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**INFLATION ANALYSIS: AN OVERVIEW**

**BY**

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The views expressed in this paper are the personal responsibility of the authors and are not necessarily held either by the Central Bank of Ireland or by the ECB. All errors and omissions are the authors'. Comments and criticisms are welcome.

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## **ABSTRACT**

The purpose of this article is to describe how inflation analysis and forecasting has been carried out in the Bank, with particular emphasis on recent research and the new challenges facing the Bank following the launch of the euro on 1 January 1999. Broadly speaking the approach adopted by the Bank over a number of years has been an eclectic one which combines judgement and a range of formal approaches. The latter include structural models which are strongly influenced by basic macroeconomic theories of the small open economy (SOE), indicator analysis, including a composite leading indicator, and time series methods such as autoregressive integrated moving average (ARIMA), vector autoregressive (VAR) and Bayesian VAR (BVAR) models. The emphasis on particular methodologies has evolved over time but in all cases judgement has played a central role.

## 1. INTRODUCTION

The primary focus of monetary policy, both in Ireland and elsewhere, has been the maintenance of price stability. In operational terms, this can be thought of as the maintenance of a low and stable rate of aggregate price inflation as defined by commonly accepted measures such as the consumer price index. In the period prior to the launch of the euro, the objective of price stability in Ireland was pursued, as in other small open economies in the European Monetary System (EMS), via an intermediate exchange rate target. Throughout the 1980s and in the 1990s (up to the end of 1998), monetary policy strategy was focused on the maintenance of the Irish pound within the exchange rate mechanism (ERM) of the EMS. The analysis of inflation played an important role in this strategy. In this context, the purpose of this article is to describe how inflation analysis and forecasting has been carried out in the Bank, with particular emphasis on recent research and the new challenges facing the Bank following the launch of the euro on 1 January 1999.

Broadly speaking the approach adopted by the Bank over a number of years has been an eclectic one which combines judgement and a range of formal approaches. The latter include structural models which are strongly influenced by basic macroeconomic theories of the small open economy (SOE), indicator analysis, including a composite leading indicator, and time series methods such as autoregressive integrated moving average (ARIMA), vector autoregressive (VAR) and Bayesian VAR (BVAR) models. The emphasis on particular methodologies has evolved over time but in all cases judgement has played a central role.

This reflects the fact that while individual formal approaches have particular advantages, they also tend to have certain limitations. In particular, model-derived forecasts often have relatively large confidence intervals around the point forecasts. Structural models are, however, useful in clarifying the relationships among the key macroeconomic variables which determine the rate of inflation and consequently provide a framework within which an eclectic approach to inflation forecasting can be applied. Unfortunately structural models often have difficulty dealing with regime changes such as the entry of the Irish pound into the EMS or the adoption of the euro. In addition, forecast errors from structural models can arise due to problems of mis-specification, measurement error and feedback from supposedly exogenous policy variables (the Lucas critique). In response to such problems, and the resulting poor forecast performance of structural models, atheoretical time series models, such as ARIMA and VAR models, are being used increasingly for forecasting in the Bank and elsewhere. These methods are not without their problems. For example, while efforts to obtain parsimony in structural modelling can lead to the exclusion of potentially useful information, time series models can suffer from overfitting problems whereby they allow for short term influences which have little explanatory power in uncovering the long term determinants of inflation. This ensures a good in-sample fit but can result in poor out-of-sample forecasting performance. The estimation of BVAR models allows the modeller to include all useful information attenuating problems of overfitting and lack of degrees of freedom.

In the Bank, ARIMA models have proved particularly useful in the analysis of short term (out to one year) trends in the overall harmonised index of consumer prices (HICP) and in sub-indices of the HICP while

BVAR analysis is more powerful when forecasting up to two years ahead. Other research topics currently underway include the estimation of core inflation and an examination of the determinants of services sector inflation.

In next section a brief outline is presented of the monetary policy strategy that will be followed by the European System of Central Banks (ESCB) and the role of inflation analysis and forecasting in this strategy. The following section will deal with structural models, indicator analysis, ARIMA and BVAR models. In addition, current research topics including, core inflation and services sector inflation are discussed.

## **2. CURRENT SETTING FOR INFLATION ANALYSIS**

The primary objective of the ECB, as mandated by the Treaty establishing the European Community, is the maintenance of price stability in the euro area. The Governing Council of the ECB has adopted the following working definition of price stability: *“Price stability shall be defined as a year-on-year increase in the Harmonised Index of Consumer Prices (HICP) for the euro area of below 2%”*. Furthermore, *“price stability is to be maintained in the medium term”* and reflecting the existence of short-term volatility in prices which cannot be controlled by monetary policy, the latter will have a *“forward-looking, medium-term orientation”*. This forward looking medium-term orientation motivates attempts to estimate accurate measures of core or noiseless inflation as discussed below.

The monetary policy strategy to be followed by the European System of Central Banks (ESCB) in pursuit of the primary objective of price stability was agreed by the governing council of the ECB at its meeting on 13 October 1998. This strategy has two key elements. First, money is assigned a prominent role and the relationship between broad monetary growth (M3) and its pre-announced reference value will be regularly and thoroughly analysed. Second, in parallel with the analysis of monetary growth, a broadly based assessment of the outlook for price developments and the risks to price stability in the euro area will play a major role in the ESCB's strategy.

Apart from their role as an input into monetary policy formulation, however, forecasts of Irish inflation are likely to have a continued - or perhaps even greater - role in other areas of economic policy-making. In particular, it has been argued that the sacrifice of monetary autonomy which results from Irish participation in EMU has increased the need to consider fiscal policy as a counter-cyclical demand management tool (or at least fiscal policy should not adopt a pro-cyclical stance). Arguably, therefore, the state of the economy and the inflation forecast should be given greater weight in the formulation of fiscal policy in Ireland than has been the case in the past. In addition, it is clearly the case that, notwithstanding the common currency which is shared by each participant in EMU, inflation differentials could arise between member states.<sup>1</sup> On the one hand, such differentials may be expected in the presence of

productivity differences between the traded and non-traded sectors of individual economies. However, should they become too large, such differentials may undermine a country's competitiveness. With a common currency in the euro area the forecast of Irish inflation is therefore essentially a forecast of the likely evolution of Irish competitiveness within the euro area. It is likely, therefore, to have an important role in the wage-bargaining process.

### **3. INFLATION ANALYSIS IN PRACTICE**

#### ***3.1 Structural Modelling of Inflation***

The SOE model of inflation and the concept of long run purchasing parity (PPP) underlie most structural models of Irish price determination both within the Bank and elsewhere. If absolute PPP holds then the price of a basket of goods domestically will equal the world price converted at the relevant nominal exchange rate. The SOE model posits that PPP holds and that domestic inflation equals the sum of the change in the world price and the change in the nominal exchange rate. Furthermore, in a fixed exchange rate regime, on the basis of price taking behaviour in a small open economy, domestic inflation will be entirely determined abroad. In a flexible exchange rate regime, however, if long-run PPP holds and the nominal exchange rate is depreciating then an analysis of domestic factors which may be contributing to the decline in the exchange rate such as

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<sup>1</sup> For a recent discussion and empirical analysis of this issue see Alberola and Tyrvaenen (1998).



excessive wage inflation, the fiscal stance and the rate of *ex ante* money creation also warrant analysis.

Most studies of Irish inflation during the 1970s when the Irish pound was linked to sterling accepted the long run implications of the SOE model, and the main area of disagreement centred on the speed of adjustment of domestic inflation to changes in world inflation. See, for example, Geary and Jones (1975), Geary (1976a, 1976b) and Bradley (1977). Since the 1980s however, following the entry of the pound into the EMS, more emphasis has been placed on domestic factors. Browne (1984), for example, found that changes in domestic monetary policy had an enduring effect on Irish inflation in the post-EMS period. Fountas, Lally and Wu (1995) found evidence of a role for wages in the determination of inflation. Callan and Fitzgerald (1989), however, found wages to be insignificant in the long-run determination of Irish inflation.

Flynn (1986) and Honohan and Flynn (1986) find support for the view that PPP holds in the long run and that changes in the exchange rate will eventually pass through fully to domestic prices. By contrast, O'Connell and Frain (1989) conclude that only about half of the effect of a change in the exchange can be identified as having passed through to domestic prices over a period of one year to eighteen months. Kenny and McGettigan (1998) find evidence to support the existence of very close to full pass through from exchange rate changes in the case of both Irish import prices and domestically competing prices in the long run but with a rather slow speed of adjustment, lending support to the existence of incomplete pass through in the short run.

Kenny and McGettigan (1999) apply a hybrid two-sector model which draws a distinction between traded and non-traded prices in order to assess the role of foreign prices, the exchange rate and wages as determinants of Irish inflation. They find strong evidence that long run PPP holds for traded goods. For non-traded goods strict PPP was rejected and a much weaker relationship was found to exist between external factors and non-traded inflation.

The emphasis in many of the structural models above was finding a model which best accounts for the in-sample properties of the data and not on forecasting performance *per se*. As discussed in Cecchetti (1995), good in-sample properties do not necessarily imply good forecasting properties. In fact, the confidence intervals around forecasts derived from structural models, even those primarily focused on forecasting performance are normally quite large and consequently need to be supplemented by complementary approaches such as indicator analysis and time series analysis

### **3.2 Inflation Indicators**

Several recent Central Bank of Ireland studies have specifically examined the information content of a variety of different inflation indicators. The basic findings of these studies are reviewed below in brief. To anticipate, these studies have in general found that the indicators under analysis invariably have *some* predictive power. However, it is also the case that the estimated econometric relationships are rarely found to be stable and this complicates their use in the formulation of monetary policy. This general finding is consistent with results in the international literature (see,

for example, Cecchetti, 1995), which point toward an inherent lack of stability in the relationships between most inflation indicators and inflation itself.

### *3.2.1 Monetary Aggregates/Financial Indicators*

Howlett and McGettigan (1995) concentrate on an analysis of the information content of monetary and credit aggregates using an astructural VAR methodology. The authors hypothesise that, following the widening of the exchange rate bands within the EMS in August 1993, the potential relevance of such variables in terms of forecasting Irish inflation may have increased. The results underline the need to extend the analysis of inflation beyond the closed economy model. Using a basic three variable VAR (including M1/M3, credit and prices), it was found that neither domestic money nor credit were strongly related to domestic consumer prices. Subsequently, the VAR was extended to include domestic output and short-term interest rates and, once again, this simple closed economy specification failed to reveal any significant explanatory power for either money or credit aggregates. However, when the VAR is extended to an open economy setting, i.e. including foreign monetary variables, the performance of the domestic monetary aggregates is enhanced. M3 is, for example, shown to have some significant predictive power at the longer forecasting horizon (5 years). Another interesting finding in this study, and one which is common across the international literature, is that prices explain a very significant proportion of their own variation.

McGettigan (1995) has examined the usefulness of the Irish term structure of interest rates as a possible tool in the construction of the inflation forecast. The paper uses discount functions to estimate the term structure

indirectly. Unfortunately, it is found that this approach to measuring the Irish term structure does not yield any significant information which could be usefully applied in the formulation of monetary policy. One possible explanation for this is that certain stocks in the Irish bond market have, in the past, been relatively illiquid and only traded infrequently.

### *3.2.2 Output Gap/Capacity Utilisation*

Following the large international literature which posits a relationship between the deviation of actual output from potential output (the output gap) and the rate of inflation, Kenny (1995) constructs a range of output gap measures for Ireland and examines their usefulness as predictors of inflation. A variety of techniques are employed to estimate the output gap for Ireland. These include simple/split trend approaches, peak-to-peak extrapolation, Hodrick-Prescott filters and also a structural model based on the estimation of an aggregate production function. The author examines the contemporaneous correlation between these output gap measures and inflation over the period 1960 - 1995. While the expected positive correlation is clearly evident over time and the output gaps are shown to Granger-cause inflation, like Cecchetti (1995), the author stresses the instability in this relationship across a number of sub-samples and, as a result, he questions the usefulness of the output gap in forecasting Irish inflation.

In another study, Kenny (1996) examines the predictive power of another measure of economic slack - capacity utilisation (CU) in the manufacturing sector. The analysis highlights the problems associated with surveyed measures of CU and emphasises the need to construct more formal estimates of CU which are grounded in economic theory. The short-run

information content of an estimated CU series is assessed by examining the contemporaneous correlation between CU and inflation and also using Granger-causality tests. A rise in CU is, in general, shown to be associated with a pick-up in inflation, but this effect is once again shown to be unstable. Interestingly, the relationship between CU and inflation is more robust for a measure of manufacturing sector CU which excludes production in the high-technology sector which is dominated by foreign multinationals. It is found, for example, that the measure of CU in the indigenous sector of Irish manufacturing explains 15% more of the variation in manufacturing output prices than does the corresponding measure for the entire manufacturing sector.

### *3.2.3 Leading Indicators*

A paper by Quinn and Mawdsley (1996) has examined the usefulness of a composite leading indicator of inflation. The methodology used is similar to that employed by Bicker (1993) for Dutch inflation. The basic idea is to find a set of time series which has cycles that resemble the inflation cycle itself. These series are then weighted together into a composite indicator using principal components techniques. A number of candidate component series were considered on the basis of economic relevance. Series were then ranked in terms of correlation with inflation and those with weak correlation or insufficient lead times were rejected. The series which were finally chosen as components of the leading indicator were M3, Irish output prices, UK output prices, manufacturing wages, world inflation (weighted using import shares) and the nominal effective exchange rate.

Rather than providing an accurate forecast of the level of inflation, the primary use of the indicator is as a predictor of inflation turning points. On this basis it has been found to perform reasonably well, especially since the mid-1980s.

### **3.3 Time Series Models**

Unlike structural models which impose restrictions based on economic theory, time series models are atheoretical models which use only the observed time series properties of data to forecast economic variables. There are a number of approaches available for forecasting economic time series. One approach, which uses only the past history of the time series being forecast plus current and past random error terms is known as univariate forecasting. Autoregressive integrated moving average (ARIMA) modelling is a specific subset of univariate modelling, in which a time series is expressed in terms of past values of itself (the autoregressive component) plus current and lagged values of a 'white noise' error term (the moving average component). An alternative approach is multivariate time series forecasting. In a multivariate model the series to be forecast is modelled as a function of current and past values of itself and other variables plus a random error term. One such model is known as the Bayesian vector autoregressive (BVAR) model. Two studies, one dealing with the use of ARIMA models (Meyler *et al*, 1998) for forecasting inflation, and another dealing with the use of BVAR models (Kenny *et al*, 1998) for the same purpose have recently been published by the Bank and are discussed below.

### 3.3.1 ARIMA Models

In their paper Meyler *et al* (1998) illustrate the use of ARIMA models in the forecasting of the harmonised index of consumer prices (HICP) and a number of sub-indices of the HICP. The forecasting of the sub-indices: unprocessed foods, processed foods, non-energy industrial goods, energy and services, is central to the short term analysis of price data which in turn complements the forecasts of inflation and the real economy over the medium term. A semi-automatic algorithm was developed for fitting an ARIMA model to stationary time series data. Optimal ARIMA models were selected using objective penalty functions which optimised the trade-off between in-sample goodness-of-fit and model parsimony. In general, for the HICP and its sub-components, a relatively parsimonious ARIMA representation was found to be optimal both for fitting in-sample and for maximising the out-of-sample forecasting performance reflecting the relative stability of inflation over the period of the sample and the dominance of seasonal influences. In terms of forecast performance, ARIMA models were most successful forecasting out to an horizon of one year. Forecast errors were lower for the overall HICP than for its sub-components. The highest root mean square error (RMSE) at 1.9 per cent per quarter was found in the case of seasonal food. For the overall HICP, the RMSE varied between 0.43 per cent and 0.38 per cent for horizons up to six quarters out implying a 90 per cent confidence interval of approximately 1.4 per cent per quarter. While this appears relatively high, it compares favourably with results reported by Cecchetti (1995) for the United States who calculated a 90 per cent confidence interval of approximately 1.3 per cent for one step ahead inflation forecasts by commercial forecasters. Over horizons of one year or less, ARIMA

models outperform BVAR models as reported below, but are less successful at longer horizons.

### 3.3.2 *Bayesian VAR Models*

Kenny *et al* (1998) use the Bayesian approach to the estimation of vector autoregressive (BVAR) models developed by Doan, Litterman and Sims (1984). In contrast to structural macroeconomic models, a VAR is a set of dynamic linear equations in which each variable is determined by every other variable in the model. VAR models have been criticised insofar as they lack strong theoretical justification over and above the use of theory as a guide in deciding which variables to include in the analysis. Doan, Litterman and Sims (1984) in an attempt to improve the forecasting performance of unrestricted VAR models suggested that they could be estimated using Bayesian techniques which take account of any prior information which may be available to the modeller. Kenny *et al* evaluate this approach to the forecasting of inflation in Ireland, as measured by the HICP. Three possible models are considered. The first baseline model was a three variable SOE model including the HICP, the import-weighted measure of foreign consumer prices and the nominal effective exchange rate. In addition, two augmented SOE models were considered, one augmented to account for the interaction between wages, prices and domestic demand, and another which extends the SOE model to account for a possible role for domestic credit and short term interest rates. In all three models, the Bayesian approach to parameter estimation resulted in a dramatic improvement in forecasting performance relative to unrestricted models. Even the best performing Bayesian autoregression, however, had a confidence interval of about 1.5 per cent per quarter based on forecast errors computed over the period 1992-1998. Reflecting the robustness of



the simple SOE model of inflation, neither of the augmented models could improve on the base line SOE model. When compared to the ARIMA model of the HICP, the Bayesian VAR approach performed better at longer horizons of five to eight quarters but was less accurate than the ARIMA model over the shorter term out to one year.

## **4. CURRENT RESEARCH**

### ***4.1 Core Inflation***

A medium term forward-looking monetary policy has been adopted by the ECB reflecting the existence of short term volatility in measured inflation which is not amenable to control by monetary instruments and is unrelated to underlying trends in inflation. In analysing high frequency price data, such as the monthly consumer price index (CPI) and HICP which has been available for Ireland since January 1997, it is important to be able to distinguish between movements in underlying price trends which constitute core inflation and short term ‘noise’. There are a number of sources of noise in high frequency price data including changing seasonal patterns, exchange rate changes, indirect tax changes and idiosyncratic shocks in specific markets.

A common approach to the estimation of underlying core inflation is to omit certain categories of goods such as mortgage interest or, most commonly, seasonal food and energy which are regarded as being more volatile than other components of the CPI. Ironically, in the case of the US, Cecchetti (1996) found that the exclusion of seasonal food and energy

resulted in a series that was more volatile than the original CPI. A statistical approach to the estimation of core inflation currently being examined in the Bank involves the construction of limited influence estimators such as trimmed means which remove outlying observations at either end of the distribution of price changes. In addition an alternative approach, developed by Quah and Vahey (1995) is being pursued which involves the estimation of a structural VAR (SVAR) model which identifies a measure of core inflation defined as that component of measured inflation which has no long-run impact on output.

#### **4.2 Services Sector Inflation**

Services constitute about one third of the overall HICP index. While traded goods price inflation, which has been anchored by strong disinflation trends in the world economy, has remained low in Ireland in recent years, there has been a gradual acceleration in underlying inflation in the services sector. Reflecting the non-traded and relatively labour intensive nature of many services, inflation in the sector is often modelled as being a function of wages adjusted for productivity improvements. However, the ‘catch all’ classification services does not represent a homogenous group of activities but covers a wide range of heterogeneous activities. As a first step in Bank research attempting to model services sector inflation in Ireland, the services sector has been decomposed into a number of sub-categories. These are administered services, alcohol-related services, services which are in transition from having essentially administered prices to being fully-contested services, and general domestically- contested services. The first two categories, administered and alcohol-related services are heavily influenced by government taxation and administrative decisions which are difficult to model. Transition

services refers to just telecommunication services, but may in the future include items such as public transport (bus), taxi or electricity. It is probable that continued price decreases will be observed in this area especially as the domestic telephony market has been opened up to competition and given the pace of technological change in this field. PPP or wage-mark-up models would be unsuitable for modelling this component, at least during the transition phase. The final category of services, general domestically-contested services is considered the most promising candidates for successful modelling.

## **5. SUMMARY AND CONCLUSIONS**

Inflation analysis constitutes a key input into euro area monetary policy and, reflecting the principle of subsidiarity, the NCBs including the Central Bank of Ireland will play an important role in this regard. In addition to its input into euro area monetary policy, analysis of Irish inflation will play an important role in assessing the appropriateness of the fiscal stance and in assessing likely trends in Irish competitiveness in the euro area.

The eclectic approach to inflation forecasting adopted in the Bank combines a range of formal approaches including structural models, time series methods and indicator analysis with an important role for judgement. Recent research has focused on the development of time series models such as ARIMA and BVAR models. Reflecting the need to uncover information about the true underlying trend in inflation from recently available monthly data and the medium term focus of policy concerns,

research is under way into the construction of a measure of core inflation. In addition research has begun into the modelling of inflation in domestically-contested services.

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