## 6. Econometric Results

It was seen from the literature review that there are many areas of controversy surrounding the determination of inflation in Ireland. The main objective of this section is to attempt to answer the major unresolved questions arising from this review. Such questions include the following:

- What are the main causes of aggregate Irish inflation, both in a proximate and an ultimate sense?
- Does there exist separate price determination processes for the traded and non-traded sectors in Ireland?
- What is the role of wages in the inflation process in Ireland?
- What part have domestic factors played in the short/long run in determining Irish inflation over the sample period?

In this section we cover all of the above questions, although a comprehensive analysis of some of the topics will form the basis of future papers. The econometric approach which appears to be most suited to these types of questions is the so-called "Johansen procedure". This procedure is a multivariate estimation technique[1] which attempts to uncover long-run stationary equilibrium relationship(s) among sets of non-stationary data. The approach also allows the user to investigate the speed of adjustment to these equilibria, along with any short-run relationships which may exist.

### *6.1 Introduction to the Johansen procedure*

A good guide to the Johansen procedure is contained in Hansen and Juselius (1995), where the maximum likelihood estimation technique is briefly explained. Johansen (1988, 1991) and Johansen and Juselius (1990) give a more elaborate (albeit highly technical) description of the estimation technique. An excellent account of the intuition behind the Johansen approach to estimation is contained in Hamilton (1994). The various steps will be further clarified as we proceed through this section, and further useful references will be cited, where appropriate.

[1] The multivariate approach, with its allowance for interactions between the determination of the variables of interest, eliminates the single-equation bias which would be problematic for many previous studies.

If $z_t$ is a $p$ x $1$ vector of stochastic variables, $\mu$ is a constant term and $D_t$ is a vector of nonstochastic variables, such as trend variables, seasonal or intervention dummies, then the Johansen procedure begins with setting out a model in error-correction form[2] as follows, where $\Delta$ is the difference operator:

$$\Delta z_t = \Gamma_1 \Delta z_{t-1} + ... + \Gamma_{k-1} \Delta z_{t-k+1} + \Pi z_{t-1} + \mu + \Psi D_t + \varepsilon_t, \quad t = 1, ... , T. \tag{6.1}$$

where:

$$\varepsilon_t \sim \text{Niid}_p (0, \Sigma) \tag{6.2}$$

and where k is the lag length. If the data are integrated of order one, hereafter I(1), then the matrix $\Pi$ has to be of reduced rank, $r$ [3]:

$$\Pi = \alpha\beta' , \tag{6.3}$$

where $\alpha$ and $\beta$ are $p$ x $r$ matrices and $r < p$. The reduced form model (6.1) and cointegration (6.3) is now given by:

$$\Delta z_t = \Gamma_1 \Delta z_{t-1} + ... + \Gamma_{k-1} \Delta z_{t-k+1} + \alpha\beta' z_{t-1} + \mu + \Psi D_t + \varepsilon_t, \quad t = 1, ... , T. \tag{6.4}$$

where $\beta' z_t$ are the r long-run cointegration relations and $\alpha$ is the matrix of adjustment coefficients. In order to properly interpret the reduced form model, however, it is necessary to impose certain restrictions on the data which are derived from economic theory. For instance, as we shall see later, one constraint we attempt to impose upon the data is that of long-run purchasing power parity. Restrictions can similarly be

[2] This allows us to distinguish between stationarity due to linear combinations of non-stationary data or to differencing. It is also an important representation in that it allows us to test a variety of interesting economic hypotheses, as we shall see later.

[3] If $\Pi$ was of full rank, this would imply that all variables were I(0). If $\Pi$ has zero rank the term $\Pi z_{t-1}$ drops out of the equation and the variables in question are not cointegrated. If 0 < rank of $\Pi$ < P, there is at least one cointegrating vector. In the absence of I(0) variables the rank of $\Pi$ equals the number of stable long-run relationships which exist among the data.

placed upon the adjustment and the short-run Γ coefficients. When a set of satisfactory restrictions have been imposed and accepted upon the basis of diagnostic tests, we have what is known as a structural model in which economic theory is properly incorporated. This is defined as follows:

$$A_0\Delta z_t = A_1\Delta z_{t-1} + \ldots + A_{k-1}\Delta z_{t-k+1} + a\beta' z_{t-1} + \mu' + \Psi' D_t + u_t, \quad t = 1, \ldots , T. \qquad (6.5)$$

where:

$$u_t \sim \text{Niid}_p\,(0, \Omega) \qquad (6.6)$$

and where:

$$\Gamma_1 = A_0^{-1}A_1,\ \ \Gamma_{k-1} = A_0^{-1}A_{k-1},\ \ a = A_0^{-1}a,\ \ m = A_0^{-1}m,'\ \ \Psi = A_0^{-1}\Psi',\ \ e_t = A_0^{-1}u_t,$$
$$\Sigma = A_0^{-1}\Omega A_0'^{-1}. \qquad (6.7)$$

The essential difference between the reduced form and structural models is that, in the former no constraints are imposed on the data[4], whereas in the latter restrictions are imposed both on the basis of economic theory and statistical exclusion tests. Basically, the $A_0$, $A_{1, \ldots ,}$ $A_{k,}$ a, μ', ψ', β, and Ω variables are restricted whereas the equivalent variables in the reduced form equation are not.

The Johansen estimation procedure proceeds in a number of steps which will become clearer as we proceed through the section. Roughly, these are as follows, although there is a good deal of interaction among the various steps and they need not proceed in a strictly sequential fashion:

1. Unit root tests;
2. Vector autoregression (VAR) order (i.e. lag length) tests;

---

[4] Restrictions are, however, usually imposed on the trend variable and are sometimes applied to the constant term.

3. Cointegrating rank tests (i.e. number of cointegrating vectors);
4. Exclusion, stationarity and weak exogeneity tests;
5. Reduced form model estimation;
6. Structural hypothesis tests and generic identification procedure;
7. Achieving model parsimony and estimation of the final structural form.

The first step involves testing for the order of integration of each variable, i.e. checking whether each variable is stationary, difference stationary, and so on. Stage two makes use of various tests which check for autocorrelation, heteroscedasticity, skewness and kurtosis in the residuals, so as to determine the appropriate order or lag length of the VAR. This step ensures that there are Gaussian errors, so that the maximum likelihood estimates of the model can be properly estimated. Step three involves testing for, and subsequently imposing, the appropriate cointegrating rank by use of maximum eigenvalue and trace tests, as well as by examining the roots of the companion matrix, after the model has been estimated. The fourth step involves batch testing the data for long-run exclusion, stationarity and weak exogeneity. As Hansen and Juselius (1995) argue, however, "the batch tests are only supplementary to a careful statistical analysis, and therefore, the results should be interpreted with caution" (p.64). The fifth step comprises the estimation of the model in its reduced form. Step six involves testing the admissibility of certain structural hypotheses. In our case, for example, we will be testing whether some form of PPP holds, in addition to whether there exists some equilibrium relationship between wages and prices. The final step involves model reduction by eliminating unnecessary variables in the VAR and thereby outlining the model in its final structural form.

Another important part of the procedure, which must be decided at the outset, is deciding on whether to include constants/trends in the model. The models considered in the Johansen methodology consist of the following combinations of constants and trends:

| Model | |
|---|---|
| I | No Constants/trends |
| II | Intercepts in the cointegration relations |
| III | + Deterministic trends in the levels (i.e. + intercept outside the cointegration relations) |
| IV | + Trends in the cointegration relations |
| V | + Quadratic trends in the levels (i.e. + trend outside the cointegration relations) |

As Hansen and Juselius argue, it is very unlikely that models I or V will hold. Models will usually at least require a constant in the cointegration space, thus eliminating Model I. Quadratic trends in logged variables are very rare and hence model V is not likely to be appropriate. Accordingly, attention is usually confined to models II to IV. Johansen (1992) discusses a procedure whereby the appropriate model and its rank can be chosen simultaneously and we use this in our analysis.

*6.2 Discussion of the appropriate data set*

To proceed with the cointegration analysis we need to define the appropriate information set ($Z_t$). At a minimum, the chosen vector must be able to shed some light on the key questions concerning the role of wages, the exchange rate and foreign prices in the inflation process in Ireland. In choosing which variables to include and which to exclude, it is inevitable that we will have to trade-off the benefits of model parsimony against the potential costs of misspecification due to certain variables being excluded. An obvious example of such a trade-off is the choice of whether or not to include money stock variables (foreign and domestic) in $Z_t$. Since our primary concern is with distinguishing between foreign as opposed to domestic sources of inflation, and not with assessing the potential long-run relations between domestic/foreign money and domestic/foreign prices, both foreign and domestic money stocks are excluded from $Z_t$. Accordingly, the analysis of specific international and/or domestic monetary transmission mechanisms, and the structural role of money in general, is left for future research.

In light of these considerations, we suggest a five variable vector which includes a measure of the domestic price level, a measure of world traded prices (P*), the exchange rate (E), domestic wage costs (W) and a proxy for productivity effects. Callan and Fitzgerald (1989), in a two-step Engle-Granger analysis, consider a similar information set. They propose the vector as a general specification which combines price mark-up elements with long-run purchasing-power-parity. However, Callan and Fitzgerald did not include a time trend to account for the potential impact of productivity on the real wage. Another significant difference is our use of the Johansen procedure which allows for the possibility of up to *p-1* cointegrating relationships among the *p* variables contained in $Z_t$. In contrast, the Engle and Granger approach allows for the possibility of only a single cointegrating relation among the variables.

The measure of world traded prices employed in this study is a weighted average of the UK and German wholesale prices indices. Such a proxy reflects the traditional trade links which exist between Ireland and both the UK and Germany. Wholesale prices are chosen since both the German CPI and the UK RPI are likely to contain sizeable non-traded elements. As in previous studies, e.g. O'Connell and Frain (1989), the nominal effective exchange rate is employed as the relevant exchange rate measure. An index of average weekly earnings in manufacturing is employed as a proxy for economy-wide earnings. Since this proxy for the possible impact of Irish wages on Irish prices is not adjusted for productivity it justifies the inclusion of the time trend[5].

Lastly, the question of which domestic price measures to employ needs to be addressed. Given its traditional importance - and central policy significance - a consumer price based measure would seem the most obvious. Accordingly, we choose an underlying measure of aggregate domestic prices which nets out the effects of changes in the mortgage interest sub-index[6]. However, a primary objective of this paper is also to assess the likely relevance of the distinction between traded and non-

[5] For a variety of reasons, the alternative productivity-adjusted measure of wage costs, unit labour costs, was not employed.

[6] The choice of a CPI based measure is another significant distinction between this study and the analysis in Callan and Fitzgerald(1989). Their analysis relates only to the manufacturing output price index.

traded prices. Consequently, the above underlying measure of domestic consumer prices has been broken down into its respective traded and non-traded components and each component is analysed independently[7]. Thus, we begin with an analysis of traded prices and analyse the long-run structure of the vector $Z_t^A$ below, i.e.

$$Z_t^A = \{ P^T, P^*, E, W, t \} \tag{6.8}$$

where $P^T$ is the traded component of the underlying consumer price series. *A priori*, we might expect a very robust long-run relationship to exist between domestic traded prices, the exchange rate and foreign prices. Conversely, the impact of foreign variables on non-traded prices may be less robust. In order to assess these possibilities, we also examine the vector $Z_t^B$ below for non-traded price determination.

$$Z_t^B = \{ P^N, P^*, E, W, t \} \tag{6.9}$$

where $P^N$ is the non-trade component underlying consumer prices. Lastly, we conclude with the analysis of the underlying aggregate price series itself.

$$Z_t^C = \{ P, P^*, E, W, t \} \tag{6.10}$$

*A priori*, one might expect the long-run structure of aggregate prices to fall somewhere between that of its traded and non-traded components.

### *6.3 Unit root tests*

In this section we check for the order of integration of the series in our study. In other words we examine whether our variables I(0), I(1) or I(2). In the first set of tests, we are checking whether variables are I(0) or of a higher order of integration, while in the second set the choice is between I(1) and higher orders of integration.

We make use of the following tests in the analysis:

[7] The construction of price indices for both traded and non-traded sectors is described in full in the Data Appendix.

- Dickey-Fuller/Augmented Dickey Fuller (DF/ADF) tests:

Under the DF/ADF methodology, the following regression is used:

$$\Delta X_t = \mu + \delta t + \beta_0 X_{t-1} + \sum_{i-1}^{n} \alpha_i \Delta X_{t-1} + \mu_t \qquad (6.8)$$

where X is the variable of interest, $\mu$ is a constant and t represents a time trend. Lags of $\Delta X_t$ are added until the errors are approximately white noise. To test for autocorrelation the Ljung-Box (1978) statistic is used. In the first stage tests, the null hypothesis is that the series is I(1) or higher, i.e. $H_o$: $\beta_o = 0$. If this is accepted then the test is employed on the first differences of the variables in question. In such second-stage tests the null hypothesis maintains that the series in question is I(2) or higher. Unfortunately, under the null hypothesis, the distribution of the test statistic is not Student's t. MacKinnon (1991) has, however, computed appropriate critical values, and these are employed in our tests (at the 5% level).

- Phillips-Perron (PP) tests.

Under the Dickey-Fuller approach, lags of $\Delta X_t$ are added until the errors are approximately white noise, so that the tests statistics are valid. In contrast, Phillips and Perron (1988) modify the test statistics themselves to take account of any serial correlation present in the errors. The critical values are the same as under the DF/ADF approach. Although the PP approach suffers from the defect that it can have serious finite sample size distortions when there is a negative moving average (MA) component in the error term, if there is a positive MA term it has been shown that the power of ADF tests is low relative to those of PP[8].

As can be seen from Tables 1 and 2 our overall conclusions point to the nominal effective exchange rate (E), the standardised unemployment rate (U) being unambiguously I(1). The results for quarterly government expenditure (G) are more ambiguous, with the ADF and PP tests providing contradictory findings. The results from Table 2 would, however, strongly suggest I(1) as opposed to I(2), behaviour.

[8] For details of both tests, see Holden and Perman (1994).

The test results given in Table 1 for the price variables (traded, non-traded, overall CPI and foreign traded prices, denoted by $P^T$, $P^N$, P and $P^*$ respectively) suggest stationarity, on the face of it. However, the fact that this is not at all in accord with economic priors, together with the tendency for the non-stationary null to be rejected in circumstances where variables are tending towards being I(2), lead us to suspect that such a conclusion would be unwarranted. In addition, in Table 2, the test results indicate strongly that the price variables are I(1) rather than being I(2). We shall assume that this is indeed the case for the remainder of the paper.

**Table 1: Unit Root Tests = I (0) V's I (1), I (2)**

| Variable | Number of Lags# | DF/ADF | PP |
|---|---|---|---|
| $P^T$ | 0 | -3.85* | N/A |
| $P^N$ | 0 | -6.04* | N/A |
| P | 0 | -4.95* | N/A |
| P* | 1 | -3.60* | -4.92* |
| E | 0 | -2.20 | N/A |
| G | 4 | -3.33 | -4.57* |
| U | 0 | -0.27 | N/A |

DF/ADF/PP = Dickey-Fuller, Augmented Dickey Fuller and Phillips Perron tests.
Critical value at the 5% level = -3.48
* Null of I (1) rejected.
# Number of lags required to achieve white noise in the residuals.

**Table 2: Unit Root Tests = I(1) V's I (2)**

| Variable | Number of Lags# | DF/ADF | PP |
|---|---|---|---|
| $\Delta P^T$ | 0 | -6.57* | N/A |
| $\Delta P^N$ | 0 | -4.30* | N/A |
| $\Delta$ P | 0 | -5.61* | N/A |
| $\Delta$ P* | 2 | -3.48* | -3.45 |
| $\Delta$ E | 0 | -6.12* | N/A |
| $\Delta$ G | 2 | -14.01* | -8.75* |
| $\Delta$ U | 0 | -4.23* | N/A |

DF/ADF/PP: Dickey-Fuller, Augmented Dickey Fuller and Phillips Perron tests.
Critical value at the 5% level: -3.48
* Null of I (1) rejected
# Number of lags required to achieve white noise in the residuals

### 6.4 *Choice of lag length*

Given that the choice of the rank of $\Pi$ should be made on the basis of a well-specified model, it is important to include the appropriate number of lags before rank tests are undertaken. Accordingly, we include the minimum number of lags which is compatible with well-behaved residuals. This is done on the basis of multivariate Lagrange Multiplier (LM)-type tests for first- and fourth-order autocorrelation and a normality test based on a multivariate version of the univariate Shenton-Bowman test - see Hansen and Juselius (1995) for details. In each case the null hypothesis is one of well-behaved residuals, and hence the lower the test statistic and the higher is the p-value, the more acceptable is the model. The results are reported in Table 3 below.

Before commenting upon the results themselves, a brief explanation of the reasons for including a time trend in the cointegration space in each of the models is in order. On the basis of economic priors we believed that there should possibly be two long run cointegrating relationships among the data covered. The first possibility is that of some type of purchasing power parity relationship between domestic prices, foreign prices and the exchange rate. The second is that of a long run equilibrium relationship between wages and prices. It would, however, be necessary to allow for long run productivity effects in this latter relationship. As a result a time trend was included to proxy for its effect[9].

In general, it can be seen that the test results do not reject the hypotheses that the residuals are well behaved. There is some evidence that there may be a problem with first order autocorrelation in Model 1, along with the possibility of non-normal residuals in Model 2. Overall, however, the results are satisfactory and suggest that we can proceed on the basis of the chosen lag lengths.

---

[9] According to the well-known Balassa-Samuelson model, we would also expect productivity differentials between countries to affect the PPP relationships between them. In our analysis we do not, however, include a trend in the PPP vector, thus making our hypothesis more likely to be rejected. The investigation of whether some productivity differential term (or indeed a time trend as a proxy) should be included in our PPP vector is left until a later paper, where the issue can be more fully investigated.

| Table 3: Choice of Lag Length | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Model** | **Chosen Lag** | **LM1(First order autocorrelation)** | | **LM4(Fourth order autocorrelation)** | | **Normality** | |
| c2 (degrees of freedom). → Combination ¯ | | $c^2$ **(16)** | **P-Value** | $c^2$ **(16)** | **P-Value** | $c^2$ **(8)** | **P-Value** |
| 1. $P^T$, W, E, P*, t | 5 | 29.391 | 0.02 | 16.146 | 0.44 | 6.772 | 0.56 |
| 2. $P^N$, W, E, P*, t | 2 | 14.450 | 0.57 | 22.325 | 0.13 | 19.914 | 0.01 |
| 3. P, W, E, P*, t | 5 | 25.137 | 0.07 | 16.454 | 0.42 | 10.230 | 0.25 |

### *6.5 Choice of cointegrating rank*

The imposition of the appropriate rank of the Π matrix is one of the most important steps of the Johansen analysis. It is critical because all the subsequent results are conditional on the choice made. If the inferred rank is too small it is likely that true long-run hypotheses will be rejected in error. On the other hand, if the rank is too large, false long-run hypotheses are likely to accepted too often.

Hansen and Juselius (1995) discuss a number of methods of choosing the cointegration rank, three of which we employ. First of all, there are the widely used maximum eigenvalue ($\lambda_{max}$) and trace test statistics, the results of which are reported below in Table 4. Secondly, graphical analysis of the estimated cointegration relations can help assess the stability of the hypothesised relationships over time. Finally, the roots of the companion matrix are examined to see how close the largest roots are to the unit circle. In order to conserve space, the latter two techniques are not reported upon in the paper. These tests, however, largely served to confirm our choice of rank in each case.

As can be seen from Table 4, there is very little ambiguity concerning the choice of model rank. In each case, our *a priori* expectation of a rank of two is strongly supported. The only minor exception to this is for Combination 3, where the Trace test narrowly accepts the hypothesis of rank 1 using the 90% critical values. The $\lambda_{max}$ test does, however, reject this hypothesis, also using 90% critical values.

| Table 4: *l* max and Trace Tests | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Combination ¯** | **Eigenval.** | ***l* max** | **90% C.V.** | **95% C.V.** | **Trace** | **90% C.V.** | **95% C.V.** | **$H_o$= r** |
| | 0.5187 | 42.41** | 19.88 | 31.5 | 83.79** | 58.96 | 63.0 | 0 |
| 1. $P^T$, W, E, P*, t | 0.3366 | 23.80* | 16.13 | 25.5 | 41.38* | 39.08 | 42.4 | 1 |
| | 0.1678 | 10.65 | 12.39 | 19.0 | 17.58 | 22.95 | 25.3 | 2 |
| | 0.1125 | 6.92 | 10.56 | 12.3 | 6.92 | 10.56 | 12.3 | 3 |
| | 0.6791 | 69.33** | 19.88 | 31.5 | 119.37** | 58.96 | 63.0 | 0 |
| 2. $P^N$, W, E, P*, t | 0.4096 | 32.14** | 16.13 | 25.5 | 50.03** | 39.08 | 42.4 | 1 |
| | 0.1754 | 11.76 | 12.39 | 19.0 | 17.89 | 22.95 | 25.3 | 2 |
| | 0.0956 | 6.13 | 10.56 | 12.3 | 6.13 | 10.56 | 12.3 | 3 |
| | 0.5040 | 40.67** | 19.88 | 31.5 | 77.19** | 58.96 | 63.0 | 0 |
| 3. P, W, E, P*, t | 0.2892 | 19.80* | 16.13 | 25.5 | 36.52 | 39.08 | 42.4 | 1 |
| | 0.1536 | 9.68 | 12.39 | 19.0 | 16.72 | 22.95 | 25.3 | 2 |
| | 0.1144 | 7.05 | 10.56 | 12.3 | 7.05 | 10.56 | 12.3 | 3 |

*    $H_o$ rejected at the 10% level

**  $H_o$ rejected at the 5% level

As explained above, Model IV (i.e. the model which allows for the inclusion of a trend in the cointegration space) seems most appropriate for our purposes, and it was simply imposed for all the above cointegration tests. To further confirm this choice we applied Johansen's (1992) procedure, which simultaneously chooses the appropriate model and rank. The procedure is applied as follows:

Start with the most restrictive model, which for our purposes is model III with zero rank (i.e. M0III). If this model is rejected, proceed to model IV with zero rank (i.e. M0IV). If this model is also rejected proceed to M1III, M1IV and so on until the hypothesis is accepted.

Results from this procedure are reported in Table 5 below, where the critical values are those of the 90% trace statistics quantiles, as indicated by the final two columns on the right hand side of the Table. The most likely choices, making use of the test procedure as a guide, are underlined for ease of reading. For traded prices model IV with a rank of 2 is clearly accepted. For non-traded prices, on the other hand, a case could be made for accepting either Model III or IV, both again indicating a rank of 2. The results for overall prices are the most ambiguous. Model IV, with a rank of unity is accepted (albeit barely) using the 90% trace statistics quantiles. The results indicate, however, that Models III or IV, with a rank of 2 are more likely. Hansen and Juselius (1995) stress that these asymptotic test statistics should be used with a good deal of caution. In the light of this, it was decided to proceed on the basis that the test results provided no strong reasons for not sticking with our model choice and rank (i.e. Model IV, rank 2) for all three sets of prices.

**Table 5: Simultaneous Choice of Rank and Model Type**

| Combin-ations® | 1. $P^T$, W, E, P*, t | | 2. $P^N$, W, E, P*, t | | 3. P, W, E, P*, t | | 90% Quantiles of trace distribution | |
|---|---|---|---|---|---|---|---|---|
| **Rank** | **Model III** | **Model IV** | **Model III** | **Model IV** | **Model III** | **Model IV** | **Model III** | **Model IV** |
| 0 | 79.514 | 83.786 | 107.642 | 119.365 | 64.837 | 72.648 | 43.844 | 58.958 |
| 1 | 39.450 | 41.378 | 38.391 | 50.034 | 31.163 | <u>38.791</u> | 26.699 | 39.077 |
| 2 | 15.788 | <u>17.579</u> | <u>10.555</u> | <u>17.894</u> | <u>11.026</u> | <u>18.366</u> | 13.308 | 22.946 |
| 3 | 5.274 | 6.924 | 1.642 | 6.131 | 1.257 | 8.594 | 2.706 | 10.558 |

*6.6 Long-run hypothesis testing*

Although at this stage it is possible to arrive at estimates of the two stationary $\beta$ cointegrating vectors after imposing the chosen rank of 2, such vectors are not necessarily meaningful or interesting. The reason for this is that any linear combination of the stationary vectors is also a stationary vector. This is, of course, the classic identification problem, which must be overcome if we are to reach meaningful conclusions. Johansen and Juselius (1992, 1994) provide a very good description of the identification issue. Johansen and Juselius (1994) (p. 8) discuss identification on three different levels.

(1) generic identification, which is related to a linear statistical model,
(2) empirical identification, which is related to the estimated parameter values
(3) economic identification, which is related to the economic interpretability of the estimated coefficients of an empirically identified structure.

In essence, generic identification of the long-run structure entails imposing restrictions on the space occupied by $\beta$ such that each cointegrating relation is <u>unique</u>. In our case, where we have two restrictions, the first $\beta$ vector is identified if no linear combination of the second vector yields a vector that "looks like" the coefficients of the first vector. Thus, the condition for generic identification simply requires that no linear combination of the second vector satisfies the restriction defining the first long-run relation. For a unique identification, it is necessary to impose at least *p(p-1)* restrictions on the short-run structural form parameters. The long-run parameters are the same in both the reduced and structural forms, however, implying that long-run identification can precede short-run identification.

The first stage in the procedure is to ensure that the model is generically identified from a long-run perspective. Johansen and Juselius (1994) develop a rank condition which must be satisfied in order for a model to be generically identified, making use of a set of $R_i$ and $H_i$ matrices associated with the long-run structural hypotheses. $R_i$ are defined as $p$ x $k_i$ matrices of full rank, and $H_i = R_{i\perp}$ are defined as $p$ x $s_i$ (where $k_i + s_i = p$) matrices, such that $H_i$ are of full rank and satisfy $R_i' H_i = 0$. There are, accordingly, $k_i$ restrictions and $s_i$ parameters to be estimated for each *i*th relationship. Each of the cointegrating relations are assumed to satisfy the restrictions $R_i' \beta_i = 0$ (with one restriction for each relation), or, equivalently, $\beta_i = H_i\varphi_i$ for each relation, where $\varphi_i$ are each of the form of a $s_i$ vector. In other words the $\beta$ matrix is made up as follows:

$$\beta = (H_1 \varphi_1, \ldots , H_r \varphi_r) \tag{6.9}$$

In our case the $\beta$ matrix is a 5 x 2 matrix, and $\beta = (H_1 \varphi_1 , H_2 \varphi_2)$. The generalised rank conditions are set out in Theorem 1 of Johansen and Juselius (1994) (p. 15). For our purposes, given that we have accepted a rank of 2, the rank conditions are as follows:

$$r_{i,j} = rank(R_i' H_j) \geq 1, i \neq j.$$

In order to clarify the above concepts it is useful to give details of how these rank values are calculated for a particular example and this is presented in Appendix 1.

The generic rank conditions were tested for the various hypothesis combinations tested in our study and these are presented in Table 6 below. Such hypotheses start off in row A with the relatively weak conditions that (1) some combination of P, E and P* be stationary and (2) some combination of W,P and t be stationary. They proceed to the strongest set of restrictions in row F which hypothesise (1) full PPP and (2) wages equalling prices plus some trend growth to account for productivity changes. The results for our example are set out in row E of the Table. It can be clearly seen from the remainder of the results that the generic identification rank conditions are satisfied for all the hypothesis combinations outlined.

| Table 6: Verification of the rank condition of generic identification in the long-run structure | | | | | |
|---|---|---|---|---|---|
| | | **Hypothesis** | **Rank $(R_1^{'} H_2)$** | **Rank $(R_2^{'} H_1)$** | **Satisfaction of generic identification** |
| A | Hyp 1 | P, E, P* stationary; W, t = 0 | 2 | 2 | √ |
| | Hyp 2 | W, P, t stationary; E, P* = 0 | | | |
| B | Hyp 1 | P, E, P* stationary; W, t = 0 | 2 | 3 | √ |
| | Hyp 2 | W = P, t stationary; E, P* = 0 | | | |
| C | Hyp 1 | P= -$q$ E + $q$ P* stationary; W, t = 0 | 2 | 1 | √ |
| | Hyp 2 | W, P, t stationary; E, P* = 0 | | | |
| D | Hyp 1 | P = -$q$ E + $q$ P* stationary; W, t = 0 | 2 | 2 | √ |
| | Hyp 2 | W = P, t stationary; E, P* = 0 | | | |
| E | Hyp 1 | P= -E + P* stationary; W, t = 0 | 3 | 1 | √ |
| | Hyp 2 | W, P, t stationary; E, P* = 0 | | | |
| F | Hyp 1 | P = -E + P* stationary; W, t = 0 | 2 | 1 | √ |
| | Hyp 2 | W = P, t stationary; E, P* = 0 | | | |

The results of the long-run hypothesis tests, which were shown to be generically identified in the previous Table, are contained in Tables 7(a) to 7(c) below and make for some very interesting reading[10]. As Johansen and Juselius (1992, 1994) argue, the types of hypotheses tested for below give rise to a likelihood ratio test that is asymptotically distributed as $\chi^2$. These tests can be used to check for non-rejection of the restrictions imposed. For the case of traded prices, the strongest joint hypothesis of full PPP, together with wage/price equality in the long-run (along with a time trend in the latter relationship to take account of productivity factors) is accepted with a probability value of 0.09. In the case of non-traded prices, however only the weakest joint hypotheses are accepted on the basis of the likelihood ratio test results and their p-values (comparing restricted and unrestricted estimations). As would be expected, given the above findings, the results for the overall price index falls somewhere in between those for the traded and non-traded groupings. Whereas the weakest form of

[10] The hypothesis of weak exogeneity with respect to the other variables in the system was tested for each variable. Contrary to our expectations, there was no evidence in favour of weak exogeneity, even for the foreign price variable. This somewhat unusual result could be caused by the fact that some variable outside the system, such as foreign money could be the driving factor behind both sets of prices. The finding should not, however, be in any way interpreted as implying two-way causality between Irish and foreign prices!

joint hypothesis is given strong backing, the strongest form is only accepted with a probability value of 0.04.

**Table 7(a): Traded Prices:Long-run hypothesis test results= ($P^T$, W, E, P* and t)**

| Test | | Hypotheses | Test Results | Significance | Estimated long-run relationship |
|---|---|---|---|---|---|
| 1a | Hyp 1 | P, E, P* | $c^2(2) = 0.87$ | ** | P = -0.405 E + 0.921 P* |
| | Hyp 2 | W, P, t | P-Value = 0.65 | | W = 1.203 P + 0.004 t |
| 2a | Hyp 1 | P, E, P* | $c^2(3) = 1.40$ | ** | P = -0.490 E + 0.969 P* |
| | Hyp 2 | W = P + $a$ t | P-value = 0.71 | | W = P + 0.005 t |
| 3a | Hyp 1 | P = -$q$ E + $q$ P* | $c^2(3) = 6.59$ | * | P = -0.638 E + 0.638 P* |
| | Hyp 2 | W, P, t | P-value = 0.09 | | W = 1.170 P + 0.006 t |
| 4a | Hyp 1 | P = -$q$ E + $q$ P* | $c^2(4) = 6.76$ | ** | P = -0.753 E + 0.753 P* |
| | Hyp 2 | W = P + $a$ t | P-value = 0.15 | | W = P + 0.006 t |
| 5a | Hyp 1 | P = -E + P* | $c^2(4) = 9.21$ | * | P = -E + P* |
| | Hyp 2 | W, P, t | P-value = 0.06 | | W = 0.885 P + 0.005 t |
| 6a | Hyp 1 | P = -E + P* | $c^2(5) = 9.58$ | * | P = -E + P* |
| | Hyp 2 | W = P + $a$ t | P-value = 0.09 | | W = P + 0.005 t |

** Joint hypothesis acceptable with a probability value above 0.10
* Joint hypothesis acceptable with a probability value above 0.05
† Joint hypothesis acceptable with a probability value above 0.01

**Table 7(b): Non-traded prices: Long-run hypothesis test results = ($P^N$, W, E, P* and t)**

| Test | | Hypothesis | Test Results | Significance | Estimated long-run relationship |
|---|---|---|---|---|---|
| 1b | Hyp 1 | P, E, P* | $c^2(2) = 0.52$ | ** | $P_N$ = -0.308 E + 1.242 P* |
| | Hyp 2 | W, P, t | P-Value = 0.77 | | W = 0.518 $P_N$ + 0.006 t |
| 2b | Hyp 1 | P, E, P* | $c^2(3) = 17.27$ | | Not Applicable |
| | Hyp 2 | W = P + $a$ t | P-Value = 0.00 | | Not Applicable |
| 3b | Hyp 1 | P = -$q$ E + $q$ P* | $c^2(3) = 16.73$ | | Not Applicable |
| | Hyp 2 | W, P, t | P-Value = 0.00 | | Not Applicable |
| 4b | Hyp 1 | P = -$q$ E + $q$ P* | $c^2(4) = 28.68$ | | Not Applicable |
| | Hyp 2 | W = P + $a$ t | P-Value = 0.00 | | Not Applicable |
| 5b | Hyp 1 | P = -E + P* | $c^2(4) = 21.67$ | | Not Applicable |
| | Hyp 2 | W, P, t | P-Value = 0.00 | | Not Applicable |
| 6b | Hyp 1 | P = -E + P* | $c^2(5) = 30.52$ | | Not Applicable |
| | Hyp 2 | W = P + $a$ t | P-Value = 0.00 | | Not Applicable |

** Joint hypothesis acceptable with a probability value above 0.10
* Joint hypothesis acceptable with a probability value above 0.05
† Joint hypothesis acceptable with a probability value above 0.01

| Table 7(c): Overall prices:Long-run hypothesis test results = (P, W, E, P* and t) | | | | | |
|---|---|---|---|---|---|
| **Test** | | **Hypothesis** | **Test Results** | **Significance** | **Estimated long-run relationship** |
| 1c | Hyp 1 | P, E, P* | $\chi^2(2) = 1.77$ | ** | P = -0.357E + 1.080P* |
| | Hyp 2 | W, P, t | P-Value = 0.41 | | W = 1.352P + 0.001 t |
| 2c | Hyp 1 | P, E, P* | $\chi^2(3) = 2.54$ | ** | P = -0.432E + 1.113P* |
| | Hyp 2 | W = P + $\alpha$ t | P-Value = 0.47 | | W = P + 0.003 t |
| 3c | Hyp 1 | P = -$\theta$ E + $\theta$ P* | $\chi^2(3) = 6.40$ | * | P = -1.506E + 1.506P* |
| | Hyp 2 | W, P, t | P-Value = 0.09 | | W = 0.390P + 0.007 t |
| 4c | Hyp 1 | P = -$\theta$ E + $\theta$ P* | $\chi^2(4) = 10.82$ | † | P = -0.760E + 0.760P* |
| | Hyp 2 | W = P + $\alpha$ t | P-Value = 0.03 | | W = P + 0.006 t |
| 5c | Hyp 1 | P = -E + P* | $\chi^2(4) = 11.85$ | † | P = -E + P* |
| | Hyp 2 | W, P, t | P-Value = 0.02 | | W = 0.928P + 0.005 t |
| 6c | Hyp 1 | P = -E + P* | $\chi^2(5) = 11.90$ | † | P = -E + P* |
| | Hyp 2 | W = P + $\alpha$ t | P-Value = 0.04 | | W = P + 0.005 t |

** Joint hypothesis acceptable with a probability value above 0.10
* Joint hypothesis acceptable with a probability value above 0.05
† Joint hypothesis acceptable with a probability value above 0.01

Full empirical and economic identification of our model is not possible until we examine the short-run properties of the data and complete the identification process. Nevertheless, we shall comment briefly on some of the most important long-run results obtained, before proceeding with our short run identification. First, there is the strong and intuitively pleasing result, that foreign price influences seem to be stronger in the traded sector than in the non-traded sector, with overall price behaviour falling in between the two. For traded prices, we identified the existence of a long-run purchasing power parity relationship with a measure of world traded prices. This relationship is consistent with the SOE model of domestic traded price determination. For non-traded prices, the strict version of purchasing power parity was completely rejected. Instead, a weaker stationary relationship was identified with correctly signed and economically meaningful co-efficients[11]. The results for aggregate prices, perhaps not surprisingly, fall somewhere in between those for its traded and non-traded components. The strict version of PPP is almost acceptable (at the 4% level) and a stationary relationship with the exchange rate and the foreign price level with sensible coefficients was also identified with a high probability value. In addition, the cointegration analysis has uncovered a trend stationary real wage. This is so whether

[11] Froot and Rogoff (1995) have commented on the fact that PPP coefficients obtained from the various international studies they surveyed varied enormously and were often implausible.

the real wage is measured in terms of its purchasing power over traded, non-traded or aggregate consumer prices. Second, there is the fact that all the long-run coefficients reported in right hand columns, of each Table are correctly signed and are, for the most part, very sensible. Given the short sample period considered, it is, perhaps, surprising that any support was found for PPP using our dataset. Nevertheless, as discussed in Section 5.3.3, there has been a fair degree of support for PPP in previous Irish studies, in spite of this shortcoming. Leddin (1988) is alone in unambiguously rejecting PPP. Thom (1989), Callan and Fitzgerald (1989) Wright (1993, 1994) and Leddin and Hodnett (1995) all lend varying degrees of support to the proposition. It is our intention in a future paper to proceed along the lines of Leddin and Hodnett (1995), by employing longer time series of data, in order to further investigate this important issue.

### *6.7 Completing the process: Short-run identification*

Thus far, we have uncovered the likely long-run structure between three domestic price series ($P^T$, $P^N$ and P) and a measure of world traded prices, domestic wages and the nominal effective exchange rate. While the uncovering of such long-run structures in the data is of immense interest and relevance in itself, it does not, however, complete the picture. In particular, we have not identified the structural economic model corresponding to the reduced form which has been estimated. Johansen and Juselius (1994) highlight the problems associated with drawing conclusions about economic structure from the estimated reduced form. In particular, they point to the overparameterisation of the VAR structure in (6.4). As a result, several of the parameters, including the highly relevant short-run adjustment parameters contained in the matrix $\alpha$ may be inefficiently estimated. Furthermore, as implied by the matrix $A_o$ of equation (6.5), any structural economic model would have to identify possible simultaneous effects between the variables of the system. This is of particular importance in the context of wage-price dynamics which many economists believe to be determined simultaneously.

The short-run identification approach used here follows that of Johansen and Juselius (1994). To move to a more parsimonious model we re-estimate each system of equations using the restricted (identified) cointegrating vectors uncovered in the previous section. In all cases, we condition on both the exchange rate and the world traded price variable[12]. This allows us estimate a two equation system for both wages and prices conditional on the long-run structure identified in the previous section. Standard conditional inference techniques are employed in reducing the parameterisation of the model: variables are dropped from the system if they are not significant and if their removal does not generate undesirable properties in the residuals (autocorrelation problems etc.)[13].

### *6.7.1 Traded Prices*

Table 8 below reports parameter values for the short-run conditional wage/traded price system. Also reported in the Table are diagnostic statistics for residual autocorrelation and normality[14]. The equations are estimated conditional on the long-run PPP relationship ($ECM^1$) and also the stationary real wage ($ECM^2$). Several features of the Table warrant commentary. Firstly, in the equation for traded prices, the adjustment coefficient to the long-run relations contained in $ECM^1$ imply reasonably swift adjustment to PPP at 9.8% per quarter. Since this is the strict version of PPP, equivalent to equation 5.1 of Section 5, it implies complete long-run pass-through from any change in the exchange rate or world traded prices into domestic traded prices, with completed pass-through being effected in approximately ten quarters, or two and a half years. It is also interesting to note that the cointegrating real wage relation is also significant in the equation for traded prices and enters with an intuitively appealing positive sign. This suggests that any increase in the level of the real wage, above that which is warranted by changes in productivity, may result in upward pressure on traded price inflation. The real wage cointegrating relation also enters significantly into the equation for wage inflation with a negative sign. This

---

[12] Only if the variables have been found to be weakly exogenous is one strictly justified in conditioning on it in formulating a structural economic model. Otherwise, one is discarding potentially relevant information contained in the data. For traded prices, for example, we unambiguously reject the hypothesis of weak exogeneity. However, since our principal focus is on wage-price dynamics *given* movements in the exchange rate and foreign prices, we have chosen to assume the weak exogeneity of E and P* in all data sets.

[13] The estimation and system reduction is carried out using full information maximum likelihood estimation in the PcFiml package. See Doornik and Hendry(1994).

[14] See Doornik and Hendry (1994), Chapter 10, for a description of these test statistics and for further references.

underlines the endogeneity of wages in a SOE and the strong tentency for wages to converge toward their, productivity-adjusted equilibrium. Furthermore, at 18.4% per quarter, the adjustment of wages to the strict PPP relation is even more rapid than the adjustment of traded-prices. These observations suggest that in the long-run, there exists bidirectional feedback between wages and prices in the traded sector.

Economic theory has less to say concerning the coefficients on the short-run variables in each equation. In the traded price equation, however, we note the positive sign on the coefficient for $\Delta P^T_{t-3}$ which is possibly indicative of some short-run persistence in traded price inflation. Alternatively, it could be proxying for inflation expectations in a manner consistent with an adaptive expectations/distributed lag specification. Furthermore, it can be seen that the net short-run effect of a change in foreign prices is positive. The positive sign on the coefficient for $\Delta E_{t-4}$ is more difficult to interpret but is not quite significant at the 5% level (it is, nevertheless, retained to avoid generating undesirable residual properties). Perhaps more importantly, however, it is worth pointing out that all four lags of $\Delta W$ can be deleted from the price equation without giving rise to autocorrelation in the residuals.

**Table 8: Short-run Conditional Wage-Price System: Traded Prices**

| | **Con.** | $D\mathbf{P^T_{t-3}}$ | $D\mathbf{E_{t-4}}$ | $D\mathbf{P^*_{t-1}}$ | $D\mathbf{P^*_{t-2}}$ | $\mathbf{ECM^1_{t-1}}$ | $\mathbf{ECM^2_{t-1}}$ | $\Delta U_{t-1}$ | $\Delta G_{t-1}$ |
|---|---|---|---|---|---|---|---|---|---|
| $D\mathbf{P^T_t}$ | **0.475** (4.25) | **0.379** (4.24) | **0.112** (1.91) | **0.781** (3.58) | **-0.494** (-2.43) | **-0.098** (-3.97) | **0.110** (3.04) | -0.045 (-1.32) | -0.027 (-1.54) |
| | **Con.** | $D\mathbf{W_{t-1}}$ | $D\mathbf{E}$ | $D\mathbf{E_{t-4}}$ | **-** | $\mathbf{ECM^1_{t-1}}$ | $\mathbf{ECM^2_{t-1}}$ | $\Delta U_{t-1}$ | $\Delta G_{t-1}$ |
| $D\mathbf{W_t}$ | **0.836** (7.39) | **-0.306** (-2.73) | **-0.193** (-2.92) | **0.269** (3.81) | **-** | **-0.184** (-7.49) | **-0.098** (-2.15) | -0.055 (-1.35) | -0.045 (-2.06) |

$ECM^1$: [ $P^T$ + E - P* ] Vector AR(1 - 4) : $F(16, 80) = 1.038[0.427]$

$ECM^2$: [ W - $P^T$ - 0.005 t ] Vector Normality: $\chi^2(4) = 2.531[0.639]$

Another contentious issue in the debate on Irish inflation concerns the possible short-run impact of demand variables on prices. Is there, for example, any evidence of a negatively sloped short-run Phillips curve in an Irish context? An additional question relates to the possible impact of the stance of fiscal policy on prices. We address these issues in the light of both the long and the short-run relations which have been identified above by appending both the first lag of the change in the unemployment rate ($\Delta U_{t-1}$) and the first lag of the change in current government expenditure ($\Delta G_{t-1}$) to each equation in the system[15]. This assumes that the effects of these variables will be felt after a single time period (i.e. a quarter). To avoid potential multicollinearity problems associated with the inclusion of both demand-type variables in each equation simultaneously, the conditional system is estimated for each variable independently. The estimated parameter values and t-statistics are given in the last two columns of Table 8. While the lagged change in the unemployment rate enters with the correct (negative) sign, it is not significantly different from zero in either the wage or the price equation. By implication, this suggests that, for traded prices, the short-run Phillips curve is vertical. Consequently, there is no evidence of even a short-run trade-off between traded price inflation and unemployment for policy makers to exploit. The lagged change in government expenditure is incorrectly signed in both equations.

*6.7.2 Non-Traded Prices*

Table 9 below reports parameter values and estimated t-statistics for the equivalent short-run conditional wage/non-traded price system. The system is estimated conditional on the two long run vectors that could be identified for non-traded prices (See Table 7(b)). The first of these ($ECM^1$) describes a stationary relationship between the level of non-traded prices, the level of world traded prices and the nominal effective exchange rate. This is a significantly weaker relationship than the strict version of PPP identified in the analysis of traded prices. The second relevant long-run structure ($ECM^2$) is a trend-stationary real wage measured in terms of its purchasing power over non-traded prices.

[15] The analysis of aggregate demand effects reported on here is very much tentative. For both variables, one could obviously consider the inclusion of further lags. The treatment of the fiscal policy variable, in particular, is incomplete. Future research might attempt to assess the impact of the stance of fiscal policy on a cyclically adjusted basis.

The parameter estimates from Table 9 provoke some interesting observations. The significance of $ECM^1$ in the equation for non-traded prices implies a strong long-run effect of both the exchange rate and world traded prices on non-traded prices. Adjustment to this equilibrium takes place at approximately 23% per quarter. It should be remembered, however, that it is a weaker relationship than the strict version of PPP identified for traded prices. Accordingly, in contrast to the equation for traded prices, the estimated equation for non-traded prices does not provide empirical evidence of complete 100% pass-through from any change in the exchange rate and/or world traded prices. This might be taken as evidence that the extreme SOE view of price determination does not apply to the more sheltered non-traded sector.

**Table 9: Short-run Conditional Wage-Price System: Non-Traded Prices**

| | Con. | $DP^N_{t-1}$ | $DE$ | $DE_{t-1}$ | $ECM^1_{t-1}$ | $ECM^2_{t-1}$ | $\Delta U_{t-1}$ | $\Delta G_{t-1}$ |
|---|---|---|---|---|---|---|---|---|
| $DP^N_t$ | **-0.393 (-4.11)** | **0.189 (2.27)** | **-0.112 (-2.66)** | **0.089 (2.24)** | **-0.228 (-8.80)** | **0.246 (4.60)** | -.005 (-0.27) | -0.002 (-0.17) |
| | **Con.** | $DP^N_{t-1}$ | $DW_{t-1}$ | $DE_{t-1}$ | $ECM^1_{t-1}$ | $ECM^2_{t-1}$ | $\Delta U_{t-1}$ | $\Delta G_{t-1}$ |
| $DW_t$ | **0.716 (8.77)** | **-0.466 (-3.07)** | **-0.379 (-3.84)** | **-0.159 (-2.21)** | **-** | **-0.362 (-8.63)** | -0.105 (-2.88) | -0.033 (-1.42) |

$ECM^1$: $[\, P^N + 0.308\, E - 1.242\, P^* \,]$ Vector AR(1 - 4) : F(16, 80) = 0.9686[0.4974]

$ECM^2$: $[\, W - 0.518\, P^N - 0.006\, t \,]$ Vector Normality: $\chi^2(4) = 10.691[0.030]$

More significantly, however, the real wage equilibrium enters into the equation for non-traded prices with a strong positive sign. The positive coefficient again implies that any increase in the real wages greater than that which is warranted by productivity growth feeds through to non-traded inflation. A comparison of this result with the with the output in Table 8, (to the extent that the results are comparable), suggests that the effect of wages in the non-traded sector is significantly stronger. This finding is consistent with the hypothesis of a causal role for wages in the non-traded sector consistent with the Scandinavian approach[16]. It can, however, be observed that short-

[16] The differing significance of the role of wages in the traded and non-traded sectors is consistent with the previous finding of Cassidy (1982).

run wage effects are not significant and consequently they can be excluded from the equation for $\Delta P^N$ without generating residual autocorrelation[17]. The other short-run parameters in the equation for $\Delta P^N$ are signed in a manner consistent with economic priors: a net positive impact from the lagged dependent variable (persistence in non-traded inflation), and a net negative impact from current and lagged changes in the EER. Perhaps not surprisingly in the case of non-traded prices, the net impact of short-run movements in world traded prices is not significant. The supplementary aggregate demand type effects, somewhat surprisingly, do not indicate a significant short-run role for either the change in the unemployment rate or the stance of fiscal policy.

The wage equation in Table 9 is also somewhat comparable with the equivalent equation from Table 8[18]. However, in this instance, the real wage relation - which is expressed in terms of its purchasing power over non-traded prices - dominates in terms of explanatory power. In addition, the stationary equilibrium between $P^N$, $P^*$ and E can be deleted from the wage equation. Adjustment to the real wage relation takes place at a very rapid pace of about 36% per quarter. The coefficients on the lagged short-run variables are not - apart from the significant negative impact of the lagged exchange rate - intuitively interpretable. In the supplementary aggregate demand analysis, in contrast to the results in Table 8, there is some evidence of a wage-type Phillips curve: the implied elasticity at -0.10 is, however, small. The impact of current government expenditure is signed incorrectly, and is not significantly different from zero.

[17] There is some evidence of non-normal residuals in the conditional system. This can also be seen from the diagnostics for the unrestricted VAR in Table 3. Retaining wages or any other variables does not enable one to accept the hypothesis of normal residuals, however. The lack of normality suggests possible misspecification and, accordingly, further econometric analysis of the determinants of non-traded prices may be warranted.

[18] The dependent variable is, for example, the same in each case. The equations differ insofar as in Table 9 lagged changes in non-traded prices (as opposed to traded) are employed as explanatory variables. As we have already described the ECMs also differ significantly.

*6.7.3 Aggregate Prices*

The identification of a wage-price system for the underlying CPI series is perhaps of most interest from a policy viewpoint. In some respects, the determinants of aggregate prices can be inferred from the preceding two sections. However, the analysis of traded and non-traded prices has suggested significantly divergent channels in each sector. It is, therefore, of immense interest to examine the data to see which channels dominates when the separate price series are weighted together into an aggregate series. The approach adopted here is again conditional on the generically identified long-run relations given in Table 7(c).

Table 10 below reports parameter values and t-statistics from a wage-price system conditional on the long-run relations identified under test 2c of Table 7(c). These are equivalent to a) a stationary real exchange rate ($ECM^1$) and b) a trend stationary real wage ($ECM^2$)[19]. The estimated coefficient on the stationary equilibrium between P, P* and E implies that adjustment to the identified equilibrium takes just over seven quarters[20]. Somewhat surprisingly, the long-run effect of wages on aggregate consumer price inflation is significantly weaker than implied in the disaggregated analysis of traded and non-traded prices. The coefficient on $ECM^2$ is much smaller than the comparable estimates from table 8 and 9. Given the fact that $ECM^2_{t-1}$ is the closest estimate we have to a true equilibrium real wage, the strength of feedback from wages to prices may not, therefore, be as strong as implied in either Table 8 or 9[21]. The other estimated parameters in the aggregate price equation appear to be correctly signed and accord with economic intuition: net positive impact of lagged changes in prices, net negative impact of a change in the EER and a significant net positive impact of lagged changes in world traded prices. The supplementary analysis

[19] Arguably, it is only in this case that the second ECM can be considered a meaningful measure of the real wage. This is because in this instance the real wage is measured in terms of its purchasing power over an index of the cost of living (i.e. aggregate consumer prices).

[20] The identified equilibrium does not, however, confirm the strict version of purchasing power parity associated with the extreme small open economy model. When the strict version of purchasing power parity (PPP) was imposed as an equilibrium restriction, however, it was found that it was not significant as an equilibrium relation.

[21] The absence of a causal role for wages in the determination of prices has also been a key finding in several other papers dealing with the wage-price mechanism. Gordon (1988), Mehra (1991) and Campbell and Rissman (1994) all present evidence arguing that this is the case in the U.S. while Franz and Gordon (1993) present a similar finding for Germany.

**Table 10: Short-run Conditional Wage-Price System: Aggregate Prices**

| | **Con.** | $DP_{t-1}$ | $DP_{t-3}$ | $DE_{t-1}$ | $DP^*_{t-1}$ | $DP^*_{t-4}$ | $ECM^1_{t-1}$ | $ECM^2_{t-1}$ | $\Delta U_{t-1}$ | $\Delta G_{t-1}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| D**P** | **0.213** (**6.17**) | **-0.277** (**-3.11**) | **0.377** (**4.12**) | **-0.091** (**-2.19**) | **0.531** (**3.35**) | **-0.406** (**-2.48**) | **-0.136** (**-5.97**) | **0.05** (**1.95**) | -0.05 (1.98) | -0.011 (-0.83) |
| | **Con.** | $DP_{t-2}$ | $DW_{t-1}$ | $DE_t$ | $DE_{t-4}$ | $DP^*_{t-2}$ | $ECM^1_{t-1}$ | $ECM^2_{t-1}$ | $\Delta U_{t-1}$ | $\Delta G_{t-1}$ |
| D**W** | **0.170** (**3.15**) | **0.408** (**2.94**) | **-0.297** (**-2.79**) | **-0.112** (**-1.79**) | **0.252** (**4.13**) | **-0.534** (**-2.39**) | **-0.116** (**-3.27**) | **-0.095** (**-2.52**) | -0.09 (-2.68) | -0.038 (-1.87) |

$ECM^1$: [ P + 0.432 E - 1.113P* ]

$ECM^2$: [ W - P - 0.003 t ]

Vector AR(1 - 4): $F(16,72) = 1.166[0.314]$

Vector Normality: $\chi^2(4) = 4.972\ [0.290]$

of aggregate demand-type effects shows some evidence of a significant negative impact of the lagged change in the unemployment rate. The coefficient estimate of -0.05, however, implies a relatively steep slope on the short-run Phillips curve and, consequently, little trade-off for policy to exploit. There is, however, a significantly stronger effect in the equation for wage inflation. Once again, the government expenditure variable is insignificant and incorrectly signed in both equations.

The equation for wage inflation provides further evidence on endogeneity of wages in a SOE. The significance of the stationary real exchange rate in the equation for $\Delta W$ implies, for example, that an overvalued real exchange rate will have a deflationary impact on wages. Adjustment of wages to the stationary equilibrium between P, P* and E is estimated to take place at approximately 11.5% per quarter, somewhat slower than for prices. Wages also converge toward the trend stationary real wage relationship at about 10% per quarter. Consistent with the preceding analysis, there is also some evidence of a significant, though weak, impact of $\Delta U_{t-1}$ on the rate of growth in average weekly earnings.

## 7 Summary and Conclusions

### *7.1 Background*

The main objective of the Central Bank is to maintain low inflation in Ireland. It is, accordingly, very important that the inflationary process be understood, and that a well-defined model of its underlying causes be properly formulated. Unfortunately, it is fair to say that, at present, there is no clear consensus among economists on the ways in which inflation is generated in Ireland. This is best demonstrated by the recent survey by Leddin (1995), which highlights many of the areas of disagreement. The purpose of this paper is to attempt to shed light on some of the main unresolved issues. Given that Ireland is viewed as being a classic case of a small open economy, the principal questions which we attempt to answer concern the main causes of Irish inflation, both in a proximate and an ultimate sense, and whether these are externally determined and beyond our control, or whether domestic factors have some role to play. In this context, we investigate in some depth the argument of many commentators that domestic wage costs are an independent long-run cause of Irish inflation. In addition, the consumer price index is divided into traded and non-traded components, and we investigate whether separate price mechanisms exist for each category.

Before formulating our underlying model, the main international and national literature in the area was summarised. On the international side, the role of aggregate demand was highlighted in our discussion of the Phillips-curve literature, as was the role of money in our review of international monetary theories of inflation. Finally, the Scandinavian approach, in which the traded and non-traded sectors are modelled separately, was discussed. The importance of real factors, such as productivity differentials, emerges from this modelling perspective. Many channels through which an economy's inflation is affected surface from the literature and these are highlighted in Figure 2, page 25. The Irish literature on inflation has undergone a number of distinct phases. Until the early 1970s, even though the Irish pound was pegged to sterling, a cost accounting view of inflation prevailed, in which various factors were held to "cause" inflation in proportion to their weight in an input-output table. This fallacious perspective was superseded by the small open economy view, whereby it was held that Irish inflation was fully determined abroad (i.e. in the UK) and that domestic factors had, at most, a transient role to play. In the 1980s, after our entry into the EMS, a quasi-fixed exchange rate regime, several papers emerged suggesting that domestic factors had a more important role in the inflationary process than envisaged by the small open economy (SOE) model. There is still disagreement as to whether domestic factors have anything more than a short-run role in determining Irish inflation. Many factors were covered in the various studies and these are outlined in Table I, page 39.

As a precursor to more formal econometric investigation, Section 4 of the paper presented an informal analysis of alternative measures of Irish inflation and some potential causes. While the empirical approach in this paper is grounded in the data-based general-to-specific modelling technique, it is nonetheless useful to have an underlying economic structure/model in mind prior to estimation. Accordingly, a simple model which emphasises the traded/non-traded distinction is outlined in Section 5.

### *7.2 Empirical Findings*

The primary unresolved issue concerning Irish inflation relates to its main "causes", in both a proximate and an ultimate sense. Since not every possible causal candidate can be examined fully in any one analysis, this paper focused attention on some of the most commonly cited domestic and foreign influences[22]. The econometric analysis could be loosely viewed as testing the long-run validity of i) a wage mark-up model, ii) a pure price taking SOE model or iii) a hybrid model which fuses elements of i) and ii).

Central to the empirical approach adopted in this study was the consideration of a potentially separate price determination process for the traded and non-traded sectors. The analysis was facilitated by the construction of a new dataset which, on the basis of economic priors, decomposed an underlying measure of consumer prices into its traded and non-traded components. The main distinction that can be between traded and non-traded prices relates to the identified long-run equilibria. In the case of traded

[22] The question concerning the ultimate role of money, either domestic or foreign, was deemed to be a sufficiently important issue in its own right. Accordingly, it is intended that this topic will be dealt with in a separate paper.

prices, the strongest form of the PPP relationship was shown to be consistent with the data. The estimated adjustment coefficients implied that full pass-through from a change in the nominal exchange rate or world traded prices takes about ten quarters. In the case of non-traded prices, the data rejected the strict long-run purchasing power parity paradigm. Nonetheless, non-traded prices were shown to cointegrate with both world-traded prices and the EER. This equilibrium was shown to be highly significant in an equation for non-traded inflation, thus confirming the strong role played by both the exchange rate and foreign prices even in the non-traded sector. Furthermore, the evidence suggests that in both sectors an increase in wages above that which is warranted by productivity growth may feed into inflation. The feedback from wages to prices did, however, appear to be stronger in the non-traded sector.

In the case of aggregate Irish inflation, the results confirmed the dominant long-run role of both the exchange rate and world traded prices. As would be expected, the results for aggregate prices fall somewhere between those for its traded and non-traded components. A stationary combination of the domestic consumer prices, world traded prices and the nominal exchange rate was strongly accepted by the data, while the strict version of PPP was almost accepted. The evidence on the existence of bi-directional feedback between wages and prices was somewhat weaker when aggregate consumer prices were examined on their own. In the case of aggregate underlying consumer prices, the results suggested that wages react more strongly to price developments than *vice-versa*. It was nevertheless, argued in the body of the paper that, once the nominal exchange rate is not rigidly fixed, there is some scope for domestic influences (e.g. wages or excess money) over Irish inflation, even in the long run, and that these can be gauged by examining the exchange rate. The effective exchange rate (EER) weakened significantly from our entry to the ERM until the mid-1980s, thus signalling that over this period domestic forces were adding to world inflationary pressures. However, the gradual appreciation of the EER since then suggests that domestic inflationary impulses, relative to foreign ones, have been largely subdued.

The empirical section also shed light on some potential short-run determinants of aggregate consumer price inflation. The analysis uncovered evidence of inflation inertia consistent with the strong role for price expectations. The short-run impact of aggregate demand on wage and price inflation was also investigated. In the case of aggregate consumer prices, empirical estimates of the effect of a change in the unemployment rate were ambiguous. In the case where some effect is implied, however, the parameter estimates suggest only a weak short-run trade-off between inflation and the change in unemployment. The potential inflationary impact of a change in current government expenditure was also assessed. In the case of aggregate prices, there was no evidence to suggest that a rise in current government expenditure contributed significantly to short-run increases in inflation over the sample period[23].

### *7.5 Concluding remarks*

The results reported on here have, hopefully, added to current understanding of the inflationary process in Ireland. It is nonetheless important to highlight the many important issues which have, quite clearly, not been examined at all. It was seen in the paper how, in the presence of PPP, movements in the nominal exchange rate provide an assessment of the contribution of domestic factors to our inflation record. One obvious route of further enquiry would be to attempt to model such nominal exchange rate movements for Ireland. In addition, the potential role of money, both foreign and domestic, in the inflation process in Ireland, needs to be examined. The sharp movements which occurred in the velocity of monetary aggregates in the 1980s poses difficulties, however, for any studies of this type. While the paper did seek to empirically distinguish between traded and non-traded prices, a potentially fruitful area for future research concerns the nature of the relationship between these variables themselves. Other issues, while explicitly treated in this paper, nonetheless deserve further attention. While the paper uncovered some evidence in favour of long-run purchasing power parity in an Irish context, further empirical evidence, perhaps using a much longer run of data, is still required. The coverage of the impact of fiscal policy variables (current expenditure) and aggregate demand was, to say the least, quite thin. A more in-depth and robust approach may, however require econometric estimates of the natural rate of unemployment, the potential output of the Irish economy and

[23] The chosen proxies for the potential demand effects were somewhat imperfect, however, and further analysis of this issue may be warranted.

related structurally adjusted fiscal deficits.  While this is a potentially fruitful avenue of inquiry, the exact status of such concepts, on both a theoretical and an empirical level, is unclear in a small and highly open economy like Ireland.

## References

Aiyagari S.R. (1990): "Deflating the case for zero inflation", *Federal Reserve Bank of Minneapolis Quarterly Review*, pp. 2-11, Summer.

Aiyagari S.R. (1991): "Response to a defence of zero inflation", *Federal Reserve Bank of Minneapolis Quarterly Review*, pp. 21-24, Spring.

Applebaum, E.(1979): "Testing price taking behaviour, *Journal of Econometrics*, Vol. 9, pp. 283 - 294.

Aukrust, D. (1977): "Inflation in the open economy: A Norwegian model" in L. B. Krause and W. S. Salant (eds.), Worldwide Inflation , (Washington D.C.: Brookings Institution)

Balassa, B. (1964): "The purchasing-power parity doctrine: A reappraisal", *Journal of Political Economy*, Vol. 72, pp. 584-596, December.

Ball, L. (1993): "What causes inflation?", *Federal Reserve Bank of Philadelphia Business Review*, pp. 3-12, March/April.

Barro R.J. (1995): "Inflation and economic growth", National Bureau of Economic Research Working Paper No. 5326, October.

Bradley J. (1977): "Lags in the transmission of inflation", *The Economic and Social Review*, Vol. 8, No. 2, pp. 149-154.

Briault C. (1995): "The costs of inflation", *Bank of England Quarterly Bulletin*, Vol. 35, No. 1, pp. 33-45, February.

Browne, F.X. (1982): "Modelling export prices and quantities in a small open economy", *The Review of Economics and Statistics*, Vol. LXIV, No. 2, pp. 346-347.

Browne F.X. (1983): "Price setting behaviour for traded goods - the Irish case", *Applied Economics*, Vol. 15, pp. 153-163.

Browne, F. X. (1984): "The international transmission of inflation to a small open economy under fixed exchange rates and highly interest sensitive capital flows", *European Economic Review*, Vol. 25, pp. 187-212.

Browne, F.X. (1993): "Monetary policy and the output gap", *Central Bank of Ireland Quarterly Bulletin*, pp. 31-44.

Browne, F.X. and D. McGettigan (1993): "Another look at the causes of Irish unemployment ", Central Bank of Ireland, Technical Paper 1/RT/93.

Bruno, M. (1979), "Price and output adjustment - Micro-foundations and aggregation", *Journal of Monetary Economics*, Vol. 5, No. 2, pp. 187 - 211.

Callan T. and J. FitzGerald (1989): "Price determination in Ireland: Effects of changes in exchange rates and exchange rate regimes", *The Economic and Social Review*, Vol. 20, No. 2, pp. 165-188, January.

Campbell, J.R. and E.R. Rissman (1994): "Long-run labor market dynamics and short-run inflation ", *Federal Reserve Bank of Chicago, Economic Perspectives,* Vol. 2, pp. 15-27

Canova, F. (1993): "Detrending and business cycle facts", Centre For Economic Policy Research, Discussion Paper No. 782.

Cassese, A. and J. R. Lothian (1983): "The timing of monetary and price changes and the international transmission of inflation to Ireland", in M.R. Darby, J.R. Lothian, A.E. Gandoli, A.J. Schwartz, and A.C. Stockman (eds.), The International Transmission of Inflation, pp. 58-82, (Chicago : University of Chicago Press).

Cassidy, C. (1982): "The international transmission of inflation: A survey", Central Bank of Ireland, Research Paper 9/R/82.

Chadha, B., P.R. Masson and G. Meredith (1992): "Model of inflation and the costs of disinflation", *IMF Staff Papers,* Vol. 39, No. 2, pp. 395-431.

Cross, R.B. and D.E.W. Laidler (1975): "Inflation excess demand and expectations in fixed exchange rate open economies: Some preliminary empirical results", in J.M. Parkin and G. Zis (eds.), Inflation in the World Economy, pp. 221-258, (Manchester: Manchester University Press).

De Gregorio, J. and H. Wolf (1994): "Terms of trade, productivity, and the real exchange rate", National Bureau of Economic Research Working Paper No. 4807.

De Gregorio, J., A. Giovannini and H. Wolf (1994): "International evidence on tradables and nontradables inflation", *European Economic Review,* Vol. 38, pp. 1225-1244.

Doornick, J.A. and D.F. Hendry (1994): PcFiml 8.0: Interactive Econometric Modelling of Dynamic Systems, (London: International Thomson Publishing).

Dowd, K (1995): "The damage inflation does", *Economic Review,* pp. 32-35, November.

Edgren, G., K.O. Faxen and C.E. Odhner (1973): Wage Formation and The Economy, (London: Allen and Unwin).

Edison, H. and J.T. Klovland (1987): "A quantitative reassessment of the purchasing power parity hypothesis: Evidence from Norway and the United Kingdom", *Journal of Applied Econometrics*, Vol. 2, pp. 309-333.

Federal Reserves Bank of New York (1990): Intermediate Targets and Indicators for Monetary Policy - A Critical Survey.

Fischer S. (1993): "The role of macroeconomic factors in growth", *Journal of Monetary Economics*, Vol. 32, pp. 485-512.

Flynn J. (1986): " A simulation model of the effects of exchange rate changes on inflation and the trade balance", *Central Bank of Ireland Quarterly Bulletin*, pp. 103-118, Summer.

Fountas S., B. Lally and J. Wu (1995): "The relationship between inflation and wage growth in the Irish economy", Department of Economics, University College Galway, Working Paper No. 6.

Franz, W. and R.J. Gordon (1993): " German and American wage and price dynamics: Differences and common themes", Centre for Economic Policy Research, Discussion Paper No. 777, June.

Friedman M. (1963): <u>Inflation: Causes and Consequences</u>, (Bombay: Asia Publishing House).

Friedman, M. (1968), "The role of monetary policy", *American Economic Review,* Vol. 58, No. 1, pp. 1-17, March.

Friedman, M. (1987): " Quantity theory of money", in J. Eatwell, M. Milgate and P. Newman (eds.), <u>The New Palgrave: A Dictionary of Economics</u>, pp. 3-20, (London: Macmillan Press).

Froot, K.A. and K. Rogoff (1991a): "The EMS, the EMU, and the transition to a common currency", in S. Fisher and O. Blanchard (eds.), <u>National Bureau of Economic Research Macroeconomics Annual</u>, pp. 269-317, (Cambridge, Mass.: MIT Press).

Froot, K.A. and K. Rogoff (1991b): " Government consumption and the real exchange rate: The empirical evidence", *mimeo.*, Harvard Business School.

Froot, K.A. and K. Rogoff (1995): "Perspectives on PPP and long-run real exchange rates", in G. M. Grossman and K. Rogoff (eds.), <u>Handbook of International Economics, Volume 3</u>, pp. 1647-1688, (Amsterdam: North-Holland).

Geary P.T. (1974): "The causes of inflation", *Journal of the Statistical and Social Inquiry Society of Ireland*, Vol. 23, Part 2, 1974/75, pp. 1-7.

Geary P.T. (1976a): " World prices and the inflationary process in a small open economy - the case of Ireland", *The Economic and Social Review*, Vol. 7, No. 4, pp. 391-400.

Geary, P.T. (1976b): "Lags in the transmission of inflation : Some preliminary estimates", *The Economic and Social Review,* Vol. 7, No. 4, pp. 383 - 389.

Geary, P.T. and R.M. Jones (1975): "The appropriate measure of unemployment in an Irish Phillips curve", *The Economic and Social Review,* Vol. 6, June, pp. 55-63.

Geary, P.T. and C. McCarthy (1976): "Wage and price determination in a labour exporting economy: The case of Ireland", *The Economic and Social Review,* Vol. 8, No. 3, pp. 219 - 233.

Geary, R. C. (1981): "Monetarism in Ireland: A simple statistical approach", *The Economic and Social Review,* Vol. 1, No. 3, pp. 163-168, April.

Geary, R.C., E.W. Henry and J.L. Pratsche (1970): "The recent price trend in Ireland", *The Economic and Social Review,* Vol. 1, No. 3. pp. 345-357, April.

Ghosh, A. and H. Wolf (1994): "Pricing in international markets: Lessons from the Economist", National Bureau of Economic Research, Working Paper No. 4806.

Giovannini, A. (1988): "Exchange rates and traded goods prices", *Journal of International Economics*, Vol. 24, pp. 45-68.

Gordon, R.J. (1985): "Understanding inflation in the 1980s", *Brookings Papers on Economic Activity,* Vol. 1, pp. 262-299.

Gordon, R.J. (1988): "The role of wages in the inflation process", *American Economic Review,* Vol. 78, No. 2 pp. 276-283, May.

Hackett A. and P. Honohan (1981): "Some determinants of consumer prices", Central Bank of Ireland, Technical Paper 10/RT/81.

Hamilton, J.D. (1994): <u>Time Series Analysis</u>, (Princeton: Princeton University Press).

Hansen, H. and K. Juselius (1995): <u>CATS in RATS Version 1.00 - Installation and Use Guide</u>, (Illinois: Estima).

Hanson C. and I. Weir (1992): "Measures of inflation", in P. Newman, M. Milgate and J. Eatwell (eds.), <u>The New Palgrave Dictionary of Money and Finance</u>, pp. 685-688, (London: Macmillan Press).

Himarios, D. (1987): "Devaluation, devaluation expectations and price dynamics", *Economica,* Vol. 54, pp. 299 - 313.

Holden, D. and R. Perman (1994): "Unit roots and cointegration for the economist" in B.B. Rao (ed.) <u>Cointegration for the Applied Economist</u>, pp. 47-112, (New York: St. Martin's Press).

Honohan P. (1982): "Is Ireland a small open economy?", *Administration,* Vol. 29, No. 4, pp. 356-375.

Honohan P. and J. Flynn (1986): "Irish inflation in EMS", *The Economic and Social Review,* Vol. 17, No. 3, pp. 175-191, April.

Hoskins W.L. (1991): "Defending zero inflation: All for naught", *Federal Reserve Bank of Minneapolis Quarterly Review*, pp. 16-20, Spring.

Howlett D. and D. McGettigan (1995): "Money, credit and prices: A VAR analysis", *Central Bank of Ireland Annual Report 1994*, pp. 109-130.

Hsieh, D. (1982): "The determinants of the real exchange rate: The productivity approach", *Journal of International Economics*, Vol. 12, pp. 355-362.

Humphrey, T. M. (1986): Essays on Inflation (Fifth Edition), (Richmond, Virginia: Federal Reserve Bank of Richmond).

Isard, P. (1977): "How far can we push the law of one price?", *American Economic Review*, Vol. 67, pp. 942-948.

Johansen, S. (1988): "Statistical analysis of cointegration vectors", *Journal of Economic Dynamics and Control*, Vol. 12, pp. 231-254.

Johansen, S. (1991): "Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models", *Econometrica*, Vol. 59, pp. 1551-1580.

Johansen, S. (1992): "Determination of the cointegration rank in the presence of a linear trend", *Oxford Bulletin of Economics and Statistics*, Vol. 54, pp. 383-397.

Johansen, S. and K. Juselius (1990): "The full information maximum likelihood procedure for inference on cointegration - with applications to the demand for money", *Oxford Bulletin of Economics and Statistics*, Vol. 52, pp. 169-210.

Johansen, S. and K. Juselius (1992): "Testing structural hypotheses in a multivariate cointegration analysis of the PPP and the UIP for UK", *Journal of Econometrics*, Vol. 53, pp. 211-244.

Johansen, S. and K. Juselius (1994): "Identification of the long-run and the short-run structure - An application to the ISLM model", *Journal of Econometrics*, Vol. 63, pp. 7-36.

Kennedy K.A. (1974): "Discussion", *Journal of the Statistical and Social Inquiry Society of Ireland*, Vol. 23, Part 2, 1974/75, pp. 14-16.

Kenny, G. (1995): "Some estimates of potential output and the output gap for Ireland", Central Bank of Ireland, Technical Paper 5/RT/95, July.

Kenny, G. (1996): "Capacity utilisation in Irish manufacturing", Central Bank of Ireland, Technical Paper 4/RT/96, (forthcoming).

King, M. (1994): "The transmission mechanism of monetary policy", *Bank of England Quarterly Bulletin*, pp. 261-267, August.

Laidler D. (1990): Taking Money Seriously, (London: Philip Allan).

Laidler D. and M. Parkin (1975): “Inflation: A survey”, *The Economic Journal*, Vol. 85, pp. 741-809, December.

Leddin, A. (1988): “Interest and price parity and foreign exchange market efficiency: The Irish experience in the European Monetary System”, *The Economic and Social Review*, Vol. 19, No. 3, pp. 215-231, April.

Leddin A. (1995): “The causes of Irish inflation: A survey”, Paper presented to the Irish Economic Association, Ninth Annual Conference.

Leddin A. and D. Hodnett (1995): “Purchasing power parity: Evidence from the Irish economy, 1922-92.”, *mimeo*., University of Limerick.

Levine R. and D. Renelt (1992): “ A sensitivity analysis of cross-country growth regressions”, *The American Economic Review*, Vol. 82, No. 4, pp. 942-963, September.

Lindbeck, A. (1979): “Imported and structural inflation and aggregate demand: The Scandinavian model reconstructed”, in A. Lindbeck (ed.), Inflation and Employment in Open Economies - Studies in International Economics, Volume 5., pp. 13-40, (Amsterdam: North-Holland).

Ljung, G.M. and G.E.P. Box (1978): “On a measure of lack of fit in time-series models”, *Biometrica*, Vol. 67, pp. 297-303.

Lothian J. R. (1992): “International transmission of inflation and deflation”, in P. Newman, M. Milgate and J. Eatwell (eds.), The New Palgrave Dictionary of Money and Finance, pp. 491-494, (London: Macmillan Press).

Lucas, R.E. (1973), “Some international evidence on output-inflation trade-offs”, *American Economic Review*, Vol. 63, pp. 326-334.

MacKinnon, J. (1991): “Critical values for cointegration tests”, in R.F. Engle and C.W. Granger (eds.), Long-Run Economic Relationships, pp. 267-276, (London: Oxford).

Mankiw, N.G. (1985): “Small menu costs and large business cycles: A macroeconomic model of monopoly”, *Quarterly Journal of Economics*, Vol 100, No.2, pp 529-539, May.

Marston, R. (1987): “Real exchange rates and productivity growth in the United States and Japan”, in S. Arndt and J.D. Richardson (eds.), Real Financial Linkages Among Open Economies, (Cambridge Mass.: MIT Press).

McCallum, B. T.(1990), “Inflation: Theory and evidence”, in B.M. Friedman and F.H. Hahn (eds.), Handbook of Monetary Economics,Vol II, pp. 964-1012, (Amsterdam: North Holland).

McCandless Jr. G.T. and W.E. Weber (1995): "Some monetary facts", *Federal Reserve Bank of Minneapolis Quarterly Review*, pp. 2-11, Summer.

McElhattan, R. (1985), "Inflation, supply shocks and the stable inflation rate of capacity utilisation", *Federal Reserve Bank of San Francisco, Economic Review*, No. 1, pp. 45-63, Winter.

Mehra, Y.P. (1991): "Wage growth and the inflation process: An empirical note", *American Economic Review*, Vol. 81, No. 4, pp. 931-937.

Mellis, C. (1993): "Tradeable and non-tradeable prices in the UK and EC: Measurement and explanation", Bank of England Working Paper Series, No 15.

Muth, J.F.(1961): "Rational expectations and the theory of price movements", *Econometrica*, Vol. 29, pp. 315-335.

NESC (1986): <u>Strategy for Development 1986-1990,</u> (Report No. 83), (Dublin: Stationery Office).

Nickell, S. (1990): "Inflation and the UK labour market", *Oxford Review of Economic Policy*, Vol. 6, No. 4, pp. 26-35.

Nugent, J. (1994), "An analysis of the sensitivity of inflation to exchange rate movements", *mimeo*., Central Bank of Ireland.

O'Connell, T. and J. Frain (1989): "Inflation and exchange rates: A further empirical analysis", Central Bank of Ireland Technical Paper 1/RT/89, April.

Parkin, M.(1973): "The short-run and long-run trade offs between inflation and unemployment in Australia", *Australian Economic Papers*, December 1973, pp. 127-144.

Phelps, E. (1967): "Phillips curves, expectations of inflation and optimal unemployment over time", *Economica*, Vol. 34, pp. 254-281, August.

Phillips, A.W. (1958): "The relation between unemployment and the rate of change of money wage rates in the United Kingdom, 1861-1957", *Economica*, Vol. 25, pp. 283-299, November.

Phillips, P.C.B. and P. Perron (1988): "Testing for a unit root in time series regression", *Biometrika*, Vol. 75, pp. 335-346.

Rowlatt, P.A. (1992): <u>Inflation</u>, (Chapman and Hall: London).

Samuelson, P.A. (1964): "Theoretical notes on trade problems", *Review of Economics and Statistics*, Vol. 46, pp. 145-164.

Sargent, T.J. (1973): "Rational expectations, the real rate of interest and the natural rate of unemployment", *Brookings Papers on Economic Activity*, Vol. 2, pp. 429-472.

Surrey, M.J.C. (1989): "Money, commodity prices and inflation: Some simple tests", *Oxford Bulletin of Economics and Statistics*, Vol. 51, No. 3, pp. 219-238.

Thom, R. (1989): "Real exchange rates, co-integration and purchasing power parity: Irish experience in the EMS", *The Economic and Social Review*, Vol. 20, No. 2, pp. 147-164, January.

Williamson, J. and C. Milner (1991): The World Economy - A Textbook in International Economics, (Herts. : Harvester Wheatsheaf).

Wright, J.H. (1993): "Quantifying the non-stationarity in Irish real exchange rates", *The Economic and Social Review*, Vol. 25, No. 1, pp. 109-119, October.

Wright, J.H. (1994): "A co-integration based analysis of Irish purchasing power parity relationships using the Johansen procedure", *The Economic and Social Review*, Vol. 25, No. 3, pp. 261-278, April.

# Appendix 1

This Appendix illustrates the generic identification conditions more clearly by outlining a particular example. As discussed in the paper, two long-run equilibria of interest were expected to emerge from our data. It was assumed that the first would take the form of a purchasing power parity relationship, while the second should reflect some type of connection between wages, prices and a trend variable (to account for productivity gains). Put more formally, our hypotheses are as follows:

Hypothesis 1: P = -E + P* form a cointegrating relationship and W, t = 0
Hypothesis 2: W, P, t form a cointegrating relationship (no coefficients specified) and
E, P* = 0

In this case ß should take the following form:

$$b = \begin{bmatrix} 1 & b_{12} \\ 0 & b_{22} \\ 1 & 0 \\ -1 & 0 \\ 0 & b_{52} \end{bmatrix}$$

We also know that $b$ takes the form: $b = (H_1 \varphi_1 , H_2 \varphi_2)$, where $H_i$ are $p$ x $s_i$ matrices, and $\varphi_i$ are $s_i$ x 1 vectors, where $s_z = p - k_i$ (see the discussion at the beginning of Section 6.6). In our example $p = 5$ and $k_1 = 4$ (i.e there are four restrictions imposed in the first column of $b$) and $k_2 = 2$. Hence $H_1$ is a 5 x 1 matrix and $H_2$ is a 5 x 3 matrix, and $\varphi_1$ and $\varphi_2$ are 1 x 1 and 3 x 1 vectors respectively. This is demonstrated as follows:

$b = (H_1\ \varphi_1\ ,\ H_2\ \varphi_2)=$

$$\begin{bmatrix}1\\0\\1\\-1\\0\end{bmatrix} \quad [\varphi_1] \quad \begin{bmatrix}1&0&0\\0&1&0\\0&0&0\\0&0&0\\0&0&1\end{bmatrix} \quad \begin{bmatrix}j_1\\j_2\\j_3\end{bmatrix}$$

$$= \begin{bmatrix}1 & b_{12}\\0 & b_{22}\\1 & 0\\-1 & 0\\0 & b_{52}\end{bmatrix}$$

We also know from our discussion above that $R_i$, which has to be of full rank, must also be orthogonal to $H_i$ (i.e. $H_i = R_{i\perp}$ or $R_i H_i = 0$) and that $R_i\ b_i = 0$. Hence $R_1$ must take the following form:

$$\underset{\substack{R_1'\\(k_1 \text{ x } p)}}{\begin{bmatrix}1&0&0&1&0\\0&0&1&1&0\\0&1&0&0&0\\0&0&0&0&1\end{bmatrix}} \quad \underset{\substack{b_1\\(p \text{ x } 1)}}{\begin{bmatrix}1\\0\\1\\-1\\0\end{bmatrix}} = \underset{k_1 \text{ x } 1}{\begin{bmatrix}0\\0\\0\\0\end{bmatrix}}$$

and $R_2$ must be as follows:

$$\underset{\substack{R_2'\\(k_2 \text{ x } p)}}{\begin{bmatrix}0&0&1&0&0\\0&0&0&1&0\end{bmatrix}} \quad \underset{\substack{b_2\\(p \text{ x } 1)}}{\begin{bmatrix}b_{12}\\b_{22}\\0\\0\\b_{52}\end{bmatrix}} = \underset{(k_2 \text{ x } 1)}{\begin{bmatrix}0\\0\end{bmatrix}}$$

As we saw previously, the rank conditions are as follows:

$$r_{i,j} = \text{rank}\,(R_i' \, H_j) \geq 1, \; i \neq j$$

i.e. $\quad r_{1,2} = \text{rank}\,(R_1' \, H_2) \geq 1$

and $\quad r_{2,1} = \text{rank}\,(R_2' \, H_1) \geq 1$

Given that we know the form which the $R_i$ and $H_j$ matrices take, we easily check whether the generic identification conditions hold as follows:

$$\text{Rank}\,(R_1' \, H_2) = \text{Rank} \begin{bmatrix} 1 & 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$= \text{Rank} \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} = 3 \geq 1$$

$$\text{Rank}\,(R_2' \, H_1) = \text{Rank} \begin{bmatrix} 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} 1 \\ 0 \\ 1 \\ -1 \\ 0 \end{bmatrix}$$

$$= \text{Rank} \begin{bmatrix} 1 \\ -1 \end{bmatrix} = 1 \geq 1$$

Hence, it can easily be seen that the aforementioned structural hypotheses do indeed satisfy the generic identification conditions as set out in Theorem 1 of Johansen and Juselius (1994).

# Data Appendix

## Description of Data

**Aggregate Prices:** Underlying Consumer Price Index, i.e. headline CPI net of the impact of the mortgage interest component. The relevant weights, the headline CPI and the Mortgage Interest component were obtained from the CSO.

**Traded Prices:** See **Construction of Disaggregated Price Indices** below.

**Non-Traded Prices:** See **Construction of Disaggregate Price Indices** below.

**World Traded Prices**: Computed as the weighted average of the UK and German Wholesale Prices. Source: IFS databank. In aggregating the two series, the UK WPI received a weight equivalent to the share of the UK in Irish trade and the German WPI received a weight equal to one minus the UK share. The share of the UK in Irish trade was obtained from the CSO trade statistics.

**Exchange Rate**: The nominal Effective Exchange Rate Index. Source: Central Bank of Ireland.

**Wages**: Index of average weekly earnings in Manufacturing Industries. Source:CSO.

**Government Expenditure:** Current Government expenditure, quarterly issues, Source: CSO.

**Unemployment Rate:** A quarterly standardised measure of unemployment which combines the monthly measure of unemployment from the live register with annual Labour Force Survey data. Source: CSO

**Construction of Disaggregated Price Indices**
The data series employed in the construction of the traded/non-traded price series were obtained from the CSO.

The construction of separate indices for traded and non-traded prices reflects economic intuition concerning certain goods (e.g. highly perishable commodities and some “public goods”) which may fall into the non-traded category. Equally, it takes account of some items which are classified under Services but which could reasonably be deemed to be traded (e.g. Expenditure Abroad). The series were built up from individual sub-indices of the CPI. The classification of these sub-indices in terms of the traded and non-traded categories is outlined in the Table below. The Table also provides the relevant weights for traded and non-traded sectors based on their shares in the underlying consumer price series. In the actual aggregation of individual sub-indices into traded and non-traded components, the weights were allowed to vary according to the changes introduces by the CSO in 1975, 1982 and 1989. For example, the weight attributed to the non-traded sector rose steadily over the sample period from 27.8% in 1975 to 29.6% in 1982 and to 33.6% in 1989. In part, this reflects the growing weight attached to non-traded services and non-

| Disaggregated Price Series | Weight(%) | | |
|---|---|---|---|
| | 1975 | 1982 | 1989 |
| **Non-Traded Prices** | | | |
| - Non-Traded Food (Bread, Fresh Milk, Eggs, Meals Out) | 7.9 | 6.8 | 7.9 |
| - Fuel and Light | 6.0 | 6.3 | 6.1 |
| - Housing net of Local Authority Charges, Mortgage Interest, Repairs and Decorations | 1.7 | 1.5 | 2.2 |
| - Non-Traded Transport (Motor Tax and Registration, Motor Insurance, Repairs and Maintenance, Other Vehicle Costs, Bus Fares, Train Fares, Other Travel) | 4.0 | 4.7 | 4.7 |
| - Services net of the Expenditure Abroad | 8.1 | 10.3 | 12.7 |
| | 27.8% | 29.6% | 33.6% |
| **Traded Prices** | | | |
| - Food net of Bread, Fresh Milk, Eggs, Meals Out | 23.1 | 18.8 | 18.8 |
| - Alcoholic Drink | 11.7 | 12.6 | 12.2 |
| - Tobacco | 4.5 | 3.5 | 3.5 |
| - Clothing and Footwear | 11.0 | 8.3 | 7.0 |
| - Repairs and Decorations | 2.0 | 1.7 | 1.5 |
| - Household Durables | 4.9 | 5.2 | 4.9 |
| - Other Goods | 5.3 | 5.8 | 6.1 |
| - Traded Transport(Motor Cycles, Motor Cars, Other Vehicles, Motor Fuel, Motor Oil, Spare Parts) | 9.5 | 12.4 | 9.6 |
| - Expenditure Abroad | 0.03 | 2.00 | 3.0 |
| | 72.2% | 70.4% | 66.4% |

traded transportation goods and services. To avoid the problem of compounding a base effect with a significant change in the weight, the individual sub-indices were broken down into the three sub-periods, i.e. 1975:Q4 - 1982:Q4, 1982:Q4 - 1989:Q4 and 1989:Q4 - 1995:Q3. Each series was then rebased to equal a 100 at the beginning of each sub-period and the appropriate weights were applied to each series. Whole sample traded and non-traded price series could then be calculated by linking the weighted series for each sub-period. Lastly, the resulting traded and non-traded price indices were then rebased to equal 100 in 1989 Q4.