EXCHANGE RATE CHANGES AND
THE TRANSMISSION OF INFLATION

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Introduction

The focus of much of the research into the determinants of Irish inflation has, in the past, concentrated on whether Purchasing Power parity (PPP) does or does not hold. There has also been much research into this issue for other countries. The results of this research suggest that PPP probably does hold in the long run but that the long run can be quite long. However, it is clear that the process driving inflation in the short-run is rather different and more complex. Short-run changes in the exchange rate clearly do not have an immediate effect on the rate of inflation in consumer prices in Ireland and the deviations from PPP can be quite large and sustained for some considerable time. This paper concentrates on the factors driving inflation in consumer prices in the short run in Ireland.

What makes the Irish case unusual is the extent of integration of the retail sectors in Ireland and the United Kingdom. Many of the retailers in Ireland are branches of UK chains and many of the goods sold by Irish retailers are sourced in the UK. With the growing integration of the retail chains in Europe in general, and in Ireland and the UK in particular, it is likely that this pattern of behaviour may be extended throughout the EU, one of the expected outcomes from the completion of the internal market. The implications of this for firms was early recognised in Smith and Venables (1987); with monetary union the ability to operate a differentiated pricing policy between different markets may be significantly reduced putting downward pressure on profitability and consumer prices.

Until the end of the 1970s, while there was a fixed relationship between the Irish pound and sterling, there was evidence that the Irish rate of inflation was externally determined by developments in the UK and that Irish prices adjusted quite rapidly to

price changes in the UK (Geary and McCarthy (1975) and Bradley (1977)).[1] While the retail sectors in the two jurisdictions were much less integrated than they are to-day, this relationship between the Irish and the UK inflation rates was not affected by the uncertainties induced, for both buyers and sellers, by fluctuations in exchange rates.

With the breaking of the sterling link in the first quarter of 1979 the situation changed markedly. Models of the inflationary process for the years after 1979 show a more uncertain picture with much slower adjustment to external shocks, in particular to changes in the exchange rate (O'Connell and Frain (1989), and Kenny and McGettigan, (1997). Callan and Fitz Gerald (1989) examined the pass through of exchange rate changes into domestic output prices and found that, while PPP probably held, the pass through of exchange rate changes was much slower than was the case for changes in foreign currency prices. They also found evidence of a change in regime in 1979, around the time of the break in the link with sterling when Ireland joined the EMS. Wright (1994) using output prices also concluded that PPP held in the long run.

The advent of monetary union from 1999 can also be expected to lead to a regime change. Part of the logic behind monetary union was that it would increase competitive pressures on firms throughout the Union putting downward pressure on prices (European Commission (1990)). Calmfors (1997) suggests just such an impact in Sweden if they were to join the Union. There is little of the micro-economic evidence available which would be needed to assess the likelihood of such an outcome. Within the Monetary Union itself there will obviously be no further exchange rate changes. However, for Ireland the fact that the UK remains outside the Union will be important. However, this does not mean that the UK itself will be immune from the effects of the regime change. Any increase in integration of the Union market may have consequential effects on the UK market. There could be a change in the speed of transmission of exchange rate shocks to the UK price level in

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[1] The evidence on the determinants of inflation in Ireland has been reviewed in Kenny and McGettigan (1997).

the future. It may also affect the pricing policy of UK firms in selling into the Union market. Whereas before EMU differentiation between markets in France and Germany or between markets in the Netherlands and Ireland may have been the norm, there may be a movement to a common euro price.

In Ireland much interest to-day focuses on why the rate of consumer price inflation has, until now, remained low in the face of a substantial fall in the effective exchange rate and there is considerable speculation that the rate of inflation may speed up in the immediate future. Does the unexpectedly slow adjustment to the change in the effective exchange rate indicate that a change is already taking place in the transmission of inflation to the Irish (and possibly the British) economy in the face of impending monetary union?

This paper considers the latest evidence on how the external rate of inflation is transmitted to consumer prices in Ireland. It focuses on the speed of adjustment of the domestic price level to changes in exchange rates in the short run, relying on the evidence from Wright (1994) and Kenny and McGettigan (1997) that PPP holds in the long run. Because of the importance of the UK as a source of Irish consumer goods, special attention is given to the effect of external shocks to the UK economy on the UK rate of inflation and on the pricing behaviour of UK firms on the Irish market. While exogenous to the Irish economy, the UK rate of inflation is itself affected by changes in the external price level and in the value of sterling. To understand the forces driving the rate of inflation in Ireland to-day it is necessary to model the adjustment process in Ireland jointly with that of the UK.

In modelling the inflationary process in Ireland we are interested in establishing:

- the pattern of adjustment of Irish consumer prices to external shocks, especially to changes in the exchange rate;

- whether there is any evidence that impending monetary union is resulting in changes in firms pricing behaviour;

- what the implications of our results are for the rate of inflation in coming months;

- the implications of our results for appropriate long run exchange rate parities.

Section 2 of this paper considers models of price determination at both a micro-economic and a macro-economic level. Section 3 estimates the model of price determination for consumer prices in Ireland and the UK. Section 4 considers the implications of these results.

Models of Price Setting

Firm Behaviour

The key to understanding the process whereby exchange rate changes affect prices lies in the behaviour of individual firms. If the market is perfectly competitive then price is equal to marginal cost and any change in the marginal cost of supplying a good in a particular country must be passed through as a rise in the price. For example, for a UK firm selling a product in the Irish market, assuming the market is perfectly competitive, any change in the bilateral exchange rate must be passed through as a change in the domestic (Irish pound) price. If this did not happen the firm would be operating at a price below its marginal cost, resulting in its closure. However, there is clear evidence that pass through of exchange rate changes is not instantaneous (see Hooper and Mann (1989) for the US, Menon (1996) for Australia, and Kenny and McGettigan (1996) for Ireland. Goldberg and Knetter (1997) review the evidence for all countries).

For many of the individual goods and services bought by consumers the markets are better characterised as being imperfectly competitive. As a result, in equilibrium, firms are likely to charge a price that is above marginal cost, with the mark-up being a function of the elasticity of demand in individual markets. Under these circumstances individual firms may pass through less than the full amount of any change in exchange rates with a consequential change in the margin. The larger the margin over marginal cost the greater the scope a firm has to vary the speed with which it passes through exchange rate changes.

Whether there is less than full pass through of exchange rate changes in the short run will depend on the degree of integration of the market. In a fully integrated market the possibility of arbitrage prevents firms from discriminating between different countries

to maximise profits. Under these circumstances the results should be close to the perfectly competitive case, with fairly full pass through of exchange rate changes into prices in individual retail markets. Thus if arbitrage by consumers (or by retailers) is likely, when the Irish pound changes against all other currencies the manufacturer will pass through the full effects of the exchange rate change, leaving the price in the different markets identical in common currency terms.

However, where firms are able to discriminate between markets, producers will maximise profits by charging different prices in each of them. Under these circumstances there is the real possibility that some of the effects of a change in exchange rates may not be fully passed through in the short run. This ability to discriminate between markets is facilitated by barriers to trade such as tariffs, excise taxes, and cultural factors giving rise to different marketing strategies by firms.

In an imperfectly competitive market, for many of the products sold to consumers the vendors have to invest significant amounts in market development, for example through marketing. Under such circumstances, where firms have to make irreversible investments in developing a market, they must be forward looking. As with all other forms of investment, such forward looking behaviour means that firms have to deal with the problem of uncertainty; uncertainty about the market itself, about competitors behaviour and, in particular, uncertainty about the future path of the exchange rate.

For branded products manufacturers invest heavily in different forms of marketing to build up their "brand image". This investment may take place over many years and the costs involved may be quite significant in terms of the overall cost of the product, and especially in terms of the profit margin. Even if a firm is losing money in the short-run it may be unwise to pull out of a market because of sunk costs in marketing. Decisions on pricing and overall market strategy must be considered within this wider context. This "investment" in developing a market means that firms have got to be forward looking.

Venables (1990) sets out a model of pricing to market which illustrates the importance of sunk costs (in developing a market) in determining pricing behaviour in the short run. Using his notation, the number of foreign firms is n^f, and the number of

domestic firms is n^d, each supplying one unit of output.[2] The price p is assumed to be a linear function of the quantity supplied with a being a constant.

$$P = a - \{n^d + n^f\} \tag{1}$$

The price will fall as the quantity (number of firms) increases. The cost of production for foreign firms is assumed to be one unit of foreign currency or e units of domestic currency where e is the exchange rate. For a foreign firm the short run profitability π^f of a unit of a unit of production sold on the domestic market is:

$$\pi^f = p - e \tag{2}$$

However, the cost of entering the market is significant. It is assumed that the cost for each firm is a fixed amount F in domestic currency terms per unit of output. Given sunk costs, firms will continue to operate in the domestic market provided that the profit which they earn is non-zero. It is only if the short run marginal cost is higher than the price that firms will exit. The exit of firms will push the price back up (1) until firms cease to exit. If the profit rises above the cost of entry then more firms will enter the market with a consequential dampening effect on prices. The market will be in equilibrium where condition (3) is satisfied:

$$F \geq \pi^f \geq 0 \tag{3}$$

For this model equation 3 describes a range within which prices will not change because there is no incentive for entry or exit. This equation applies just as much to changes in the cost of production as to changes in exchange rates. If e is interpreted as the cost of production in the firms "termed" foreign then any change in that cost of production will not produce price changes (entry or exit) if equation (3) still holds good.

So far this model does not suggest any difference in the response of prices to changes in costs compared to changes in exchange rates. What makes exchange rate changes

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[2] The domestic firms could also be firms located in a third country within the monetary union.

different is the uncertainty about their future path. In the case of increases in costs, especially labour costs, changes tend to be slow and relatively predictable compared to exchange rate changes. In modern economies it is very rare for labour costs to fall; generally they ratchet upwards. In a period of relatively low inflation, such as the present, the changes in any one year tend to be small relative to the changes which occur in exchange rates. On the other hand, exchange rates can change by large amounts in either direction causing a foreign firm's cost of production, denominated in domestic currency, to rise or fall by large amounts.

In the model discussed above, because there are costs to entering a market firms have got to plan ahead. If, for example, the exchange rate were to change (the domestic currency devaluing) so that profit, defined in (2) is negative, then under condition (3), where there is only a single period, firms would drop out raising prices. However, where firms are optimising over many periods the firms' decisions after period one will crucially depend on expectations about period two and subsequent periods. If they feel that the exchange rate will revert to its previous level and stay there then if they drop out in period one it will be profitable to them to re-enter in period two. However, under these circumstances they would have to pay the fixed cost for re-entry to the market and it may be profitable for them to maintain the option of access to the market by staying in for one period and taking a loss.

The result of such behaviour, where firms value the option of market access and when they are faced with an uncertain future exchange rate, would be to extend the range of exchange rates over which there would be no entry or exit and, hence, no change in prices. Delgado (1991) shows that even with quite small menu costs (fixed entry costs in this model), exchange rates may have to change by large amounts before prices might change. Delgado suggests that even with menu costs of only 0.1% of production costs, where a firm begins in the middle of the range (3), the exchange rate might have to change by 7% before prices would change. With menu costs of 1% exchange rates would have to move by 13%. In addition, he finds that under certain circumstances, with menu costs of 1% of production costs, the exchange rate can move by 50% and prices would still not be changed.

What this highlights is the importance of uncertainty about its future values in determining the potential pass through of exchange rate changes into prices. Dixit (1989) indicates that the greater the exchange rate volatility the more valuable the entry and exit options and, therefore, the less likely they are to be exercised. Because this uncertainty about the future is much greater for exchange rate changes than for changes in other costs, it is to be expected at a macro level that prices will react more slowly to changes in exchange rates than to changes in foreign country costs.

The size of the fixed cost of entry and the resulting cost of changing prices (menu costs) will differ depending on the type of firm and the nature of the good produced. For manufacturing firms the "investment" in market development will be a function of marketing, and for heavily branded goods, it could be quite high relative to the cost of the good itself. However, for a retailer the margin will typically be much smaller than for a manufacturer and the costs of changing price on individual items will be rather smaller.

The implications of this are that retailers can change price somewhat more rapidly than can manufacturers and that they have much less scope to absorb big changes in their costs without passing them through to their customers. Nonetheless evidence from the US suggests that the menu costs of changing individual prices are non-trivial at around 0.7% of revenue or 35% of net margins (Levy, Bergen, Dutta, and Venable (1997)). In the context of the model set out above, for retailers the cost of entry (F) for an individual product is likely to be small relative to the price of the good p. As a result, the range of values of the exchange rate within which retailers will not pass through price changes is likely to be small.

The implications of this are that effect of fluctuations in exchange rates on the costs of the retail sector are likely to be very large relative to the margins of retailers and that they will not be in a position to carry those risks. Retailers then have three possible choices:

- they pass the effects of exchange rate changes on to consumers as frequent price changes;

- they hedge against exchange rate changes; or

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- the manufacturer carries the exchange rate risk, contracting with retailers in their domestic currency.

The experience in Ireland and elsewhere is that consumers do not generally carry the risks involved in fluctuating exchange rates. The evidence is that pass through of exchange rate changes in Ireland and elsewhere is low in the short-term. This must reflect the fact that such uncertainty is costly for consumers. Indirect evidence of the effects of such uncertainty generated by price changes on consumer sentiment was provided by some of the work on the determinants of consumption in Ireland and the UK in the 1970s (Honohan (1979) and Davidson and Hendry (1977)).

Sinn (1990) took a rather apocalyptic view of the process of completing the internal market suggesting that all price differences (including those due to tax differences) would be eliminated through arbitrage by consumers;[3] a wave of cross-border shopping would sweep Europe enforcing PPP. While this could provide an alternative discipline forcing price adjustment, this has clearly not happened and Fitz Gerald, Johnston and Williams (1995) show that, because of travel costs, arbitrage by consumers (cross-border shopping) will only affect prices in narrow border areas.

While retailers could insulate themselves from the effects of exchange rate shocks in the short-run by hedging, this does not appear to be the norm. The slow speed of adjustment to exchange rate changes – typically more than a year – would be more difficult to hedge against in practice.

The evidence on the speed of exchange rate pass through in practice, and on the currency in which trade is usually denominated, strongly suggests that exchange risk is normally borne by the manufacturer. Mottiar and O'Reilly (1981) and Bannon (1996) indicate that the bulk of Irish exports are denominated in foreign currencies. This pattern is reflected in other countries, such as Sweden, where exports are increasingly denominated in foreign currencies (Friberg and Vredin (1996)). Hooper

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[3] The evidence on the determinants of inflation in Ireland has been reviewed in Kenny and McGettigan (1997).

and Mann, (1989) show that it is common practice for Japanese firms selling into the US market to hold their prices in dollars in spite of what are perceived to be temporary changes in the exchange rate. However, in the long run exchange rate changes do pass through into output prices and where firms in countries are price takers, such as in Ireland, relative purchasing power parity holds at the level of manufacturing prices.

With the completion of the internal market and the enforcement of rights to parallel import[4] one would expect that the commercial pressures enforcing purchasing power parity would increase. Consultations with the retail trade in Ireland tend to confirm this. In the face of major changes in exchange rates the large distribution firms in Ireland tend to put pressure on their suppliers to adjust their Irish pound prices, even if the terms of contracts do not necessarily require it. Presumably, similar pressures are exerted when exchange rates move in the opposite direction.

The micro-economic evidence on the behaviour of firms in the Irish market is limited. The report of the Restrictive Practices Commission (1988) which discussed pricing policy with a small number of Irish firms, gives evidence that firms take a medium term view of the likely path of exchange rates and set their prices accordingly. They are not normally blown off course by what may prove to be temporary fluctuations in the exchange rate. This policy reflects the fact that purchasers of the output of Irish firms like to be certain of the price they will pay in their own currency for the goods for which they contract. More of the risk from exchange rate changes is borne by the producer rather than by the consumer.

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[4]While a derogation from the treaty rules on competition is allowed permitting firms to grant exclusive distribution rights for their goods in different countries it is illegal for firms to prevent retailers in one country purchasing their goods in another country and importing it themselves (parallel importing). This acts as an important channel preventing significant long-term departures from purchasing power parity.

Modelling Price Determination

If the possibility that firms operating in Ireland face menu-costs or other costs significant enough to affect the rate and magnitude of their adjustment to changes in the exchange rate, and furthermore, if the market structure allows them to do so if they believe such changes are temporary, this has implications for the modelling of the Irish inflationary process. We cannot simply relate Irish prices directly to actual British prices; we must take account of the deviation of British prices from their long-run level. This means that we need to model Irish prices jointly with British prices. By developing long-run relationships for the UK and Ireland we can specify an error-correction model of Irish price determination in which the deviation of British prices from their trend level affects the pass-through of exchange rate changes into Irish prices.

Most models of British consumer prices use some sort of purchasing power parity relationship augmented by domestic variables such as wages, unemployment or the level of capacity utilisation. We make use of a model developed by Greenslade et $al.$ (1998), which uses a vector error correction methodology to study the movements of domestic (British) wages, consumer prices and import prices as a system which can be expressed in the following form.

$$\Delta Y_t = A(L)\Delta Y_{t-1} + B(L)\Delta X_t + \theta Z_{t-1} + v_t \tag{4}$$

Y_t represents the vector of wages, consumer prices and import prices, X_t represents a vector of weakly exogenous variables (productivity, the unemployment rate, world prices and the exchange rate, among others) and $Z = (Y, X)$. $A(L)$ and $B(L)$ are matrices of polynomials in the lag operator (L) and θ is a matrix of coefficients on the error-correction terms. By estimating all three equations together, they avoid arbitrary restrictions on the coefficients and are able to test the ones they do apply.

As it happens, Greenslade et $al.$ deduce that θ is in fact a diagonal matrix or, in other words, that there is only one cointegrating vector in each equation in wages, consumer prices and import prices. They are shown below, normalised about the dependent variable:

$$w^{UK} + \lambda_{11}p^{UK} + \lambda_{12}\Pi^{UK}$$

$$p^{UK} + \lambda_{21}w^{UK} + \lambda_{22}\Pi^{UK} + \lambda_{23}p^{IM}$$

$$p^{IM} + \lambda_{21}e^{UK} + \lambda_{21}p^{W}$$

where w^{UK}, p^{UK} and p^{IM} represent wages, consumer prices and import prices respectively, Π^{UK} represents productivity in the manufacturing sector, p^{W} represents world prices and e^{UK} is the UK effective exchange rate. This makes interpretation of each vector much easier – the dynamic adjustment in each equation achieves a long run equilibrium for the level of the dependent variable of the equation in question – and means that for our purposes we need only estimate the reduced form of the first two vectors. The short-run dynamics of the system need not concern us here, since, in this case, it is only the long-run consumer price relationship (shown below) that will feed into the model of Irish prices:[5]

$$p^{UK} = \beta_0 + \beta_1 p^{IM} + \beta_2 \Pi^{UK} + u_t, \qquad (5)$$

where u_t is the stochastic term, to give

$$p^{UK*} = b_0 + b_1 p^{IM} + b_2 \Pi^{UK}, \qquad (6)$$

where p^{UK*} represents long-run British consumer prices.

A number of studies (outlined above) have confirmed the existence of purchasing-power parity between Irish and British prices, in the long-run at any rate. Our own initial tests confirmed this and also ruled out any domestic wage component or any direct role German prices.[6] A more simplified approach will suffice, therefore, for modelling the long-run Irish relationship. We follow Wright's (1994) approach of

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[5] We could reduce the equation even further by substituting world prices and the UK effective exchange rate for import prices, but this is not necessary for the Irish model.

[6] German prices will of course indirectly affect the model through their effect on the UK trend level of prices.

testing for a simple PPP relationship augmented with short interest rates in both countries. The putative cointegrating vector in this case is the following:

$$p^{IR} - e - p^{UK} - \alpha_1 r^{IR} + \alpha_2 r^{UK} + 1, \tag{7}$$

where e is the bilateral exchange rate (IR£ per pound sterling), r represents the interest rate and $\alpha_1, \alpha_2 \geq 0$. We now have two long-run relationships to feed into the full error-correction model (ECM) of Irish prices. The ECM therefore explains the observed change in the dependent variable by three factors: observed changes in the short-run independent variables, adjustment towards the two long-run equilibrium relationships in British and Irish prices and a random component. This can be expressed as follows:

$$\Delta p_t^{IR} = \beta_0 + \sum_{i=0}^{k} \beta_{1i} \Delta p_{t-i}^{UK} + \sum_{i=0}^{k} \beta_{2i} \Delta e_{t-i} + \sum_{i=0}^{k} \beta_{3i} \Delta p_{t-i}^{UK*}$$
$$+ \gamma_1 \left(p^{IR} - e - p^{UK} - \alpha_1 r^{IR} + \alpha_2 r^{UK} + 1 \right)_{t-k-1} + \gamma_2 \left(p^{UK} - p^{UK*} \right)_{t-k-1} + u_t \tag{8}$$

$\sum_{j=0}^{3} \sum_{i=0}^{k} \beta_{ji}$ gives the short-run adjustment in Irish prices to changes in the short-run, independent variables; γ_1 and γ_2 represent the long-run speed of adjustment to the PPP relationship and misalignment of British prices.

Data

Data for the UK come from the OECD and the Office for National Statistics' *Economic Trends*. Irish data come from the CSO Databank. Both data-sets run from 1967Q1 to 1997Q4. We use as our price indices the goods component of the respective consumer price indices. In other words, the housing and services components of both have been excluded. What we are left with is essentially the traded elements of both indices, for which, *a priori*, a stronger purchasing power parity relationship is expected.[7] Making use of the Irish constant-tax price index (the

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[7] Initial estimation using the complete consumer price index or using the consumer price index excluding housing only indicated that this was the case.

CPI adjusted for changes in indirect taxes) has some intuitive appeal and would be expected to produce a stronger relationship than the CPI alone. Unfortunately, however, there is no British analogue over the requisite period.

Estimation

Examining the estimation process ex-ante leads one to divide it into three sections: (i) estimation of the long-run price relationship for the UK (a benchmark against which deviations in UK prices can be measured); (ii) verification of some form of long-run purchasing-power parity relationship between Irish and British prices using the Wright (1994) methodology; and (iii) the incorporation of both long-run relationships into a fully specified error-correction model of Irish price behaviour.

Estimating the reduced form in consumer (goods) prices of Greenslade *et al.*'s three cointegrating vectors (equation (5), above) gives the results shown in Table 1 below for the period 1967Q1 to 1997Q3:

Table 1: Parameter Values and T-statistics for Long-Run UK Relationship

	Coefficient	T-statistic	P-value
β_0	-0.322	-2.31	0.023
β_1	0.983	53.37	0.000
β_2	-0.096	-2.06	0.041

The value of near unity for β_1 implies almost full pass-through of changes in import prices to changes in consumer prices, modified by a small productivity component, β_2. Tests for non-stationarity as suggested by Dickey and Fuller (1981) are shown in Table 2 below. The model selection criteria all suggest selecting a regression of order 4 which gives a test statistic considerably greater than the 5 per cent significance level. The fitted values of this equation therefore form the trend long-run price series against which any misalignment can be measured. Figure 1 plots this misalignment (calculated as $p^{UK} - p^{UK*}$, both in natural logarithms) for the EMS period.

Table 2: Dickey-Fuller and Autoregressive Dickey-Fuller Tests for Non-Stationarity

	Test Statistic	LL	AIC	SBC	HQC
DF	-1.2072	321.05	320.05	318.67	319.49
ADF(1)	-2.1374	335.41	333.41	330.64	332.29
ADF(2)	-2.7284	339.34	336.34	332.18	334.65
ADF(3)	-3.1667	341.33	337.33	331.79	335.080
ADF(4)	-4.3807	349.31	344.31	337.39	341.50
ADF(5)	-3.7972	349.51	343.51	335.20	340.13
ADF(6)	-3.6418	349.56	342.56	332.86	338.62

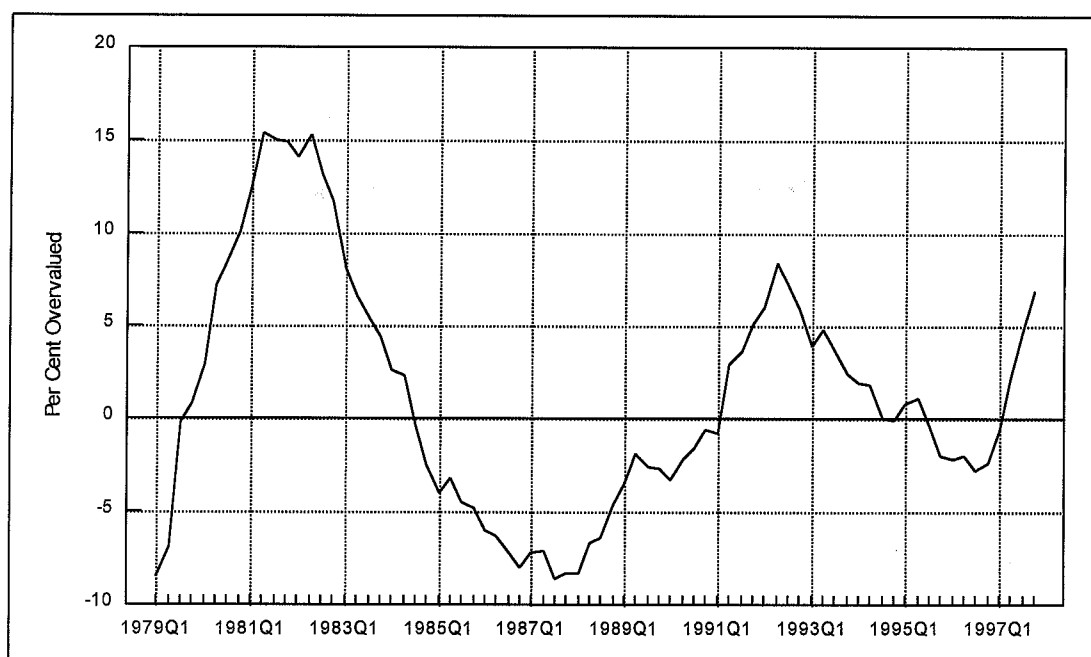95 per cent critical value for the Dickey-Fuller statistic = -3.8146

LL = Maximized log-likelihood   AIC = Akaike Information Criterion

SBC = Schwarz-Bayesian Criterion   HQC = Hannan-Quinn Criterion

*Figure 1: Sterling Misalignment 1979Q1-1997Q4 (Per Cent Over- or Undervalued)[8]*

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[8] Expressing the deviation from long-run UK prices as a sterling misalignment is, of course, tentative as this is only the case as long as British import prices do not deviate from their long-run relationship with world prices.

The pattern is fairly familiar and consistent with those produced by other commentators (see, for example, Barrell and Pain (1998)) and would indicate, as one would expect, that by the end of 1997 sterling was approximately 7 per cent overvalued (he bilateral rate for the fourth quarter of last year was IR£1=£0.89) Sterling has appreciated since with no manifest acceleration in Irish inflation. *A priori* we would expect the upward pressure on Irish prices due to the appreciation of sterling to be counteracted by this misalignment as UK firms expect the exchange rate to revert to its long-run mean value.

Having calculated a long-run relationship for the British prices, the next step is to calculate a similar long-run relationship for Irish goods prices. Some simple graphical analysis is useful at this point. Assuming, for a moment, that a pure purchasing power parity relationship holds between Irish and British prices, Figure 2, below, plots the notional cointegrating vector (1, -1, -1), representing Irish prices, the bilateral exchange rate (IR£ per pound sterling) and British prices respectively.

Figure 2: Error-Correction Term Assuming Pure PPP for Irish Prices (1979Q1-1997Q4)
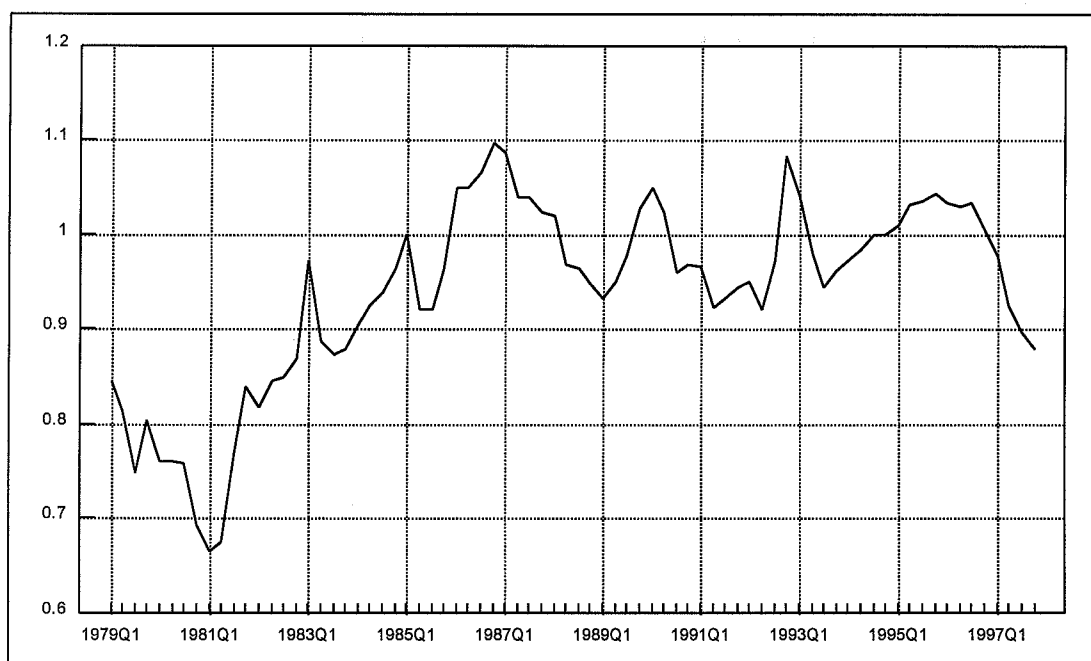
It is not clear that this is a stationary series over the period examined, and indeed Dickey-Fuller tests fail to reject the possibility of a unit root. Wright (1994), examining the wholesale price index, suggests the introduction of forward looking

expectations formation through the augmentation of the pure PPP relationship with short interest rates in both countries. The cointegrating vector then becomes $(1,-1,-1,-\alpha_1,\alpha_2)$, where $\alpha_1, \alpha_2 \geq 0$, and we find some evidence that this may be the case for goods prices also.[9] Unit-root tests on the residuals of such a relationship are shown in Table 3, below.

Table 3: Dickey-Fuller and Autoregressive Dickey-Fuller Tests for Non-Stationarity

	Test Statistic	*LL*	*AIC*	*SBC*	*HQC*
DF	-2.5927	121.83	119.83	116.50	118.69
ADF(1)	-2.9702	123.09	120.09	116.59	118.69
ADF(2)	-2.3618	124.17	120.07	115.51	118.31
ADF(3)	-2.2723	124.18	119.18	113.35	116.85
ADF(4)	-2.2071	124.18	118.18	111.19	115.38

95 per cent critical value for the Dickey-Fuller statistic = -2.88

LL = Maximized log-likelihood   AIC = Akaike Information Criterion

SBC = Schwarz-Bayesian Criterion   HQC = Hannan-Quinn Criterion

The selection criteria suggest a regression of order 1 (although the issue is not clear cut) giving a test statistic above the critical value and thus rejecting possibility that there is no long-run relationship.

So having established long-run relationships for Ireland and the UK we are now in a position to estimate the full error-correction model, which, excluding seasonal dummies, takes the following form:

$$\Delta p_t^{IR} = \beta_0 + \sum_{i=0}^{k} \beta_{1i} \Delta p_{t-i}^{UK} + \sum_{i=0}^{k} \beta_{2i} \Delta e_{t-i} + \sum_{i=0}^{k} \beta_{3i} \Delta p_{t-i}^{UK*}$$
$$+ \gamma_1 \left(p^{IR} - e - p^{UK} - \alpha_1 r^{IR} + \alpha_2 r^{UK} + 1 \right)_{t-k-1} + \gamma_2 \left(p^{UK} - p^{UK*} \right)_{t-k-1} + u_t \tag{9}$$

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[9] The situation where $\alpha_1 = \alpha_2$ has more intuitive economic appeal but a Wald test rejected this restriction on the data.

Estimation over the period 1979Q1 to 1997Q4 gives the results shown in Table 4, below.[10]

Table 4: Results of Initial Estimation of Error-Correction Model

	Coefficient	T-Ratio	P-Value
β_0	0.061	3.4364	0.001
β_{10}	0.333	2.5764	0.012
β_{11}	0.287	2.3427	0.022
β_{21}	0.154	4.3542	0.000
β_{22}	0.055	1.6289	0.108
β_{23}	0.127	4.1377	0.000
β_{24}	0.116	3.7662	0.000
β_{25}	0.067	2.1827	0.033
β_{26}	0.136	4.4876	0.000
β_{31}	0.361	2.4265	0.018
γ_1	-0.052	-3.6137	0.001
γ_2	-0.009	-0.3657	0.716

$R^2 = 0.79$ Standard Error = 0.0083   Durbin-Watson = 1.64

At first glance, the fit of the model looks quite good. Almost 80 per cent of the variation in the Irish goods prices is explained by the dependant variables and all the short-run coefficients are correctly signed and significant. Changes in UK prices are passed through almost fully within two quarters (remembering that when sterling is not out of line, $p^{UK} = p^{UK*}$, so that the pass through of price changes is $\beta_{10} + \beta_{11} + \beta_{31} = 0.98$), while exchange rate changes are passed through to Irish prices much more slowly. 65 per cent of the change is passed on by the sixth quarter, while

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[10] The procedure adopted for establishing the order of the autoregressive terms was to begin with a large lag length and to delete insignificant lags providing that the F-test version of the Lagrange Multiplier test indicated no serial correlation at the 5 per cent level.

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only half of this $(\sum_{i=1}^{6} \beta_{2i} - \beta_{31})$ is passed through if sterling is out of line. After the sixth quarter, just over 5 per cent of the remaining difference if closed each quarter.

Interestingly, however, sterling misalignment only seems to make a difference to pass-through in the short run. The coefficient on the long-run UK relationship is insignificant. The simplest explanation for this would be that over the period examined sterling was never misaligned for more than six quarters at a time. However, referring back to Figure 1, above, this is clearly not the case. It is possible that there is more subtle explanation. Figure 3, below, plots Irish goods-price inflation during the EMS period.

Figure 3: Annual Irish Goods-Price Inflation 1979Q1-1997Q4
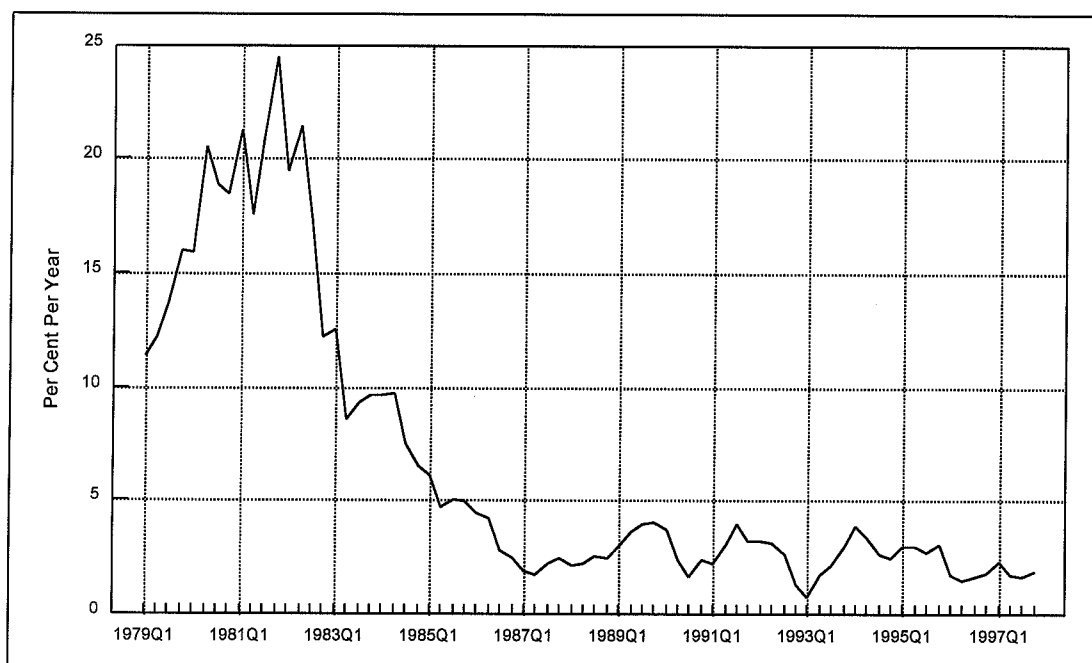
The first thing one notices is that during the period Ireland went from being a country with a high, fluctuating rate of inflation, to a low and stable inflation economy. Could there be a structural break here? Figure 4 plots the Chow-test results derived from successive tests for structural breaks during the period 1984Q2 to 1988Q4.

Figure 4: Chow-Test Statistic for Structural Breaks 1984Q2-1988Q4
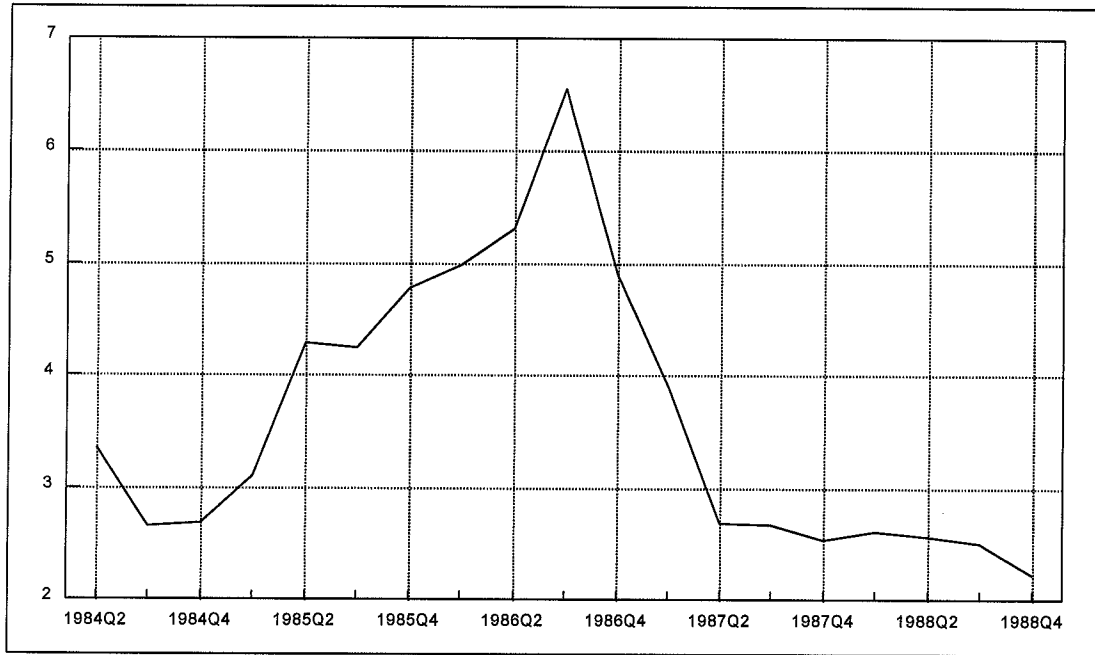
As one can see, the Chow test statistic peaks during 1986 just at the point when, judging from Figure 3, Ireland's inflation rate became stable.[11] Could it be that the cost of passing through exchange rate changes is less when prices are themselves changing rapidly, so that in the medium-run they are passed through even if the exchange rate is misaligned? Any explanation must be speculative, but to test this possibility, we re-estimate the model, this time modifying the long-run UK relationship so that it only comes into effect after 1986. The re-estimated equation is as follows:

$$\Delta p_t^{IR} = \beta_0 + \sum_{i=0}^{1} \beta_{1i} \Delta p_{t-i}^{UK} + \sum_{i=1}^{6} \beta_{2i} \Delta e_{t-i} + \beta_{31} \Delta p_{t-1}^{UK*}$$
$$+ \gamma_1 \left(p^{IR} - e - p^{UK} - \alpha_1 r^{IR} + \alpha_2 r^{UK} + 1 \right)_{t-7} + \gamma_2 \left(p^{UK} - p^{UK*} \right)_{t-7} . d^{86} + u_t$$

(10)

The results of the estimation are shown in Table 5, below.

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[11] There is also some evidence of a structural break during 1983, but there are not enough degrees of freedom to verify this.

Table 5: Results of Final Estimation of Error-Correction Model

	Coefficient	T-Ratio	P-Value
β_0	0.050	2.9504	0.004
β_{10}	0.399	3.7154	0.000
β_{11}	0.333	3.1371	0.003
β_{21}	0.143	4.3902	0.000
β_{22}	0.050	1.5643	0.123
β_{23}	0.125	4.1767	0.000
β_{24}	0.114	3.8293	0.000
β_{25}	0.067	2.2213	0.030
β_{26}	0.138	4.6341	0.000
β_{31}	0.303	2.7444	0.008
γ_1	-0.043	-3.1114	0.003
γ_2	0.044	1.3747	0.174

$R^2 = 0.80$ Standard Error = 0.0081   Durbin-Watson = 1.71

As one can see the short-run coefficients are almost exactly the same as before, although in all cases the *t*-statistics improve. The fit of the model is slightly better, both in terms of the coefficient of determination and the standard error of the regression, and it is also more stable. Further Chow-tests do not repeat the pattern of Figure 4, above. Although the coefficient on the long-run UK relationship, γ_2, is still not significant at the 5 or even 10 per cent level, its magnitude is almost exactly the same as that on the error-correction term for Irish prices. The implication is that if sterling is still out of line after six quarters, there will be no further adjustment. This corresponds with Greenslade et al.'s (1998) result that in the long-run, adjustment to the trend price level occurs more through exchange rate changes than through prices

changes. It is unlikely that a more significant value for this term is possible given the small number of misalignment 'cycles' since 1986.

Implications

Irish Goods Price Inflation

So how does this model work in practice? Figure 5 shows one example of the transmissions mechanism. If there is a 10 per cent appreciation in the value of sterling *vis á vis* the Irish pound the rate of pass-through differs depending on whether or not sterling is out of line.[12]

*Figure 5: Effects of a 10 per cent Sterling Appreciation on Irish Prices*
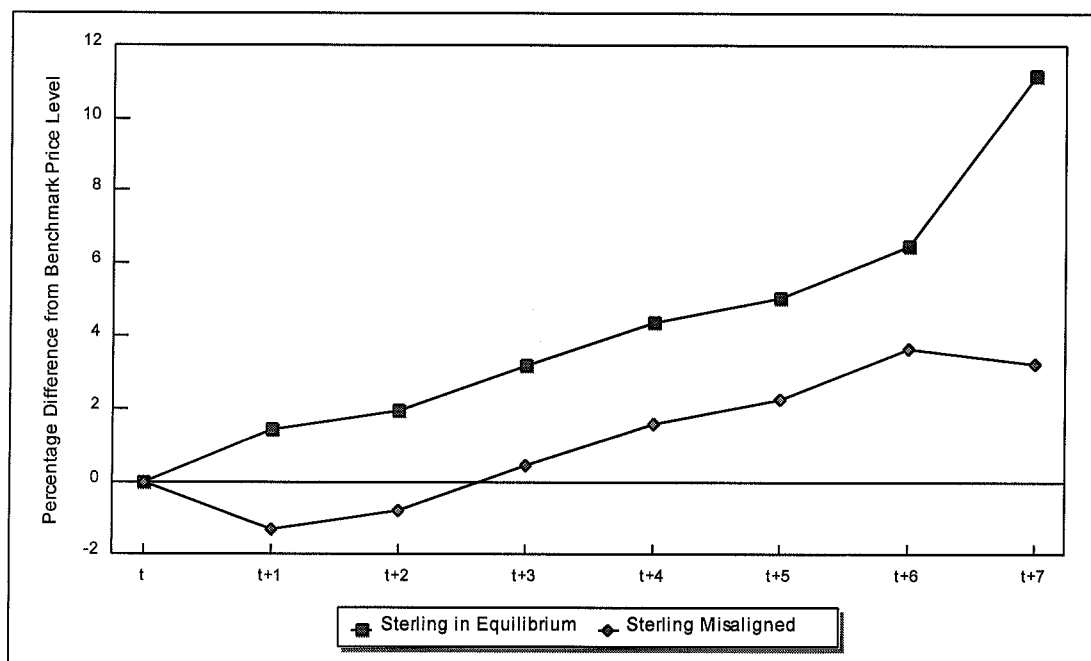
If the appreciation of sterling means that the currency is now misaligned, UK firms, expecting this to be a temporary phenomenon, are slower to pass through this change to the Irish market than if the appreciation represents a change in the long-run relationship.

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[12] Of course if sterling were misaligned, the effect of the exchange rate change would eventually be moderated by a fall in British prices. The magnitude and speed of such a fall would depend on the coefficients in a fully specified British model.

Figure 6 considers the forecasting power of this model in the present situation. It contrasts the forecasts produced by the model from 1998Q1 to 1999Q3 and with those produced by a simple PPP model between Ireland and Britain which has no sterling misalignment element.[13]

Figure 6: Forecasts of Irish Goods Price Inflation
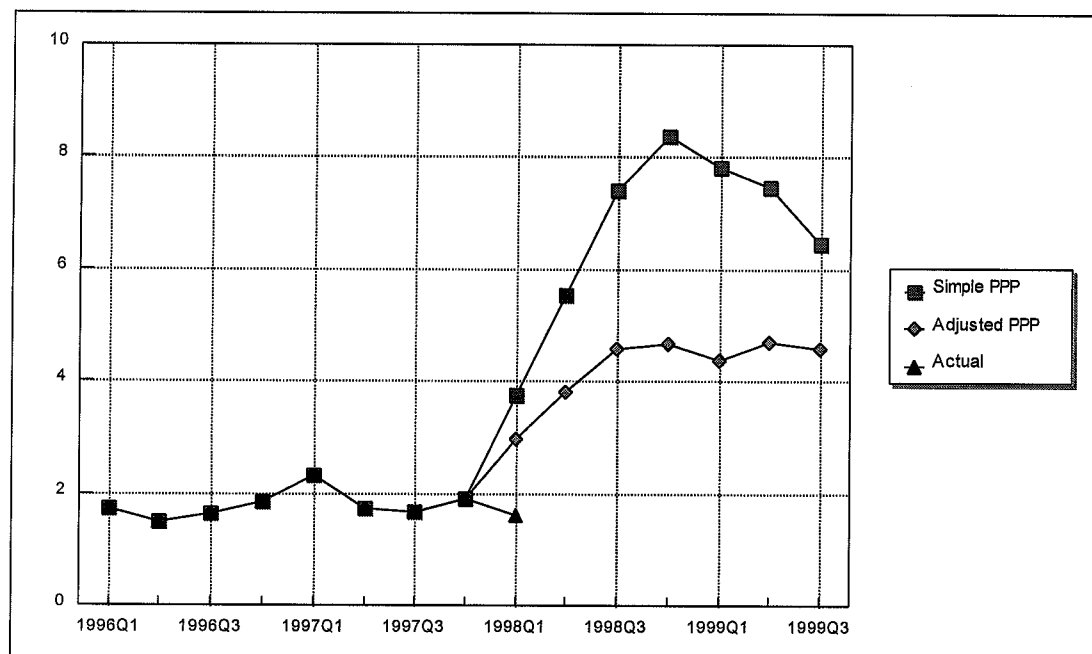
As one would expect, the significant recent appreciation in sterling feeds through fully into the simple PPP model, an inflation rate of over 8 per cent being predicted by the end of the year. The adjusted PPP model produces forecasts which are much lower, as it takes account of sterling's position compared to its trend level. Both however give significantly higher predictions for the first quarter of this year than was actually the case. This may be further evidence that a regime change is under way as more and more British firms begin to price in ECUs or euros as EMU approaches.

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[13] We take our forecasts of UK import prices from the National Institute of Economic and Social Research's NiGEM model.

One widely used measure of a sustainable real exchange rate is the concept of the Fundamental Equilibrium Exchange Rate (FEER) (Williamson (1991)). This is defined as the exchange rate which is consistent with external balance as well as internal equilibrium. In this sense it is the rate which should be sustainable in the long run, given the structure of the economy and the current values of the other exogenous variables in the model. In calculating the FEER for a country knowledge is needed of the key relationships determining the external balance – the elasticities of demand for imports and exports - as well as the factors determining internal balance. The NiGEM model of NIESR can be used to determine the FEER for the UK or other countries. In using such a world model it is possible to simultaneously calculate FEERs for all countries so that they are mutually consistent, representing the appropriate combination of rates that would simultaneously leave all economies in long-term equilibrium. However, this approach is quite complex requiring a (an albeit small) model of the UK and other economies.

Using this approach Barrell (1998) suggests that at the present time a rate of exchange for sterling equivalent to DM2.40 to DM2.60 per pound would constitute the FEER for the UK. While Barrell considers that some long-term improvements in the performance of the UK economy suggests that a slightly higher rate might be appropriate, it would not greatly differ from the range obtained using the current model. This would suggest that if the UK were to join EMU at the current rate it would have to experience 10 to 15 years in which inflation was below its UK competitors before it reached its FEER. This mirrors the position in which the UK joined the EMS in the early 1990s.

In modelling the long-run relationship between the UK price level and the foreign price level, or between the Irish price level and the UK or foreign price level, we are considering the "equilibrium" real exchange rate from a different point of view. In this paper we have considered what level of prices would be consistent with a given nominal exchange rate. This in turn reflects the views of a myriad of individual firms as to what price level would be consistent with their own internal objectives in the long run, given their cost structures and the demand curves which they face. The

difference between the actual price level and the long-run level is then a measure of the overvaluation or undervaluation of the currency from the point of view of individual firms. However, it has no direct relationship with the appropriate balance on internal or external account and may not be an "equilibrium" level in that sense.

In addition, because it is calculated separately for each country (or jointly with the UK in the case of the Irish measure) the rate arrived at may not be consistent with equilibrium (in this sense) for firms world wide. The world prices used in the equations may not represent the appropriate long-run level of world prices for world firms.

However, even taking account of these caveats, this measure of the long-run exchange rate can convey interesting information concerning the sustainability of a particular current exchange rate. If the long-term rate is substantially below the actual rate, implying an overvaluation, then it indicates that domestic firms selling on the Irish market will be facing fairly severe competition and that the deflationary pressures will be painful for them. On the other hand, if the current rate is below the long-term rate then there is a likelihood that prices will tend to rise, while foreign (UK) competitors on the Irish market will face reduced margins. Subject to these caveats the long-run relationship for Ireland suggests that the appropriate bilateral rate with the UK should be around the St£0.94 per Ir£1.00.

Conclusions

The results suggest that world inflation is transmitted to Ireland through UK consumer prices; the addition of inflation in Germany adds nothing to the model of Irish consumer price inflation. This contrasts with the evidence in Callan and Fitz Gerald that German prices play a significant role in determining Irish manufacturing output prices.

The speed of adjustment to shocks in the UK inflation rate is rapid. There is a much slower response to shocks to the bilateral exchange rate. This is consistent with the behaviour one would expect from firms operating in imperfectly competitive markets where market segmentation is possible. Under such circumstances, the uncertainty

associated with firms' expectations of future values of the exchange rate can be expected to lead to slow pass through of exchange rate changes.

The model developed here differentiates between changes in the bilateral sterling Irish pound exchange rate due to movements in sterling against all other currencies and changes due to movements in the Irish pound against all other currencies. Where sterling moves away from its expected long-run value there is a much more attenuated impact on the Irish inflation rate. However, where the Irish pound moves against all other currencies there is a more rapid and complete pass through into the Irish inflation rate. These results suggest that UK firms when exporting are effectively tending to price in euros. When sterling is out of line with their expectations the danger of losing market share on the European market constrains them from passing through the effects of the change in exchange rates. However, if the Irish pound is changing against all other currencies the dangers of losing market share through changing prices are reduced as their potential foreign competitors face the same problems on the Irish market.

The results suggest a change in behaviour around 1986. After that date misalignment in sterling slows adjustment of Irish consumer prices to changes in the bilateral exchange rate whereas before that date there is no evidence of such behaviour. This result is consistent with the single market, introduced in the late 1980s, leading to greater integration of the EU market for consumer goods. However, this may be a coincidence as these results are by no means conclusive.

The forecasts produced by this model, while better than those from any model which excludes the term for UK misalignment, seem poor out of sample, with a substantial underprediction of the inflation rate in early 1998. This could be due to a change in regime as EMU approaches with increasing integration of the EU market **including** the UK. However, it will be some considerable time before such a possibility can be tested for at this level of aggregation. If there is no regime change and the model remains valid, then it suggests that, unless sterling falls significantly in value over the course of the year, the annual rate of inflation in consumer prices in Ireland could rise to 4 per cent by the end of the year.

Finally, the long run relationship between Irish and UK prices suggests that current price levels in the two countries are consistent with a bilateral exchange rate of St£0.94 for IR£1.00. Given the NIESR estimate that the equilibrium rate for the UK may is in the region DM2.40 to DM2.60, or maybe a little above it, it would suggest that the current Irish rate against the DM, and the likely entry rate into EMU, is broadly appropriate. When sterling eventually adjusts to its long-term equilibrium level it will leave the Irish price level broadly unchanged at its current level, implying no major long-term inflationary impulse.

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