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STRUCTURAL MODEL OF IRISH INFLATION

BY

GERALDINE SLEVIN

CENTRAL BANK AND
FINANCIAL SERVICES AUTHORITY
OF IRELAND

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Economic Analysis, Research and Publications Department, Central Bank and Financial Services Authority of Ireland, P.O. Box 559, Dame Street, Dublin 2. Tel: +353-1-4344466.
Email: geraldine.slevin@centralbank.ie

ABSTRACT

The aim of this paper is to determine the underlying causes of Irish inflation. This issue is addressed by disaggregating the data into the traded and non-traded sectors of the economy. The results indicate that traded price inflation is determined by long-run purchasing power parity. In the non-traded sector prices are determined by wages and productivity growth. The results imply that long-run purchasing power parity provides a reasonable forecast for traded prices. In the case of non-traded prices a long-run model linking wages, productivity and trend effects produces a reasonably accurate forecast.

INTRODUCTION:

This paper attempts to explain the determinants of Irish inflation. The process of price determination is examined in the traded and non-traded sectors of the economy. The econometric methodology is based on both the Johansen procedure and the Autoregressive Distributed Lag (ARDL) model approach to cointegration. Prices in the traded sector are in the long-run determined by purchasing power parity (PPP) and thus are modelled on world prices and the exchange rate. In the non-traded sector a wage-price mark-up model is estimated. The results indicate acceptance of long-run PPP in the traded sector and wage/price equality in the non-traded sector. The ARDL model does not impose pure PPP in the traded sector but finds almost complete exchange rate pass-through. This model implies a quicker and more significant adjustment back to long-run equilibrium than the model that imposes PPP. In the non-traded sector the ARDL model allows for wages, productivity, trend and seasonality effects and finds significant adjustment back to long-run equilibrium. Both sets of models are used for forecasting purposes. The best model in terms of its forecasting performance in the traded sector is the model that imposes long-run PPP. In the non-traded sector the model that provides the best forecasting statistics is the one that allows for trend and seasonality effects.

The structure of this paper is as follows: In Section 2 a short review of the studies of inflation in Ireland is discussed. Section 3 outlines the econometric methodology. Section 4 discusses the data used and the results obtained for the traded and non-traded sectors. Section 5 presents the forecasting statistics of each model. Section 6 concludes.

2. REVIEW OF THE LITERATURE:

Most studies of Irish inflation have reflected upon the long-run implications of purchasing power parity (PPP). Absolute PPP states that the price of a basket of goods in one country (P_t) will equal the price of the same basket of goods in a foreign country (P^*_t) converted at the relevant nominal effective exchange rate (E_t). This relationship can be expressed in logs as:

$$P_t = P^*_t + E_t \qquad (1)$$

Before joining the European Monetary System (EMS) in 1979, it was widely accepted that Irish inflation was determined by UK inflation and thus the authorities had no independent control over it. Geary (1976a) found that the UK retail price index directly influenced Irish inflation during this time period. He found that it took at least eight quarters for UK inflation to be transmitted to the Irish economy. Browne (1984) also found support for the small open economy (SOE) price-taking hypothesis as he found that UK monetary policy had a long-run one-for-one effect on Irish inflation.

When the link with sterling was broken in 1979 and the Irish pound was directly pegged to the DM, Irish inflation could deviate from that of the countries to which it was tied. While the exchange rate was effectively pegged to the DM within a narrow band, it was no longer fixed. The UK stayed outside the ERM until October 1990 and thus the Irish pound began to float with the UK, and this was the country with which it conducted a large proportion of its trade. Ireland could avoid "importing" UK inflation by allowing the Irish pound/sterling exchange rate to appreciate. During this time period there was greater potential for domestic factors to influence Irish inflation. Browne (1984) found that changes in domestic monetary policy had an enduring effect on Irish inflation in the post-EMS period. O'Connell and Frain (1989) also attribute a significant role to domestic excess money creation in explaining Irish inflation between 1977 and 1985.

Callan and Fitzgerald (1989) found evidence of a long-run role for German prices in the determination of Irish inflation. However, Leddin and Hodnett (1995) found no evidence of cointegration between German and Irish prices. Kenny and McGettigan (1996) used a Scandinavian model of inflation which permits separate analysis of the price determination processes in the traded and non-traded sectors of the economy. They tested the long-run validity of (i) a wage mark-up model, (ii) a pure-price taking small open economy (SOE) model and (iii) a hybrid model that fuses elements of (i) and (ii). In the traded sector full PPP as a long-run equilibrium relationship was found to be consistent with the data. Their results imply that if all of the adjustment back to equilibrium is effected through traded prices themselves, a half life of deviations away from PPP takes approximately 6.8 quarters. In the non-traded sector they reject pure long-run PPP, however, non-traded prices were found to be cointegrated with a combination of world prices and the exchange rate. Aggregate prices were found to occupy an intermediate position, with full PPP being almost acceptable. They also demonstrate that strong bi-directional causality exists between prices and wages.

The above review suggests that there is little agreement on the causes of Irish inflation since joining the EMS. This paper aims to examine the importance of internal and external influences on Irish inflation, by examining the role of wages and the exchange rate in the inflation process. In order to do this, the methodology used in Kenny and McGettigan (1996) will be adopted whereby traded and non-traded prices will be separated into their respective components.

3. ECONOMETRIC METHODOLOGY:

This paper adopts the Scandinavian model of inflation whereby a two-sector economy is examined. The relevant sectors to be analysed are the traded and non-traded sectors. In this approach traded prices are assumed to be determined externally, while non-traded prices are influenced by domestic wages and productivity effects. Traded prices are assumed to be determined by world price inflation adjusted for any change in the exchange rate. This implies that traded inflation can never deviate from that prevailing abroad if the exchange rate is fixed. Non-traded price inflation is modelled as arising from mark-up behaviour over wages adjusted for productivity effects. Thus the following long-run hypotheses are tested (expressed in logs)[1]:

$$P^T_t = \text{Constant} + P^*_t + E_t \qquad (2)$$

$$P^N_t = \text{Constant} + W_t + PROD_t \qquad (3)$$

where P^T_t and P^N_t refer to traded and non-traded prices and are defined as in Kenny and McGettigan (1996)[2]. P^*_t refers to world prices, E_t is the nominal effective exchange rate. W_t represents wages and $PROD_t$ is a measure of productivity effects[3].

[1] The constant allows for differentials between price levels that can be caused by transaction costs or measurement problems.
[2] Attempts were made to analyse the effects of wages and productivity in the traded sector, but they were found to be insignificant. Similarly in the non-traded sector, world prices and the exchange rate were insignificant.
[3] The data used and the definitions of these variables will be discussed later.

The first equation imposes purchasing power parity (PPP). This implies that traded prices are determined by world prices adjusted for any change in the exchange rate. If PPP holds, this does not mean that there is no room for domestic influences on Irish inflation. This depends on the movement of the nominal exchange rate. If the exchange rate is fixed and PPP holds, then given that Ireland is a small open economy, it is plausible that world prices determine Irish traded prices and that domestic influences are transitory at most. However, if PPP holds, and the exchange rate is under our control and depreciating, this implies that domestic factors are contributing to Irish inflation in the long-run, and causing it to exceed world inflation. Therefore if PPP is acceptable as a long-run proposition, then the size of the domestic contribution to Irish traded inflation could be measured from movements in the nominal effective exchange rate (Kenny & McGettigan, 1996)[4].

The second equation examines the domestic causative factors affecting inflation where non-traded inflation is modelled as arising from a mark-up behaviour over wages adjusted for productivity growth. We would expect to find a significant relationship between prices and wages. Both Geary (1976a) and Browne (1984) find wages to be significant in their empirical formulations. This significance is often interpreted as evidence in favour of *cost-push* inflation whereby wages are pushing up prices in the non-traded sector. However Kenny & McGettigan (June 1996) note that this is not enough to constitute evidence in favour of domestic cost-push inflation as it cannot be assumed that wages are exogenous to the system. It would be surprising if wages and prices did not move together and they note that this correlation could be due to a common external exogenous factor. This wage/price relationship will be examined later in the analysis and the exogeneity of wages will be tested.

The econometric analysis employs both the Johansen procedure and Autoregressive Distributed Lag (ARDL) models. The reason for using the two methodologies is that the Johansen procedure will enable us to identify the number of cointegrating relationships among a set of variables. A shortcoming of the ARDL approach is that it assumes that there is only one dependent variable. Therefore the Johansen procedure will allow us to determine the number of long-run relationships among the variables

[4] Given that the exchange rate is no longer under our control movements in the nominal effective exchange rate measure the size of the external contribution to Irish traded inflation.

and test long-run hypotheses. The ARDL approach can then also be used to estimate long-run equilibrium relationships among the cointegrating variables identified in the Johansen procedure. Firstly the Johansen procedure will be outlined.

a) Introduction to the Johansen procedure

If x_t is a (p x 1) vector of stochastic variables, μ is a constant term and D_t is a vector of nonstochastic variables, such as trend variables or seasonal dummies, then the Johansen procedure begins by setting out the model in error-correction form as follows[5]:

$$\Delta x_t = \gamma_1 \Delta x_{t-1} + \ldots\ldots\ldots\ldots + \gamma_{k-1} \Delta x_{t-k+1} + \Pi\, x_{t-1} + \mu + \theta D_t + \varepsilon_t \qquad (4)$$

where

$$\varepsilon_t \sim \text{NIID}(0, \Sigma) \qquad (5)$$

where k is the lag length. If the data is integrated of order 1, i.e. I(1), then the matrix Π is of reduced rank,r,:

$$\Pi = \alpha\beta' \qquad (6)$$

where α and β are p x r matrices and r < p. The reduced form model (4) may be written as:

$$\Delta x_t = \gamma_1 \Delta x_{t-1} + \ldots\ldots\ldots\ldots + \gamma_{k-1} \Delta x_{t-k+1} + \alpha\beta' x_{t-1} + \mu + \theta D_t + \varepsilon_t \qquad (7)$$

where $\beta' x_t$ are the r long-run cointegration relations and α is the matrix of adjustment coefficients. μ and θ[6] can be decomposed into constants and trends in the cointregrating space and in the data. There are 5 possible cases:

[5] Thanks to Gerard O'Reilly for kindly supplying the Johansen methodology to me.
[6] Assuming θ is the coefficient on the trend variable.

Case 1: No intercepts and no trends. In this model there are no deterministic components in the data or in the cointegrating relationships.

Case 2: Restricted intercepts and no trends. This model does not allow for linear trends in the data. The only deterministic components are the intercepts in the cointegration relations.

Case 3: Unrestricted intercepts and no trends. This model allows for linear trends in the data and possible intercepts in the cointegrating relationships but it is assumed that there are no trends in the cointegrating relations.

Case 4: Unrestricted intercepts and restricted trends. There are trends in the data and also the cointegrating space has a trend.

Case 5: Unrestricted intercepts and trends. This model is consistent with linear trends in the differenced series Δx_t and thus quadratic trends in x_t. There are also possible trends in the cointegrating relationships.

The Johansen estimation procedure requires a number of steps. These are as follows:

1. Unit root tests.
2. Lag length tests.
3. Choice of Johansen model.
4. Cointegration rank tests.
5. Exclusion, stationarity and weak exogeneity tests.
6. Reduced form model estimation and goodness of fit tests.
7. Structural hypothesis testing.
8. Achieving model parsimony and estimation of the final structural form.

The first step involves testing whether each variable contains a unit root. The second step uses various tests based on autocorrelation, heteroscedasticity, skewness and kurtosis in the residuals to determine the appropriate lag length of the VAR. The third step determines whether the model should include unrestricted/restricted constants and trends in the cointegration space. The fourth step tests the appropriate cointegrating rank using maximum eigenvalue and trace tests, and examines the roots of the companion matrix. The fifth step tests the data for long-run exclusion, stationarity and weak exogeneity. The model is then estimated in its reduced form in the sixth test. Autocorrelation, heteroscedasticity, skewness, kurtosis and goodness of fit tests are carried out. The seventh step involves testing the plausibility of long-run hypotheses by imposing identifying restrictions on the long-run relationships and testing over-identifying restrictions. In this analysis we will test whether PPP holds and if there is some equilibrium relationship between wages and prices. The final step involves model reduction by eliminating unnecessary variables and this outlines the model in its final structural form. The Autoregressive Distributed Lag (ARDL) model will now be outlined.

b) The ARDL Model approach to cointegration:

An Autoregressive Distributed Lag (ARDL) Model of the following form is estimated for the traded sector:

$$P^T_t = \text{constant} + \beta_1 P^T_{t-1} + \beta_2 P^T_{t-2} + \beta_3 P^T_{t-3} + \beta_4 P^T_{t-4} + \gamma_1 P^*_t + \gamma_2 P^*_{t-1} + \gamma_3 P^*_{t-2} + \gamma_4 P^*_{t-3} + \gamma_5 P^*_{t-4} + \alpha_1 E_t + \alpha_2 E_{t-1} + \alpha_3 E_{t-2} + \alpha_4 E_{t-3} + \alpha_5 E_{t-4} + \chi D_t + \phi S_t + \varepsilon_t \quad (8)$$

where D_t and S_t refer to dummy and seasonal variables respectively. The dummy variable relates to the early 1980s when traded prices were substantially high and volatile[7]. The model data used in this analysis has been seasonally adjusted whereas the price data that is used for the traded and non-traded sectors are not. Therefore seasonality variables are included in the equation. Standard conditional inference techniques are employed in reducing the parameterisation of the model. Thus variables are dropped from the system if they are not significant and if their removal does not generate undesirable properties in the residuals. The results of this analysis will be discussed later.

The above model allows us to calculate the long-run solution for traded prices as follows:

$$P^T_t = \text{constant} + \left(\frac{\gamma_1+\gamma_2+\gamma_3+\gamma_4+\gamma_5}{1-\beta_1-\beta_2-\beta_3-\beta_4}\right)P^*_t + \left(\frac{\alpha_1+\alpha_2+\alpha_3+\alpha_4+\alpha_5}{1-\beta_1-\beta_2-\beta_3-\beta_4}\right)E_t +$$

[7] Indirect taxes were quite high in the early 1980s and thus these were excluded to see if the results changed dramatically. The effect was minimal on the overall results.

$$\left(\frac{\chi}{1-\beta_1-\beta_2-\beta_3-\beta_4}\right)D_t + \left(\frac{\phi}{1-\beta_1-\beta_2-\beta_3-\beta_4}\right)S_t + u_t \qquad (9)$$

This can be rewritten as:

$$P^T_t = \text{constant} + \mu P^*_t + \theta E_t + \rho D_t + \eta S_t + u_t \qquad (10)$$

where $\mu = \left(\frac{\gamma_1+\gamma_2+\gamma_3+\gamma_4+\gamma_5}{1-\beta_1-\beta_2-\beta_3-\beta_4}\right)$, $\theta = \left(\frac{\alpha_1+\alpha_2+\alpha_3+\alpha_4+\alpha_5}{1-\beta_1-\beta_2-\beta_3-\beta_4}\right)$,

$\rho = \left(\frac{\chi}{1-\beta_1-\beta_2-\beta_3-\beta_4}\right)$ and $\eta = \left(\frac{\phi}{1-\beta_1-\beta_2-\beta_3-\beta_4}\right)$

Equation (10) thus identifies the long-run response of traded prices to a unit change in world prices and the exchange rate. The long-run coefficients can thus be analysed to test the appropriateness of the purchasing power parity proposition.

The following ARDL model is estimated for the non-traded sector:

$$P^N_t = \text{constant} + \beta_1 P^N_{t-1} + \beta_2 P^N_{t-2} + \beta_3 P^N_{t-3} + \beta_4 P^N_{t-4} + \gamma_1 W_t + \gamma_2 W_{t-1} + \gamma_3 W_{t-2} + \gamma_4 W_{t-3} + \gamma_5 W_{t-4} + \alpha_1 PROD_t + \alpha_2 PROD_{t-1} + \alpha_3 PROD_{t-2} + \alpha_4 PROD_{t-3} + \alpha_5 PROD_{t-4} + \pi t_t + \chi D_t + \phi S_t + \varepsilon_t \qquad (11)$$

where t refers to a trend variable. As in equation (8) variables are dropped from the system if they are insignificant and if their removal does not lead to undesirable properties in the residuals. The long-run solution for the non-traded sector is as follows:

$$P^N_t = \text{constant} + \mu W_t + \theta PROD_t + \varphi t_t + \rho D_t + \eta S_t + u_t \qquad (12)$$

where $\varphi = \left(\frac{\pi}{1-\beta_1-\beta_2-\beta_3-\beta_4}\right)$

This long-run equilibrium equation allows us to identify the long-run response of wages and productivity on non-traded prices. When the long-run equilibrium equations for both the traded and non-traded sectors have been estimated we can proceed to estimate the short-run response of inflation to changes in world prices and the exchange rate etc. This is achieved by transferring the variables to a stationary representation and re-estimating the model. The error correction term refers to the residuals from the long-run relationship. The following short-run equations can be estimated for the traded and non-traded sectors:

$$\Delta P^T_t = \text{constant} + \alpha_1 \Delta P^T_{t-1} + \alpha_2 \Delta P^T_{t-2} + \alpha_3 \Delta P^T_{t-3} + \alpha_4 \Delta P^*_{t-1} + \alpha_5 \Delta P^*_{t-2} + \alpha_6 \Delta P^*_{t-3} + \alpha_7 \Delta E_{t-1} + \alpha_8 \Delta E_{t-2} + \alpha_9 \Delta E_{t-3} + \alpha_{10} D_t + \alpha_{11} S_t + \phi ECM^T_{t-1} + \nu_t \quad (13)$$

and

$$\Delta P^N_t = \text{constant} + \lambda_1 \Delta P^N_{t-1} + \lambda_2 \Delta P^N_{t-2} + \lambda_3 \Delta P^N_{t-3} + \lambda_4 \Delta W_{t-1} + \lambda_5 \Delta W_{t-2} + \lambda_6 \Delta W_{t-3} + \lambda_7 \Delta PROD_{t-1} + \lambda_8 \Delta PROD_{t-2} + \lambda_9 \Delta PROD_{t-3} + \lambda_{10} D_t + \lambda_{11} S_t + \chi ECM^N_{t-1} + \nu_t \quad (14)$$

where ECM^T and ECM^N refer to the error correction term in the traded and non-traded sectors respectively. In the traded sector, the Johansen procedure tests whether PPP holds in the long-run and the ARDL methodology identifies a long-run equation relating traded prices to world prices, the exchange rate and seasonality effects. Thus there are two short-run equations estimated for the traded sector.

Similarly there are two equations estimated for the non-traded sector. The first equation includes the error correction term identified using the Johansen procedure and the second approach includes the long-run equilibrium relationship obtained from the ARDL estimation. The coefficients ϕ and χ are estimates of the speed of adjustment. They provide estimates of the deviation from long-run equilibrium in period (t-1). If $\phi = 0$, then traded price inflation does not respond at all to the deviation from its long-run equilibrium in period (t-1). The speed of adjustment coefficients and their significance are very important in determining how quickly prices return to their long-run equilibrium value. The other short-run variables and their significance will also be examined. Variables will be dropped from the system if they are insignificant and if their removal does not cause autocorrelation or heteroscedasticity in the residuals. When the models have been finally formulated and are acceptable, their forecasting performance will be assessed to determine which model is the most appropriate. The next section will outline the data used and the results achieved.

4. DATA AND RESULTS:

The data used in this analysis is taken from the interpolated series of the National Income Accounts prepared at the Central Bank of Ireland. The data was interpolated between 1980:01 and 1999:04[8]. The data was subsequently updated using most recent National Income Accounts data and internal Central Bank of Ireland estimates[9]. Thus the estimation sample relates to the period 1980:01 – 2002:04. Wages are derived by dividing total compensation of employees in the economy by the total number of people employed. Productivity is defined as output divided by numbers employed, where output is defined as Gross Domestic Product (GDP) at constant (1995) market prices. The exchange rate is defined as the bilateral Irish pound dollar exchange rate. World prices are measured as a weighted average of competitors export prices (measured in dollars)[10]. Traded and Non-traded prices are constructed using the individual expenditure weights of the Consumer Price Index[11] and are separate to the internal model dataset of the Central Bank.

ECONOMETRIC RESULTS:

Cointegration Analysis 1: Johansen procedure:

a) UNIT ROOT TESTS:

Cointegration analysis suggests that there exists some long-run relationship between a set of I(1) variables which is I(0), i.e. the residuals from a regression of I(1) variables

[8] See McGuire, M., O'Donnell N. and Ryan, M. 2002.
[9] Thanks to Kieran McQuinn and Maurice McGuire for kindly supplying these to me.
[10] This data is taken from the ECB MCM Trade Block.
[11] Traded and Non-Traded prices are constructed as in Kenny and McGettigan (June 1996).

is I(0). This implies that in the long run certain combinations of these economic variables should not diverge from each other. The test results in Table 1 in Appendix 1 tests whether variables are I(0) or of a higher order. This test is based on Augmented Dickey Fuller (ADF) tests where the number of lags refers to the amount of lags of the series required to render the residuals white noise, determined by maximum AIC (Akaike Information Criterion) and SBC (Schwarz Bayesian Criterion) tests. The null hypothesis is that the series is I(1). This test for nonstationarity is around a constant and a trend. If this is not rejected then the test is employed on the first differences of the variable in question. The differenced series are tested for nonstationarity around a constant only. In this case the null hypothesis is that the series is I(2) or higher. The result of this analysis is shown in Table 2 in Appendix 1.

The non-traded and foreign prices, nominal effective exchange rate and the productivity variables all appear to contain a unit root. The results for traded prices and wages suggest stationarity on the face of it. This result does not accord with economic priors and thus the variables are tested to determine whether they are tending towards I(2) rather than I(1) in Table 2. The results suggest that the variables are not I(2). The sample period is altered to determine whether these results change[12]. In this case all variables appear to contain a unit root and this will be assumed for the remainder of the paper[13].

b) Choice of Lag Length:

The minimum number of lags are included to comply 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 is also examined. In each case the null hypothesis is based on well-behaved residuals, and hence the higher the p-value, the more acceptable the model is. The results are shown in Table 3 in Appendix 1. In each case a lag length of 4 produces acceptable models.

[12] The sample period chosen is 1986Q1-2002Q4. From Figure 1 in Appendix 4 it is clear that prices are quite high and volatile in the early 1980s.
[13] Results are available upon request.

c) CHOICE OF JOHANSEN MODEL:

The Johansen model allows for intercepts and trends in both the cointegrating relationships and in the data. The Pantula (1989) test for deterministic components was used to determine the appropriate specification. In the traded sector an unrestricted constant model was estimated which assumes that there are no trends in the cointegrating relationships. The non-traded sector specified a model with linear trends in the variables and in the cointegration space.

d) CHOICE OF COINTEGRATING RANK:

The choice of the cointegrating rank is the most important step of the Johansen analysis. All subsequent results are conditional on the choice made. If the rank is too small then it is likely that true long-run hypotheses will be rejected in error. Conversely if the rank is too large, false long-run hypotheses are likely to be accepted too often (Kenny & McGettigan, 1996).

The choice of cointegrating rank is based on the trace test statistics, the results of which are in Table 4 in Appendix 1. A graphical analysis of the estimated cointegrating relationships also helps to assess the stability of the hypothesised relationships over time. The roots of the companion matrix can also be examined to see how close the largest roots are to the unit circle.

The results in Table 4 suggests that there is only one cointegrating relationship among the three variables in the traded sector. In the non-traded sector, there also appears to be only one cointegrating relationship. The next stage investigates the variables in terms of exclusion, stationarity and weak exogeneity.

e) EXCLUSION, STATIONARITY AND WEAK EXOGENEITY:

From the analysis, the results indicate that none of the variables should be excluded and the variables are not stationary by themselves[14]. Table 5 shows the results of the

[14] Results are available on request.

stationarity tests and this corresponds to the hypothesis that all variables are I(1)[15]. The results of the weak exogeneity tests are in Table 6. In Model 1, there is one cointregrating relationship and the analysis suggests that both the exchange rate and foreign prices are weakly exogenous. Model 2 suggests that the wage variable is weakly exogenous.

f) LONG-RUN HYPOTHESIS TESTING:

The following analysis tests long-run hypotheses for both models. Table 7 shows the results for the traded sector. The first row of the Table shows the result when the traded price variable is chosen as the normalising variable. The coefficient estimates on the foreign price and exchange rate variables are quite close to the hypothesised values of 1 and -1 respectively. The strongest case of PPP is tested and is not rejected with a probability value of 0.59.

Table 8 shows the results for the non-traded sector. When the non-traded price variable is chosen as the normalising variable the coefficient estimate on the wage variable of 0.93 suggests wage/price equality in the long-run. This equality together with productivity factors is accepted with a probability value of 0.19. The productivity variable has a positive effect on prices. This appears contrary to prior beliefs, as we would expect an increase in productivity to reduce prices. Productivity is measured for the whole economy and not just the non-traded sector[16]. The model also includes a trend variable and it has a significantly negative effect on non-traded prices. A possible explanation for this contradictory result rests with the fact that productivity is measured for both the traded and non-traded sector. Aggregate productivity increases lead to increased demand in the non-traded sector causing demand-pull inflation in that sector. Therefore this is the Balassa-Samuelson effect where higher demand in the non-traded sector is pushing up wages. The negative trend coefficient may be used to estimate the limit at which the Balassa-Samuelson effect kicks in[17].

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[15] This confirms the previous unit root tests results for the shorter sample period.
[16] Unfortunately such a sectoral breakdown was not possible given the unavailability of data.
[17] The sample was split in order to check the stability of the parameters and they were found to be stable.

Cointegration Analysis 2: ARDL approach:

As an alternative to the Johansen procedure[18] an Autoregressive Distributed Lag (ARDL) Model approach to cointegration was estimated. This analysis is also based on a lag length of 4. The results from the Johansen procedure where world prices and the exchange rate were found to be weakly exogenous justifies the use of the ARDL approach. It is not as appropriate in the non-traded sector as productivity was found to be endogenous. General to specific modelling was undertaken until all coefficients were significant and the residuals well behaved. Table 1 in Appendix 2 shows the results for the traded sector. The lags of traded prices have a significant effect in explaining traded prices. World prices and the exchange rate are also quite significant. The analysis also includes a dummy variable for the early period of the 1980s when prices were substantially high and volatile. Given the nature of the series seasonality effects are also included and are very significant. The model is a good fit with an R^2 of 0.998. The statistics for the AR and ARCH errors refer to p-values. The null hypotheses are that we do not have serially correlated or ARCH errors respectively. Based on the large p-values we would not reject the null hypotheses and conclude that the residuals are not serially correlated and the model does not contain ARCH errors. Similarly the Normality Test is based on the null hypothesis of normal residuals and this cannot be rejected.

Table 2 in Appendix 2 shows the corresponding long-run solution for traded prices based on the ARDL solution in Table 1. World prices and the exchange rate are very significant. The coefficient estimates are interesting and are quite close to the expected value of 1 and –1 respectively. The dummy and seasonality variable are also significantly different from zero. The residuals were tested for a unit root and were found to be I(0) thus suggesting that a cointegrating relationship exists.

Table 3 gives the ARDL solution for the non-traded sector. The first lag of non-traded prices is very significant in explaining non-traded prices. Wages and productivity also have a significant effect on non-traded prices. The model also includes a trend variable, which is very significant. This has the effect of reducing prices. The dummy

[18] The Johansen procedure and subsequent tests were analysed and estimated using CATS in RATS. The ARDL approach was estimated in Givewin.

and seasonal variables are significant and are defined as in the traded sector. The model is a good fit with an R^2 of 0.999 and we cannot reject the null hypotheses of serially uncorrelated errors. Thus the residuals are well behaved and we cannot reject the null hypothesis that they are based on a normal distribution.

Table 4 gives the corresponding long-run solution for non-traded prices based on the ARDL solution in Table 3. The wage variable is very significant and is very close to the hypothesised value of 1. The productivity variable is significant and has a positive effect on non-traded prices and the trend coefficient is negative. This is similar to the results found when the relationship was estimated using the Johansen procedure.

SHORT-RUN DYNAMICS:

This section estimates a short-run equation for traded and non-traded inflation based on the long-run structures 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 removable does not generate undesirable properties in the residuals.

1. *Traded prices:*

Table 1 in Appendix 3 gives the short-run results for the traded sector using the long-run structure identified in Appendix 1. This error correction form imposes the long-run PPP relationship, which implies complete long-run pass-through from the exchange rate and world prices into domestic traded prices. The adjustment coefficient on the long-run PPP relationship contained in ECM1 implies significant adjustment at approximately 4.8% per quarter. This suggests a half life of deviations away from PPP of approximately 14 quarters.

Economic theory offers little insight concerning the coefficients on the other short-run variables in Table 1. The lags of traded price inflation are positively significant and indicate short-run persistence in the traded sector. The percentage change in the exchange rate and world prices are also significant in explaining traded price inflation. Oil price inflation is also included in the short-run equation and is quite significant and correctly signed. The model is a good fit and we cannot reject the hypotheses of serially uncorrelated and normal residuals.

The results in Table 2 refer to the ARDL solution for the traded sector from Appendix 2. This error correction form does not impose complete long-run pass-through from the exchange rate and world prices but it is relatively close. There is estimated to be almost complete pass-through from world prices and 86% pass-through from the exchange rate. The adjustment coefficient on this relationship is higher than in Table 1 at 6.8% per quarter. This implies a half life of deviations away from equilibrium of 10 quarters. This appears to be an improvement over the previous results. The ECM2 coefficient is also more significant than ECM1. The remaining short-run variables are similar to those in Table 1. The fit of the model at 0.75 is quite good for a differenced model and we cannot reject the null hypotheses of uncorrelated and normal residuals.

2. Non-traded prices:

Table 3 in Appendix 3 gives the short-run solution for the non-traded sector using the result identified in Table 7 of Appendix 1. The adjustment coefficient is very high and significant at 16.5% per quarter. This implies a half life of deviations away from equilibrium of 4 quarters. The other short-run variables warrant some attention. The lag of percentage changes in wages appear to have a significant and negative effect on non-traded price inflation. Productivity also has a statistically significant effect on non-traded prices. Surprisingly oil price inflation also appears to have a role to play in non-traded price inflation. This may represent the effect of external price pressures on the domestic economy. The fit of the overall model is good at 0.82 and we cannot reject the null hypotheses of uncorrelated and normal residuals.

Table 4 in Appendix 3 gives the short-run solution for non-traded prices using the ARDL approach. The coefficient on the wage variable in the long-run was found to be close to 1. The adjustment coefficient is very significant at 15.4% per quarter. This implies a half life of deviations away from equilibrium of 4 quarters. The model for the non-traded sector represents the quickest adjustment back to equilibrium (compared with 10 quarters in the traded sector). The other short-run variables are similar to Table 3. The model is a good fit with $R^2 = 0.82$ and the residuals appear to be well behaved.

In summary, the most appropriate model for traded price inflation would appear to be the model which does not impose PPP, but which allows incomplete pass-through and seasonality effects[19]. In the non-traded sector allowing for trend and productivity effects and imposing wage/price equality gives good results in terms of deviations away from long-run equilibrium. The next step is to determine the forecasting performance of the models identified above.

5. FORECASTING AND FORECAST EVALUATION:

Traded prices:

Firstly a graphical analysis will be examined in terms of the forecasting performance of each model. In Appendix 4 Figure 1 shows the quarterly percentage change in actual traded prices for the period 1980Q1 to 2002Q4. Prices were quite high and volatile until 1982Q2. Traded price inflation averaged 4.7% between 1980Q1 and 1982Q2. This compares with an average of 0.8% for the remaining period 1982Q3 to 2002Q4. The effects of the oil price shocks and fiscal intervention influenced the early period of the sample.

To assess the out-of-sample forecasting performance of the model some observations at the end of the sample period are not used in estimation but are instead forecasted using the model and then compared against the actual data. The out-of-sample forecast period is from 1997Q1 to 2002Q4. In Figure 1 the forecast for traded prices arises from the model that imposes PPP. The model performs well in terms of its forecasting performance. It clearly identifies the main turning points and is very close to the actual outcome.

[19] The Johansen model can also include seasonality effects but its main purpose was to identify the number of cointegrating relationships and exogenous variables. The results from both approaches are quite similar and are not contradictory.

Figure 2 shows the out-of-sample forecast performance of the ARDL solution for traded prices. This corresponds to the model identified in Table 2 of Appendix 3. This model also performs well in terms of its forecasting ability. However, it seems to under-forecast in the later years and based on a purely graphical analysis it is not as good as the PPP solution in forecasting traded price inflation. This is a surprising result as given the results in Tables 1 and 2 the ARDL solution had a quicker and more significant adjustment coefficient than that for PPP. This suggests that PPP may be a long-run solution and thus is better at forecasting further out. However this analysis was based purely on a graphical examination and a more appropriate test relies on the forecast error.

To compare the forecasting ability of both models the out-of-sample forecast period 1997Q1 to 2002Q4 was examined. Denoting the forecast error as $e_t = X_t - X^*_t$ (i.e. the difference between the actual and forecast value), then the following statistics can be calculated:

$$\text{ME} = \frac{1}{F}\sum_{i=1}^{F} e_t \qquad (15)$$

$$\text{MAE} = \frac{1}{F}\sum_{i=1}^{F} |e_t| \qquad (16)$$

$$\text{RMSE} = \sqrt{\frac{1}{F}\sum_{i=1}^{F} (e_t)^2} \qquad (17)$$

$$\text{Theil's U} = \sqrt{\frac{1}{F}\sum_{i=1}^{F} (e_t)^2} \Big/ \sqrt{\frac{1}{F}\sum_{i=1}^{F} (e_t^N)^2} = RMSE \big/ RMSE^N \qquad (18)$$

where ME refers to the mean error, MAE is the mean absolute error and RMSE refers to the root mean squared error. F is the number of out-of-sample observations used for forecasting and N refers to the naive forecast of no change in the series from the last available observation. If the ME's for each step is either positive or negative this suggests that the model specification can be improved. The model is forecasting too low on average if the ME is positive or too high if the ME is negative (Meyler, 1998).

If the ME is of the same magnitude as the MAE this indicates that the model is either forecasting too high (ME is negative) or too low (ME is positive). The RMSE is always as large as the MAE. They are only equal if the errors are exactly the same. The Theil's U statistic calculates the ratio of the RMSE of the model to the RMSE of the "naive" forecast. The "naive" forecast assumes no change in the dependent variable from the last period. Therefore a Theil statistic of 1 indicates that, on average, the RMSE of the model is the same as the "naive" model, and thus the "naive" model performs just as well as the chosen model. A Theil statistic greater than one would lead to a reconsideration of the model as the "naive" model performs better on average. However, a Theil statistic less than 1 does not lead to automatic acceptance of the model but it does indicate that, on average, it performs better than the "naive" model.

Table 1 in Appendix 5 shows the forecast statistics for traded prices using the PPP solution. To assess the out-of-sample forecasting ability of the model some observations at the end of the sample period are retained and are not used to estimate the model. The forecast statistics were calculated by estimating the model over the period 1980Q1 to 1996Q4 and forecasting four steps ahead recursively until 2002Q4. The mean errors are significantly lower than the mean absolute errors. This suggests that the model is neither systematically under or over forecasting traded price inflation. However the mean error is systematically positive which suggests that the model can be improved. The RMSE varies between 0.41% and 0.58% and this compares with average inflation for the forecast period of 0.82%. The Theil statistic is well below unity and thus outperforms the "naive" model.

The forecast statistics for traded price inflation using the ARDL solution are in Table 2 of Appendix 5. The mean error is consistently lower than the mean absolute error, thus suggesting that the model neither under-forecasts or over-forecasts traded prices. The RMSE is higher than in Table 1 and varies between 0.58% and 0.69%. The Theil statistic is also below unity indicating that it is better than the "naive" model but it is higher than for the PPP solution. Thus it appears as though the PPP solution is performing better in terms of its forecasting ability.

Non-traded prices:

Figure 4 in Appendix 4 shows the quarterly percentage change in non-traded prices for the period 1980Q1 to 2002Q4. Similar to traded prices, non-traded prices were quite high and volatile in the early period of the sample. Between 1980Q1 and 1982Q2 the quarterly percentage change in non-traded prices was approximately 4.3%. For the remaining period 1982Q3 to 2002Q4 the quarterly percentage change was approximately 1%. The out-of-sample forecast period in the graph refers to the period 1997Q1 to 2002Q4. The forecast refers to the wage/price equality model in Table 3 of Appendix 3. The model appears to over-forecast in the early period and under-forecast in the later period.

Figure 5 in Appendix 4 shows the forecast performance of the ARDL solution for the non-traded sector (Table 4 Appendix 3). This model had a large and significant adjustment coefficient. The model seems to perform well in terms of forecasting, particularly in the later years. Figure 6 compares both models. Both models identify the turning points quite well, however the forecast from the ARDL solution appears to be closer to the actual data.

Table 3 in Appendix 5 gives the forecast statistics for the wage/price equality solution. The mean error is consistently lower than the mean absolute error which implies that it is neither under or over-forecasting non-traded price inflation. The RMSE varies between 0.46% and 0.51%. This compares with a quarterly average in non-traded prices of 1.5%. The Theil statistic is below unity but quite high at 0.95.

The results for the ARDL solution are in Table 4. The sign of the mean error varies by step and it is lower than the mean absolute error, therefore the model neither systemically under-forecasts or over-forecasts non-traded inflation. The RMSE is lower for the ARDL solution and varies between 0.42% and 0.44%. The Theil statistic is also lower for the ARDL model and thus it performs better than the “naive” model. Based on the forecast statistics and graphical analysis the preferred forecasting model for the non-traded sector would have to be that based on the ARDL solution.

6. CONCLUSION:

This paper attempted to model the price determination process in Ireland. Prices were divided between the traded and non-traded sectors of the economy. In the traded sector prices were modelled on world prices and the exchange rate. In the non-traded sector wages and productivity effects were assumed to determine prices. In the case of traded prices, pure purchasing power parity (PPP) was not rejected by the data. The estimated adjustment coefficient in this case demonstrated that a half life of deviations away from equilibrium would take approximately 14 quarters. In the case of non-traded prices wage/price equality was not rejected by the data. When this was imposed the adjustment coefficient implied a half life of deviations away from equilibrium of approximately 4 quarters.

Both models were used for forecasting purposes. In the traded sector the model that performed best in terms of its forecasting performance was the model that imposed PPP. This suggests that PPP may represent a long-run solution. In the non-traded sector the model that produced the best forecasts was the one that allowed for trend and seasonality effects and did not impose wage/price equality.

The results highlight the difference between the determinants of traded and non-traded inflation. An interesting area for future research would produce a model that links these two sectors together. An attempt was made in this analysis to link the two sectors together by estimating 3 equations: wages, traded and non-traded prices. The unemployment rate was included in the wages equation. This proved to be insignificant. As an alternative to link the sectors together, the expression $(W_t - P^T{}_t)_{-1}$ i.e. the lag of the real wage in the traded sector was included in the short-run equation for non-traded prices. However, this was found to be insignificant. Perhaps estimation of a production function for both the traded and non-traded sectors of the economy would be useful. In this way wages in the traded sector could influence prices in the non-traded sector. However this is beyond the scope of this paper and is an area for future work.

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APPENDIX 1:

COINTEGRATION ANALYSIS 1: JOHANSEN PROCEDURE

TABLE 1: UNIT ROOT TESTS

Variable	Number of Lags	ADF
P^T	1	-7.7912*
P^N	3	-2.1043
P^*	1	-1.4200
W	1	-3.8304*
E	1	-2.1034
PROD	1	-1.7403

ADF = Augmented Dickey Fuller Tests.
Critical value at the 5% significance level = -3.4614.
* Null of I(1) is rejected.

TABLE 2: UNIT ROOT TESTS

Variable	Number of Lags	ADF
ΔP^T	3	-6.5912*
ΔP^N	3	-3.5298*
ΔP^*	0	-6.6914*
ΔW	2	-4.7975*
ΔE	0	-6.8192*
ΔPROD	0	-15.4801*

ADF = Augmented Dickey Fuller Tests.
Critical value at the 5% significance level = -2.8951.
* Null of I(2) is rejected.

TABLE 3: CHOICE OF LAG LENGTH

Model	Lag length	LM1	LM4	Normality
		p-value	p-value	p-value
1 P^T, E, P^*	4	0.18	0.89	0.48
2 P^N, W, PROD	4	0.35	0.95	0.50

TABLE 4: TRACE TESTS

Model	Eigenvalue	Trace	90% C.V.	H_0=r
1 P^T, E, P^*	0.1696	33.86*	26.70	0
	0.0699	11.27	13.31	1
	0.0318	0.04	2.71	2
2 P^N, W, PROD	0.3675	53.22*	39.08	0
	0.1147	14.28	22.95	1
	0.0451	3.92	10.56	2

TABLE 5: STATIONARITY TESTS

Model	r	$\chi^2(5)$	P^T	E	P^*
1 P^T, E, P^*	1	5.99	16.68	17.37	17.24
	2	3.84	8.30	8.47	8.23

Model	r	$\chi^2(5)$	W	PROD	P^N
2 P^N, W, PROD	1	7.81	36.05	35.39	35.86
	2	5.99	8.29	9.03	8.67

TABLE 6: WEAK EXOGENEITY TESTS

Model	r	$\chi^2(5)$	P^T	E	P^*
1 P^T, E, P^*	1	3.84	19.68	1.48	0.77
	2	5.99	30.03	1.89	3.92

Model	r	$\chi^2(5)$	W	PROD	P^N
2 P^N, W, PROD	1	3.84	1.77	20.13	15.12
	2	5.99	7.60	21.32	15.22

TABLE 7: TRADED PRICES: LONG-RUN HYPOTHESIS TEST RESULTS

Test	Hypothesis	Test Results	Significance	Estimated long-run relationship
1	$P^T = -\alpha E + \alpha P^*$			$P^T = -0.996E + 1.226P^*$
2	$P^T = -E + P^*$	$\chi^2(2) = 1.06$ P-value = 0.59	**	$P^T = -E + P^*$

TABLE 8: NON-TRADED PRICES: LONG-RUN HYPOTHESIS TEST RESULTS

Test	Hypothesis	Test Results	Significance	Estimated long-run relationship
1	$P^N = \mu W + \varphi PROD + t$			$P^N = 0.93W + 0.504PROD - 0.01trend$
2	$P^N = W + \varphi PROD + t$	$\chi 2(1) = 1.71$ P-value = 0.19	**	$P^N = W + 0.514PROD - 0.011trend$

APPENDIX 2:

COINTREGRATION ANALYSIS 2: ARDL APPROACH TO COINTEGRATION:

TABLE 1: ARDL SOLUTION FOR TRADED PRICES

	Coefficient	**t-value**
Constant	0.30	2.80
P^T_{t-1}	0.77	8.37
P^T_{t-2}	0.51	4.28
P^T_{t-4}	-0.38	-5.80
P^*_t	0.17	3.43
P^*_{t-3}	-0.35	-3.02
P^*_{t-4}	0.28	2.78
E_t	-0.13	-4.41
E_{t-3}	0.18	3.00
E_{t-4}	-0.13	-2.33
dummy	-0.01	-2.25
$Seasonal_{t-1}$	0.01	4.88
$Seasonal_{t-2}$	0.01	3.23

$R^2 = 0.998$ AR(1-5) = 0.18
DW = 1.91 ARCH(1-4) = 0.21
Normality Test = 0.66

Note: Statistics for normality and serial correlation refer to p-values.

TABLE 2: LONG-RUN SOLUTION FOR TRADED PRICES

	Coefficient	**t-value**
Constant	3.41	7.53
P^*_t	1.12	6.59
E_t	-0.86	-6.33
dummy	-0.14	-2.36
$Seasonal_t$	0.21	2.38

Long-run sigma = 0.09

TABLE 3: ARDL SOLUTION FOR NON-TRADED PRICES

	Coefficient	t-value
Constant	-0.33	-2.62
P^N_{t-1}	0.82	17.0
W_t	0.11	3.26
W_{t-4}	0.08	2.01
$PROD_{t-1}$	0.09	3.40
$Seasonal_t$	0.001	1.51
Trend	-0.002	-4.04
dummy	0.01	5.46

R^2 = 0.999 AR(1-5) = 0.60
DW = 1.81 ARCH(1-4) = 0.94
Normality Test = 0.16

TABLE 4: LONG-RUN SOLUTION FOR NON-TRADED PRICES

	Coefficient	t-value
Constant	-1.82	-2.22
W_t	1.05	10.3
$PROD_t$	0.50	3.15
$Seasonal_t$	0.01	1.35
Trend	-0.01	-4.93
dummy	0.08	2.89

Long-run sigma = 0.0260678

APPENDIX 3: SHORT-RUN DYNAMICS

TABLE 1: SHORT-RUN TRADED PRICES SYSTEM: PPP SOLUTION

	Constant	ΔP^T_{t-2}	ΔP^T_{t-3}	ΔE_{t-2}	ΔE_{t-3}	ΔP^*_{t-2}	ΔP^*_{t-3}	ΔOIL_t	$ECM1_{t-1}$
ΔP^T_t	0.214	0.386	0.268	-0.09	0.111	0.161	-0.23	0.172	-0.0478
	(2.86)	(4.93)	(3.37)	(-2.1)	(2.43)	(1.94)	(-2.7)	(5.38)	(-2.94)

$R^2 = 0.75$ DW=2.2

AR(1-5) = 0.40

Normality = 0.06

Note 1: $ECM1_t = P^T - P^*_t + E_t$.
Note 2: Statistics for normality and serial correlation relate to p-values.

TABLE 2: SHORT-RUN TRADED PRICES SYSTEM: ARDL SOLUTION

	Constant	ΔP^T_{t-2}	ΔP^T_{t-3}	ΔE_{t-3}	ΔP^*_{t-3}	ΔOIL_t	$ECM2_{t-1}$
ΔP^T_t	0.2278	0.3794	0.2133	0.096	-0.213	0.1654	-0.0678
	(7.57)	(5.65)	(3.26)	(2.30)	(-2.78)	(5.62)	(-7.51)

$R^2 = 0.75$ DW=2.2

AR(1-5) = 0.66

Normality = 0.27

Note: $ECM2_t = P^T - 1.12{*}P^*_t + 0.86{*}E_t + 0.14{*}dummy - 0.21{*}seasonal$.

TABLE 3: SHORT-RUN NON-TRADED PRICES SYSTEM: W/P SOLUTION

	Constant	ΔW_{t-1}	$\Delta PROD_{t-1}$	ΔOIL_t	ΔOIL_{t-2}	$ECM3_{t-1}$
ΔP^N_t	-0.269	-0.068	-0.059	0.09	0.048	-0.165
	(-5.79)	(-1.53)	(-1.89)	(4.21)	(2.44)	(-6.23)

$R^2 = 0.82$ DW=2.15

AR(1-5) = 0.42

Normality = 0.30

Note: $ECM3_t = P^N - W_t - 0.514{*}PROD + 0.011{*}trend$.

TABLE 4: SHORT-RUN NON-TRADED PRICES SYSTEM: ARDL SOLUTION

	Constant	ΔW_{t-1}	$\Delta PROD_{t-1}$	ΔOIL_t	ΔOIL_{t-2}	$ECM4_{t-1}$
ΔP^N_t	-0.282	-0.08	-0.065	0.10	0.047	-0.154
	(-10.6)	(-1.8)	(-2.13)	(4.67)	(2.30)	(-10.8)
	R^2 = 0.82		DW=1.97			
	AR(1-5)	= 0.87				
	Normality	= 0.56				

Note: $ECM4_t = P^N_t - 1.05*W_t - 0.50*PROD_t - 0.01*seasonal + 0.01*trend - 0.08*dummy$.

APPENDIX 4: FORECAST PERFORMANCE

Figure 1: Traded prices and forecast: PPP solution

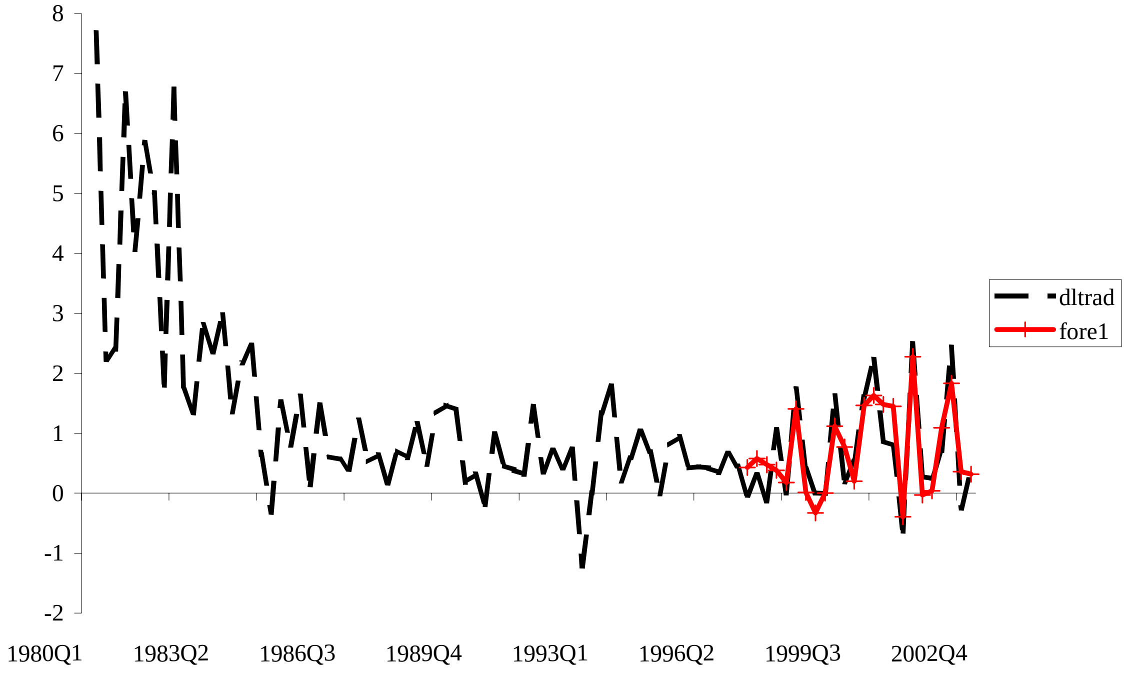


Figure 2: Traded prices and forecast: ARDL approach

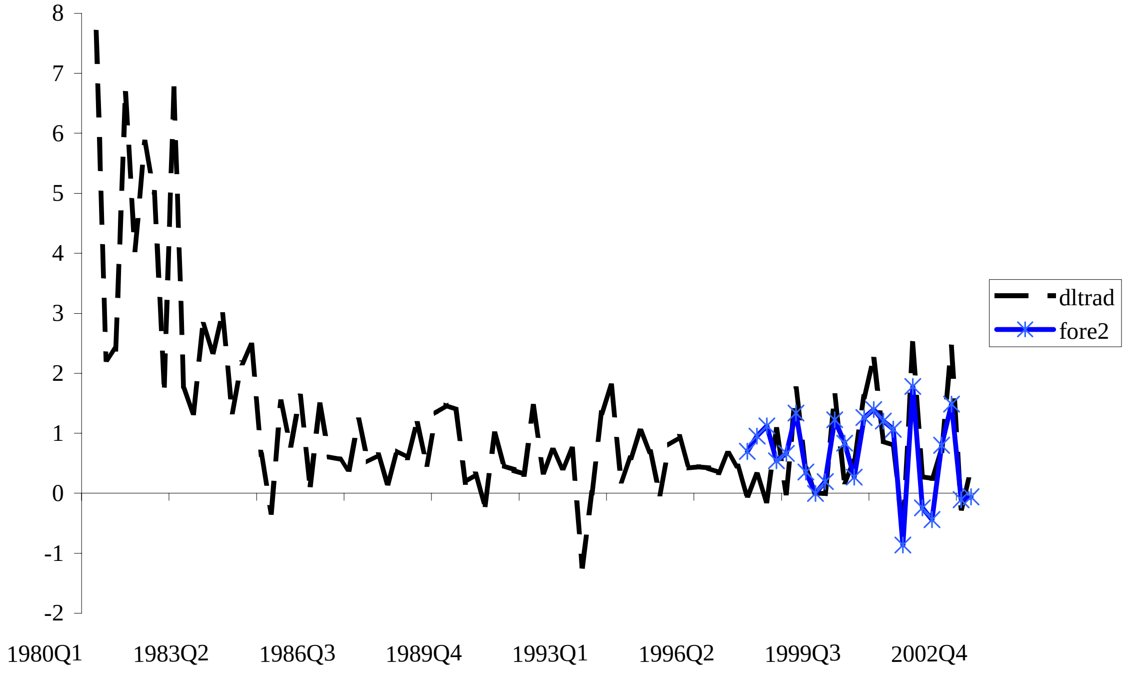


Figure 3: Traded prices and forecasts

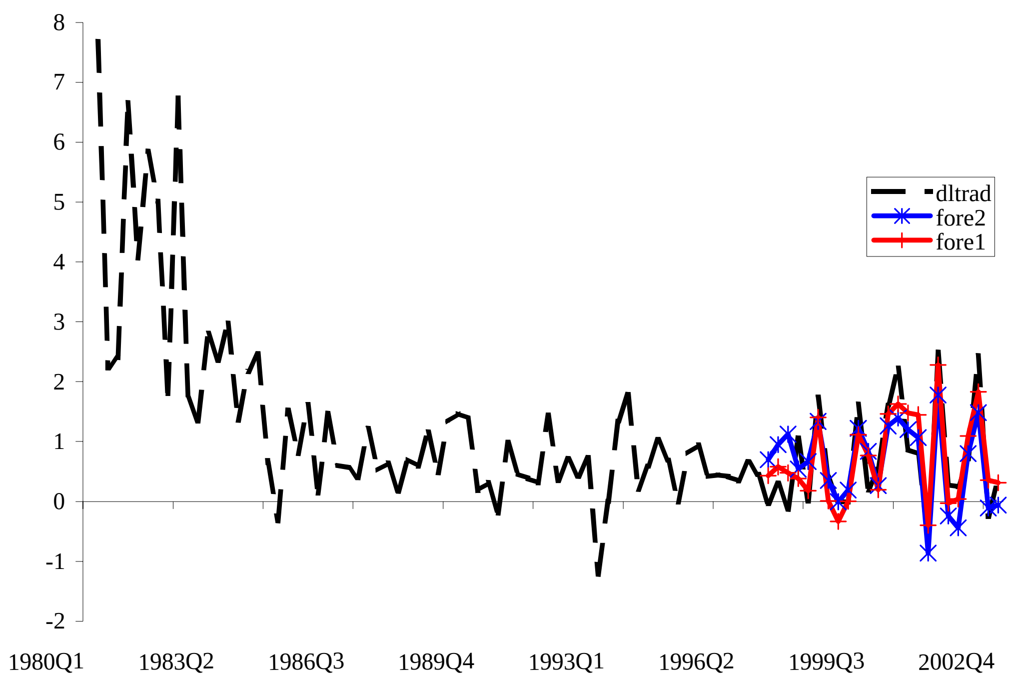


Figure 4: Nontraded prices and forecast: real wage solution

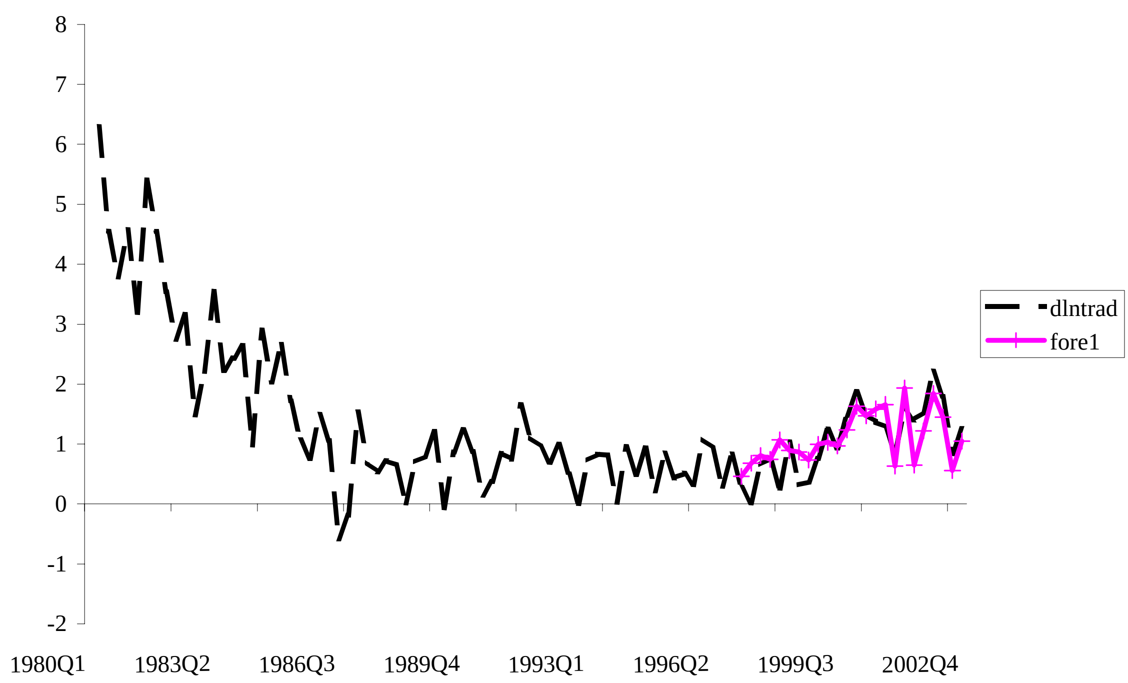


Figure 5: Nontraded prices and forecast: ARDL approach

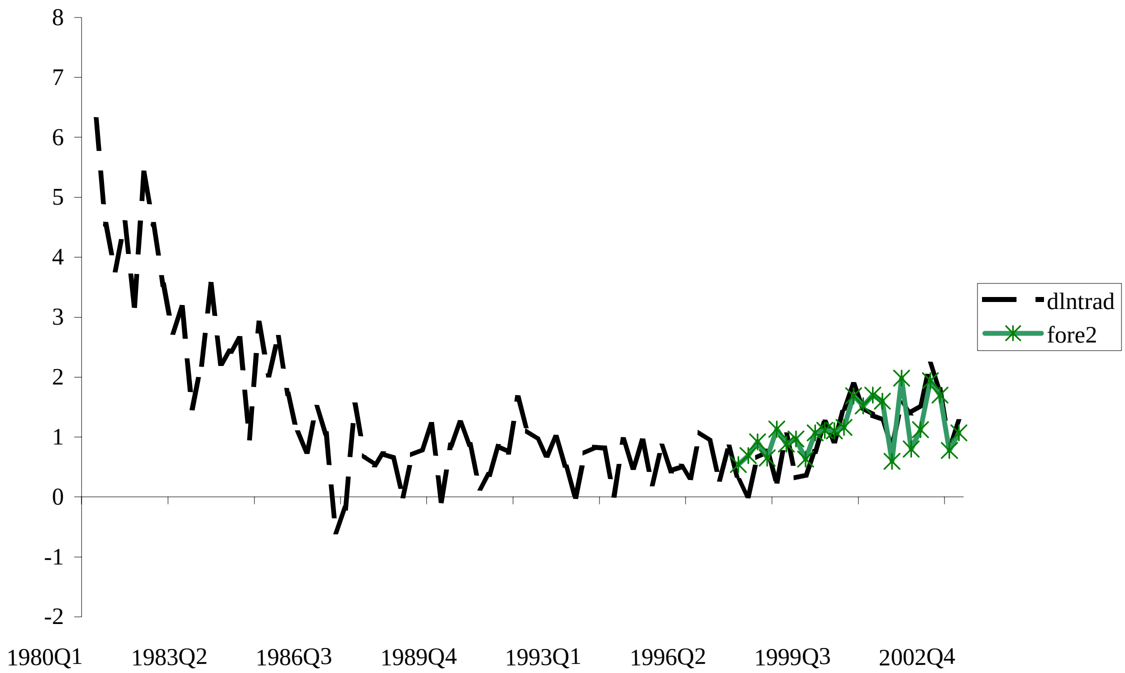
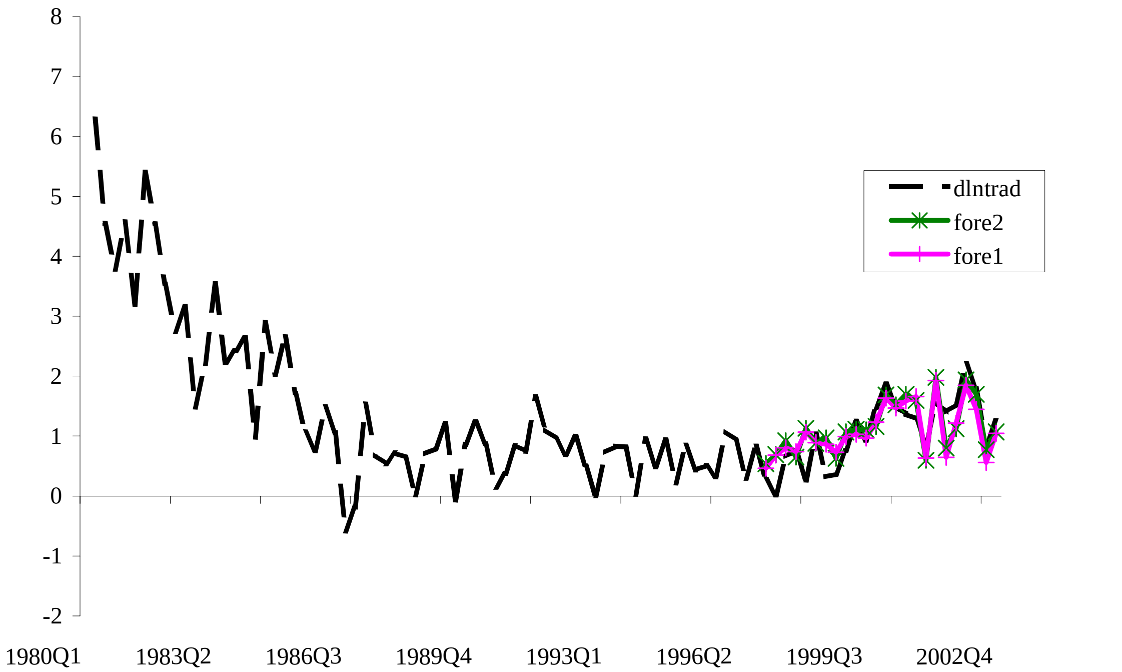


Figure 6: Nontraded prices and forecasts



APPENDIX 5: FORECAST STATISTICS

TABLE 1: FORECAST STATISTICS FOR TRADED PRICES: PPP SOLUTION[20]

Step	Mean Error	Mean Abs. Error	RMS Error	Theil U	N.Obs
1	0.08	0.47	0.55	0.41	24
2	0.11	0.46	0.54	0.42	23
3	0.18	0.49	0.58	0.46	22
4	0.26	0.43	0.50	0.58	21

TABLE 2: FORECAST STATISTICS FOR TRADED PRICES: ARDL SOLUTION

Step	Mean Error	Mean Abs. Error	RMS Error	Theil U	N.Obs
1	0.13	0.53	0.62	0.46	24
2	0.16	0.52	0.61	0.48	23
3	0.25	0.58	0.69	0.54	22
4	0.35	0.49	0.58	0.67	21

TABLE 3: FORECAST STATISTICS FOR NON-TRADED PRICES: W/P SOLUTION

Step	Mean Error	Mean Abs. Error	RMS Error	Theil U	N.Obs
1	0.08	0.36	0.46	0.95	24
2	0.11	0.37	0.47	0.81	23
3	0.16	0.37	0.48	0.89	22
4	0.18	0.39	0.51	0.82	21

[20] The statistics for Mean Error, Mean Absolute Error and RMS Error have been multiplied by 100.

TABLE 4: FORECAST STATISTICS FOR NON-TRADED PRICES: ARDL SOLUTION

Step	Mean Error	Mean Abs. Error	RMS Error	Theil U	N.Obs
1	-0.05	0.35	0.42	0.87	24
2	-0.04	0.36	0.44	0.75	23
3	0.00	0.35	0.42	0.79	22
4	0.02	0.36	0.44	0.70	21