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The Exchange Rate and Inflation in the UK

by Amit Kara and Edward Nelson

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Bank of England

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Abstract

The United Kingdom is a highly open economy, and has a monetary policy strategy of targeting inflation in consumer prices. In this paper, we look at the evidence from the UK on inflation behaviour, and examine the propositions from several theoretical models about inflation dynamics in an open economy, focussing in particular on the hypothesised connections between the exchange rate and consumer price inflation. Theoretical open-economy macroeconomic models 'cover the waterfront' on this issue, ranging from 'exchange rate disconnect' to a rigid link between nominal exchange rate changes and inflation. We estimate on UK data the open-economy Phillips curves implied by the alternative explanations. We argue that, of the alternatives considered, only a model where imports are modelled as an intermediate good, as in McCallum and Nelson (1999), provides a reasonable match with the data. Unlike the standard model, in which imports are treated as a final consumer good, the intermediate-goods specification provides support for a policy of CPI inflation targeting.

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1. Introduction

As Johnson (1974, p. 223) argues, 'The distinction between an open and a closed economy in monetary analysis is fundamental.' The United Kingdom is a highly open economy, and also has a monetary policy strategy of targeting inflation in retail prices. Insights from theory and data on the behaviour of inflation in a small open economy can help in implementing this strategy. In this paper, we look at the evidence from the UK data on inflation behaviour, and use the data to examine the propositions from several theoretical models about inflation dynamics and inflation targeting in an open economy.

Svensson (2000, pp 157–158) argues that the 'analysis of inflation targeting [in] a small open economy', relative to a closed-economy baseline, is principally affected by 'the additional channels for the transmission of monetary policy' arising from the exchange rate. He lists three channels: the extra aggregate-demand channel arising from the sensitivity of net trade to the exchange rate; the 'direct' exchange rate channel due to the presence of imported goods in consumer price indices; and finally, the link between the CPI and the exchange rate due to imported intermediate goods. In discussing the implications of openness for inflation targeting in the United Kingdom, we focus on the second and third channels in Svensson's list—namely, the connections between the exchange rate and consumer prices.

The importance of these channels is a subject of considerable debate in both theoretical and policy discussions. As we detail further in Section 2, theoretical open-economy macroeconomic models 'cover the waterfront' on the issue of the importance of exchange rate movements for inflation behaviour. At one extreme are versions of the 'Scandinavian' or 'monetary approach' model that predicts a close and mechanical link between exchange rate changes and consumer price inflation (e.g. Laffer and Miles, 1982). At the other extreme are certain 'pricing-to-market' models in which price-setting decisions regarding all components of the CPI, including imported goods prices, are determined independently of exchange rate movements, promoting a 'disconnect' of the exchange rate from other macroeconomic variables (see Devereux and Engle, 2002). In between these extremes, other models allow for some link between the exchange rate and goods prices, but vary greatly on such issues as the role of domestic factors in import price-setting, the extent and speed of pass-through, the relative importance of intermediate and consumer good imports, and the degree to which the monetary policy reaction function governs the response of the aggregate price level and inflation to an exchange rate depreciation (see e.g. Wilson, 1976; Batten and Ott, 1983; Engel, 1993, 2002a, 2002b; Monacelli, 1999; Galí and

Monacelli, 2000; McCallum and Nelson, 2000; Adolfson, 2001; Allsopp, 2001; Batini, Harrison, and Millard, 2001; Burstein, Eichenbaum, and Rebelo, 2002; Campa and Goldberg, 2002; Kollmann, 2002; and Smets and Wouters, 2002).

Discussion of the exchange rate and inflation in UK policy debates has evolved over time with experiences of different monetary regimes. As of 1976, the Government believed that '[t]he first round-effect of a 10 per cent depreciation would be to increase… the retail price index by about 2.9 per cent' after a year.[1] During the early 1990s period of UK membership of the Exchange Rate Mechanism (ERM), the Government stressed a strong exchange rate/inflation relationship, arguing that 'freedom of trade, combined with the commitment to the ERM, means… UK costs and prices will not be able to move independently of those of our competitors for any length of time' (HM Treasury, 1992, p. 8). When announcing the details of the new inflation-targeting framework for monetary policy, following the UK's return in 1992 to a floating exchange rate, Chancellor Lamont stated, 'Some people insist that movements in the exchange rate are just a change in relative prices which need not affect the rate of inflation. Others argue more pragmatically that disinflationary forces are currently so strong, that such pressures pose no threat. I am not persuaded by either of these arguments' (Lamont, 1992, p. 49). On the other hand, the March 1993 Budget documents noted that 'there is as yet little experience of any effect on retail prices from the lower exchange rate' (HM Treasury, 1993, p. 24). The Bank of England's *Inflation Report* of February 1994 maintained that 'UK import prices would be expected to change one-for-one with any change in the exchange rate' (Bank of England, 1994a, p. 30), and that this had occurred following the 1992 depreciation. The May 1994 *Report* argued that a depreciation due to a real shock would be felt not only in higher import prices but also in a permanently higher total price level and temporarily higher CPI inflation, unless monetary policy acted to reverse the depreciation (Bank of England, 1994b, p. 40). More recently, the appreciation of sterling from 1996 led the Monetary Policy Committee (MPC) in its May 2001 deliberations to note the 'dampening effects on inflation of sterling's appreciation' (MPC, 2001, p. 6). As we discuss in Sections 2 and 3, different models have varying degrees of success in matching the UK evidence. And the alternative models imply different conclusions regarding the appropriateness of the UK's strategy of consumer price inflation targeting.

Our paper will be concerned principally with aggregate or macroeconomic consequences of the exchange rate/inflation relationship. We will discuss the

[1] From a written answer in Parliament by Edmund Dell on behalf of the Chancellor of the Exchequer, House of Commons *Hansard*, 24 March 1976, p. 215.

relationship between CPI inflation and the exchange rate, investigate how dependent this relationship is on model specification and on policy regime, and draw some implications for the appropriate formulation of monetary policy targets. We will not explore in detail the relationship between the exchange rate and import price inflation, nor will we examine micro-level data. A more microeconomic approach appears in a recent paper by Campa and Goldberg (2002), who are concerned with the relationship between import price inflation and the exchange rate in several OECD countries. Finding less than complete pass-through of exchange rate changes to import prices, these authors analyse whether the source of the incomplete pass-through is 'microeconomic' or 'macroeconomic'. For monetary policy analysis, however, a more appealing distinction is that between *policy-invariant* and *non-policy invariant* factors affecting the exchange rate/inflation relationship. For example, in the models we explore below, all the factors driving the relationship are 'macroeconomic' in the sense that they can be indexed by a small number of parameters in a compact macroeconomic model. But even in such wholly macroeconomic environments it is important to distinguish between factors driving the relationship that will remain invariant to monetary policy regime—e.g. production function parameters—and those that are functions of the monetary policy in force—e.g. expectational terms in Phillips curve relationship. If the latter prove to be quantitatively the most important influences on the correlation between exchange rate movements and inflation, then one would expect the relationship to depend closely on monetary policy regime, as Taylor (2000) and Gagnon and Ihrig (2002) argue is the case. On the other hand, if the structural parameters describing the supply side of the model place major limits on the degree to which the exchange rate matters for inflation, then policy regime is less crucial—at least for moderate changes in monetary policy arrangements.

We will argue that in fact the exchange rate/inflation relationship in the UK has exhibited some regularities that are robust to monetary policy regime. The relationship between consumer price inflation and the exchange rate tends to be quite weak across regimes, which itself rules out some key open-economy models. On the other hand, consistent with Campa and Goldberg's results, we find that the 'exchange rate disconnect' or pricing-to-market approach fails to account for key features of UK data. On the whole, we contend that, of the alternative models that we consider, one in which imports serve as intermediate goods, as in Wilson (1976) and McCallum and Nelson (1999, 2000), delivers the best approximations of the actual empirical relationships. This model is also notable for providing the strongest support for the policy of CPI inflation targeting followed in the UK in the last decade.

2. Theoretical models of the exchange rate/CPI relationship

In this section, we examine the predictions of several alternative open-economy models for the exchange rate/inflation relationship. We begin with some notational and definitional preliminaries, then look at several models in turn: the 'monetary approach' (Section 2.2), pricing-to-market (Section 2.3), a New Keynesian open-economy specification (Section 2.4), and traditional backward-looking open-economy Phillips curves (Section 2.5).

2.1 Some common identities

In our discussion of various models of the exchange rate/inflation relationship, we will be using several simple identities (or approximations) that are common across the models. The first of these is a consumer price index (CPI) identity of the form

$$P_t = s_D P^D{}_t + s_M P^M{}_t, \tag{1}$$

where P_t is the CPI in quarter t, P^D is the index of goods prices that are both produced and sold domestically, and P^M is an index of imported consumer goods prices. The parameter $s_D = (1 - s_M)$ is the share of domestically produced goods in the CPI, with s_M the import share. The resulting expression for the annualized percentage change in CPI inflation is:

$$\pi_t = (1 - s_M)\, \pi_t{}^D + s_M \pi^M{}_t, \tag{2}$$

where $\pi_t{}^D$ can be interpreted as either $4 \cdot \Delta \log P_t^D$, or the closely related percentage-change formula, $(P_t^D/P_{t-1}{}^D)^4 - 1$. In our empirical work, we measure π^D and other rate-of-change variables using the percentage-change formula.

2.2 The 'monetary approach' model

We consider first the 'Scandinavian' or 'monetary approach' model of inflation determination in an open economy. The simplest version of this model assumes that the domestic economy's price level can be characterised as an aggregate of tradable goods, with international arbitrage implying that the Law of One Price holds when goods prices from different countries are expressed in the same currency. This implies, *inter alia*, that there is complete 'pass-through' of exchange rate changes and world price changes to domestic import prices:

$$P_t^M = P_t^W S_t, \tag{3}$$

where P^W is an index of rest-of-world consumer goods prices.[2]

In addition, with all domestically produced goods tradable, the operation of the Law of One Price means that domestically produced goods equal the exchange rate-adjusted world price index:

$$P_t^D = P_t^W S_t, \tag{4}$$

so that overall CPI inflation is given by:

$$\pi_t = (1 - s_M)\,\pi_t^{\,D} + s_M\,\pi_t^M = (1 - s_M)\,(\pi_t^{\,W} + \Delta s_t) + s_M\,(\pi_t^{\,W} + \Delta s_t) = \pi_t^{\,W} + \Delta s_t\,, \tag{5}$$

where Δs_t is the annualized quarterly change in the nominal exchange rate. CPI inflation in this model is therefore equal to the sum of world inflation and domestic nominal exchange rate change. The textbook of Laffer and Miles (1982, p. 237) took this perspective, arguing, '[T]here appears to be little, if any, reason, to presume independence among countries' rates of inflation or other price data. Adjustments appear to be quick and complete to the extent that data exist. Inflation is a one-market world phenomenon and will differ among countries to the extent, and to the full extent, of changes in their exchange rates.' Similarly, Johnson (1974, p. 223) argued that 'prices are determined in world markets, the only qualification being that the authorities can change the nominal domestic currency price level relative to the foreign price level by changing the exchange rate.'

The CPI equation (5) in this set-up still implies that a central bank in a floating exchange rate regime can determine its own country's inflation rate, since a tighter monetary policy at home than abroad will tend to promote exchange rate appreciation, and so, according to equation (5), to low inflation relative to abroad. But the equation would also appear to suggest that, when world inflation is stable, successful inflation targeting at home will be associated with stability in the nominal exchange rate.

If a tradable/non-tradable goods distinction is allowed for but the model is not otherwise altered, then a relation similar to equation (5) still holds. On the assumption that prices and wages are flexible in all sectors, and prices in each sector are proportional to costs, then arbitrage tends to equalise nominal wages across the economy. The condition then becomes

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[2] The simplest case in which P^W is the appropriate index to use is that where the rest of the world produces a single, tradable good.

$$
\begin{aligned}
\pi_t &= (1 - s_M)\, \pi_t{}^{D} + s_M \pi^{M}{}_t \\
&= (1 - s_M)\, (\delta\pi_t{}^{N,D} + (1-\delta)\pi_t{}^{T,D}) + s_M \pi^{M}{}_t \\
&= (1 - s_M)\, (\delta\pi_t{}^{N,D} + (1-\delta)(\pi_t{}^{W} + \Delta s_t)) + s_M (\pi_t{}^{W} + \Delta s_t) \\
&= (1 - s_M)\, (\delta(\pi_t{}^{W} + \Delta s_t - (\mu_N - \mu_T))) + (1-\delta)(\pi_t{}^{W} + \Delta s_t)) + s_M (\pi_t{}^{W} + \Delta s_t) \\
&= \pi_t{}^{W} + \Delta s_t - (1 - s_M)\delta(\mu_N - \mu_T), \qquad (6)
\end{aligned}
$$

so that domestic CPI inflation differs from the exchange-rate-adjusted world rate only to the extent that there are differences between the rates of productivity growth, μ_N and μ_T, in the domestic non-tradables and tradables sectors; see e.g. Kierzkowski (1976, p. 234) or Makin (1996, pp. 74–76).

If—as has occurred in practice in the UK for most of the last 40 years[3]—quarterly variation in nominal exchange rates is high relative to that in either rest-of-world inflation or rates of productivity growth across sectors, then the monetary-approach model, whether in the form that implies equation (5) or (6), leads to a tight relationship between UK exchange rate change (Δs) and retail price inflation (π). But the relationship is, in fact, extremely loose, as both Table 1 and Figure 1, which give correlation and graphical evidence respectively using quarterly data since 1958, show. A high and positive correlation implies a close observed relation between exchange rate depreciation and inflation. Instead of being close to +1.0 as suggested by the monetary approach, the correlation is close to zero for the full sample.[4] And instead of being clustered tightly around the 45-degree line in the scatter diagram, the observations are spread across the whole area of the diagram, implying a very loose relationship between the two series. The chart and table also split the observations between pre- and post-1980, the latter period being associated with more internationally integrated financial and goods markets. Rather than becoming closer as the monetary approach would suggest, the relationship is considerably weaker after 1980—indeed, the correlation between inflation and exchange rate change before 1980, while low, is positive and statistically significant, which is not the case in the later sample.[5] The monetary approach does not appear to be a useful tool for the analysis of UK inflation dynamics in the post-war period.[6]

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[3] The very large commodity price movements of the early 1970s are an exception to this generalisation.
[4] This is so also in those results in the table that control for tax changes whose sizeable effect of the retail price index is demonstrated in our econometric work below.
[5] Consistent with these results, Artis (1993, p. 254) found that nominal exchange rate change had no predictive power for UK retail price inflation for the period January 1970–September 1990.
[6] *IFS* data on industrial-country aggregate CPI inflation is available for the sub-sample 1968 Q2–2001 Q4. If we add this series to Δs and use it as a proxy for nominal exchange-rate adjusted world inflation ($\Delta s+\pi^{w}$), the relationship with π is stronger than that between π and Δs, but only marginally. The correlations (with tax-adjusted partial correlations in parentheses) are: 1968 Q2–2001 Q4: 0.277 (0.329); 1968 Q2–1979 Q2: 0.382; 1980 Q1–2001 Q4: 0.099 (0.105).

2.3 Pricing-to-market models

A branch of the recent 'new open economy macroeconomics' literature (see Lane, 2001, and Engel, 2002a, for surveys) uses a form of the 'pricing-to-market' assumption, whereby import price setters simply set prices equal to that prevailing for domestic goods, and do not adjust them in light of world price or exchange rate variations. Imports are consumer goods only in these models, so the intermediate-goods channel of transmission mentioned by Svensson (2000) is unimportant. Imported consumer goods are priced so that they equal domestic goods prices, implying $\pi^M = \pi^D$, and there is no pass-through at all, so equation (3) fails to hold. At the extreme, such pricing-to-market models imply 'exchange rate disconnect' (Devereux and Engel, 2002): most of the channels through which the exchange rate matters for costs and prices are shut off by the failure of import prices to adjust to exchange rate movements.

At first glance, this type of model seems compelling, as it can rationalise a weak relationship between exchange rate movements and aggregate inflation. Pricing-to-market models also imply, however, little or no relation between the rate of import price inflation and exchange rate change. This observation is contradicted by the UK data, as Table 2 and Figure 2 show. The relationship is positive and significant both for the period as a whole and for the individual sub-samples.[7] The correlation, while well below 1, is strong; and, perhaps surprisingly, remains so after 1980.[8]

We conclude that the import price inflation/exchange rate change relationship in the UK data is strong throughout the last four decades, even though exchange rate changes and CPI inflation are weakly related. This observation is in line with Engel's (2002a, p. 28) observation, based on cross-country evidence, that 'there is much more pass-through of exchange rates to imported goods prices than to final consumer prices… [though] the pass-through is certainly not 100 per cent', and Burstein, Eichenbaum, and Rebelo's (2002, p. 2) 'key fact' that '[t]he prices of imports… move much more closely with the exchange rate than [does] the CPI.' It is also in keeping with Campa and Goldberg's (2002) finding for OECD countries over 1975−1999 that 'there is compelling evidence of partial pass-through in the short run'.

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[7] Adding *IFS* data on industrial-country aggregate CPI inflation to Δs to obtain, as before, a proxy for nominal exchange-rate adjusted world inflation ($\Delta s+\pi^w$), leads to similar but somewhat stronger correlations. The correlations between ($\Delta s+\pi^w$) and import price inflation are: 1968 Q2–2001 Q4: 0.622; 1968 Q2−1979 Q2: 0.600; 1980 Q1−2001 Q4: 0.655.

[8] It is true that the slope of the scatter-plot is flatter after 1980. But this may simply be because of the static nature of the plot. There is evidence that complete or near-complete adjustment of UK import prices to exchange rate movements take place within a year—the adjustment of import prices in Table 3 below after the 1992 depreciation being one example. The same phenomenon is not observed for the adjustment of the CPI as a whole.

While our analysis focuses on UK data since 1958, there are grounds for thinking that the same conclusion applies for the whole postwar period; the *Economist* (1967, p. 873) noted that a year after the 1949 devaluation of sterling, 'British import prices were some 22 per cent higher than they had been a year before, but the old retail price index was only 2 per cent higher'. Table 3 provides some evidence based on three episodes in the UK's experience corresponding to major devaluations during, or at the end of, fixed exchange rate arrangements—1949, 1967, and 1992.[9] It shows the cumulative changes in the nominal exchange rate, import prices, and retail prices prior to, and in the wake of, each episode. In each case, import prices followed exchange rates in moving by a double-digit rate.[10] But in the cases of the 1949 and 1992 devaluations, the rate of retail price inflation actually *fell* compared to its pre-devaluation level. The 1967 episode, on the other hand, featured a rise in RPI inflation of about ⅓ the size of the devaluation. This experience was probably the principal basis for policy-makers' estimate in the 1970s[11] of an approximately one-third elasticity of inflation with respect to exchange rate changes. Even the 1967 episode is characterised by a rise in aggregate retail prices that is small compared to the rise in import prices. This points to the need for a model which—unlike the monetary approach and pricing-to-market—makes different predictions for import price inflation vs. total inflation. In the remainder of this paper, we consider some candidate models of this type, beginning with a baseline open-economy New Keynesian specification.

2.4 The New Keynesian open-economy Phillips curve

Much of the current closed-economy macroeconomics literature uses as its price-setting specification the 'New Keynesian Phillips curve' (NKPC) (see e.g. Roberts, 1995, Galí and Gertler, 1999, and Sbordone, 2002), which is based on dynamic obstacles to goods-price adjustment of the Calvo (1983) type. Early applications of the NKPC to an open-economy context include Kollmann (2001) and Galí and Monacelli (2002). In baseline versions of this model type, the nominal prices of domestically produced goods are sticky, but imports are flexible-price. And there are no imported intermediate goods—an important omission that we will return to in Sections 3 and 4. Allowing for an exogenous disturbance term u_t, the 'Phillips curve' for domestic goods inflation is:

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[9] The use of the term 'devaluation' rather than 'depreciation' to describe the 1992 episode is common but might be questioned, as this exchange-rate movement marked the start of a renewed float of the pound.

[10] The rise in import prices after the 1949 devaluation seems to be lower than the movement in the exchange rate. However, the discrepancy might reflect our data source, as the change in import prices for this episode reported by the *Economist* (1967) is much closer to the change in the exchange rate.

[11] Quoted in the Introduction.

$$\pi_t^D = \beta E_t \pi_{t+1}^D + \alpha ulc_t + u_t, \tag{7}$$

where β is a discount factor near unity, $\alpha > 0$, and *ulc* is log real unit labour cost, the latter serving (rather than the output gap) as the measure of domestic demand pressure. From equation (2), $\pi_t = (1 - s_M)\, \pi_t^D + s_M \pi_t^M = \pi_t^D + s_M(\pi_t^M - \pi_t^D)$, and making the full pass-through assumption, we obtain $\pi_t = \pi_t^D + s_M(\Delta s_t + \pi_t^W - \pi_t^D)$, or $\pi_t^D = \pi_t - s_M \Delta q_t$. Substituting this into the domestic-inflation NKPC gives the following Phillips curve for CPI inflation:

$$\pi_t = \beta E_t \pi_{t+1} + \alpha mc_t + \phi(\Delta q_t - \beta E_t \Delta q_{t+1}) + u_t \text{ , } \alpha > 0, \phi > 0. \tag{8}$$

As in the closed-economy NKPC, CPI inflation depends on its expected next-period value and on real marginal cost. Openness conditions this relationship by adding the term $(\Delta q_t - \beta E_t \Delta q_{t+1})$—current real exchange rate depreciation relative to next period's expected depreciation.

To evaluate the empirical success of this specification, we estimate equation (8) on UK data for 1964 Q2–2001 Q4 by instrumental variables, controlling for once-and-for-all movements in the measured RPIX series due to large changes in the tax system and the imposition and removal of price controls.[12]

Our estimates, reported in Table 4, deliver values of β and λ that are of plausible magnitude and sign for the full sample. But the estimated value of ϕ is of the wrong sign, regardless of estimation period: the elasticity of inflation with respect to exchange rate depreciations does not take its expected positive value. Table 4 establishes that this is also true if the equation is estimated separately on pre-1980 and post-1980 subsamples. Note that 'incomplete pass-through' by itself cannot rationalise this result: if only a fraction of period-*t* exchange rate changes are passed through to import prices, this would rescale the coefficient on the real exchange rate term in (8) without altering its predicted sign or significance.

2.5 Pure backward-looking Phillips curves

A possible reason why the NKPC gives puzzling results is the assumption, built into the specification, of completely forward-looking behaviour by price-setters. At the opposite extreme, one could specify both domestic-goods prices and import prices as being set as rule-of-thumb functions of past data:

[12] The Phillips curve estimates reported here are extensions of the work reported in Nelson (2002), now allowing for further price level shifts and exploring different sample periods.

$$\pi_t = b_0 + \Sigma_{i=1}^{3}\beta_i\, \pi_{t-i} + \Sigma_{i=1}^{3}\, \phi_i\, \Delta q_{t-i} + \Sigma_{i=1}^{3}\, \lambda_i\, ulc_{t-i} + \text{dummies} + u_t \qquad (9)$$

Implicit in this equation is the assumption that domestic-goods prices adjust only with lags to changes in costs, and that import prices similarly only adjust slowly to the real exchange rate. Under certain conditions, equation (9) could be regarded as a reduced-form equation that emerges in equilibrium from the structure of an economy governed by equation (8)—but then the coefficients in equation (9) would change with monetary policy regime. If they are instead constant across regimes then equation (9) is structural, and there is no forward-looking behaviour in price setting. An alternative formulation of (9) replaces costs as the domestic demand pressure variable with a measure of the output gap, as in Ball (1999). A quarterly approximation of Ball's equation is:

$$\pi_t = b_0 + \Sigma_{i=1}^{3}\beta_i\, \pi_{t-i} + \Sigma_{i=1}^{3}\, \phi_i\, \Delta q_{t-i} + \Sigma_{i=1}^{3}\, \lambda_i\, (y - y^*)_{t-i} + \text{dummies} + u_t \qquad (10)$$

In equation (10), Ball sets $\Sigma_{i=1}^{3}\beta_i = 1$ to restrict the equation to exhibit a version of the 'vertical Phillips curve' property.

Tables 5 and 6 report our estimates of equations (9) and (10). In estimating equation (10), we use the standard (but problematic) assumption that the output gap can be approximated by detrended output. The parameter that corresponds to our coefficient sum on exchange rate changes in Ball (1999) is γ. He sets $\gamma = 0.2$: 'a one percent appreciation reduces inflation [after a lag] by two tenths of a point' (1999, p. 130). Our estimate of this parameter is less than half this value, at 0.08 for the full sample. In the pre-1980 sample, it is, at 0.14, quite close to Ball's calibrated value, and is statistically significant, but the point estimate shrinks to one tenth of its pre-1980 value in the 1980–2002 sample. Admittedly, Ball's calibration was not designed for the UK; he describes his calibration as 'meant to apply to medium-to-small open economies such as Canada, Australia, and New Zealand' (1999, p. 130). But as the UK is more open than these economies, the exchange rate term should in principle have a larger coefficient than Ball's choice, not a smaller one. So—conditional on Ball's specification—the results for the UK are quite discouraging for the view that the exchange rate channel is important: the coefficient on the exchange rate in the UK data seems to be very small relative even to Ball's choice, which was explicitly intended to give the exchange rate only a modest and delayed role in determining inflation.

Our estimates of backward-looking Phillips curves do provide generally 'correct' signs on the exchange rate term, unlike the NKPC estimates. But they have problems of their own: the coefficient sums on the demand pressure term (unit labour costs or detrended output) are highly unstable across sample periods and, in the case of the labour costs term, wrongly signed in the 1980–2002 sample; and the coefficient sum on the exchange rate term diminishes in size drastically after 1979. So backward-looking Phillips curves for the UK do not appear to provide constant or interpretable specifications.

2.6 Summary

The examination in this section of alternative open-economy models has been notable for what it rules out:

1. CPI inflation and nominal exchange rate changes are too loosely related for the 'monetary approach' model to be a reasonable approximation.

2. On the other hand, the reasonably close import price inflation/exchange rate relationship reduces the appeal, for analysis of UK data, of the most basic pricing-to-market models.

3. Estimates of the New Keynesian Phillips curve fail to deliver interpretable estimates on UK data, because (conditional on costs) they predict a tight relationship between real exchange rate change and inflation that is not supported by the data.

4. Resorting to backward-looking models does not resolve the problem.

In the next section, we explore some possible explanations for these findings. But the negative results in this section make the following set of model features attractive:

a. Continued reliance on models based on formal optimising behaviour.

b. Model elements capable of simultaneously rationalising the weak CPI inflation/exchange rate relationship and the strong import price inflation/exchange rate relationship in the data.

We will argue that modelling imports as (exclusively) an intermediate good is an approach that meets the above criteria.

3 Some candidate explanations

In this section we explore some candidate explanations for the empirical regularities and modelling problems that we encountered in Section 2. We first investigate whether simply putting import prices (rather than the exchange rate) into the Phillips curve resolves empirical problems, and find that it does not. Sections 3.2 and 3.3 instead explore Phillips curve specifications that imply explicit terms involving the level of the real exchange rate.

3.1 Import prices instead of the exchange rate

Some work on the effect of openness in inflation dynamics puts import prices in the Phillips curve directly (e.g. Debelle and Wilkinson, 2002). At first sight, this is likely to be more general and valid than including the exchange rate itself. For example, if there is full and complete pass-through of exchange rate movements to import prices, then real import price changes and real exchange rate changes will give the same information; while if pass-through is slow or incomplete, then real import price movements may be a better index of external influences than the real exchange rate. On the other hand, if import prices are highly insensitive *to world factors* as well as to the exchange rate, then estimated coefficients cannot be interpreted as capturing the influence of openness or external factors on inflation dynamics.

As it happens, substituting import prices for the exchange rate does not generate stabler or more interpretable results for any of our Phillips curve specifications. Table 7 shows that the same problems as before emerge if one uses real import price inflation instead of real exchange rate changes. The forward-looking specification delivers incorrectly signed coefficients; and all Phillips curve estimates deliver coefficients that diminish to economically and statistically insignificant values in post-1979 samples. That specifications with import prices and exchange rates deliver similar results is consistent with our finding that nominal exchange rate change and nominal import price inflation are quite strongly related in the UK.

3.2 Allowing for level effects of the exchange rate

Our results in Section 2 appear to give a weak or negligible role to *changes* in the exchange rate. The exchange rate may nevertheless be crucial for inflation, if the *level* of the exchange rate is important. We now report the results of estimates of the above Phillips curves supplemented to include a ‘level’ term in the real exchange rate. The specifications we consider are:

$$\pi_t = b_0 + \beta E_t\pi_{t+1} + \lambda\ ulc_t + \phi(\Delta q_t - \beta E_t\Delta q_{t+1}) + \delta\ q_t + \text{dummies} + u_t \quad (11)$$

$$\pi_t = b_0 + \Sigma_{i=1}{}^3\beta_i\ \pi_{t-i} + \Sigma_{i=1}{}^3\ \phi_i\ \Delta q_{t-i} + \Sigma_{i=1}{}^3\ \lambda_i\, ulc_{t-i} + \delta\ q_{t-1} + \text{dummies} + u_t \quad (12)$$

$$\pi_t = b_0 + \Sigma_{i=1}{}^3\beta_i\ \pi_{t-i} + \Sigma_{i=1}{}^3\ \phi_i\ \Delta q_{t-i} + \Sigma_{i=1}{}^3\ \lambda_i(y-y^*)_{t-i} + \delta\ q_{t-1} + \text{dummies} + u_t\,, \quad \Sigma_{i=1}{}^3\beta_i = 1 \quad (13)$$

The level term can be interpreted as capturing the presence of intermediate imported goods as in McCallum and Nelson (1999, 2000), and, so, a role for q in the expression for marginal cost or potential output.[13] We consider the implications of this model feature in detail in Section 4. Alternatively, 'levels effects' can be rationalised by models in which domestic price setters' markup over costs is influenced by the level of foreign prices (expressed in domestic currency units) (e.g. Martin, 1997; Batini, Jackson, and Nickell, 2000) or models where discrepancies between the consumption and product wage directly influence price determination (e.g. Modigliani and Papademos, 1975). In all cases, the expected sign on q in the equations is positive.

Estimates are summarised in Table 8 for different specifications and subsamples. The results for the forward-looking specification are in many respects encouraging. The coefficient on the levels term takes the expected positive sign for the full sample, albeit not significantly. Moreover, the coefficient on q_t becomes more significant for both the pre-1980 sample and the post-1992 sample, and is of roughly the same magnitude in both cases. When the 1980–2001 estimation period is used, the coefficient on q_t is of the wrong sign, but still not significantly different from its estimated magnitude in the other sample periods. Therefore, while the 1980-1991 observations do present difficulties, our results here are more consistent over time than were the results for the baseline New Keynesian Phillips curve considered in Section 2. Moreover, the exchange-rate change terms in Table 8 continue to have uninterpretable and significant coefficients, so consistent relationships seem isolated to the level term. Dropping the exchange-rate change term from equation (11) does not significantly alter the estimated coefficients on the levels term.

Our result that exchange-rate changes are insignificant but the level of q matters in the Phillips curves is consistent with what we would expect to find in a model where

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[13] McCallum and Nelson (1999, p. 558, eq. (5)) employ the CES production function $Y_t = [a_1(A_tN_t)^{v1} + (1-a_1)(IM_t)^{v1}]^{1/v1}$, where A_t is a labour-augmenting technology shock, N_t is labour input, IM_t is the quantity of imports, and $0 < a_1 < 1$. Application of standard formulae for marginal cost under CES technology (e.g. Varian, 1992, pp. 55–56) establishes that real marginal cost is a combination of productivity-shock-deflated real wages, $(W_t/P_t)/A_t$, and the real import price. Log-linearising this expression, assuming full pass-through, and using ulc_t to approximate $\log[(W_t/P_t)/A_t]$, lead to a Phillips curve specification where q_t should enter with a positive coefficient.

imports are intermediate goods. This is documented in stochastic simulations, discussed presently.

3.3 Evidence from model simulations

We now investigate the issue of what exchange-rate/inflation regression output we should expect to find from the data if the data are actually generated by certain open economy models. The specific models that we examine differ only in the specification of how the exchange rate enters the Phillips curve. The first model features a standard New Keynesian open-economy Phillips curve in which imports are a consumer good, the other the McCallum-Nelson (2000) model in which imports are solely intermediates.

We need to specify the remainder of the model—the aggregate demand equation and policy rule. We assume that preferences are separable across time and that labour is inelastically supplied. Assuming foreign inflation and output are constant, and using the uncovered interest parity (UIP) condition to absorb the exchange-rate channel on aggregate demand into the interest elasticity of the IS equation, the alternative models have common IS and UIP equations:

$$y_t = E_t y_{t+1} - \sigma(R_t - E_t \pi_{t+1}) + v_t \quad (14)$$

$$q_t = E_t q_{t+1} - \tfrac{1}{4}(R_t - E_t \pi_{t+1}) + e_{uipt} \quad (15)$$

where $\sigma > 0$, and the shock v_t is an exogenous term embodying domestic demand shocks, shocks to global demand for domestic output, as well as some influence of UIP shocks. The models also agree in their definition of the output gap as the difference between the detrended logs of output and potential output,

$$gap_t = y_t - y_t^*. \quad (16)$$

The models differ on the supply side. In the baseline New Keynesian case (NK), potential output is a function of the technology shock alone, and the Phillips curve describing the CPI has a separate term involving the exchange rate channel:

$$y_t^* = a_t, \quad (17)$$

$$\pi_t = \beta E_t \pi_{t+1} + \alpha_g gap_t + \phi(\Delta q_t - \beta E_t \Delta q_{t+1}) + u_t \ , \alpha_g > 0, \phi > 0., \quad (18)$$

(Here we have simplified the NK model so that the output gap and unit labour costs are proportional, which is not the case in general.) In the intermediate-imports variant, the Phillips curve applies to the whole CPI and the exchange rate enters only via its relevance for potential output:

$$y_t{}^* = a_t + \omega q_t \tag{19}$$

$$\pi_t = \beta E_t \pi_{t+1} + \alpha_g gap_t + u_t \ , \tag{20}$$

where $\omega < 0$. Following McCallum and Nelson (2000), we set $\omega = -0.05$. For the other parameters, we set $\alpha_g = 0.20$,[14] $\beta = 0.99$, and $\sigma = 0.6$. The Phillips curve shock u_t is assumed to be white noise with annualized standard deviation 2%, the IS shock and UIP shocks AR(1) with AR parameters 0.33 and 0.92 and innovation standard deviation 1% and 0.9% respectively.

For both models we simulate with an estimated policy rule for the UK. The rule we use is one estimated on quarterly data for 1992 Q4–1997 Q1 (the early inflation targeting period in the UK):

$$\begin{aligned} R_t = \underset{(0.007)}{0.010} + \underset{(0.102)}{0.381} R_{t-1} &+ (1-0.381)\cdot\underset{(0.484)}{1.457}(0.25E_t\pi_{t+1} + 0.25\pi_t + 0.25\pi_{t-1} + 0.25\pi_{t-2}) \\ &+ (1-0.381)\cdot\underset{(0.145)}{0.528}\, y_t^{hp} \end{aligned} \tag{21}$$

$R^2 = 0.85$, SEE = 0.25%.

which resembles a 'Taylor rule' in having a long-run estimated response to inflation of 1.5 and HP-filtered output of 0.5.

We estimate on the data generated from each of the models a forward-looking open economy Phillips curve,

$$\pi_t = b_0 + b_1\pi_{t+1|t-1} + b_2 gap_{t|t-1} + b_3\Delta q_{t|t-1} + b_4\Delta q_{t+1|t-1}, \tag{22}$$

where $X_t|_{t-1}$ denotes a projection of X_t conditional on the information from a set of lagged data. We consider the following question: if the exchange rate mattered for inflation in the manner suggested by equation (8), would econometric estimates of

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[14] In line with empirical estimates, this choice corresponds to an output gap coefficient in the Phillips curve of 0.05 when inflation is expressed in quarterly units.

these Phillips curves, as in regression (22), uncover a significant relationship? Or would instrumental-variables estimates be too imprecise to uncover this link? Conversely, we ask what we would expect estimates of equation (22) to produce in an environment where imports are an intermediate good, and so, no term in Δq is justified in the Phillips curve.[15] To answer these questions, we simulate the two models above, completed by a policy rule estimated on UK data, then estimate the open-economy Phillips curve (22) on the simulated data.

The results are reported in Table 9. The most striking feature of the table is that the exchange-rate change term is highly significant when the New Keynesian Phillips curve with imported consumer goods is the data generating process. In other words, when the data are generated by equation (8), we should expect instrumental variables estimation to detect extremely significant influences of exchange rate changes on inflation. The fact that we cannot find such significant terms in the UK data undermines the plausibility of the New Keynesian specification. On the other hand, the intermediate-goods specification delivers insignificant coefficients on the exchange-rate-change terms, in keeping with what he have found in the data.

4. Implications of openness for policy rules

We turn now to the implications of the specification of open-economy inflation dynamics for monetary policy rules and welfare. The Phillips curves that we have focussed on—namely the NKPC with imported consumer goods and the corresponding Phillips curve when imports are intermediates—are open-economy generalizations of the New Keynesian model, and optimal monetary policy in that model has been studied in Goodfriend and King (1997), Rotemberg and Woodford (1997), King and Wolman (1999), and Woodford (2002), among others. These papers have focussed on the inefficiencies to which the economy is subject in the presence of nominal rigidities. The nominal rigidities underlying the New Keynesian Phillips curve are an incipient source of output gaps—deviations of output from its flexible-price equilibrium level. With flexible-price equilibrium output corresponding to the efficient level (or if it is assumed, following Rotemberg and Woodford, that inefficiencies are dealt with by microeconomic policies), the optimal role for monetary policy is to cancel out the effects of nominal rigidities. Such a monetary policy produces demand and cost conditions that imply no pressure to move on those prices that are sticky, so that the impediments to adjustment of those prices do not, in fact, produce costly deviations of the economy from its flexible-price equilibrium.

[15] Thus, the Phillips curve implied by the McCallum-Nelson open economy model is nested within specification (22), corresponding to the parametric restriction $b_3 = b_4 = 0$.

The standard New Keynesian model in which this result is obtained is a closed-economy New Keynesian model with a single sector, sticky prices, and flexible wages. Under these conditions, the nominal stickiness applies to the whole of the price index, and so CPI inflation targeting is optimal. A modified version of this result obtains under more general assumptions regarding nominal stickiness in the economy. The principle that monetary policy should adopt as its target the index of prices that corresponds to the sticky prices in the economy is clearly stated in Friedman (1967, fn. 11), who noted that if factor prices (such as wages) are sticky and prices are not, there is a case for targeting zero inflation in factor prices. Formalisations of this principle for particular variants of the New Keynesian model appear in Aoki (2001), Erceg, Henderson, and Levin (2000), and, in an explicitly open-economy context**,** Clarida, Galí, and Gertler (2001, 2002).[16] In particular, Aoki finds that in a two-sector model in which wages as well as prices in one sector are flexible, monetary policy should target inflation in the sticky-price sector; Erceg, Henderson, and Levin show that when both wages and prices are staggered, then the welfare function depends on both wage and price inflation.

For the implications of these principles for inflation targeting in an open economy, let us first consider the case where the CPI contains a substantial category of imported items, whose prices vary closely with the nominal exchange rate-adjusted foreign price level. Meade (1951, p. 106) advocated maintaining constant the domestic-goods price index in such an environment.[17] This preference arose, as explained in Meade (1978, p. 429), from a rejection of CPI targeting on the grounds that an unfavourable terms-of-trade shock would require aggregate demand policies that produced offsetting declines in nominal domestic prices, which would be costly in terms of the output gap because of the stickiness of those prices. Assuming that domestic prices are sticky but wages are flexible,[18] domestic-goods price inflation targeting eliminates the inefficiencies from stickiness while permitting the exchange rate to perform its expenditure-switching function—terms of trade movements are permitted to manifest themselves in fluctuations in the CPI relative to a constant value for the domestic basket. These advantages led Clarida, Galí, and Gertler (2001) to recommend domestic price inflation targeting for a small open economy, a recommendation they

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[16] Kollmann (2002) endorses the principle in a quantitative model.
[17] Similarly, Simons (1948, p. 329) recommended targeting 'an index made up primarily of prices of "domestic," rather than of internationally traded goods,' but added 'it would probably not be possible to construct an index of this kind'.
[18] In Meade's (1951) programme, the prescription was for wage rigidity to be eliminated by microeconomic reforms. Meade (1978) concluded that this scenario was too optimistic and that the risk of wage rigidities ruled out domestic-goods price targeting.

reaffirmed for a two-country model provided that coordination opportunities were absent (Clarida, Galí, and Gertler, 2002).

This recommendation is, however, not robust to the assumption that imports serve as final consumer goods. McCallum and Nelson (1999, 2000) advocate instead modelling imports as a flexibly-priced intermediate good, which serves as an input in the production of sticky-price final consumer goods.[19] The observation that some consumer goods are imported is so familiar that an approach that suggests otherwise may seem unappealing. But it is crucial to note that, as Wilson (1976, p. 5) observed, "all imports require the services of domestic factors… [and] all domestic output, or virtually all, requires imported inputs at some stage in the production process." On that basis, Wilson argued that treating all imports as intermediates was valid for analysis of UK inflation behaviour. The treatment of imports as intermediates in this approach therefore does not rest on the quantitative importance of imports that are specifically categorised as raw materials. In fact such a motivation is unattractive for the UK, since the UK's reliance on imported oil—which is the principal commodity invoked as an imported raw material in the literature (e.g. Findlay and Rodriguez, 1977)—has not been at all constant in the postwar period, owing to the advent of North Sea oil. Yet we have found that the empirical failure of models that treat imports as final consumer goods is pervasive across sample periods; and so we favour an approach that rethinks the appropriateness of labelling *any* final goods as wholly imported. If the intermediate-goods approach is adopted, welfare implications follow immediately. Provided that all final goods are produced using a mix of domestic factors and imported inputs, and price stickiness applies to final goods prices, then CPI inflation targeting is optimal for an open economy.[20]

The implications of a policy of 'domestic-goods price inflation targeting' in a world where imports are, in fact, intermediate goods, can perhaps best be illustrated by first considering a hypothetical closed-economy monetary policy regime of 'aggregate wage inflation targeting'. Suppose that it was *believed* by the authorities that the sole source of nominal stickiness in the economy lay in nominal wages, with the observed stickiness of prices simply reflecting the static dependence of prices on nominal costs. The central bank is therefore assigned the task of stabilising an index of nominal wage

[19] More recent work that advocates modelling imports as an intermediate good includes Erceg (2002) and Obstfeld (2002a, 2002b).

[20] Note that this interpretation of consumer goods in the McCallum-Nelson model is distinct from that provided by Engel (2002b), who states that 'nominal consumer prices of imported goods are not sticky' in this model. Our view is rather, that there are no imported consumer goods in this model, and that all consumer prices in the model are sticky, in the sense that there are welfare losses from complete, instant adjustment of final consumer prices to movements in costs (including the cost of imported inputs).

costs (or its rate of growth); no attempt is made to stabilise prices other than via the stabilisation of wages. Suppose further that *in fact* the source of nominal stickiness in the economy is in (all) final goods prices, not wages. In practice, in a world of differentiated goods, the labour component will vary in the production functions of various goods. The policy of nominal wage targeting will tend to promote the greatest stability in the prices of those final goods whose cost structure is the most wage-intensive. The 'effective' goods price index targeted by monetary policy will be one that gives lower weight to prices of goods whose production process is less labour-intensive. But with the true nominal rigidity being in consumer prices, this policy will be sub-optimal; the appropriate index to be targeted should be the CPI, and the variability permitted by monetary policy in the prices of less labour-intensive costs will be costly to household utility.

Now consider an analogous exercise in an open economy. Specifically, consider the 'domestic-goods price inflation targeting' policy when, in fact, all imported goods serve only as intermediate goods, and all consumer prices (and no factor prices) are sticky. Some goods will be more intensive than others in domestic inputs compared to imported inputs; and conversely, some goods will require a larger imported component in their production. Thus, for any given degree of stickiness in goods prices, the import-intensive goods will tend to move more closely with movements in the exchange rate and world prices than other consumer prices; and this characteristic, together with the observation that they have more of the physical characteristics of foreign-produced goods, could lead to these goods being labelled 'imported consumer goods' by statistical agencies in the collection of price indices. But in truth there are no genuine 'imported consumer goods' in this hypothetical economy, and, furthermore, all final goods are equally sticky, in the sense that the costs of adjusting nominal prices are the same across consumer goods. The 'important distinction' between CPI inflation and domestic inflation stressed by Clarida, Galí, and Gertler (2002, p. 880) does not apply in this economy; or, to put it another way, the price index that is costly to adjust and which monetary policy should stabilise is the CPI. Attempts to classify a sub-category of the CPI as 'domestically produced goods' and make the price index of these goods the target of monetary policy, would impose welfare losses on the economy relative to a policy of CPI targeting.

We can consider these ideas more directly via simulations of the New Keynesian model with imported consumer goods, under alternative policy rules. In this model, the loss function for the community may be written, as shown in Clarida, Galí, and

Gertler (2001), as:[21]

$$\Sigma_{i=0}^{\infty} \beta^j[\pi_{t+j}^{D\,2} + \lambda_y gap_{t+j}^{\;2}], \qquad (23)$$

and an optimal policy that minimizes these discounted values of domestic-inflation and output-gap fluctuations would satisfy a first-order condition of the form:[22]

$$\pi_t^D = -(\lambda_y/\alpha)\,(gap_t - gap_{t-1}). \qquad (24)$$

If imports instead served as intermediate goods, the appropriate loss function and optimality condition would instead refer to CPI inflation:

$$\Sigma_{i=0}^{\infty} \beta^j[\pi_{t+j}^{\;2} + \lambda_y gap_{t+j}^{\;2}], \qquad (25)$$

$$\pi_t = -(\lambda_y/\alpha)\,(gap_t - gap_{t-1}). \qquad (26)$$

We simulate the New Keynesian imported-consumer-goods model under both rule (24) and (26). That is, in a model in which domestic price inflation targeting is optimal, we consider both a rule (24) that would achieve close to the social optimum, as well as a form of CPI inflation targeting (rule (26)), which, according to the model, is a sub-optimal policy.[23]

Results are given in Table 10.[24] The domestic-goods price inflation targeting policy does succeed in achieving a low loss-function value as judged by (23). Targeting domestic inflation leads to high CPI inflation volatility—considerably more than would occur under CPI inflation targeting, as the results with rule (26) confirm. While we have little confidence in the New Keynesian model with imported consumer goods as a description of the UK data, the result that stabilisation of domestic-goods price inflation would mean creating some CPI inflation variability, is likely to be robust to alternative models, as discussed above.

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[21] Detailed discussions of the conditions under which a loss function such as (23) is a valid approximation of household welfare appear in Batini, Harrison, and Millard (2001), Benigno and Benigno (2002), and Galí and Monacelli (2002).

[22] This is an open-economy analogue of the central bank's first order condition in New Keynesian models under one version of commitment (see e.g. Woodford, 2002, Chs. 7–8).

[23] When we evaluate loss function (25), we use an output gap definition (i.e. using equation (19) rather than (17)) that would be appropriate if imported goods were intermediates. This has essentially no effect on the welfare comparisons, but is consistent with our approach of evaluating alternatives to CPI inflation targeting by several criteria, including by a loss function that is consistent with CPI inflation targeting were optimal.

[24] These employ a loss-function weight on output gap volatility of 0.8 (equivalent to a weight of 0.05 had inflation not been annualised units in functions (23) and (25)).

On the other hand, continuing to take the New Keynesian model at face value, the results in Table 10 suggest that CPI inflation targeting is stabilising for CPI inflation but results in only a minor increase in loss as judged by function (23). So CPI inflation targeting would appear to have quite desirable properties: it is optimal in the model which appears most consistent with UK data (i.e., the imported-intermediates model) and is only mildly sub-optimal in a more conventional but less empirically successful model (i.e. the New Keynesian model with imported consumer goods).

5. Conclusions

This paper has looked at the relationship between the exchange rate and inflation in the UK, contrasting the predictions and policy recommendations of four models: ‘pricing-to-market’ or ‘exchange rate disconnect’ models, the ‘Scandinavian’ or ‘monetary approach’ model, the standard New Keynesian open economy model, and a model where imports serve as intermediate goods.

As Obstfeld (2002b) notes, the extreme cases of exchange-rate disconnect and the Scandinavian model have been used to support the same policy recommendation. On the one hand, using a particular version of the pricing-to-market model, Engel (2002a, p. 15) notes that a fluctuating exchange rate does not provide a resource-reallocating role, and so argues that ‘fixed exchange rates are optimal’ in the model. On the other hand, advocates of the monetary approach have contended that nominal exchange rate changes and aggregate inflation in the domestic country move so closely together that stability in the one implies stability in the other. Relatedly, they have argued that a floating nominal exchange rate serves no useful allocative function, as it does not imply movements in the real exchange rate. Laffer and Miles (1982, p. 390) went so far as to say that Friedman’s (1953) case for flexible exchange rates “can be dismissed” for this reason.

For the UK, we find that neither of the above extremes can be justified. In line with Campa and Goldberg (2002), we find in the UK a close correspondence between exchange rate changes and rates of change in prices of products labelled imported consumer goods. This undermines a key element of the ‘pricing-to-market’ or ‘exchange rate disconnect’ approach. But we also find little relation between CPI inflation and nominal exchange rate changes. Together, these elements suggest that the exchange rate in the UK is one vehicle for relative-price adjustment and resource allocation, as argued by Obstfeld (2002b).

Another modelling approach, which includes the baseline New Keynesian Phillips curve described in Section 2 above, allows for exchange rates and import prices to move together while also distinguishing between CPI inflation and import price inflation. The policy recommendation of this approach is that the exchange rate should be permitted to float and that domestic-goods price inflation should be targeted (Clarida, Galí, and Gertler, 2001). We find, however, that the CPI inflation dynamics implied by this approach are not supported by the data. The approach predicts that CPI inflation and real exchange rate changes should have quite a strong relationship, but this relationship is consistently weak in UK data. Put another way, CPI inflation in the data behaves much like domestic-goods price inflation.

We have argued, following Wilson (1976) and McCallum and Nelson (1999, 2000), that a model that characterises all imported goods in the economy as intermediates provides the most attractive alternative. From a positive perspective, while not able to explain all the puzzles in UK data, this model is able to rationalise several key regularities: the low correlations between CPI inflation and nominal exchange-rate change, the high correlations between 'import price inflation' and nominal exchange-rate change, and the generally positive coefficients on the level of the real exchange rate in estimated open-economy Phillips curves. From a normative perspective, this modelling approach is one of few in open-economy analysis that can simultaneously justify the policies of CPI inflation targeting and a floating exchange rate. As Svensson (2000, pp. 157, 159) observes, 'all real-world inflation-targeting economies are quite open economies' and 'all inflation-targeting countries have chosen to target CPI inflation… None of them has chosen to target domestic inflation…' The model for which we have found support can therefore be regarded as consistent with the CPI inflation-targeting strategy followed in the UK and other open economies.

Data Appendix

P: RPIX series constructed and seasonally adjusted as in Nelson and Nikolov (2002, p. 40).

pm: Log of import price deflator. Deflator defined as in Bank of England (2000, p. 62).

q: Log of inverse of effective real exchange rate index. This index was obtained from the IMF's *International Financial Statistics* (*IFS*) (using the real effective exchange rate series computed from value-added deflators) for 1975–2001, and from the Liverpool model dataset (series kindly supplied by Patrick Minford) for 1968–75. Data for 1963–67 were constructed from raw *IFS* series on consumer prices, trade weights, and nominal exchange rates, with Germany and the United States as the rest-of-world proxy.

s: Log of inverse of UK nominal effective exchange rate index. Source: *IFS* and Bank of England.

ulc: Log of real unit labour costs. This cost series is an updated version of the Batini, Jackson, and Nickell (2000) labour share series, with pre-1978 data on employment constructed as in Neiss and Nelson (2001, p. 34).

y^{hp}: Deviations of log quarterly real GDP from an HP-filter based trend. HP-filter computed over 1955 Q1–2002 Q1 using filter parameter 1600. GDP series is ONS series ABMI.Q.

Δx defined as annualised percentage change ($\Delta x_t = (\exp(x_t)/\exp(x_{t-1}))^4 - 1$) in Tables 1, 2, 4–6, and 8; as four times the log-difference of variable $\exp(x)$ in Tables 5 and 9.

Indirect tax and price control dummies are defined as in Nelson and Nikolov (2002, pp. 18–19).

Figure 1: Scatter diagram of quarterly annualised rates of change of UK retail prices and nominal effective exchange rate, 1958 Q4 – 2002 Q2

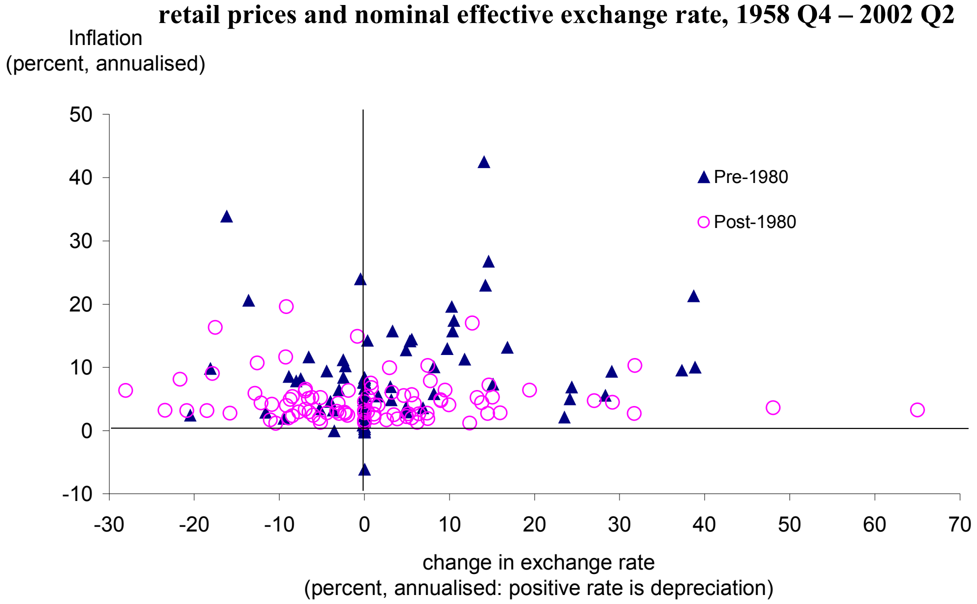

Figure 2: Scatter diagram of quarterly annualised rates of change of UK import price and nominal effective exchange rate, 1958 Q4 – 2002 Q1

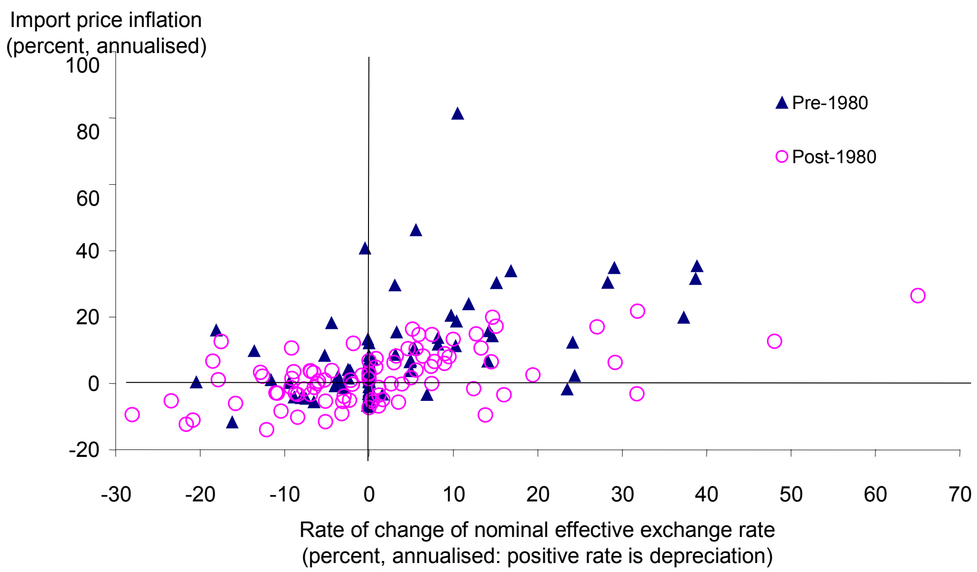

Table 1. Correlations between UK retail price inflation and nominal effective exchange rate change	
1958 Q4–2002 Q2	0.103
1958 Q4–2002 Q2, controlling for 1979 and 1990 tax changes	0.153[a]
1958 Q4–1979 Q2	0.289[a]
1980 Q1–2002 Q2	–0.073
1980 Q1–2002 Q2, controlling for 1990 tax change	–0.071

a. Statistically different from zero at 0.05 significance level.

Table 2. Correlations between UK import price inflation and nominal effective exchange rate change	
1958 Q4–2002 Q1	0.499[a]
1958 Q4–1979 Q2	0.478[a]
1980 Q1–2002 Q1	0.575[a]

a. Statistically different from zero at 0.05 significance level.

Table 3. The behaviour of the nominal exchange rate, import prices, and retail prices in three devaluations

1949 devaluation (using annual data)			
Change in:	Year before devaluation	Year after devaluation	Difference
Exchange rate	7.50	24.32	16.82
Import price deflator	2.82	13.17	10.36
Retail price index	3.07	2.77	–0.30
1967 devaluation			
	Year before devaluation	Year after devaluation	Difference
Exchange rate	–2.61	10.38	12.99
Import price deflator	0.30	13.21	12.91
Retail price index	1.61	5.68	4.07
1992 devaluation			
	Year before devaluation	Year after devaluation	Difference
Exchange rate	–0.58	10.30	10.88
Import price deflator	–1.34	11.08	12.42
Retail price index	5.31	2.86	–2.45

Table 4. Estimates of open-economy Phillips curves for United Kingdom			
Specification: $\pi_t = b_0 + \beta E_t\pi_{t+1} + \lambda\, ulc_t + \phi(\Delta q_t - \beta E_t\Delta q_{t+1})$ + dummies + u_t			
	Sample period		
Coefficient	1964 Q2–2001 Q4	1964 Q2–1979 Q4	1980 Q1–2001 Q4
β	0.976 (0.074)	0.812 (0.148)	0.984 (0.127)
λ	0.217 (0.162)	0.576 (0.358)	0.082 (0.169)
ϕ	–0.038 (0.047)	–0.007 (0.067)	–0.076 (0.041)
Dummy variables for:			
Heath price controls	–0.004 (0.001)	–0.003 (0.002)	—
VAT cut and food subsidies, 1974 Q3	–0.060 (0.035)	–0.059 (0.045)	—
Increase in VAT, 1979 Q3	0.230 (0.026)	0.221 (0.036)	—
Poll tax introduction, 1990 Q2	0.076 (0.025)	—	0.079 (0.020)

Instruments: constant, price shock dummies, lags 1–5 of inflation, and lags 1–4 of *ulc*, Δq, and HP-filtered log output.

Table 5. Estimates of backward looking open-economy Phillips curve for the UK			
Specification: $\pi_t = b_0 + \Sigma_{i=1}^3 \beta_i \, \pi_{t-i} + \Sigma_{i=1}^3 \, \phi_i \, \Delta q_{t-i} + \Sigma_{i=1}^3 \, \lambda_i \, ulc_{t-i}$ + dummies + u_t			
	Sample period		
Coefficient	1964 Q1–2002 Q2	1964 Q2–1979 Q4	1980 Q1–2002 Q2
$\Sigma_{i=1}^3 \beta_i$	0.827 (0.060)	0.584 (0.146)	0.772 (0.057)
ϕ_1	–0.001 (0.019)	–0.005 (0.046)	–0.019 (0.013)
ϕ_2	0.035 (0.020)	0.027 (0.045)	0.015 (0.013)
ϕ_3	0.021 (0.019)	0.079 (0.046)	0.003 (0.013)
$\Sigma_{i=1}^3 \phi_i$	0.056 (0.031)	0.101 (0.071)	–0.001 (0.021)
$\Sigma_{i=1}^3 \lambda_i$	0.025 (0.157)	0.668 (0.420)	–0.075 (0.104)
Dummy variables for:			
Heath price controls	–0.000 (0.001)	–0.000 (0.002)	—
VAT cut and food subsidies, 1974 Q3	–0.050 (0.035)	–0.050 (0.046)	—
Increase in VAT, 1979 Q3	0.260 (0.034)	0.274 (0.047)	—
Poll tax introduction, 1990 Q2	0.072 (0.034)	—	0.091 (0.018)
R^2	0.735	0.739	0.771
SEE	0.033	0.044	0.018
p–value, χ^2 test for $\phi_i = 0 \; \forall i$	0.157	0.289	0.364

Table 6. Estimates of backward-looking open-economy Phillips curve for the UK			
Specification: $\pi_t = b_0 + \Sigma_{i=1}^{3}\beta_i\,\pi_{t-i} + \Sigma_{i=1}^{3}\,\phi_i\,\Delta q_{t-i} + \Sigma_{i=1}^{3}\,\lambda_i\,y^{hp}_{t-i}$ + dummies + u_t			
	Sample period		
Coefficient	1964 Q1–2002 Q2	1964 Q2–1979 Q4	1980 Q1–2002 Q2
$\Sigma_{i=1}^{3}\beta_i$	1.0 (—)	1.0 (—)	1.0 (—)
ϕ_1	0.015 (0.020)	0.069 (0.046)	–0.014 (0.015)
ϕ_2	0.049 (0.020)	0.065 (0.045)	0.020 (0.015)
ϕ_3	0.015 (0.019)	0.003 (0.046)	0.008 (0.014)
$\Sigma_{i=1}^{3}\phi_i$	0.080 (0.031)	0.138 (0.067)	0.015 (0.024)
$\Sigma_{i=1}^{3}\lambda_i$	0.672 (0.231)	1.376 (0.533)	0.129 (0.172)
Dummy variables for:			
Heath price controls	–0.001 (0.001)	–0.002 (0.002)	—
VAT cut and food subsidies, 1974 Q3	–0.100 (0.037)	–0.115 (0.053)	—
Increase in VAT, 1979 Q3	0.218 (0.038)	0.214 (0.058)	—
Poll tax introduction, 1990 Q2	0.059 (0.035)	—	0.082 (0.021)
R^2	0.721	0.696	0.722
SEE	0.034	0.047	0.020
p–value, χ^2 test for $\phi_i = 0\ \forall i$	0.031	0.161	0.388
Sum of coefficients, $\Sigma_{i=0}^{3}\phi_i$ when β_i sum unconstrained	0.073 (0.030)	0.139 (0.066)	0.006 (0.022)

Table 7. Phillips curves with real import price inflation ($\Delta pm_t - \Delta p_t$) instead of Δq_t

	Coefficient or coefficient sum on real import price inflation		
Specification	1964 Q1–2002 Q2	1964 Q1–1979 Q4	1980 Q1–2002 Q2
Forward-looking, *mc* domestic variable, β unrestricted[a]	–0.053 (0.059)	0.061 (0.100)	–0.140 (0.067)
Forward-looking, *mc* domestic variable, β = 0.99 imposed[a]	–0.053 (0.058)	0.029 (0.087)	–0.141 (0.067)
Backward-looking, *mc* domestic variable, β unrestricted	0.167 (0.032)	0.202 (0.050)	0.018 (0.035)
Backward-looking, y^{hp} domestic variable, $\Sigma\beta_i = 1$ imposed	0.175 (0.033)	0.230 (0.060)	0.025 (0.039)

[a] From 1964 Q2 and up to 2001 Q4.

	Table 8. Effect of adding the level of exchange rate		
	Sample and specification	Estimate of ϕ or $\Sigma_{i=1}^{3}\phi_i$	Coefficient on q_t or q_{t-1}
	Full sample (1964 Q1–2002 Q2)		
A	Equation (8) (forward-looking NKPC) (q_{t-1} extra instrument)[a]	–0.044 (0.048)	0.007 (0.017)
B	Equation (10) (Backward looking, with detrended output)	0.075 (0.032)	0.010 (0.015)
C	Equation (9) (Backward looking with unit labour cost)	0.031 (0.032)	0.036 (0.015)
	1964 Q1–1979 Q4		
A	Equation (8) (forward-looking NKPC) (q_{t-1} extra instrument)[b]	–0.010 (0.070)	0.015 (0.074)
B	Equation (10) (Backward looking, with detrended output)	0.112 (0.084)	0.055 (0.105)
C	Equation (9) (Backward looking with unit labour cost)	0.123 (0.084)	–0.049 (0.098)
	1980 Q1–2002 Q2		
A	Equation (8) (forward-looking NKPC) (q_{t-1} extra instrument)[c]	–0.075 (0.042)	–0.006 (0.029)
B	Equation (10) (Backward looking, with detrended output)	0.018 (0.026)	–0.007 (0.021)
C	Equation (9) (Backward looking PC, with unit labour cost)	–0.005 (0.023)	0.008 (0.019)
	1992 Q1–2002 Q2		
A	Equation (8) (forward-looking NKPC) (q_{t-1} extra instrument)[d]	–0.004 (0.023)	0.021 (0.014)
B	Equation (10) (Backward looking, with detrended output)	0.028 (0.023)	–0.002 (0.014)
C	Equation (9) (Backward looking with unit labour cost)	–0.004 (0.025)	0.016 (0.016)
	Equation (8) (forward-looking NKPC) (q_{t-1} extra instrument)		
	Full sample (1964 Q1–2001 Q4)	–	0.004 (0.016)
	1964 Q2–1979 Q4	–	0.013 (0.072)
	1980 Q1–2001 Q4	–	–0.017 (0.022)
	1992 Q1–2001 Q4	–	0.020 (0.013)

[a] Sample period 1964 Q2–2001 Q4. [b] Sample period 1964 Q2–1979 Q4.
[c] Sample period 1980 Q1–2001 Q4. [d] Sample period 1992 Q1–2001 Q4.

Table 9. Estimates of open-economy Phillips curve on simulated data

Regression estimated: $\pi_t = b_0 + b_1\pi_{t+1|t-1} + b_2 gap_{t|t-1} + b_3\Delta q_{t|t-1} + b_4\Delta q_{t+1|t-1}$

Case 1: Data Generation Process = Open Economy Model with Conventional NKPC				
	Coefficient on:			
	$\pi_{t+1\|t-1}$	$gap_{t\|t-1}$	$\Delta q_{t\|t-1}$	$\Delta q_{t+1\|t-1}$
	0.946 (0.120)	0.384 (0.364)	0.243 (0.039)	–0.268 (0.057)
Case 2: Data Generation Process = Imported Intermediates				
	Coefficient on:			
	$\pi_{t+1\|t-1}$	$gap_{t\|t-1}$	$\Delta q_{t\|t-1}$	$\Delta q_{t+1\|t-1}$
	0.983 (0.212)	0.296 (0.624)	0.002 (0.036)	–0.004 (0.050)

Table 10. Effects of policy rules on welfare measures in New Keynesian model

Policy	Value of loss function (23)	Value of loss function (25)
Domestic-goods price inflation targeting (rule (24))	3.27	11.41
CPI inflation targeting (rule (26))	3.33	6.49

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