-1}w^{no}_{t+n-1} = w^{no}_{t+n-1}.
\tag{3d}
$$

Taking expectations at t+n-4, and using the law of iterated expectations, we find that

$$
\begin{aligned}
&w_{t+n-1} - {}_{t+n-4}w_{t+n-1} = \\
&\quad (1/n)({}_{t+n-3}w^{n-1o}_{t+n-2} - {}_{t+n-4}w^{n-1o}_{t+n-2} + {}_{t+n-2}w^{no}_{t+n-1} \\
&\quad - {}_{t+n-4}w^{no}_{t+n-1}) + ((1-\theta)/n)({}_{t+n-3}p^c_{t+n-1} - {}_{t+n-4}p^c_{t+n-1}) \\
&\quad - ((1-\theta)/n)({}_{t+n-3}p^c_{t+n-2} - {}_{t+n-4}p^c_{t+n-2}) \\
&\quad + (n-2)(\theta/n)(p^c_{t+n-2} - {}_{t+n-4}p^c_{t+n-3}) \\
&\quad + (n-1)(\theta/n)(p^c_{t+n-2} - {}_{t+n-4}p^c_{t+n-3}) \\
&\quad - (\theta/n)({}_{t+n-3}p^c_{t+n-2} - {}_{t+n-4}p^c_{t+n-2})
\end{aligned}
\tag{4a}
$$

Backdating n-1 periods and re-arranging terms:

$$w_t - {}_{t-3}w_t = \tag{4b}$$
$$(1/n)({}_{t-2}w^{n-1o}{}_{t-1} - {}_{t-3}w^{n-1o}{}_{t-1} + {}_{t-1}w^{no}{}_t - {}_{t-3}w^{no}{}_t)$$
$$+ ((1-\theta)/n)(({}_{t-2}p^c{}_t - {}_{t-2}p^c{}_{t-1}) - ({}_{t-3}p^c{}_t - {}_{t-3}p^c{}_{t-1}))$$
$$- (\theta/n)({}_{t-2}p^c{}_{t-1} - {}_{t-3}p^c{}_{t-1}) + (n-2)(\theta/n)(p^c{}_{t-2} - {}_{t-3}p^c{}_{t-2})$$
$$+ (n-1)(\theta/n)(p^c{}_{t-1} - {}_{t-3}p^c{}_{t-1}).$$

Consider the term ${}_{t-2}w^{n-1o}{}_{t-1} - {}_{t-3}w^{n-1o}{}_{t-1}$. This is the change from periods t-3 to t-2 in the market-clearing nominal wage for cohort n-1 expected to prevail in period t-1. This is equal to the change in producer prices expected for that period, plus the expected value of a series of supply and demand shocks which alter the market-clearing real product wage. I assume these shocks to be white noise, and denote the vector of shocks ξ_{n-1t}. Thus, with $E_{t-j}\xi_{n-1t} = 0$, $j > 0$,

$${}_{t-2}w^{n-1o}{}_{t-1} - {}_{t-3}w^{n-1o}{}_{t-1} = {}_{t-2}p_{t-1} - {}_{t-3}p_{t-1}. \tag{4c}$$

Similarly,

$${}_{t-1}w^{no}{}_t - {}_{t-3}w^{no}{}_t = {}_{t-1}p_t - {}_{t-3}p_t \tag{4d}$$

and so

$$w_t - {}_{t-3}w_t = \tag{4e}$$
$$(1/n)({}_{t-2}p_{t-1} - {}_{t-3}p_{t-1} + {}_{t-1}p_t - {}_{t-3}p_t)$$
$$+ ((1-\theta)/n)(({}_{t-2}p^c{}_t - {}_{t-2}p^c{}_{t-1}) - ({}_{t-3}p^c{}_t - {}_{t-3}p^c{}_{t-1}))$$
$$- (\theta/n)({}_{t-2}p^c{}_{t-1} - {}_{t-3}p^c{}_{t-1}) + (n-2)(\theta/n)(p^c{}_{t-2} - {}_{t-3}p^c{}_{t-2})$$
$$+ (n-1)(\theta/n)(p^c{}_{t-1} - {}_{t-3}p^c{}_{t-1}) + \eta_t.$$

The aggregate wage level at time t is a function of lagged prices, lagged price expectations, expectations of the current wage level and two parameters: the contract length n and the indexation parameter θ. In addition, random shocks η_t, representing wage bargains which occur outside the contracting system, affect the aggregate wage level in every period. These shocks need not be white noise. Indeed we might expect a wage shock in one period to affect wages in subsequent periods; furthermore, the variance of these shocks could well vary from period to period. (These possibilities are taken into account at the estimation stage.) Equation (4e) cannot be estimated in its current form since the expectations variables are unobservable. The conversion of equation (4e) into a form suitable for estimation is discussed in Section 4.

(ii) The Goods Market

I assume that output in each country is produced by a representative firm that competes in the international goods market with other firms/countries. The market structure is monopolistic (so that there is no strategic interaction, as would occur with an oligopoly) with each firm setting the profit maximizing price of its product. However, there exist convex costs to changing prices. Following Giovannini and Rotemberg (1986), the firm's objective function is

$$\text{Min } E_t \sum_{j=0}^{\infty} \delta^t[(p_{t+j} - p^o_{t+j})^2 + C(p_{t+j} - p_{t+j-1})^2] \tag{5}$$

where p^o_{t+j} is the price level that clears the goods market at time t+j, δ is a constant discount factor, E_t is the expectations operator, conditional on information at time t and C, $(0 < C < 1)$, represents the cost of changing prices. The first order conditions for this problem can be written as (Giovannini, 1988)

$$p_t = cp_{t-1} + \delta c_t p_{t+1} + (1-c-\delta c)p^o_t \tag{6}$$

where $c = C/[1 + (1 + \delta)C]$, $0 < c < (1/(1+\delta))$, and ${}_tp_{t+1}$ is the (rational) expectation of p for time t+1, held at time t. Only when c=0 will p_t be equal to its equilibrium (profit-maximizing) price p^o_t.

Under the assumptions of a Ricardian technology with constant returns and no inputs other than labour, p^o_t will be a constant mark-up over the nominal wage. This mark-up will be uniform across countries (equation 7a), with the relative price of domestic and foreign goods (the real exchange rate) determined by relative labour costs (equation 7b).

$$p^o_t - w_t = (e_t + pf_t) - (e_t + wf_t) + u_t \tag{7a}$$

$$p^o_t - (e_t + pf_t) = w_t - (e_t + wf_t) + u_t \tag{7b}$$

$$p^o_t = w_t - wf_t + pf_t + u_t \tag{7c}$$

$$u_t = u_{t-1} + \varepsilon_t \tag{7d}$$

where wf_t is the log of the foreign wage.

Up to a stochastic shock u_t, the equilibrium is characterized by domestic and foreign real product wages being equalized, each measured in its own currency. The competitive equilibrium arises as a special case of this model. If domestic wages are perfectly flexible, then nominal wages at home and abroad will be equalized (in common currency terms) by international competition in the goods market, thus

$$w_t = e_t + wf_t \tag{7e}$$

and so

$$p^o{}_t = e_t + pf_t + u_t. \tag{7f}$$

In addition, if c = 0, then

$$p_t = e_t + pf_t + u_t. \tag{7g}$$

In the absence of nominal rigidites, PPP will be obtained in the short-run, up to the shock u_t.[5] If nominal rigidities are present, however, real exchange rates will deviate from their (competitive) equilibrium values.

This is the well-known result established by Dornbusch (1976). If we assume that shocks which cause the exchange rate to deviate from its equilibrium path are unanticipated, then a corollary to that result is that the variance of exchange rate innovations will be larger the more pronounced are the short-run rigidities to nominal wages and prices.

u_t can be thought of as a supply shock, e.g. to productivity, with ε_t a stationary ARMA process. A positive shock to productivity will create a series of current account surpluses. An appreciation of the real exchange rate is then required for intertemporal

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[5] I assume that prices and wages are flexible in the long-run and so PPP will eventually be obtained. Thus the transversality condition for the firm's optimization problem is:

$$\lim_{t \to \infty} ({}_tp_{t+r} - {}_tp^o{}_{t+r}) - C({}_tp_{t+r} - {}_tp_{t+r-1}) = 0$$

equilibrium. This occurs via a decrease in p_t and a more than offsetting decrease in e_t.

(iii) Foreign Prices

I assume that the log of the exchange rate, e, and the log of the foreign price level, pf, both evolve as random walks:

$$e_t = e_{t-1} + v_{et} \tag{8a}$$

$$pf_t = pf_{t-1} + v_{pft} \tag{8b}$$

The foreign wage, wf, is determined as an error-correction mechanism

$$wf_t = wf_{t-1} + \beta(w_t - e_t - wf_{t-1}) + \tau_t \tag{8c}$$

where τ_t represents disturbances that cause divergences between domestic and foreign wages e.g. country-specific productivity shocks. Complete nominal wage flexibility ($w_t = e_t + wf_t$) occurs when $\beta = 1$. A test of PPP is thus a test of the joint hypothesis that $\beta = 1$ and $c = 0$.[6]

(iv) Price Dynamics and Persistence

When nominal rigidities are present, the price level p_t is directly

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[6] Note that equation (8c) does not imply that the domestic wage causes changes in the foreign wage, only that, in equilibrium, domestic and foreign wages will be equalized. Domestic and foreign wages are jointly determined by equations (4e) and (8c). Distortions in either domestic or foreign labour markets will cause $\beta = 1$. The terminology "inflexible nominal wages" in this model has the particular meaning "slow convergence of nominal wages between a country and its trading partners".

affected by four shocks. These are the real shocks u_t, the shocks to foreign prices v_{pft}, and the shocks to domestic and foreign wages, η_t and τ_t.[7] I assume that real shocks have a permanent effect on the price level and so u_t is specified to be a non-stationary process. The effect on the inflation rate, however, is temporary. (In the competitive case the price level jumps immediately to its new equilibrium value and the inflation rate changes instantaneously.)

The cost of changing prices imparts serial correlation to the price level; p follows a multivariate autoregressive process when c is not equal to zero. The nominal shocks v_{pft}, η_t and τ_t have no effect on the steady state price level, but their effects may still be very persistent, depending on the value of c and the process generating ${}_tp_{t+1}$, the expected price level one period hence. Only in the special case of no wage and price rigidities will the wage shocks have no effect on the price level.

3. OPTIMAL WAGE CONTRACTS

The optimal degree of wage indexation, θ^o, is the value of θ that makes the real product wage as close as possible to the labour market-clearing real product wage. A union which seeks to minimize unemployment for cohort 1 will thus have the following problem:

$$\min_{\theta} \; E_{t-1} \left\{ \sum_{i=0}^{n-1} \delta^{\,i+1} \left((w^1_{t+i} - {}_{t+i-1}p_{t+i}) - (w^1_{t+i} - {}_{t+i-1}p_{t+i})^o \right)^2 \right\} \tag{9a}$$

where $(w^1_{t+i} - {}_{t+i-1}p_{t+i})^o$ is the market-clearing real wage for cohort 1 in period t+i. Since p_{t+i} isn't observed until the end of

[7] The shocks to the nominal exchange rate, v_{et}, have no direct effect on p_t, but they do have an indirect effect via w_t.

period t+i, it is the expected value of this price level held in the previous period that is relevant to employment decisions in t+i.

As a practical matter, the problem (9a) cannot be solved because $(w^1_{t+i} - {}_{t+i-1}p_{t+i})^o$ is unobservable. However, suppose the problem is the following:

$$\min_{\theta} E_{t-1} \{ \sum_{i=0}^{n-1} \delta^{i+1}[((w^1_{t+i} - {}_{t+i-1}p_{t+i}) - (w^1_{t+i} - {}_{t+i-1}p_{t+i})^o) - {}_{t-1}((w^1_{t+i} - {}_{t+i-1}p_{t+i}) - (w^1_{t+i} - {}_{t+i-1}p_{t+i})^o)]^2\} \tag{9b}$$

i.e. the union aims to minimize the discounted sum of squared innovations in the excess real wage. The minimand (9a) reduces to (9b) when ${}_{t-1}(w^1_{t+i} - {}_{t+i-1}p_{t+i}) = {}_{t-1}(w^1_{t+i} - {}_{t+i-1}p_{t+i})^o$ i.e. when the expected real wage is equal to the expected market-clearing real wage in period t+i, for all i. Under the maintained hypothesis of optimal wage indexation, unions will rationally expect to set real wages to clear the labour market. In such a case, (9a) is equivalent to (9b) as a behavioural hypothesis.

The advantage of (9b) over (9a) is that it can be re-arranged into an expression with no unobservable terms. To see this, consider (without loss of generality) the simple case of n = 2. The problem is then:

$$\begin{aligned}\min_{\theta} E_{t-1} \{ &\delta[((w^1_t - {}_{t-1}p_t) - {}_{t-1}(w^1_t - {}_{t-1}p_t)) - ((w^1_t - {}_{t-1}p_t)^o - {}_{t-1}(w^1_t - {}_{t-1}p_t)^o)]^2 \\ &+ \delta^2[((w^1_{t+1} - {}_tp_{t+1}) - {}_{t-1}(w^1_{t+1} - {}_tp_{t+1})) - ((w^1_{t+1} - {}_tp_{t+1})^o - {}_{t-1}(w^1_{t+1} - {}_tp_{t+1})^o)]^2\}.\end{aligned} \tag{9c}$$

Assuming that expectations of the aggregate price level are unaffected by cohort 1's wages,

$$(w^1{}_t - {}_{t-1}p_t)^o = (w^1{}_t{}^o - {}_{t-1}p_t) \qquad (9d)$$
$$(w^1{}_{t+1} - {}_tp_{t+1})^o = (w^1{}_{t+1}{}^o - {}_tp_{t+1}), \qquad (9e)$$

the problem becomes:

$$\underset{\theta}{\text{Min}}\ E_{t-1}\ \{\delta[(w^1{}_t - {}_{t-1}w^1{}_t) - (w^1{}_t{}^o - {}_{t-1}w^1{}_t{}^o)]^2 + \delta^2[(w^1{}_{t+1} - {}_{t-1}w^1{}_{t+1}) - (w^1{}_{t+1}{}^o - {}_{t-1}w^1{}_{t+1}{}^o)]^2\} \qquad (9f)$$

From equation (1a)

$$\delta[\cdot] = 0. \qquad (9g)$$

From equation (1c)

$$w^1{}_{t+1} - {}_{t-1}w^1{}_{t+1} = \theta(p^c{}_t - {}_{t-1}p^c{}_t). \qquad (9h)$$

The innovation in the market-clearing nominal wage for t+1, $w^1{}_{t+1}{}^o - {}_{t-1}w^1{}_{t+1}{}^o$ is the sum of two parts. They are the surprise in the price level, ${}_tp_{t+1} - {}_{t-1}p_{t+1}$ and the white noise shocks ξ_{1t}.

Cohort 2's problem is identical to cohort 1's, with the time subscripts moved forward one period. The union's optimization problem is to find the value of θ that minimizes the sum of the quadratic loss functions for the two cohorts. Assuming that consumer and producer prices are covariance stationary, so that e.g.

$$E_{t+i}(p^c{}_{t+i-1} - {}_{t-i}p^c{}_{t+i-1})^2 = E_{t+j}(p^c{}_{t+j-1} - {}_{t-j}p^c{}_{t+j-1})^2 \qquad (10)$$
$$i,j = -1,0,$$

and that ξ_{1t} is uncorrelated with the innovation in the consumer price level, the problem is easily solved and the optimal value of θ is found:

$$\theta^o = \frac{cov(p^c_t - {}_{t-1}p^c_t)({}_tp_{t+1} - {}_{t-1}p_{t+1})}{var(p^c_t - {}_{t-1}p^c_t)}. \tag{11}$$

In the general case of n-period contracts,

$$\theta^o = N/D \tag{12}$$

where

$$\begin{aligned} N = \; & cov(p^c_t - {}_{t-1}p^c_t)({}_tp_{t+1} - {}_{t-1}p_{t+1}) \\ & + \delta cov(p^c_{t+1} - {}_{t-1}p^c_{t+1})({}_{t+1}p_{t+2} - {}_{t-1}p_{t+2}) \\ & + \delta^2 cov(p^c_{t+2} - {}_{t-1}p^c_{t+2})({}_{t+2}p_{t+3} - {}_{t-1}p_{t+3}) \\ & \cdot \\ & \cdot \\ & \cdot \\ & + \delta^{n-2} cov(p^c_{t+n-2} - {}_{t-1}p^c_{t+n-2})({}_{t+n-2}p_{t+n-1} - {}_{t-1}p_{t+n-1}) \end{aligned}$$

$$D = var(p^c_t - {}_{t-1}p^c_t) + \sum_{i=1}^{n-2} \delta^i var(p^c_{t+i} - {}_{t-1}p^c_{t+i})$$

The empirical question of interest is to compare the estimated values of θ and θ^o, derived from equation (12). θ^o will tend to be small if the covariance between the j period innovation in the consumer price level in period t+j-1 and the revision, between periods t-1 and t+j-1, of the producer price level expected in period t+j+1 is small, or if the variances of the innovations to the consumer price level are large. Both will occur if the innovations to the nominal exchange rate have a large variance, which will occur, in turn, if the degree of nominal price and wage rigidities is large.

The model leaves open the possibility both nominal prices and wages are sticky ($c \neq 0$, $\beta \neq 1$) but the real product wage is not ($\theta \leqslant \theta^{O}$). This apparent contradiction is reconciled by recalling that θ^{O} is the degree of wage indexation to consumer prices that minimizes the excess real product wage.

Suppose that following an adverse supply shock the real product wage is above its equilibrium level, and that nominal wages and prices are insufficiently flexible to restore this equilibrium. There are two alternative equilibrating mechanisms. The first is that the exchange rate appreciates, generating a fall in consumer prices and subsequently the nominal wage (via indexation) to restore the equilibrium real product wage. (Domestic prices will also fall, but not by as much as the fall in wages.) The second is that the exchange rate depreciates, leading to an increase in nominal wages. Domestic prices also increase, in this case by more than wages. Since the exchange rate, under both mechanisms, responds to unanticipated shocks, the underlying volatility in the exchange rate will be reinforced.[8]

We should, however, recognize that these mechanisms provide the possibility, but do not guarantee, that the equilibrium real product wage will be attained. Since it is set exogenously, θ might still exceed θ^{O}. Recall that θ^{O} decreases when the variance of nominal exchange rate innovations increases. As nominal wages and prices become more rigid, this variance - which provides the essential link between real and nominal rigidities in this model - will

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[8] The direction and size of the change in the exchange rate depends (implicitly) on the extent to which (or whether) the shock is accommodated by monetary policy. Fahrer (1989) examines this issue in detail.

increase and thus so will the likelihood that the actual degree of wage indexation exceeds its optimum.

If the value of θ estimated from the wage equation exceeds θ^{o}, then we can safely conclude that real wage rigidities are at least partially responsible for any observed rise in unemployment, either because wage setters have miscalculated θ^{o} or because they have deliberately chosen a value of θ in excess of θ^{o}. A more difficult issue is how the result $\theta \leqslant \theta^{o}$ should be interpreted. The most apparent explanation would be that, since under these circumstances wages are no more than optimally indexed to the price level, excessively high real wages cannot be a cause of unemployment.

However, this conclusion needs some qualification. The model assumes, but does not test, that the real wage that is set at the commencement of each contract for each cohort clears the labour market for that cohort. Obviously, this need not necessarily be the case. Suppose the economy is hit by a shock that necessitates a downward movement in the real wage. If this change does not take place a rise in unemployment will occur, which could be propagated beyond the length of all existing overlapping contracts even if wages are optimally indexed to prices thereafter.[9]

It is also worth noting that since any of the covariances that form the numerator of (12) could be negative, the optimal degree of wage indexation could itself be negative. The intuition behind this seemingly curious result again stems from the assumption that

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[9] Optimal wage indexation can therefore be entirely consistent with the observation of high and increasing unemployment. However, the cause of the unemployment cannot be then ascribed to excessive wage indexation causing insufficient flexibility in the real wage. Rather, it is the cumulative effects of the initial shock (and perhaps subsequent shocks) which are responsible.

wages are indexed to consumer prices but employment is a function of real product wages. Suppose that consumer prices are *ex-post* under-predicted and that, simultaneously, expectations of future producer prices are revised downwards, resulting in a negative covariance. The fall in expected producer prices implies an increase in the expected real product wage with consequent adverse effects on employment. These effects will be mitigated by a negative rate of wage indexation to consumer price innovations.

We should also note that even in the case of no nominal wage or price rigidities, the optimal degree of wage indexation will not be equal to unity, implying that the economy's aggregate supply curve will not be vertical. To see this, recall that in the market-clearing case

$$p_t = e_t + pf_t + u_t. \tag{7f}$$

This implies that

$$p^c{}_t - {}_{t-1}p^c{}_t = v_{et} + v_{pft} + \sigma\varepsilon_t \tag{13}$$

and

$${}_tp_{t+1} - {}_{t-1}p_{t+1} = v_{et} + v_{pft} + \varepsilon_t. \tag{14}$$

The optimal degree of wage indexation, θ^0 is then given by

$$\frac{\text{cov}(v_{et} + v_{pft} + \sigma\varepsilon_t)(v_{et} + v_{pft} + \varepsilon_t)}{\text{var}(v_{et} + v_{pft} + \sigma\varepsilon_t)} \tag{15}$$

which, for non-zero ε, is equal to unity only in the closed-economy case of σ=1. The wedge between producer and consumer prices makes the aggregate supply curve non-vertical even in the case of competitive goods and factor markets.[10]

4. ESTIMATION

The model to be estimated is:

$$\begin{aligned} w_t = {}& {}_{t-3}w_t + (1/n)({}_{t-2}p_{t-1} - {}_{t-3}p_{t-1} + {}_{t-1}p_t - {}_{t-3}p_t) \\ &+ ((1-\theta)/n)(({}_{t-2}p^c{}_t - {}_{t-2}p^c{}_{t-1}) - ({}_{t-3}p^c{}_t - {}_{t-3}p^c{}_{t-1})) \\ &- (\theta/n)({}_{t-2}p^c{}_{t-1} - {}_{t-3}p^c{}_{t-1}) + (n-2)(\theta/n)(p^c{}_{t-2} - {}_{t-3}p^c{}_{t-2}) \\ &+ (n-1)(\theta/n)(p^c{}_{t-1} - {}_{t-3}p^c{}_{t-1}) + \eta_t, \end{aligned} \tag{16}$$

$$p_t = cp_{t-1} + \delta c_t p_{t+1} + (1 - c - \delta c)p^o{}_t, \tag{17}$$

$$p^o{}_t = w_t - wf_t + pf_t + u_t, \tag{18}$$

$$u_t = u_{t-1} + \varepsilon_t, \tag{19}$$

$$wf_t = wf_{t-1} + \beta(w_t - e_t - wf_{t-1}) + (1-\beta)(pf_t - pf_{t-1}) + \tau_t. \tag{20}$$

Expressions for the expectations variables in terms of observable variables need to be derived before the model can be estimated. These are found by estimating the following quasi-VAR system.

$$p_t = \sum_z \sum_{i=1}^{4} a_{ipz} z_{t-i} + v_{pt}, \tag{21a}$$

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[10] The optimal wage indexation literature usually posits θ^o as a function of the variance of nominal and real shocks, the presence of the latter implying that θ^o is less than unity. The optimality condition (15) is entirely consistent with this result. In the presence of real shocks, $\varepsilon \neq 0$, and $\theta^o < 1$. If $\varepsilon = 0$, however, then $\theta^o = 1$.

$$w_t = \sum_z \sum_{i=1}^{4} a_{iwz} z_{t-i} + v_{wt}, \tag{21b}$$

$$wf_t = \sum_z \sum_{i=1}^{4} a_{iwfz} z_{t-i} + v_{wft}, \tag{21c}$$

where $z = p,w,wf,pf,e$

$$e_t = e_{t-1} + v_{et}, \tag{21d}$$

$$pf_t = pf_{t-1} + v_{pft}. \tag{21e}$$

The parameters a_{izz} are estimated consistently and efficiently by Seemingly Unrelated Regressions. The estimates are of no intrinsic interest and so are not reported here; they are available on request from the author. The expectations terms are found by successive substitution into (21a) and (21b).

The expectations terms so derived are substituted into equations (16) and (17), with the parameters δ, σ and n imposed prior to estimation. The data are quarterly and the sample period is 1973(1) - 1988(4). I assume an annual real interest rate of five per cent and so δ, the discount rate, is equal to 0.98788. σ is the average share of imports in consumption over the sample period. Stationarity tests reveal that the variables p,w,wf,e and pf contain a unit root and so first differences of the data were taken prior to estimation. The use of stationary variables is particularly important with this model since the optimality conditions are derived under the assumption of stationarity in the data.

Estimation of the model in first differences also serves two other useful purposes. First, it permits a test of the weak form of PPP, that percentage changes in the nominal exchange rate are equal to the difference between the domestic and foreign rates of price inflation. Tests of the strong form of PPP - that the exchange rate is equal to the ratio of the two price levels - are bedeviled by index number and other measurement problems that are largely avoided by testing the weak form. Second, dealing with inflation rates rather than price levels circumvents the use of the awkward non-stationary process u_t.

Three structural parameters are to be estimated: θ, the degree of wage indexation, and c and β, respectively the price and nominal wage rigidity parameters. Equations (16) - (20) are estimated by Hansen's (1982) Generalized Method of Moments, with allowance made for possible heteroscedasticity and serial correlation in the structural shocks η_t, ε_t and τ_t. The expected values of the endogenous variables (derived from the system (21a)-(21e)) are used as instruments.

Data definitions and sources are detailed in the Appendix.

5. RESULTS

The first issue to be resolved was the choice of lag length, n, for the wage contracts. In practice, contracts of different lengths will exist in each country; the value of n that is chosen will be, by necessity an approximation. I employed the following Bayesian method for estimating n. Under the prior that n is equal to 2 or 4, equation (16) was estimated by non-linear least squares, yielding a freely estimated value for n. Next, depending on whether this point estimate was closer to 2 or 4, the hypothesis that n = 2 (or 4) was tested. This hypothesis was rejected in only one case, leading to an estimate of n = 2 (contracts of six months duration) for Australia and the United States, and n = 4 (contracts of one year's duration) for the other seven countries.[11,12]

The estimated values of θ, c, β and θ^{O} (the optimal value of θ) are reported in Tables 1a and 1b. The estimates of θ show a low to moderate amount of indexation to inflation innovations, for all countries in the sample. (θ is estimated with the wrong sign for Australia and Austria, but is not significantly different from zero). For those countries where the point estimate of θ implies a moderate degree of indexation (France, Italy, the United Kingdom) the standard errors are small relative to this estimate.

The estimates of θ^{O} range from a low of -0.135 for Germany to a high of 0.636 for Italy. In general, these estimates are quite low (the median estimate is 0.181), suggesting that the uncertainty created by nominal exchange rate volatility has led to a relatively high degree of uncertainty regarding the association between consumer and producer price inflation, relative to the variance of consumer price inflation innovations.

The hypothesis that θ is equal to its optimal value is tested with the results reported in Table 2. These show that the degree of wage indexation to inflation innovations significantly exceeded its

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[11] n could not be estimated for Austria, so its wage contract length was made equal to that of its major trading and financial partner, Germany.

[12] The exception was Canada, where the estimated value of n was significantly greater than 4. However, for computational reasons, I used n = 4 for Canada. This decision was of no consequence since the estimate of θ turned out to be unaffected by the choice of n.

Table 1a
Structural Parameter Estimates
(standard errors in parentheses)

	Australia	Austria	Canada	France	Germany
θ	-0.095	-0.076	0.055	0.229	0.014
	(0.071)	(0.157)	(0.050)	(0.047)	(0.036)
β	0.117	0.084	0.088	0.127	0.187
	(0.031)	(0.020)	(0.195)	(0.050)	(0.072)
c	0.392	0.495	0.364	0.459	0.504
	(0.047)	(0.013)	(0.080)	(0.051)	(0.231)
θ^o	0.039	0.084	0.183	0.181	-0.135
SEE_w	1.431	1.585	0.287	0.396	0.300
SEE_{wf}	0.611	0.238	0.535	0.341	0.630
SEE_p	1.278	0.269	0.810	0.794	0.892
SEE_e	6.225	1.725	1.766	2.793	3.634
SEE_{pf}	0.379	0.653	0.406	0.484	0.376

all SEE's x100

Table 1b
Structural Parameter Estimates
(standard errors in parentheses)

	Italy	Japan	United Kingdom	United States
θ	0.420	0.041	0.242	0.122
	(0.049)	(0.031)	(0.009)	(0.216)
β	0.055	0.081	0.030	0.036
	(0.065)	(0.078)	(0.030)	(0.198)
c	0.379	0.454	0.506	0.501
	(0.139)	(0.064)	(0.039)	(0.025)
θ^o	0.636	0.478	0.010	0.194
SEE_w	0.530	0.354	0.549	0.404
SEE_{wf}	0.289	0.350	0.289	0.887
SEE_p	0.897	0.543	0.179	0.363
SEE_e	2.978	5.224	5.182	3.155
SEE_{pf}	0.489	0.383	0.384	0.549

all SEE's x100

Table 2
Tests of Restrictions

	$\theta + \pi = 1$	$\theta = \theta^O$	Overindentifying w	wf	p
Australia	0.831	0.060	0.861	0.829	0.674
Austria	0.245	0.310	0.263	0.051	0.228
Canada	0.000	0.010	0.068	0.798	0.328
France	0.000	0.303	0.119	0.301	0.246
Germany	0.838	0.000	0.050	0.689	0.647
Italy	0.110	0.000	0.158	0.341	0.246
Japan	0.133	0.000	0.676	0.472	0.123
United Kingdom	0.000	0.000	0.202	0.072	0.426
United States	0.838	0.739	0.229	0.234	0.193

The numbers in the Table are P-values i.e. the minimum level of significance needed to reject the null hypothesis.

optimal value in only two countries, the United Kingdom and Germany. For Canada, Italy and Japan, θ is significantly smaller than its optimal value. Table 2 also reports test of the overidentifying restrictions for the w,p and wf equations, and tests of the restriction $\theta + \pi = 1$. The P-values suggest that the restrictions are consistent with the data.

The estimates of c and β show that every country exhibits a substantial degree of price and nominal wage rigidity. The countries with the most rigid prices are Germany, the United Kingdom and the United States, where c is estimated to be virtually at its theoretical upper bound. Prices in Australia, Canada and Italy are estimated to be relatively more flexible, but in each of these countries only about 25 per cent of the change in the equilibrium inflation rate (of producer prices) is reflected in the actual inflation rate in each quarter. The estimated value of c,for every country, is very well determined with the standard errors of the estimates being exceptionally small. The estimates of β, which are small and often insignificantly different from zero, indicate that nominal wage rigidity, at least in the short term, is substantial in all of the major industrial countries.

The conclusion to be drawn from Tables 1a and 1b appears to be very clear. The failure of PPP to hold is due to both price and nominal wage rigidities. Economists and policy makers who focus exclusively on one of these rigidities as a source of volatile real exchange rates are ignoring an important part of the explanation.

Of course, we should remember that the sample period for this study is relatively short, and that a longer time series might be more favourable to the market-clearing hypothesis.[13] Indeed, the model employed in this paper implies that PPP must hold true as a long run proposition, given the transversalilty condition on prices and the eventual convergence of domestic and foreign wages implicit in the error-correction mechanism (8c). Of course, the proposition that domestic and foreign prices will converge in the long run is of little practical use.

As mentioned above, the degree of wage indexation exceeded the optimum in Germany and the United Kingdom, *ex post*, leading to the conclusion that this factor was at least partially responsible for the considerable rise in unemployment in those two countries over the sample period. Why would unions have bargained for a

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[13] Frankel and Meese (1987), in a study of the mean-reverting properties of the UK/US real exchange rate, are unable to reject PPP using a sample length of 116 years.

degree of wage indexation which led to high unemployment? One possibility is that wages were set by union "insiders" who did not consider the effects of their actions on the "outsiders"; the latter bearing the unemployment consequences of the wage bargains (Lindbeck and Snower, 1988).

Another possibility, consistent with the evidence in this paper, is that the unions overestimated the optimal degree of wage indexation. This might happen, for instance, if the variance of nominal exchange rate innovations was underestimated. This misperception - even assuming rational expectations - by unions who negotiated wage contracts led to excessive wage indexation and hence the large rise in unemployment in those countries. This rise in unemployment reflects the welfare cost of nominal wage and price rigidities. Without these rigidities, PPP would be obtained, the variance of the innovations to nominal exchange rates would be small and costly misperceptions about changes in a country's optimal degree of wage indexation would not take place.

One of the major premises of this model is that the greater the degree of nominal wage and price rigidity the more unpredictable will be the nominal exchange rate. Denote the metric of these nominal rigidities by the sum

$$\Omega = (c(1+\delta) + (1-\beta))/2.$$

Ω lies between zero and unity, the lower bound being reached in the case of no wage or price rigidities, the upper bound being reached when prices and nominal wages are completely inflexible.

Table 3 presents two rankings for the nine countries in this study. The first is based on Ω, with the rank of 1 going to the country

Table 3
Nominal Rigidities versus
Nominal Exchange Rate Unpredictability

	Ω	SEE_e
Australia	8	1
Austria	3	9
Canada	9	8
France	6	7
Germany	5	4
Italy	7	6
Japan	4	2
United Kingdom	1	3
United States	2	5

The first column ranks countries in terms of nominal wage and price rigidities, with a rank of 1 referring to the greatest degree of rigidity, etc. The second column ranks countries in terms of nominal exchange rate unpredictability, with a rank of 1 going to the country with the largest variation of exchange rate innovations, etc.

with the largest value of Ω i.e. the greatest degree of nominal rigidities. The second ranking is based on unpredictability of the nominal exchange rate with the highest ranking going to the country with the largest SEE from its exchange rate equation.

The correspondence between the rankings isn't perfect, but is very good nonetheless. Countries which have relatively flexible wages and prices also have relatively predictable nominal exchange rates, and *vice versa.* The two outliers in this test are Australia and Austria.[14] Australia has relatively flexible nominal prices and wages, but a relatively volatile nominal exchange rate; the converse is true for Austria. In both cases, we don't have to search far to find plausible explanations for these results. Australia's real exchange rate (and hence in the short-term, the nominal exchange rate) is in large part determined by changes in its terms of trade (Blundell-Wignall and Gregory, 1990). The sample period under consideration has seen considerable volatility in Australia's terms of trade, and the these effects have, in all likelihood, dominated the effects of nominal rigidities on the exchange rate.

The relative stability of Austria's nominal exchange rate is easy to explain, given the close ties between Austrian and German monetary policy and the large weight attached to Germany in Austria's trade weighted nominal exchange rate index (see the Appendix). The effects of nominal rigidities on Austria's exchange rate are outweighed by this effect. Significantly, Austria and Germany both exhibit a similar degree of nominal rigidities (they are ranked respectively, 3 and 5), but Germany's nominal exchange rate is more volatile than Austria's. This is also easy to explain. While changes in the value of the Deutschemark effectively dominate the value of Austrian Schilling, the converse is not true. Austria has only a relatively small weight in the DEM index.

6. SUMMARY AND CONCLUSIONS

This paper has used a model of wage and price setting to examine two issues. Nominal wages and prices have been found

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[14] Excluding these outliers, the relative rankings are never more than two places apart.

to be universally sticky in that the growth rates of domestic and foreign wages converge only slowly, and prices cannot be changed without cost. This stickiness is associated with increased volatility in both nominal and real exchange rates. However, real wage rigidities - in the sense of wage indexation to inflation innovations at a rate greater than the optimum - have been found to exist in only two of the major industrial countries, Germany and the United Kingdom.

In those countries where real wage stickiness has not been found to exist, the requisite flexibility in real product wages has been made possible by the indexation of wages to consumer prices, with changes in nominal exchange rates driving a wedge between consumer and producer price inflation. These changes reinforce the volatility of nominal exchange rates brought about by the inflexibility of nominal wages and prices.

The policy implications of these results depend largely on whether excessive real exchange rate volatility has large welfare costs. If not, a reasonable second-best method of achieving real wage flexibility when faced with nominal wage and price stickiness will be via increased exchange rate flexibility. However, this solution is dependent on wage setters correctly identifying the optimal degree of wage indexation and acting accordingly. As the UK and German cases show, volatile real exchange rates could confound this identification. In such a case, the preferred policy prescription is to attack the nominal rigidities at their source.

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Appendix

Data Definitions and Sources

Definitions:

p: GNP(GDP) deflator
w: hourly earnings
e: trade weighted nominal exchange rate
pf: trade weighted foreign GNP(GDP) deflator
wf: trade weighted foreign hourly earnings

The data are seasonally adjusted.

The sources for the data were the *International Financial Statistics*, published by the International Monetary Fund and the *OECD Economic Outlook*. The data are available from the author on request.

Table A1 below shows the relative trade weights and import shares. The source for the trade weights is the IMF's publication, *Direction of Trade*. The source for the imports weights (imports divided by GDP) is the time series database *DataExpress*, supplied by EconData Pty Ltd.

Table A1
Relative Trade Weights and Import Shares

	Australia	Austria	Canada	France	Germany
Australia	-	0.00	0.01	0.01	0.01
Austria	0.00	-	0.00	0.02	0.10
Canada	0.04	0.01	-	0.02	0.02
France	0.04	0.07	0.01	-	0.28
Germany	0.08	0.60	0.02	0.38	-
Italy	0.04	0.16	0.01	0.23	0.20
Japan	0.42	0.03	0.06	0.04	0.06
United Kingdom	0.11	0.07	0.04	0.15	0.15
United States	0.27	0.06	0.84	0.15	0.18
Import Share	0.17	0.36	0.25	0.21	0.27

Table A1 (cont)
Relative Trade Weights and Import Shares

	Italy	Japan	United Kingdom	United States
Australia	0.01	0.12	0.04	0.03
Austria	0.04	0.00	0.02	0.00
Canada	0.02	0.08	0.06	0.40
France	0.29	0.03	0.19	0.06
Germany	0.36	0.08	0.26	0.10
Italy	-	0.02	0.10	0.05
Japan	0.03	-	0.06	0.26
United Kingdom	0.10	0.06	-	0.10
United States	0.15	0.61	0.27	-
Import Share	0.22	0.13	0.27	0.10