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EMPIRICAL STRUCTURAL EVIDENCE ON WAGES, PRICES AND EMPLOYMENT IN THE US

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ABSTRACT

In this paper, I investigate US post war price, wage and employment dynamics by identifying and estimating a price and a wage equation. I reach the following two main conclusions :

Nominal wages adjust faster to prices than prices do to nominal wages. This may be taken as evidence that price inertia is more important empirically than nominal wage inertia.

The wage equation implies that the effect on wage inflation of a permanent increase in unemployment, given prices, is largely temporary. This can be interpreted in various ways. One is that, if the wage equation is interpreted as a Phillips curve, both the rate of change and the level of unemployment play an important role in wage determination.

The methodology of the paper is somewhat different from the traditional approach to the estimation of price and wage equations. Its spirit is to impose on the reduced form a just identifying set of restrictions. In this way, a structural interpretation is made possible, while the data are left free to speak.

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In this paper, I investigate US post war price, wage and employment dynamics by identifying and estimating a price and a wage equation. I reach the following two main conclusions :

Nominal wages adjust faster to prices than prices do to nominal wages. This may be taken as evidence that price inertia is more important empirically than nominal wage inertia.

The wage equation implies that the effect on wage inflation of a permanent increase in unemployment, given prices, is largely temporary. This can be interpreted in various ways. One is that, if the wage equation is interpreted as a Phillips curve, both the rate of change and the level of unemployment play an important role in wage determination.

The methodology of the paper is somewhat different from the traditional approach to the estimation of price and wage equations. Its spirit is to impose on the reduced form a just identifying set of restrictions. In this way, a structural interpretation is made possible, while the data are left free to speak. This methodology is an extension of that introduced in Blanchard and Watson (1986). It is related to the approaches of Hall (1979), Taylor (1984) and more recently Bernanke (1985) and Sims (1986).

The paper is organized as follows :

Section 1 presents the model and the conceptual and econometric issues associated with estimation. Section 2 gives the results of estimation of the reduced form. Section 3 discusses identification and presents estimates of the structural model under alternative identification restrictions. Section 4 studies the characteristics of the wage and price equations. Section 5 concludes.

Section 1 Setting up the model

I start by defining the structural model I want to recover and the associated reduced form.

Let P, W and N be the logarithms of the price level, nominal wage and employment. Let Y be the vector [P W N]'. Let X be the vector of variables which affect either price or wage decisions, or aggregate demand. Then the structural model is defined as :

$$(1)\ A\ Y = A(L)\ Y(-1) + B(L)\ X + e$$

where A is a 3x3 matrix, normalized so that the diagonal elements are equal to unity. A(L) and B(L) are matrix lag polynomials of order k, and e is a vector of iid disturbances, with covariance matrix V.

The three structural equations have the following interpretation. The first two give the prices and wages as set by price and wage setters respectively, as a function of current and lagged values of wages, prices and employment, of other variables included in X, and of disturbance terms e_p in the price equation, e_w in the wage equation. The third equation gives employment as the derived demand for labor given the production function and aggregate demand, and may also depend on current and lagged values of wages, prices and employment, other variables in X and a disturbance term e_n.

It is useful to give two simple examples of such a system. Ignoring for notational simplicity X variables and disturbances, the first one is given by :

$$P = W + a_1 N - a_2 N(-1)$$

$$W = P + b_1 N - b_2 N(-1)$$

$$N = -c_1 P$$

Firms set prices as a function of wages and the level and rate of change of employment. This price equation can be rewritten with employment on the left, giving employment as a function of the real wage and lagged employment. A similar interpretation holds for the wage equation, which can be rewritten as a dynamic labor supply function. The last equation gives the employment level given aggregate demand, which is itself assumed to be a decreasing function of the price level. This system is thoroughly classical, with employment and real wages being determined by the first two equations, and the price level by the third. Apart from the treatment of expectations (to which I return below), it is similar to the model developed by Sargent (1979) and Kennan (1985).

The second example is, in contrast, closer to the "wage price mechanism" described by Tobin in 1972. It is given by, again ignoring X variables and disturbances :

$$P = W$$

$$W = W(-1) + a_1 (P(-1)-P(-2)) + a_2 N$$

$$N = -c_1 P$$

Price setters mark up over wages. Wages are determined by a Phillips curve relation. Aggregate demand is a decreasing function of the price level. In this case, because of the dynamic relation between wages and prices, aggregate demand can affect employment and affects the dynamics of prices, nominal wages and the real wage. This model underlies much of the empirical work on prices and wages.

The reduced form associated with model (1) is given by :

$$Y = A^{-1}A(L)\ Y(-1) + A^{-1}B(L)\ X + A^{-1}e,$$

or defining matrix polynomials C(L) and D(L) appropriately,

$$(2)\quad Y = C(L)\ Y(-1) + D(L)\ X + u\ ,\ E(uu') \equiv \Sigma = A^{-1}V\ A'^{-1}$$

Assuming for the moment that X and u are uncorrelated, the reduced form (2) can be estimated by OLS. To go from (2) to (1) requires knowledge of the matrix A, which gives the contemporaneous interactions between W, P and N. The strategy of the paper will be to use information from estimated Σ, the covariance matrix of the reduced form, as well as a priori restrictions on both V, the structural covariance matrix, and A, to construct A and go from (2) to (1).

Before estimation proceeds, I briefly discuss four issues.

1. Is (1) a structural model ?

It may be validly argued that the model given by (1) is not "structural". Structural equations would treat expectations explicitly and distinguish between the dynamic structure of the equation and the dynamic of the structural disturbance term. Model (1) can then be thought of as derived from a structural model, where expectations have been solved out, and the equations have been transformed - premultiplied by the appropriate lag polynomial- to have white noise disturbance terms. The reason for working with model (1) is clear : it is relatively easy to go from (2) to (1). The shortcomings are equally clear and have been pointed out by Lucas ; care must be used in the interpretation of the lag structures of the estimated equations in (1). With this caveat in mind, I shall keep using the word "structural" to denote (1) and refer when needed to the underlying model with expectations and serially correlated disturbances as "deep structural" (This convenient expression was coined by Sargent).

2. Are there restrictions on (2) ?

The question arises of whether theory imposes any restriction on the reduced form (2) which should be imposed in estimation. The answer is yes.

Barring money illusion, all deep structural models must have an homogeneity property, namely that a proportional increase of all nominal variables, including expected and lagged nominal variables, leaves all real variables unchanged. Equivalently, the sum of coefficients on nominal variables, actual, expected or lagged, in each equation, must be equal to one if the left hand side variable is nominal, to zero if it is real. The question is whether this property applies to (1) and in turn to (2).

The answer is that this property will apply if expectations of nominal variables depend on nominal variables with sums of coefficients equal to one. This will in turn hold, under rational expectations, if the equation characterizing the process generating nominal money has sum of coefficients on nominal variables equal to one. This is shown in appendix 1. If money is exogenous, this will be true if the process generating nominal money has a unit root. All nominal variables appear empirically to have unit roots in our sample and the condition is likely to have been satisfied. It will therefore be imposed in estimation below.

3. How to treat the X variables in (2) ?

The reduced form (2) includes a set of variables X which are left unexplained. If such variables were not included, if for example we only estimated the trivariate representation of W, P and N, it would be impossible to go from such an estimated representation to a form like (1), to give a structural interpretation to the results[1].

The X variables may however be correlated with the white noise disturbances e. They may a priori fall into three categories. They may be contemporaneously uncorrelated with e. They may be contemporaneously correlated with e, but not affect Y contemporaneously. They may be contemporaneously correlated with e and affect Y contemporaneously. In the first case, current and lagged X can be included without bias. In the second case, only lagged X's should included. In the third, the X variable must be treated as an endogenous variable and the size of the Y vector accordingly increased.

The X variables I shall use fall in three categories (The exact list will be given in the next section). The first are tax rates, which probably belong to the first category above. The second are relative prices. These prices are partly determined in commodity markets and thus are likely to respond within the quarter (which is the time unit we use) to unexpected movements in e ; but they are likely to have a slow effect on aggregate prices, wages and employment. Treating them as belonging to the second category above is likely to imply only a small bias. The third category are policy variables such as nominal money. Like relative prices, nominal money is likely to be affected contemporaneously by e, but not to affect much

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[1] A similar approach was advocated by Gordon and King (1982), who call it "hybrid VAR methodology".

p, w and n within the quarter[2].

Therefore, in estimation below, the maintained assumption -which is in effect a set of identification restrictions- will be that the X variables have no contemporaneous effect on W, P and N and only lagged values of X's will be used in (2). (An alternative assumption is to use current and lagged values of tax rates, and lagged values of the other variables. The results we emphasize below are robust to using this alternative assumption)

4. Should variables be specified in levels or first differences ?

Technically, whether Y variables should be specified in levels or first differences depends on the number of unit roots in the polynomial (A-A(L)L), or equivalently (I-C(L)L), which characterizes the process followed by W, P and N conditional on X.

If this polynomial has three unit roots, then taking first differences is appropriate and leads to consistent estimates of C(L) and D(L), and allows to use standard hypothesis tests, i.e. to do tests using standard distributional assumptions.

As we shall see, the empirical evidence, although not clear cut, suggests that (I-C(L)L) has less than three unit roots. If this is the case, first differencing Y would yield inconsistent estimates. This leaves the following choice : One can either do cointegrated estimation of the system (2), or one can do estimation in levels.

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[2] See for example Barro and Rush (1980) or Mishkin (1983), or the older evidence on the monetary mechanism. Much of this evidence is based on econometrics which do not pay full attention to the issue of simultaneity. The simultaneity bias works however in the direction of finding a contemporaneous effect of money on output where in fact there is none.

Cointegrated estimation, conditional on the correct assumption as to the number of roots, yields consistent estimates and allows to use standard hypothesis tests (see Granger and Engle 1985, Stock 1985); if the assumption about the number of roots is incorrect, estimates will be inconsistent. Estimation in levels yields consistent estimates but the distribution of estimates is non standard, making standard hypothesis testing potentially misleading (Phillips and Durlauf 1985). I shall in the text report the results of estimation in levels, but report in appendix 2 the results of cointegrated estimation. Results are, for the most part, similar.

Section 2 Estimation of the reduced form

1. The choice of variables

I shall report results of estimation using the following variables for W, P and N (all variables are quarterly):

W is the logarithm of average hourly earnings in manufacturing

P is the logarithm of the CPI for wage earners, excluding shelter

N is the logarithm of civilian employment

We know that a more detailed reduced form would include for example at least two price indices, one relevant to workers such as the CPI, one to firms such as the GNP deflator or the PPI. The choice here is to limit ourselves to only three endogenous variables and thus to choose only one price index. One wants however to know whether using one price index or another makes a difference to the main conclusions. Thus, I have also studied two alternative systems, one in which the GNP deflator replaces the CPI and one in which unemployment replaces employment[3]. While the three systems have somewhat different dynamics, the two main conclusions stated in the introduction hold across alternative specifications. I shall indicate major differences between the three systems in footnotes along the way.

The vector X includes the following variables :

X1 is a linear time trend

X2 is the logarithm of the crude materials PPI, minus p

X3 is the logarithm of the crude fuel PPI, minus p

X4 is the direct tax rate, from Poterba, Rotemberg Summers (1985)

X5 is the indirect tax rate, same source

X6 is the logarithm of M1

X7 is a set of 4 separate dummies for 1972, 1973, 1974 and 1975

X8 is a set of 4 seasonal dummies

This list is based on a review of past empirical work and includes variables which plausibly enter one or more of the structural equations and have been found to be important by others. The separate dummies for 1972 to 1975 are introduced to capture the effects of price and wage controls, following the work of Gordon [1983].

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[3] The variables I use for the results reported in the paper are the same as those used by Sargent (1978). Empirical studies differ widely in the variables which are used : Altonji (1982) uses an overall wage index, the GNP deflator and manufacturing employment. Geary and Kennan (1984) use manufacturing average hourly earnings, the PPI for manufacturing and industrial production. Ashenfelter and Card (1982) use manufacturing hourly earning, the CPI and the unemployment rate. Poterba, Rotemberg and Summers (1985) use manufacturing average hourly earnings, the CPI and GNP.

2. The choice of sample and subsample stability

Gordon has documented that the behavior of prices is quite different pre and post 1954. Thus, I have chosen the period of estimation to be 1954-4 to 1984-4. Even for this period, I find evidence of subsample instability, for each of the equations and for the reduced form as a whole ; results are reported in appendix 3[4]. There is no clear break point, which suggests slowly changing coefficients rather than two different regimes. Thus, rather than dividing the sample, I estimate the sample as a whole, but with the caveat that reported coefficients may be means of coefficients which have slowly changed during the sample[5].

3. The reduced form

The results of estimation are presented in table 1. χ^2 tests indicate that three lags on X and Y variables are sufficient to capture the dynamics of the reduced form. The table has five parts :

The first part reports point estimates of the coefficients on the lagged endogenous variables, obtained by OLS. The second reports the results of estimation

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[4] The evidence presented by others is mixed. Gordon and King (1982) find stability of their price equation, allowing however for a shift in the coefficient on lagged prices after 1966. The increase over time in the coefficient on the proxy for expected inflation in the Phillips curve is a matter of record. Englander and Los (1983) however conclude, using a battery of tests, that the Phillips curve has been approximately stable since 1961.

[5] An alternative is to allow for random coefficients, as suggested by Sims (1982). The specification of the randomness combined with the other constraints imposed in estimation introduces additional conceptual and econometric issues, and this is left to future research.

Table 1 Reduced form ; estimation results

1. Coefficients on lagged variables*

	W(-1)	W(-2)	W(-3)	P(-1)	P(-2)	P(-3)	N(-1)	N(-2)	N(-3)	Σ(X6)[a]	Σ(P,W,X6)[b]	time[c]
W	.83	-.10	.10	.30	.09	-.32	.31	-.21	.00	.00	.90	.08
P	.13	-.21	.14	.95	.04	-.07	.05	.04	.08	-.01	.99	-.04
N	.10	-.31	.20	-.06	.14	-.11	1.22	-.31	-.02	.06	.02	.03

* Period of estimation 54,4 to 84,4
All regressions include three lags of all Y and X variables (except time trend and dummies ; only the coefficients on Y variables, nominal money and the time trend are reported in the table.
a) sum of coefficients on nominal money
b) sum of coefficients on nominal variables
c) time = .01 in 54,4, incremented by .01

2. Coefficients on lagged variables ; homogeneity restriction imposed **

	W(-1)	W(-2)	W(-3)	P(-1)	P(-2)	P(-3)	N(-1)	N(-2)	N(-3)	Σ(X6)[a]	Σ(P,W,X6)[b]	time[c]
W	.89	-.04	.12	.34	.04	-.36	.26	-.24	.02	.00	1.00 (.09)[d]	.00
P	.15	-.19	.15	.96	.02	-.08	.03	.03	.08	-.02	1.00 (.38)[d]	-.07
N	.09	-.32	.20	-.06	.15	-.11	1.23	-.30	-.02	.05	.00 (.73)[d]	.04

** The sum of coefficients on nominal variables is constrained to be equal to one in the first two equations, equal to zero in the third
All results below,in this table and following tables, are based on equations with the homogeneity restriction imposed.
d) significance level of the F test of the homogeneity restriction

3. Standard errors of the reduced form innovations and correlation matrix

			u_w	u_p	u_n
se(u_w)	$.42\text{x}10^{-2}$	u_w	1.00	0.00	0.29
se(u_p)	$.26\text{x}10^{-2}$	u_p		1.00	-0.08
se(u_n)	$.33\text{x}10^{-2}$	u_n			1.00

(Table 1 continued)

4. Significance of sets of coefficients (homogeneity restriction imposed)[e]

	W	P	N	X2,X3	X4,X5	X6	(X2 to X6 and dummies)[f]
W	$.40x10^{-7}$	$.34x10^{-1}$	.24	$.35x10^{-1}$	.93	.12	$.19x10^{-1}$
P	$.13x10^{-4}$	$.40x10^{-7}$	$.46x10^{-2}$	$.10x10^{-2}$	$.57x10^{-1}$	$.20x10^{-1}$	$.80x10^{-4}$
N	$.21x10^{-1}$	.60	$.40x10^{-7}$	$.50x10^{-1}$	.20	$.57x10^{-4}$	$.45x10^{-3}$

e) significance level of the F test that all coefficients on a variable or a set of variables in a given equation are equal to zero.
f) test of the joint significance of X2, X3, X4, X5, X6 and the dummies for 1972 to 1975

5. Tests of sums of coefficients on right hand side variables(homogeneity restriction imposed)[g]

	W	P	N	X6
W	(Σ=1):.48	(Σ=0):.58	(Σ=0):.62	(Σ=0):.72
P	(Σ=0):$.1x10^{-4}$	(Σ=1):$.8x10^{-4}$	(Σ=0):$.41x10^{-3}$	(Σ=0):.11
N	(Σ=0):.32	(Σ=0):.33	(Σ=1):$.57x10^{-1}$	(Σ=0):$.14x10^{-2}$

g) significance level of the F test that the sum of coefficients on a given variable in a given equation is equal to the number indicated in the table (0 or 1) imposing the homogeneity constraint, which is imposed from then on. The third reports the estimated covariance matrix of the reduced form disturbances. The last two report the results of tests of significance of coefficients on variables or sets of variables, and the results of tests that the sums of coefficients on specific variables are equal to zero or one[6].

As the reduced form equations are linear combinations of the structural equations, it makes little sense to examine the pattern of coefficients in table 1 in detail. I shall limit myself to the following remarks :

The unconstrained reduced form equations nearly satisfy the homogeneity restriction. Thus when imposed, the restriction changes the point estimates little and is easily accepted.

The time trends play a quantitatively small role, especially when the homogeneity restriction is imposed.

The X variables play a statistically significant role in all equations, so that the estimated reduced form is significantly different from a trivariate representation of P, W and N.

The estimated correlation matrix of reduced form disturbances, has only one significant off diagonal element, the correlation between the reduced form price and employment disturbances[7].

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[6] As mentioned above, such tests have non standard distributions in the presence of unit roots, so that reported significance levels may be misleading. Test statistics, computed from cointegrated estimation under the assumption of the presence of one unit root, have however, if the assumption of one unit root is correct, standard asymptotic distributions and are reported in the appendix. The conclusions given in the text below hold also for the results obtained under cointegration

[7] In the alternative system using the GNP deflator rather than the CPI, the correlation between the reduced form price and wage equation residuals is also positive and significant.

Few variables other than the wage and the price level are significant in the reduced form wage equation[8]. The sums of coefficients on wages and other variables are not significantly different respectively from one and zero, suggesting that the equation can be written in terms of first differences.

By contrast, most variables are significant in the reduced form price equation. This is true both of lagged employment and wages, as well as of most X variables. The sums of coefficients on lagged prices and other variables are significantly different from one and zero respectively.

Lagged wages are significant in the reduced form employment equation but lagged prices are not. Nominal money is highly significant.

The task is now to go from these estimated equations to the structural wage, price and employment equations. This is done in the next section.

Section 3 Identification

Let lower case w, p and n denote the reduced form disturbances of the wage, price and employment equations respectively, so that the vector of reduced form disturbances is given by $u = [w\ p\ n\ ]'$. By construction, w, p and n are the

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[8] This is in particular true of employment which has a significance level of .23. In the alternative system using unemployment rather than employment, the significance level is .54. These findings are consistent with the findings of non Granger causality of wages by employment reported by Sargent (1978) and Neftci (1978).

unexpected components of W, P and N, where expectations are conditional on lagged values of Y and X variables. From equation (1), the relation of these disturbances to the structural disturbances is given by :

(3) $A\ u = e, \quad E(ee') = V$

or, equivalently by the three equations :

$$w = a_1\ p + a_2\ n + e_w$$

$$(3') \qquad p = b_1\ w + b_2\ n + e_p$$

$$n = c_1\ p + c_2\ w + e_n$$

To go from the reduced form (2) to the structural model (1), we need to obtain A. In the absence of prior restrictions on the distributed lag structures A(L) and B(L) in (1) (such as traditional exclusion restrictions), identification of A in (1) is equivalent to identification of A in (3). I shall now discuss identification of A in (3) and return later to the use of exclusion restrictions on lag polynomials.

Sample information on (3) is summarized by the estimated covariance matrix of u, Σ , reported in table 1. This covariance matrix contains 6 separate variances and covariances. A contains 6 unknown parameters and V contains 6 unknown covariances and variances. Thus, in the absence of prior restrictions on either A or V, we are 6 parameters short of identification. The strategy of this paper is to impose further restrictions on both A and V to reduce the class of allowable A matrices, and to then study the common characteristics of structural models for alternative allowable A matrices. I now discuss the restrictions I impose on A and V.

1. Restrictions on A

I use an agnostic approach to impose restrictions on the matrix A. It is simply to specify what I believe to be plausible lower and upper bounds on the parameters of A. I impose the following bounds :

I assume the contemporaneous effects of prices and employment on wages to be non negative. I also assume the contemporaneous effects of wages and employment on prices to be non negative. Thus a_1, a_2, b_1 and b_2 are non negative. The upper bounds are clearly more controversial. I assume that a_1 and b_1 are less than .4 ; as the variables are in logarithms, the coefficients are elasticities, so that the assumption implies that the effect within the quarter of a 1% unexpected increase in prices increases wages by no more than .4% and similarly for the effect of wages on prices. I also assume that b_1 and b_2 to be less than .4.

A standard assumption is that the main effect of nominal prices and wages on aggregate demand is through real money balances. Thus I set c_2 equal to zero, and assume c_1 to be non negative. Empirical evidence suggests the effect of real money on output to be slow, and thus c_1 to be small. Thus, I assume c_1 to be between zero and -.3.

A possible approach would then be to look at each structural equation for all allowable values of the parameters above and see what common characteristics hold across such equations[9]. This approach however ignores information contained in Σ, which is inappropriate if we think we know something about V. I now turn to restrictions on V.

2. Restrictions on V

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[9] This was the approach used in the first draft of this paper. The two results stated in the introduction hold across all such equations

A simple assumption would be to assume V to be a diagonal matrix[10]. This assumption is however not acceptable here :

How should we think of the structural disturbances in (1) ? In Blanchard and Kiyotaki (1985) for example, I have derived a model of prices, wages and employment, based on monopolistically competitive price setters in the goods markets, and wage setting unions in the labor market, which has the same form as (1). In that model, the three structural disturbances have the following interpretation: e_w is a taste or a union push disturbance, reflecting a shock to the utility function of suppliers of labor, or unions. e_p is a productivity disturbance, affecting the pricing of firms given wages, employment and the prices of other inputs. The third disturbance e_n is however the sum of two disturbances, $e_n = \propto e_p + e^d$, where e_d is a disturbance to aggregate demand, and $\propto$ is positive and depends on the technology. This is because the third equation is derived by using the production function to obtain employment given aggregate demand. An adverse productivity shock will increase prices in the second equation but will also increase employment given output, given aggregate demand. Thus, even if one assumes that e_w, e_p and e_d are uncorrelated, which I find a plausible assumption, this implies in general a positive correlation between e_p and e_n

While this specific interpretation of the shocks is model specific, the interpretation of disturbances will hold in other models. I shall assume that the wage, price and aggregate demand disturbances are uncorrelated. This implies that while the correlations between wage disturbances and either price or employment disturbances are equal to zero, the correlation σ_{pn} between price and employment disturbances may be positive.

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10 This is the assumption made in Blanchard and Watson (1986).

3. Allowable sets of parameters

We now have 9 unknown parameters (4 in V and 5 in A) and 6 restrictions imposed by Σ. The four parameters in V (the variances and the covariance σ_{pn}) are non negative. The five parameters in A are subject to lower and upper bounds. We can now, by doing a grid search, find the set of values of these parameters which satisfy the 6 constraints imposed by Σ. To do this grid search, it is convenient to search over the values of ρ_{pn} (the correlation between e_p and e_n), c_1 and b_1 (by increments of .1) and to solve for the implied values of the other parameters. The results are summarized in table 2.

The fact that the estimated Σ matrix has two off diagonal elements close to zero, together with the a priori restriction that many elements of A be non negative turns out to lead to a small set of allowable coefficients. In particular, the small correlation between the reduced form price and wage disturbances together with the constraint that both a_1 and b_1 be non negative implies little contemporaneous interaction between wages and prices. Similarly, the small negative correlation between the reduced form price and employment is consistent with only a small positive effect of employment on prices, even when c_1 is negative.

I choose to work below with two sets of coefficients, which are :

$\rho_{pn} = 0$; c1 = -.1 ; b1 = .0 ; b2 = .0 ; a1 = .0 ; a2 = .37 and

$\rho_{pn} = 0$; c1 = -.3 ; b1 = .0 ; b2 = .11 ; a1 = .0 ; a2 = .37

The first set has no contemporaneous effect of either current employment or wages on prices. The second has a positive effect of employment on prices. Results using ρ_{pn} =.1 are very similar and not reported.

Table 2. Decomposition of the variance covariance matrix

Coefficients :

ρ_{np}	c_1	b_1	b_2	a_1	a_2
.0	.0	.0	-.07	.01	.37
		.1	-.10	-.23	.35
	-.1	.0	.00	.01	.37
		.1	-.04	-.23	.37
	-.2	.0	.05	.02	.37
		.1	.01	-.23	.38
	-.3	.0	.11	.02	.37
		.1	.08	-.22	.39
.1	.0	.0	-.14	.01	.37
		.1	-.17	-.23	.35
	-.1	.0	-.07	.01	.37
		.1	-.11	-.23	.37
	-.2	.0	-.02	.02	.37
		.1	-.06	-.23	.38
	-.3	.0	.04	.02	.37
		.1	.01	-.22	.39

Note that identification has been achieved here without recourse to exclusion restrictions. The reason is not that these exclusion restrictions are necessarily less credible than the restrictions imposed above. It is because the purpose of the paper is to look at, and interpret, the unconstrained joint behavior of the Y variables, given X.

The two implied structural models are given in tables 3 and 4 respectively, which give the sets of coefficients in each structural equation, as well as the levels of significance of tests of sets or sums of coefficients. The next section will be devoted to an examination of the wage and price equations. I limit myself here to an examination of the dynamic effects of the structural disturbances on wages, prices and employment. The results are reported in table 5 for both sets of coefficients[11]. Figures 1 and 2 plot these dynamic effects, together with one standard deviation bands ; these are obtained by Monte Carlo simulations with 500 draws, assuming joint normality of the estimated coefficients.

4. Dynamic effects of structural disturbances

Table 5 gives the dynamic effects of one time shocks to structural disturbances on wages, prices and employment. The other variables X, including nominal money are kept constant. For the two sets of coefficients we consider, structural disturbances are assumed uncorrelated, increasing one disturbance, keeping the others constant,

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[11] These dynamic responses to one time shocks to disturbances correspond to impulse responses in the VAR methodology. Subject to our identification conditions being correct, they however have as simple structural interpretation, which standard impulse responses do not have. See Bernanke (1985) and Cooley and LeRoy (1985) for further discussion.

Table 3.

Structural model (using the first set of contemporaneous structural parameters)

1. Coefficients on endogenous variables

	W	W(-1)	W(-2)	W(-3)	P	P(-1)	P(-2)	P(-3)	N	N(-1)	N(-2)	N(-3)	se(e)
W		.86	.07	.04	.00*	.36	-.01	-.32	.37*	-.19	-.13	.03	$.41 \times 10^{-2}$
P	.00*	.15	-.19	.15		.96	.02	-.08	.00*	.03	.03	.08	$.26 \times 10^{-2}$
N	.00*	.11	-.34	.21	-.10*	.03	.15	-.11		1.23	-.30	-.02	$.33 \times 10^{-2}$

* coefficients constrained (see text)

2. Significance of sets of coefficients [a]

	lagged W's	lagged P's	lagged N's	X2,X3	X4,X5	X6	(X2 to X6,dummies)
W	$.40 \times 10^{-7}$	$.36 \times 10^{-1}$	*	$.52 \times 10^{-1}$	.84	.52	$.16 \times 10^{-1}$
P	$.13 \times 10^{-4}$	$.40 \times 10^{-7}$	$.46 \times 10^{-2}$	$.10 \times 10^{-2}$	$.57 \times 10^{-1}$	$.20 \times 10^{-1}$	$.80 \times 10^{-4}$
N	$.15 \times 10^{-1}$	*	$.40 \times 10^{-7}$	$.35 \times 10^{-1}$	.18	$.60 \times 10^{-4}$	$.23 \times 10^{-3}$

a) significance level of the F test that all coefficients on a variable or a set of variables in a given equation are equal to zero.

* test not well defined as contemporaneous effect is assumed different from zero

3. Tests of sums of coefficients on right hand side variables[b]

	W	P	N	X6
W	.97 $(\Sigma=1)$:.66	.03 $(\Sigma=0)$:.39	.08 $(\Sigma=0)$:.27	-.01 $(\Sigma=0)$:.53
P	.11 $(\Sigma=0)$:$.1 \times 10^{-4}$	.90 $(\Sigma=1)$:$.8 \times 10^{-4}$	.14 $(\Sigma=0)$:$.41 \times 10^{-3}$	-.02 $(\Sigma=0)$:.11
N	-.02 $(\Sigma=0)$:.52	-.03 $(\Sigma=0)$:.20	.91 $(\Sigma=1)$:.10	.06 $(\Sigma=0)$:$.20 \times 10^{-2}$

b) the first line gives the sum of coefficients, including when relevant the coefficient on the contemporaneous value. The second line gives the significance level of the F test that the sum of coefficients on a given variable in a given equation is equal to the number indicated in the table (0 or 1)

Table 4.

Structural model (using the second set of contemporaneous structural parameters)

1. Coefficients on endogenous variables

	W	W(-1)	W(-2)	W(-3)	P	P(-1)	P(-2)	P(-3)	N	N(-1)	N(-2)	N(-3)	se(e)
W		.86	.07	.04	.00*	.36	-.01	-.32	.37*	-.19	-.13	.03	$.41\text{x}10^{-2}$
P	.00*	.15	-.16	.13		.97	.01	-.07	.10*	-.10	.06	.09	$.27\text{x}10^{-2}$
N	.00*	.14	-.38	.24	-.30*	.22	.15	-.13		1.24	-.29	.00	$.33\text{x}10^{-2}$

* coefficients constrained (see text)

2. Significance of sets of coefficients [a]

	lagged W's	lagged P's	lagged N's	X2,X3	X4,X5	X6	(X2 to X6,dummies)
W	$.40\text{x}10^{-7}$	$.36\text{x}10^{-1}$	*	$.52\text{x}10^{-1}$	.84	.52	$.16\text{x}10^{-1}$
P	$.26\text{x}10^{-4}$	$.40\text{x}10^{-7}$	*	$.22\text{x}10^{-2}$	$.72\text{x}10^{-1}$	$.17\text{x}10^{-1}$	$.17\text{x}10^{-3}$
N	$.69\text{x}10^{-2}$	*	$.40\text{x}10^{-7}$	$.15\text{x}10^{-1}$	.14	$.80\text{x}10^{-4}$	$.88\text{x}10^{-4}$

a) significance level of the F test that all coefficients on a variable or a set of variables in a given equation are equal to zero.
* test not well defined as contemporaneous effect is assumed different from zero

3. Tests of sums of coefficients on right hand side variables[b]

	W	P	N	X6
W	.97 $(\Sigma=1)$:.66	.03 $(\Sigma=0)$:.39	.08 $(\Sigma=0)$:.27	-.01 $(\Sigma=0)$:.53
P	.12 $(\Sigma=0)$:$.1\text{x}10^{-4}$	.91 $(\Sigma=1)$:$.18\text{x}10^{-3}$	.15 $(\Sigma=0)$:$.21\text{x}10^{-3}$	-.02 $(\Sigma=0)$:$.47\text{x}10^{-1}$
N	-.00 $(\Sigma=0)$:.92	-.05 $(\Sigma=0)$:$.60\text{x}10_{-1}$	.95 $(\Sigma=1)$:.29	.05 $(\Sigma=0)$:$.47\text{x}10^{-2}$

b) the first line gives the sum of coefficients, including when relevant the coefficient on the contemporaneous value. The second line gives the significance level of the F test that the sum of coefficients on a given variable in a given equation is equal to the number indicated in the table (0 or 1)

Table 5. Dynamic effects of structural disturbances

1. Using the first set of structural coefficients

Effects of :	e_w				e_p				e_n			
on	w	p	n	w-p	w	p	n	w- p	w	p	n	w-p
at time:												
1	1.00	.00	.00	1.00	-.04	1.00	-.10	-1.03	.37	.00	1.00	.37
2	.89	.15	.09	.74	.28	.95	-.19	-.67	.59	.09	1.26	.50
3	.83	.09	-.13	.74	.59	.99	-.08	-.39	.62	.17	1.18	.44
4	.81	.20	-.19	.61	.55	.91	-.11	-.35	.66	.38	.98	.28
5	.80	.28	-.23	.51	.50	.82	-.21	-.32	.73	.61	.78	.11
6	.83	.34	-.24	.49	.42	.77	-.27	-.35	.84	.83	.60	.02
7	.85	.38	-.24	.47	.37	.72	-.30	-.35	.96	1.00	.44	-.04
8	.86	.41	-.26	.45	.33	.66	-.31	-.32	1.04	1.14	.29	-.09
9	.85	.43	-.27	.42	.30	.59	-.30	-.29	1.10	1.24	.14	-.13
10	.84	.46	-.28	.39	.26	.52	-.30	-.26	1.14	1.31	.00	-.17
15	.77	.50	-.33	.28	.04	.19	-.22	-.14	1.08	1.31	-.43	-.22
20	.66	.44	-.33	.22	-.09	-.02	-.10	-.06	.80	.97	-.55	-.16
30	.42	.26	-.25	.16	-.16	-.16	.05	.00	.23	.20	-.32	.02

2. Using the second set of structural coefficients

Effects of :	e_w				e_p				e_n			
on	w	p	n	w-p	w	p	n	w- p	w	p	n	w-p
at time:												
1	1.00	.00	.00	1.00	-.10	.96	-.29	-1.07	.36	.10	.97	.25
2	.89	.15	.09	.74	.15	.90	-.43	-.75	.60	.19	1.22	.41
3	.83	.09	-.13	.74	.45	.92	-.31	-.47	.67	.28	1.15	.39
4	.81	.20	-.19	.61	.41	.81	-.30	-.40	.70	.47	.95	.23
5	.80	.28	-.23	.51	.34	.67	-.36	-.33	.77	.69	.74	.08
6	.83	.34	-.24	.49	.24	.59	-.38	-.34	.87	.89	.56	-.02
7	.85	.38	-.24	.47	.17	.50	-.38	-.32	.98	1.06	.40	-.08
8	.86	.41	-.26	.45	.12	.42	-.35	-.29	1.06	1.18	.25	-.12
9	.85	.43	-.27	.42	.08	.33	-.32	-.25	1.11	1.27	.11	-.16
10	.84	.46	-.28	.39	.03	.25	-.29	-.22	1.14	1.34	.00	-.20
15	.77	.50	-.33	.28	-.16	-.06	-.13	-.10	1.06	1.31	-.45	-.24
20	.66	.44	-.33	.22	-.24	-.21	.00	-.03	.78	.94	-.55	-.16
30	.42	.26	-.25	.16	-.20	-.20	.10	.00	.21	.18	-.31	.02

Figure 1. Dynamic effects of structural disturbances on W,P,N

First set of structural parameters

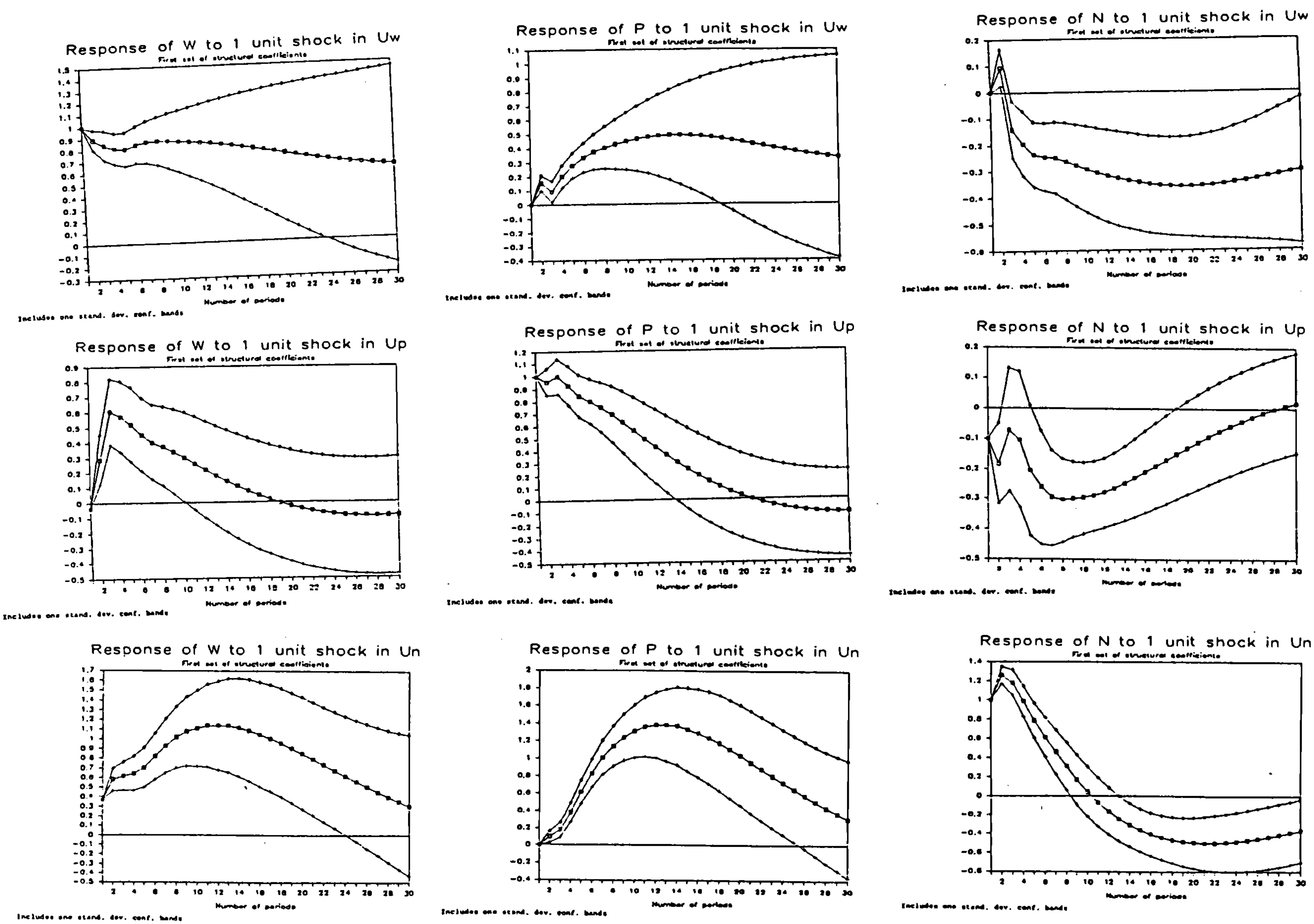
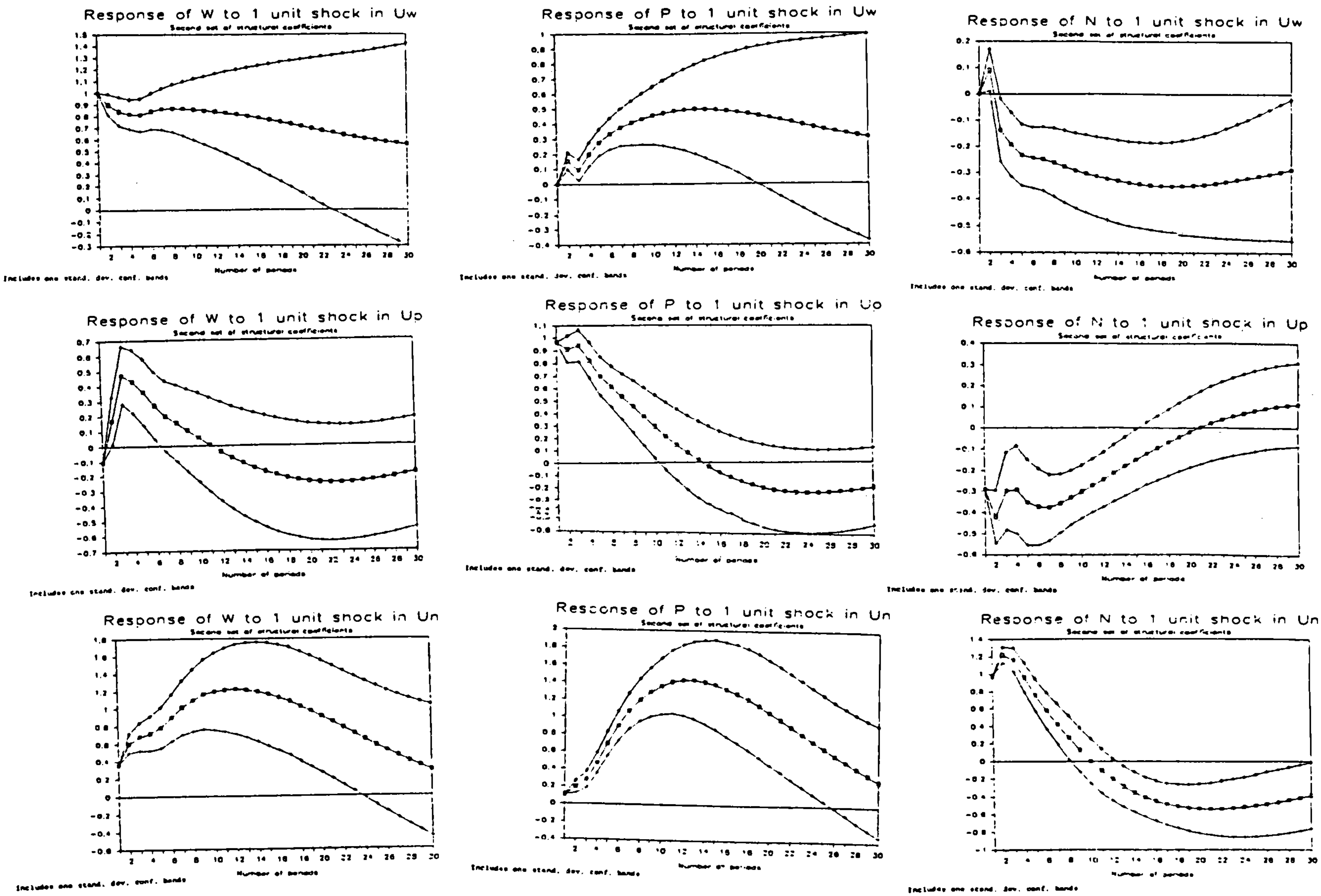


Figure 2. Dynamic effects of structural disturbances on W,P,N

Second set of structural parameters



corresponds to a sample experiment. The plausibility of these dynamic responses provides an informal test of the identification restrictions but is interesting in its own right.

A positive shock to nominal wages has long lasting effects on wages, prices and employment. (The persistence, which is due to the presence of estimated roots close to the unit circle implies that confidence intervals increase rather than decrease with time, so that the reported long run responses are not reliable). Prices adjust slowly over time, while employment decreases. Thus, wage shocks imply a long period of higher real wages and lower employment, a negative correlation between real wages (which are reported in the last column) and employment.

A positive shock to prices, which reflects for example an adverse productivity shock, leads to lasting effects on prices. Wages adjust over time and employment is lower for a long period of time. Thus, price -productivity- shocks lead to sustained lower wages and lower employment, to a positive correlation between real wages and employment.

A positive shock to employment, from an increase in aggregate demand for example, leads to an increase in employment of roughly three years[12]. The effect on wages and prices is however much more persistent, lasting for over 8 years. Wages increase initially faster than prices, so that the real wage initially increases ; prices eventually catch up, leading to a decrease in the real wage. Real wages and employment both initially increase and later decrease, so that the correlation between employment and real wages is again positive.

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[12] The main difference between these results and those obtained under cointegration assuming one unit root is that the own effect of an employment shock is much more persistent under cointegration. See Figures 5 and 6 in appendix 2.

These three dynamic responses are very much consistent with the traditional Keynesian view of the interaction between aggregate demand, employment, wages and prices. Supply shocks, either to workers or firms lead to higher prices and wages and lower employment. Demand shocks lead to higher prices, wages and employment. The correlation between real wages and employment depends very much on the source of disturbances, being negative for shocks to the wage equation, positive in the two other cases. This may explain the difficulty of finding a significantly negative effect of wages in neo classical demand for labor equations.

To understand these dynamics better, one needs to look at each equation individually. In the next section, I look at the price and wage equations.

Section 4. The price and wage equations.

I first look at the dynamic cross effects of prices and wages, then at the effects of employment on wages and prices. I finally consider sundry other issues, such as the role of X variables and the relation of the wage equation to the Phillips curve. As my interest is mainly in these two equations, I do not consider the employment equation further.

1. The cross effects of prices and wages

Consider the dynamic relation between two variables x and y :

$$a(L)x = b(L)y + c(L)e$$

where a(L), b(L) and c(L) are lag polynomials and e is a white noise disturbance. Suppose that our interest is in characterizing the dynamic effect of y on x, or more precisely to learn about b(L)/a(L). Suppose that we have estimated this dynamic relation by allowing for enough lags on x and y to obtain a white noise residual. That is, we have estimated :

$d(L)x=f(L)y + e$, where from above $d(L)=c(L)^{-1}a(L)$ and $f(L)=c(L)^{-1}b(L)$

From our estimated relation, we cannot recover b(L) and a(L) separately without assumptions on c(L). We can however recover b(L)/a(L) easily by doing long division of the lag polynomials on x and y as

$$f(L)/d(L) = c(L)^{-1}b(L)/c(L)^{-1}a(L) = b(L)/a(L)$$

An easy and intuitive way of doing this long division is to trace the dynamic effects of a one time shock in y on x. This is the approach I use to look at the dynamic effects of, for example, wages on prices in the price equation.

Table 6 gives the dynamic effects of wages on prices and prices on wages. There are three pairs of columns. The first pair gives the dynamic effects of prices on wages in the wage equation. The other two pairs give the dynamic effects of wages on prices in the two price equations corresponding to the two alternative sets of assumptions about contemporaneous effects. For each pair, the first column gives the effect of a one time increase of 1 of prices at time 1 ; the second column gives the effect of a permanent increase of 1 in prices, and is simply the cumulated sum of coefficients in the first column. Figure 3 plots the cumulative effects, together with one standard deviation bands.

Table 6. Dynamic effects of prices on wages and wages on prices

	Wage equation: Effect of an increase in prices (a_1=.0, a_2=.37)		Price equation: Effect of an increase in wages (b_1=.0, b_2=.0)		(b_1=.0 , b_2=.11)	
time	marginal	cumulative	marginal	cumulative	marginal	cumulative
1	.00	.00	.00	.00	.00	.00
2	.36	.36	.15	.15	.14	.14
3	.30	.67	-.04	.11	-.02	.12
4	-.03	.64	.11	.22	.11	.23
5	.01	.65	.09	.31	.09	.33
6	.02	.67	.08	.40	.09	.43
7	.02	.69	.08	.49	.09	.52
8	.02	.70	.08	.57	.08	.60
9	.02	.72	.07	.64	.07	.67
10	.02	.74	.06	.70	.06	.73
20	.01	.90	.02	1.06	.02	1.11
30	.01	1.02	.00	1.13	.01	1.25

Table 7 Dynamic effects of employment on wages and prices

	Wage equation: Effect of an increase in n (a_1=.0, a_2=.37)		Price equation: Effect of an increase in n (b_1=.0, b_2=.0)		(b_1=.0 , b_2=.11)	
time	marginal	cumulative	marginal	cumulative	marginal	cumulative
1	.37	.37	.00	.00	.11	.11
2	.03	.40	.03	.03	.00	.11
3	.05	.45	.06	.09	.07	.18
4	.05	.50	.15	.24	.15	.33
5	.05	.56	.14	.38	.14	.47
6	.05	.61	.13	.51	.14	.61
7	.05	.67	.12	.63	.12	.73
8	.05	.73	.11	.74	.11	.84
9	.06	.79	.10	.84	.10	.94
10	.06	.85	.09	.93	.09	1.03
20	.07	1.50	.03	1.20	.03	1.30
30	.07	2.24	.01	1.37	.01	1.37

Figure 3. Dynamic effects of wages on prices and prices on wages

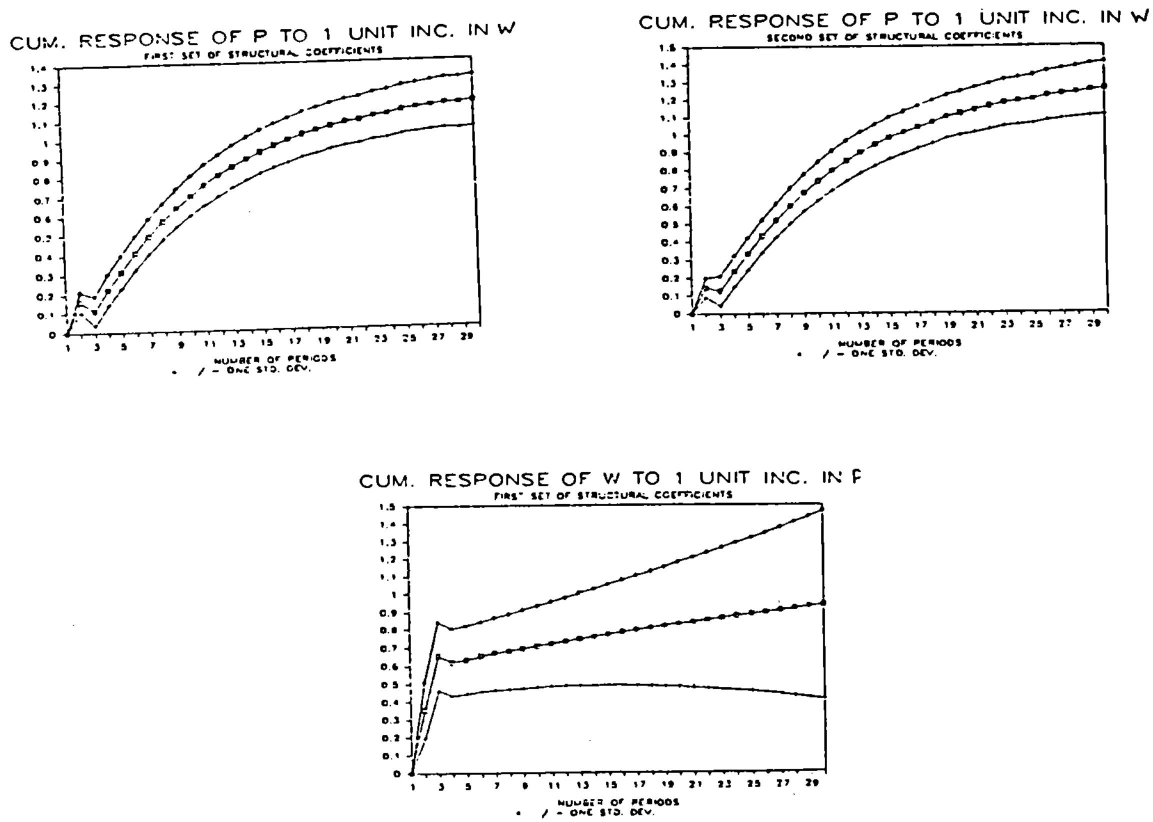
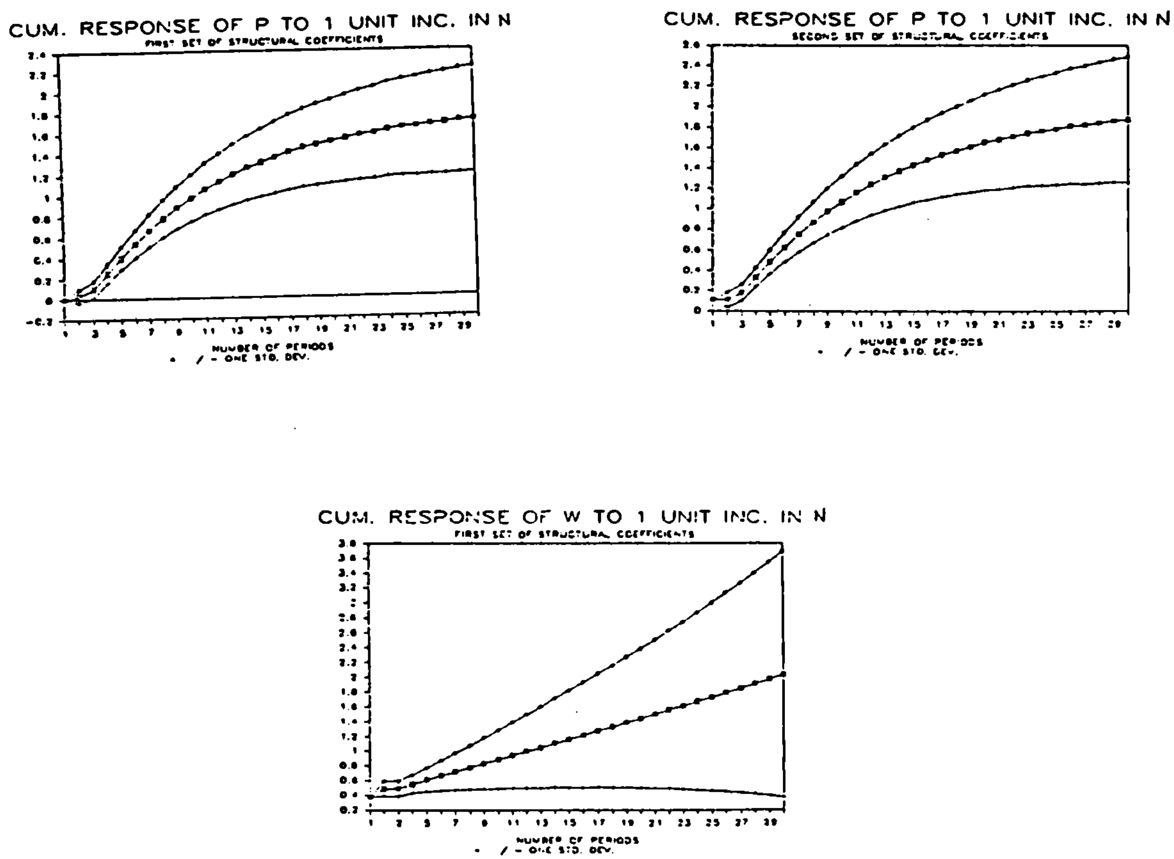


Figure 4. Dynamic effects of employment on prices and wages



The dynamic effect of prices on wages is fast. After three quarters, wages have adjusted by two thirds of the increase in prices (although the first quarter effect is assumed equal to zero). The adjustment thereafter is slow, with the numbers in the first column being small and not significantly different from zero after quarter 4.

By contrast, the dynamic effect of wages on prices is much slower. The increase in prices to a permanent increase in wages is less than one fourth after a year, less than two thirds after two years. The results are very similar under the two alternative assumptions about contemporaneous effects[13].

This asymmetry is somewhat at variance with the traditional view of prices adjusting faster to wages than wages to prices, as well as with estimated equations which support the traditional view. The equations differ from those mainly in two ways. The first is the use of levels rather than first differences. The second is the use of unconstrained lag structures[14]. The second is probably the main source of differences.

What does this asymmetry imply ? This depends on whether the estimated lag structures result from expectational lags, or from lags due to overlapping nominal contracts or asynchronization in price setting. I have argued elsewhere (Blanchard 1983) that the large number of interrelated price decisions, together with asynchronization, may lead to substantial price inertia even if the length of time

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[13] The asymmetry between the effects of prices on wages and wages on prices also holds for the two alternative systems in which either employment is replaced by unemployment, or in which the CPI is replaced by the GNP deflator. It also remains true even when the contemporaneous correlation between the GNP deflator and wages, which is positive and significant, is attributed entirely to an effect of wages on prices. The contemporaneous effect is then equal to .2, but increases slowly therefter

[14] A potential third difference was suggested to me by R. Gordon. It is that the lag structure used here is too short to capture the full dynamic interactions of prices and wages. I have looked at the effects of increasing lag length and found it did not affect this result.

between price changes is short for each price . If this is what this slow dynamic response of prices reflects, this implies that a large portion of price level inertia comes not from contracts in the labor market, but from price setting in goods markets. In that case, indexation of nominal wages for example may only partially decrease price level inertia and leave substantial output effects of aggregate demand. To distinguish between expectational and other lags clearly requires imposing much more structure than I have imposed here[15].

2. The effects of employment on wages and prices

The dynamic effects of employment on wages in the wage equation and on prices in the price equation are given in Table 7. Table 7 gives the effects of a one time and of a permanent increase in employment. Figure 4 plots the cumulative responses with one standard deviation bands.

To interpret the dynamic effect of employment on wages, I find useful to think of the relation implied by the Phillips curve. The following are three simple versions of the Phillips curve :

$W-W(-1) = a(\text{expected inflation}) + b\,N$

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[15] One can however look at the univariate processes for wages and prices and see how they differ. Good univariate integrated autoregressive representations for wages and prices for the sample we consider are (seasonal and wage price control Gordon dummies are included but not reported):

$\Delta W = .15\ \Delta W(-1) + .11\ \Delta W(-2) + .19\ \Delta W(-3) + .14\ \Delta W(-4) + \Phi_w$

and $\Delta P = .55\ \Delta P(-1) + .02\ \Delta P(-2) + .29\ \Delta P(-3) + \Phi_p$

The difference in these two processes implies that even if prices depended on expectations of wages in the same way as wages depended on expectations of prices, and if expectations of wages and prices were formed by extrapolating optimally from lagged own values, the observed dynamic effect of wages on prices would be slower than the dynamic effect of prices on wages. Thus some of the difference between the dynamic responses we have found may come from differences in expectation formation.

$$W-W(-1) = a(\text{expected inflation}) + b\ N - c(W(-1)-P(-1))$$

$$W-W(-1) = a(\text{expected inflation}) + b\ N - c\ N(-1)$$

The first is the standard Phillips curve relation, implying, given expected inflation, a relation between the rate of wage inflation and the level of unemployment (employment). The second allows for an effect of the lagged real wage on wage inflation ; it differs from the first is that it implies, in equilibrium, a relation between the level of the real wage and the level of employment, a pseudo labor supply curve. The third allows for an effect of current and lagged unemployment. If c is positive, there is a positive effect of both the level and the rate of change of unemployment on wage inflation ; if c is equal to b, it is the rate of change, not the level of unemployment which affects nominal wage inflation.

Each of these three versions has different implications for the dynamic effects of a one time increase in employment on nominal wages. The first implies a permanent increase in wages to a new higher level. The second implies an initial increase in wages, with a return to the initial value at rate 1-c. The third implies an initial increase, with a decrease to a new level, equal to the initial value if c=b, higher than the initial level if c is less than b.

Table 7 is inconsistent with the first version and appears to be most consistent with the third version. Wages increase in the first quarter, but decrease to a lower value which appears to be roughly constant from then on. Put another way, a permanent increase in employment leads to a large increase in wage inflation in the quarter in which it happens, and to steady but lower wage inflation thereafter (given expected price inflation) (Note however the large standard deviation bands in Figure 4 : we should not have much confidence in the estimated cumulative response). Thus, one interpretation of this dynamic effect of employment on wages is that the rate of change of unemployment (employment) plays a more important role than the level in determining wage inflation [16].

The dynamic effects of employment on prices are quite different. The effect of a one time increase in employment affects prices slowly over time, the maximum effect being obtained after a year. Equivalently, a permanent increase in employment leads to a slow adjustment of prices to a new higher level. While, as indicated above, the uncertainty associated with the long run response is large because of the presence of non stationarity, price inflation appears to die out, in contrast to the results obtained in the wage equation. One fourth of the adjustment is completed after a year, three fourths after two years. This result is consistent with the traditional view that, given wages, prices adjust slowly, if at all, to movements in demand.

3. The effects of X variables on wages and prices

Traditional identification restrictions rely on exclusion restrictions on some of the X variables in the wage and price equations. Such restrictions have been criticized on the grounds that, even if the variables do not enter the equation directly, they may do so indirectly by affecting expectations. Given that these restrictions have not been used to identify the wage and price equations, I can look at these two equations and see which variables enter significantly.

Relative prices of non labor inputs, indirect taxes paid by firms and nominal money are usually excluded from the wage equation. The significance level associated

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[16] This result also holds for the two alternative systems, using unemployment, or the GNP deflator. The effect of the rate of change of employment is also present but less strong when annual data is used (see Blanchard and Summers (1986). I have not yet reconciled the two sets of results

with the hypothesis that coefficients on x2, x3, x5 and x6 are all zero is .18. There is indeed little evidence that these variables enter the wage equation.

Direct taxes on individuals and nominal money are usually excluded from price equations. The significance level associated with the hypothesis that coefficients on x4 and x6 are all zero is equal to .05 under the first set of structural parameters, equal to .03 under the second. This marginal rejection comes mostly, as is clear from tables 4 and 5, from the significance of nominal money. This can be interpreted in two ways. It means either that our identification restrictions are incorrect, or that nominal money affects prices directly, either through expectations or through other channels. The sum of coefficients on nominal money is however small, negative and insignificant in one case, significant at the 5% level in the other.

4. The wage equation and the Phillips curve

Does the estimated wage equation look like a Phillips curve ? Gathering results from table 3 (or 4) and from the discussion above, the answer is mixed.

From above, the restriction that relative prices, indirect taxes and nominal money do not belong to the equation is easily accepted. From table 3 or 4, the restriction that the sum of coefficients on wages is one and the sum of coefficients on prices is equal to zero is easily accepted. The significance level associated with this joint hypothesis is .78. Thus, the equation can be rewritten in terms of wage inflation as a function of price inflation and unemployment. This is evidence in favor of a Phillips curve interpretation of the wage equation.

But table 3 also shows that the sum of coefficients on unemployment is not significantly different from zero. The significance level associated with this hypothesis that the sum of coefficients on wages is one, the sum of coefficients on prices is zero and the sum of coefficients on unemployment is zero is .84. This is inconsistent with the standard specification, and implies, under the Phillips curve interpretation, a strong effect of the rate of change of unemployment.

The fact that the equation can be rewritten in terms of rates of change of wages, prices and unemployment suggests another interpretation, that of a relation between the level of the wage, the price level and employment, with a non stationary disturbance term. This interpretation is however unappealing. The equation so obtained violates the homogeneity restriction strongly, with the sum on coefficients on nominal variables equal to .56, and significantly less than unity.

Section 5. Conclusion

In this paper, I have estimated the reduced form of a model of prices, wages and employment. I have then made alternative assumptions on the contemporaneous interaction between variables to go from the reduced to the structural form.

I have reached the following main conclusions.

The first is that the structural models so obtained are quite consistent with the traditional Keynesian model of fluctuations. Demand shocks are associated with higher employment, and an increase in wages and prices. Supply shocks, either from suppliers of labor or from technology, lead to increases in prices and wages. The correlation between real wages and employment depends very much on the source of the shocks, being negative for shocks to labor supply but positive in the two other cases.

The effect of prices on wages in the wage equation is faster than the effect of wages on prices in the price equation. This result appears robust to the use of alternative variables and is partly at odds with received wisdom.

While the data partly support the interpretation of the wage equation as a Phillips curve, they indicate a strong effect of the rate of change of unemployment on wage inflation. The effect is stronger than in estimated Phillips curves which have a tighter specification than the one allowed for in the paper.

There are obvious extensions to the research presented here.

The first follows from the strong evidence of subsample instability. To the extent that the approach used here allows for a larger set of control variables in each equation than the traditional equation by equation estimation, one may have expected subsample instability to be less severe. This is not the case. I do not believe that addition of other variables in X will lessen the problem. Estimation using random coefficients is both appropriate and useful, as it can shed light on the change in the dynamic relations between variables over time.

The second is an investigation of the sources of non stationarity of Y given X. It is often believed that the main source of non stationarity in real variables is the presence of a unit root in the process for productivity. This can be interpreted as the presence of a common factor (1-L) in the price equation ; a cursory examination of the results of the paper do not support this hypothesis. Instead, non stationarity appears to come from the wage equation.

Finally, as discussed in the paper, the estimated model is not structural in the sense of distinguishing between expectations and actual variables. The natural next step is to build and estimate a model which does so. The results of this paper give clear leads as to which models might or might not explain the data.

Appendix 1. Homogeneity property

To avoid notational complexity, I shall consider the following simple "deep structural" model :

(A1) $P = a\, P(-1) + b\, E(P(+1)|\cdot) + (1-a-b)\, M + u_p$

where P is the price level, M is nominal money, and u_p is a white noise disturbance.

The homogeneity property is assumed to hold for this model so that the sum of coefficients on nominal variables on the right hand side is equal to one. The proof given below is easily extended to allow for a more complex lag structure, or for P and M to be vectors, or for the presence of real variables.

The equation describing the behavior of nominal money is assumed to have the following form :

(A2) $M = c_1\, M(-1) + \ldots + c_k\, M(-k) + d_1\, P(-1) + \ldots + d_k\, P(-k) + u_m$

where u_m is white noise.

I now show that, if the sum of the coefficients on the right hand side variables of (A2) is equal to unity, then the structural and reduced forms of the above model will satisfy the homogeneity property.

If money follows the above process, and if the sum of coefficients is equal to unity, the equation for money can be rewritten as :

(A3) $M-M(-1) = \gamma(L)(M(-1)- M(-2)) + \delta(L)(P(-1)-M(-1)) + u_m$

where :

$$\gamma(L) \equiv -\sum_{2}^{k} (c_i+d_i) - \sum_{3}^{k} (c_i+d_i)L \ldots - (c_k+d_k)\, L^{k-2}$$

and

$$\delta(L) \equiv b_1 + \ldots + b_k\, L_{k-1}$$

Substracting M from both sides of (A1) gives :

$$(A4) \quad P-M = a(P(-1)-M) + b(E(P(+1)|\ )-M) + u_p$$

Using (A3) to express M(-1) and E(M(+1)|) as functions of M and replacing in (A4) gives :

$$(A5) \quad P-M = a(P(-1)-M(-1)) + b(E(P(+1)-M(+1))|\ ) + a\ \gamma(L)(M(-1)-M(-2))$$
$$+ \ a\ \delta(L)\ (P(-1)-M(-1)) - b\ \gamma(L)(M-M(-1)) - b\ \delta(L)(P-M)$$
$$+ \ a\ u_m + u_p$$

The system composed of (A3) and (A5) is a dynamic rational expectation system in (P-M) and (M-M(-1)) which can be solved using standard techniques of solution. The solution will express (P-M) as a distributed lag of itself, of (M-M(-1)) and of disturbances. Because all variables are differences of nominal variables, the solution will satisfy the homogeneity property.

Appendix 2. Cointegrated estimation

The first step is to determine the number of unit roots. Computing the eigenvalues associated with the reduced form reported in table 1, with homogeneity imposed, gives the following three largest roots : .97 , .91+.08i and .91-.08i (modulus .91). (The next root is .52). This suggests the presence of either one or three unit roots. (These are the roots of (I-C(L)L), the roots of the system characterizing the behavior of Y given X).

As these roots are obtained from conditional VAR estimation, the distribution theory needed to know whether these roots are significantly different from unity is not yet available[1]. I have proceeded on the assumption of one unit root. The Durbin Watson statistics of the first step regressions for cointegration provide some supportive informal evidence.

Assuming one unit root, I proceed in two steps (see Granger and Engle 1985). In the first, I obtain two cointegrating vectors, by regressing current W on current N and the conditioning vector X (with the same lag structure as in Table 1) and W on P and X. The results are as follows :

$W = .33\ P\ (+\ A(L)\ X) \quad DW = .85$

$W = .24\ N\ (+\ B(L)\ X) \quad DW = .64$

The second step is to use the two implied cointegrating vectors to estimate equation (1). I do so imposing also homogeneity, so the results reported below are derived under the maintained assumptions of one unit root and homogeneity. I report the results in the same way as in table 1.

[1] Stock and Watson (1986) derive the distribution of eigenvalues for the case of unconditional VAR estimation. I have computed their q_d statistic. The estimated statistic does not shed light on whether there is one or more unit roots : significance levels associated with the hypothesis that there is one, two or three roots are very similar.

Given that time is in the conditioning vector, one can also look at Fuller (1976) who has derived distributions of the root for the case where time appears as a regressor in a univariate first order regression. Using his distribution as the correct distribution, the significance level associated with the test that the first root is a unit root is 4%.

1. Coefficients on lagged variables

	W(-1)	W(-2)	W(-3)	P(-1)	P(-2)	P(-3)	N(-1)	N(-2)	N(-3)	Σ(X6)[a]	time[b]
W	.90	-.04	.12	.35	.04	-.39	.24	-.24	.00	.00	.01
P	.17	-.20	.15	1.00	.04	-.15	.01	.05	.01	-.01	-.04
N	.07	-.32	.20	-.11	.13	-.03	1.28	-.32	.06	.04	.00

* Period of estimation 54,4 to 84,4
All regressions include three lags of all Y and X variables (except time trend and dummies ; only the coefficients on Y variables, nominal money and the time trend are reported in the table. Homogeneity restriction imposed
a) sum of coefficients on nominal money
b) time = .01 in 54,4, incremented by .01

2. Standard errors of the reduced form innovations and correlation matrix

			u_w	u_p	u_n
$se(u_w)$	$.43\times10^{-2}$	u_w	1.00	0.00	0.27
$se(u_p)$	$.27\times10^{-2}$	u_p		1.00	-0.14
$se(u_n)$	$.34\times10^{-2}$	u_n			1.00

3. Significance of sets of coefficients[c]

	W	P	N	X2,X3	X4,X5	X6	(X2 to X6 and dummies)[d]
W	.00	$.55\times10^{-2}$	.26	$.34\times10^{-1}$	.89	.14	$.16\times10^{-1}$
P	$.47\times10^{-5}$	.00	$.14\times10^{-4}$	$.17\times10^{-3}$	$.87\times10^{-2}$	$.56\times10^{-1}$	$.23\times10^{-5}$
N	$.19\times10^{-1}$	.90	.00	.25	.27	$.87\times10^{-4}$	$.10\times10^{-2}$

c) significance level of the F test that all coefficients on a variable or a set of variables in a given equation are equal to zero.
d) test of the joint significance of X2, X3, X4, X5, X6 and the dummies for 1972 to 1975

4. Tests of sums of coefficients on right hand side variables[e]

	W	P	N	X6
W	$(\Sigma=1)$:.52	$(\Sigma=0)$:.71	$(\Sigma=0)$:.86	$(\Sigma=0)$:.54
P	$(\Sigma=0)$:$.3\times10^{-5}$	$(\Sigma=1)$:$.7\times10^{-6}$	$(\Sigma=0)$:$.47\times10^{-5}$	$(\Sigma=0)$:.48
N	$(\Sigma=0)$:.20	$(\Sigma=0)$:.90	$(\Sigma=1)$:.38	$(\Sigma=0)$:$.11\times10^{-1}$

e) significance level of the F test that the sum of coefficients on a given variable in a given equation is equal to the number indicated in the table (0 or 1)

A comparison of this results to those in table 1 suggests minor differences only. The coefficients on lagged own values are more significant under cointegration.

To compare the results in another way, the next two tables give the dynamic impulse responses associated with a one standard deviation shock to each of the reduced form disturbances, both for the system estimated in levels and the system estimated with cointegration. As is emphasized in the text, these dynamic responses have no structural interpretation. They however provide a simple way of characterizing the differences in the dynamic behavior of both estimated systems. (As the two estimated covariance matrices of reduced form disturbances are similar, similarity of these dynamic responses implies similarity of dynamic responses to structural disturbances). Figures 5 and 6 plot these responses together with one standard deviation bands, using 500 Monte Carlo simulations assuming normality of the estimates.

5) Dynamic effects of reduced form disturbances, using results from level estimation

Effects of :	e_w				e_p				e_n			
on	w	p	n	w-p	w	p	n	w- p	w	p	n	w-p
at time:		($\times10^{-2}$)				($\times10^{-2}$)				($\times10^{-2}$)		
1	.49	.00	.00	.49	.00	.30	.00	-.30	.00	.00	.39	.00
2	.45	.08	.04	.37	.10	.29	-.02	-.19	.10	.01	.47	.09
3	.42	.05	-.07	.37	.20	.30	.01	-.10	.12	.05	.48	.07
4	.40	.10	-.09	.30	.19	.29	.00	-.10	.14	.11	.41	.03
5	.40	.14	-.12	.26	.17	.26	-.04	-.09	.16	.19	.33	-.03
10	.42	.23	-.14	.19	.11	.19	-.09	-.08	.32	.44	.04	-.08
20	.33	.22	-.16	.11	.00	.02	-.05	-.02	.21	.31	-.16	-.10
30	.21	.13	-.12	.08	-.04	-.04	.00	.00	.03	.04	-.09	-.01

6) Dynamic effects of reduced form disturbances, using results from cointegrated estimation

Effects of :	e_w				e_p				e_n			
on	w	p	n	w-p	w	p	n	w- p	w	p	n	w-p
at time:												
		(x10^{-2})				(x10^{-2})				(x10^{-2})		
1	.49	.00	.00	.49	.00	.31	.00	-.31	.00	.00	.39	.00
2	.45	.08	.03	.37	.11	.31	-.03	-.20	.09	.00	.50	.09
3	.42	.06	-.08	.36	.21	.34	-.03	-.13	.11	.03	.52	.08
4	.41	.12	-.15	.29	.21	.32	-.05	-.11	.12	.06	.50	.06
5	.41	.16	-.18	.25	.19	.29	-.08	-.10	.12	.09	.49	.03
10	.46	.30	-.30	.16	.11	.20	-.12	-.09	.22	.27	.46	-.05
20	.36	.27	-.59	.09	.00	.03	-.15	-.03	.29	.46	.34	-.17
30	.14	.02	-.80	.12	-.06	-.08	-.13	.02	.26	.45	.22	-.19

The dynamic responses are qualitatively the same in both cases. The own effects of n shocks are more persistent under cointegration. Cross effects are also stronger under co-integrated estimation.

Figure 5. Dynamic effects of structural disturbances on W,P,N Level Estimation

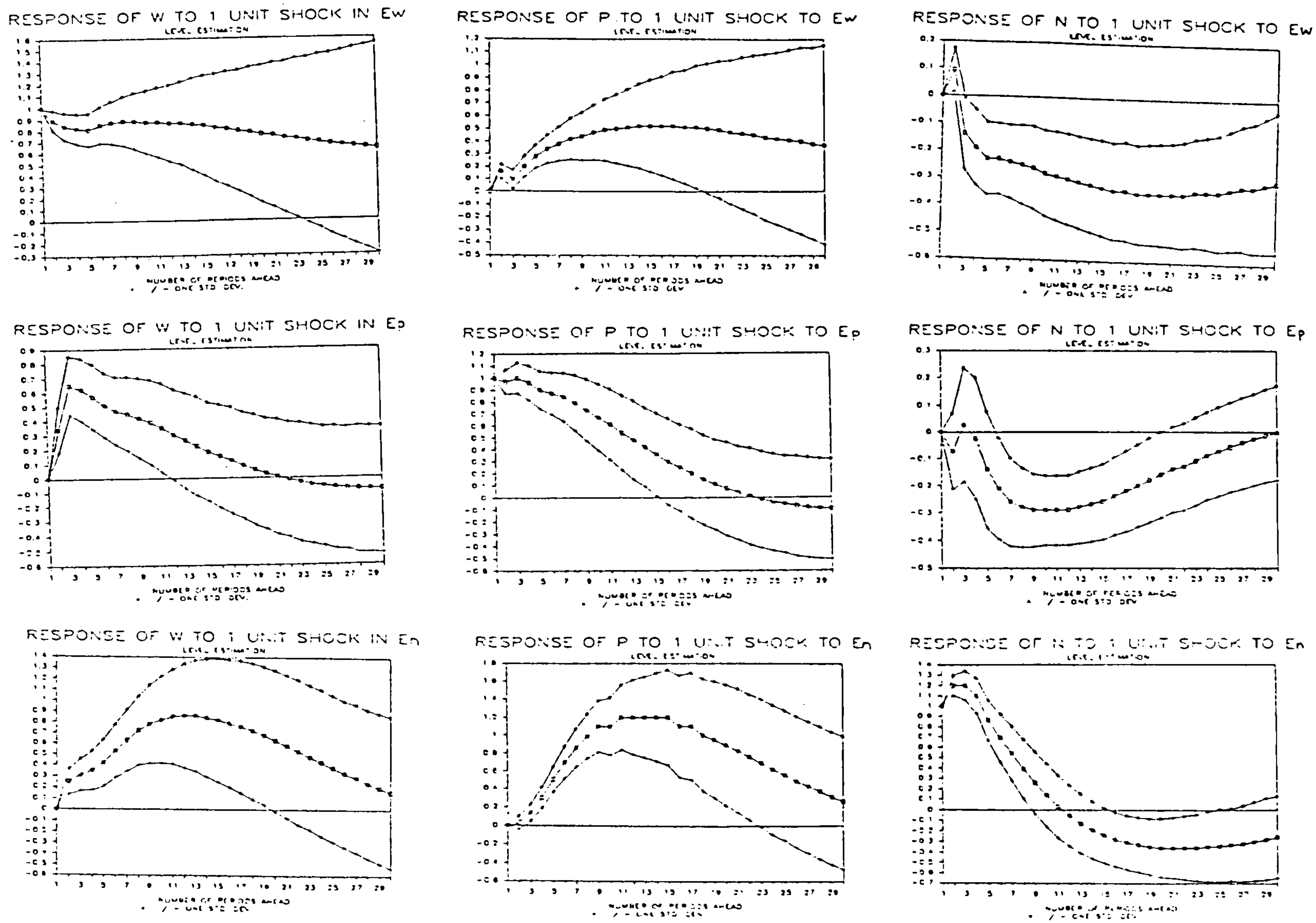
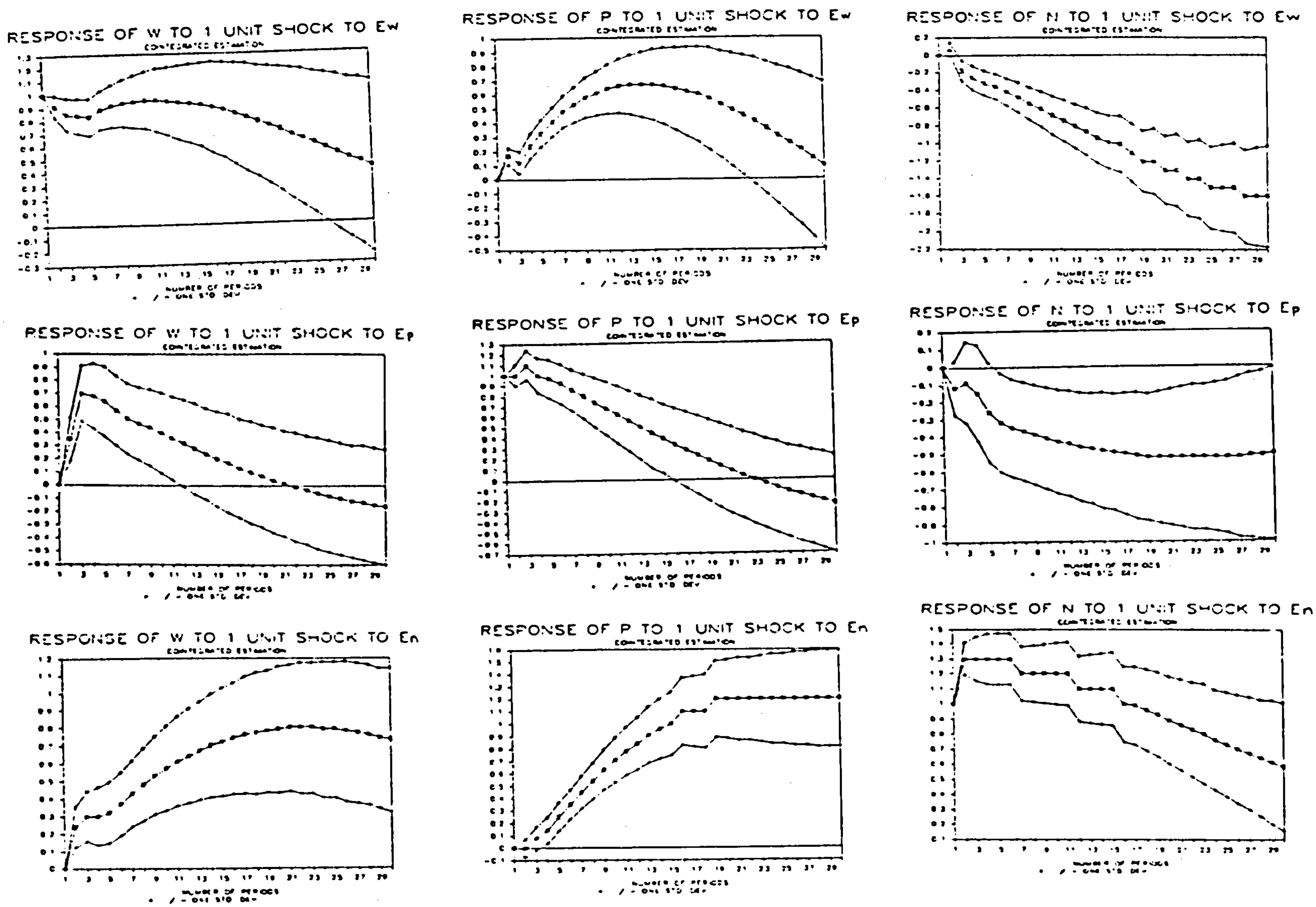


Figure 6. Dynamic effects of structural disturbances on W,P,N
Cointegration Estimation



Appendix 3. Subsample stability tests

Reduced form equation	w	p	n	System
	$\chi^2(34)$	$\chi^2(34)$	$\chi^2(34)$	$\chi^2(105)$
Cut in quarter :				
1968-4	48.6	79.4	66.2	191
1969-4	52.4	82.4	65.9	197
1970-4	55.8	80.7	73.2	210
1971-4	70.2	71.3	69.4	206
1972-4	71.6	68.6	66.2	202

The values reported for a given year are values of the χ^2 statistics associated with the hypothesis that the coefficients of the particular equation (system in the last column) are the same in the sample ending at that date and the one strating in the following quarter.

Significance levels : $\chi^2(34)$: 56.0 at 1%
$\chi^2(105)$: 142.0 at 1%

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