SPEED LIMIT AND ASYMMETRIC INFLATION EFFECTS FROM THE OUTPUT GAP IN THE MAJOR SEVEN ECONOMIES

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INTRODUCTION

((Fastgrowing economies, like champagne parties, have a habit of spinning out of control, unleashing inflation ... Typically, policy makers wait too late to spoil the fun, and they thereby increase the likelihood that growth will turn abruptly to recession.»

The Economist magazine (10 December 1994)

((Employment growth was rapid and the OECD-wide unemployment rate was brought down to 6¼ per cent in 1990, ... OECD inflation fell to a 25-year low of less than **3** per cent in 1986. This was a missed opportunity to lock in low inflation given the acknowledged cost of disinflation.»

OECD (1994a)

Economic commentators and policy-makers often emphasise that timing is important in macroeconomic policy-making and that mistakes can be costly, as illustrated by the quotations above. Such views contrast with the predictions of much empirical modelling of the inflation process where linear, or near linear, relationships between inflation and output predominate. A linear relationship implies that an increase in inflation resulting from excessive output can be reversed by following policies which ensure an equivalent reduction in output.] Thus, no permanent penalty, in terms of higher inflation or lost output, is ultimately paid for errors in macroeconomic policy-making or, as De Long and Summers (1988) put it, « policies can do no first order good or harm on the output side without permanently raising or lowering the inflation rate». This paper considers the empirical evidence of some alternatives to the simple linear relationship between output and inflation which imply a more important role for macroeconomic policy.

A common approach to empirical modelling of inflation involves estimates of the «output gap», namely the difference between «potential» output and actual output.[2] This approach assumes that there exists some identifiable path of potential output, such that if output rises above it, then there will be an increase in inflation (possibly with some lag) and conversely if output falls below potential output then there will be a fall in inflation. For example, commenting on the relationship between inflation and the output gap for the major seven economies, similar to that shown in Figure I, the OECD (1991) argued that :

Figure I. *Inflation and the output gap for the* major *seven OECD economies*
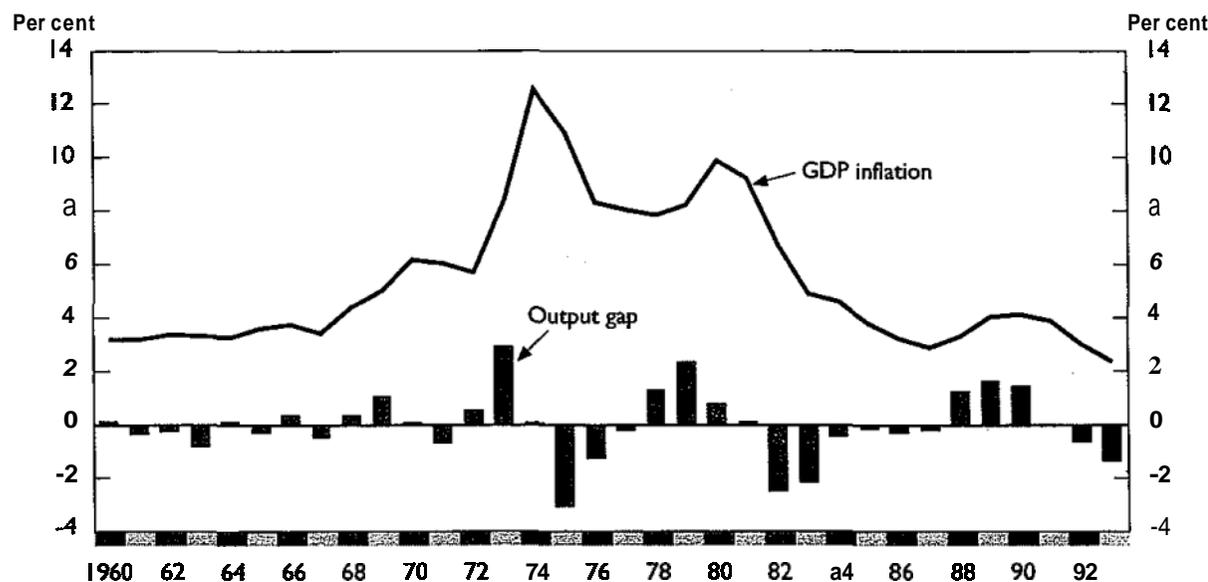
Per cent   Per cent

Source: OECD.

« There appears to be a relatively close link over time between the size of the output gap and the change in average inflation for the aggregate of the major OECD economies. As a rule of thumb, a negative output gap of 1 per cent has been associated with a reduction in inflation, as measured by the GDP deflator, of slightly more than ½ percentage point each year in the major countries taken together. Large divergences from this pattern have not occurred since the first oil shock. »

The concept of potential output is thus similar *to* that of the non-accelerating wages/inflation rate of unemployment (NAWRU or NAIRU) for the labour market. Indeed, Torres and Martin (1990) derive series for potential output by substituting a measure of potential employment which is consistent with the NAWRU into an estimated production function for the main OECD economies. This work has been updated by Giorno *et al.* in an article in this issue. Other less theoretically based approaches to deriving a measure of potential output involve simply smoothing actual output, for example using moving average method or a Hodrick-Prescott filter.[3]

In addition to evaluating the size of the output gap it is necessary to have some view of the nature of the relationship between the output gap and inflation in order to assess inflationary risks. This paper focuses on two departures from the simple linear relationship whereby inflationary pressures are judged in direct proportion to the size and sign of the output gap.[4] The first is whether there is empirical evidence of a « speed limit » effect such that if the gap between actual and potential output is closed quickly, then inflation can increase, even though output never rises above

potential. Such « speed limit » effects can be represented as a special case of a linear relationship between the output gap and inflation. The second issue concerns a complete departure from the linear model, namely whether there is evidence of an asymmetry in the inflationary effect of output gaps so that the inflationary effect of output being above potential is greater than the deflationary effect of output being below potential.

The remainder of the paper is organised as follows. In the first section the estimation of reduced form equations explaining inflation for each of the major seven OECD economies is described. The issue of speed limits is examined by reference *to* these equations in the section on speed limit effects in the linear model. In the third section variants of the equations are estimated in which allowance is made for possible asymmetric effects from negative and positive output gaps. Finally, the main results from the paper are summarised and the implications for policy are discussed in the final section. Various algebraic proofs are in given in Annex *1* and details of the estimation results are given in Annex 2.

ESTIMATION OF REDUCED FORM EQUATIONS TO EXPLAIN INFLATION

For each of the major seven OECD economies a reduced form equation for the change in inflation is estimated as a dynamic function of the output gap, using annual data starting in the early 1960s. Inflation is measured in terms of the non-oil GDP deflator at factor cost, in order to exclude the direct effect of oil shocks on those economies [the United States, Canada and the United Kingdom) with significant oil production sectors as well as to exclude the effect of changes in net indirect taxes. The output gap is defined as the percentage deviation of real GDP from potential, the latter being proxied by using a Hodrick-Prescott filter on (the logarithm of) actual GDP (see Annex 2 for further details).[5] The change in inflation is regressed on contemporaneous and lagged output gap variables as well as other variables designed to capture the effect of supply shocks.

The variables included to capture the effect of supply shocks can mostly be described as various measures of the « wedge »[6] or components of it : tax rates, import prices (weighted according to the weight of imports in total expenditure), total domestic demand prices and consumer prices. The price variables enter the equation either in terms of relative inflation rates (*e.g.* consumer price less output price inflation) or relative price levels (*e.g.* the level of consumer prices relative to the level of output prices), according to which is preferred statistically. The latter functional form implies stronger real wage resistance, since inflation responds not only to current and recent lagged differences in relative inflation rates, but also to all past differences reflected in relative price levels. In addition, a number of country specific dummy variables are included : in the equation for Canada to capture the operation of the Anti-Inflation Board in 1976 and 1977; in the equation for France to capture the effect of the general strike in 1968; and in the equation For the United Kingdom in 1976 and 1977 to capture the effect of incomes policy.[7] The equations also include a constant which has no theoretical role [and is ignored in empirical

Table 1. **The inflationary effect of the output gap in the linear models**

	impact effect	Long-run effect	Speed limit
United States	0.23**	0.23***	1.00
Japan	0.45**	0.39**	0.83
Germany	0.22**	0.21**	0.92
France	0.16	0.60***	3.80
Italy	0.78***	0.58***	0.74
United Kingdom	0.21	0.55***	2.62
Canada	0.41***	0.41***	1.00

Notes: The "Speed limit in column (3) is calculated according to expression [1] if there is no lagged dependent variable in the equation, and according to expression [2] or [3] if there is a lagged dependend variable, depending on which gives the lower value. The speed limit measures the proportion of any negative output gap which can be closed without inflation increasing.
*, ** and *** denote the coefficient is significant at the 10, 5 and i per cent significance level respectively.
Source: See equations in first column of Tables A1 to A7 in Annex **2.**

examples), but which captures the mean effect of omitted variables as well as possible measurement errors in the output gap (discussed further below).

The equations are estimated by ordinary least squares, although all contemporaneous explanatory inflation terms (mainly the change in import price inflation) are first instrumented using lags of the explanatory variables, the contemporaneous dollar price of oil, and the average inflation rate in all major seven economies and an aggregate measure of the output gap in all major seven economies. A general-to-specific strategy of estimation is adopted, allowing effects from up to two years of lags in the explanatory variables. However, since one of the main concerns of this paper is the dynamic response of inflation to changes in the output gap, the output gap terms are kept in the equation providing they have a t-ratio of at least unity.[8]

The estimated equations (reported in full in the first column of Tables A1 to A7 in the *Annex* 2) mostly pass a set of standard diagnostic tests at conventional levels of significance. An exception was the equation for Germany where a dummy variable (which takes a positive sign) was included for the year 1970 in order to avoid the equation failing a test of the normality of the residuals at the 1 per cent significance level. In all of the equations there is a correctly signed long-run effect from the output gap which is statistically significant to at least the 5 per cent level (see Table 1). There is also an important role for the supply-shock variables in all of the estimated equations, although their importance differs substantially between different equations (for example being relatively small in Japan and Germany).

SPEED LIMIT EFFECTS IN THE LINEAR MODEL

For the purposes of this paper a « speed limit » effect will be defined to be in operation if a rise in inflation can be attributed to a reduction in the output gap, despite output not rising above the level of potential output.[9] Consider the following simple representation of the relationship between inflation, π, and the output

gap, GAP (which encompasses the linear models estimated for each of the major seven countries) :

$$An = \beta_0\ GAP + \beta_1\ GAP\text{-}, + a\text{,}An\text{-}, + \alpha_2\ An\text{-}, + \text{.. supply-side shocks,} \qquad [1]$$

where A is the first difference operator, subscripts denote lags and β_0 and $(\beta_0 + \beta_1)$ are both positive. Consider first the simple case where there is no inertia to changes in inflation so that $a\text{,} = \alpha_2 = 0$. Now suppose that in period 1 output is below potential, GAP, $=$ GAP* < 0, and that in period 2 the gap is closed and output equals potential, *i.e.* GAP, $= 0$, then for inflation to rise $(An\text{,} > 0)$ β_1 must be negative, so that the impact effect of the gap on inflation must be greater than the total effect in the period following the impact. If this condition does hold, then the extent of the speed limit is determined in terms of the **proportion**,θ, of the output gap which can be closed without increasing inflation. This speed limit can be calculated as the ratio of the impact plus lagged effect of the output gap on inflation to the impact effect of the output gap [for proof of expressions [2], [3] and [4] for the speed limit see Annex 1], thus :

$$\theta = (\beta_0 + \beta_1)/\beta_0 \qquad [2]$$

If there is inertia to changes in inflation, so that α_1 or α_2 are not zero, then the calculation of the speed limit effect is more complicated because it involves the history of past inflation. Two extreme cases are therefore considered, although these are by no means exhaustive of all possibilities. Firstly, it is assumed that there has been a zero output gap for several periods prior to the downturn in period 1 so that inflation is stable and in period 1 inflation falls at the rate predicted by equation [1], so that $An\text{,} = \beta_0\ GAP*$. In this case the speed limit is calculated as :

$$\theta = (\beta_0\alpha_1 + \beta_0 + \beta_1)/\beta_0 \qquad [3]$$

Alternatively, assume that the economy has been running a negative output gap, GAP', for a number of periods prior to period 1 so that inflation is falling (both in period 1 and prior to it) at a steady state rate of $(\beta_0 + \beta_1)GAP*/(1 - a\text{,} - \alpha_2)$, as predicted by equation [1]. In this second case the speed limit is given as the ratio of the long-run effect to the impact effect of the output gap :

$$\theta = \{(\beta_0 + \beta_1)/(1 - \alpha_1 - \alpha_2)\}/\beta_0 \qquad [4]$$

In Table 1 the speed limits for each of the major seven economies are calculated from the estimated linear equations. In those cases where there are lagged inflation terms in the estimated equation, expression [3] or [4] is chosen to evaluate the speed limit effect according to whichever gives the the most binding speed limit effect (*i.e.* the lowest value of θ).

For three of the seven countries a speed limit effect does operate, so that the value of θ is less than one, implying that only a proportion of any negative output gap can be closed without inflation rising. However, even in these cases the speed limit effect is not particularly tight with Italy, Japan and Germany being able to close up to 74, 83 and 92 per cent of any negative output gap respectively, without inflation rising[10]. For both the United States and Canada θ is close to one, so that the impact and long-run effect of the output gap on inflation are similar, implying

that inflation will respond quickly to the current gap, but that there is no speed limit effect. There is no evidence of a speed limit effect for either France or the United Kingdom, with the estimated value of θ much greater than one.

Moreover, the importance of the speed limit effect should not be over-emphasised. In particular, the change in inflation over the course of an entire recession and recovery phase will be completely independent of the existence or scale of any speed limit effect. More formally, the sacrifice ratio, the ratio of the cumulative loss in output to the reduction in inflation, is given by the reciprocal of the the long-run effect of the output gap (*i.e.* $(\beta_0 + \beta_1)/(1 - a_1 - \alpha_2)$ in terms of equation [1]) and is independent of the speed limit effect (for proof see Annex *I*).

ASYMMETRIC EFFECTS FROM POSITIVE AND NEGATIVE OUTPUT GAPS ON INFLATION

In this section the empirical evidence as to whether the inflationary effect of output being above potential is greater than the deflationary effect of output being below potential is examined. Such an asymmetry has a long tradition in macroeconomic theory, corresponding to the Keynesian idea that the aggregate supply curve is kinked, being roughly horizontal up to some notion of full employment or potential output, beyond which it becomes very steep and even vertical. Recent work by Ball and Mankiw *(1994)* provides some microeconomic basis for asymmetrical inflation effects. They describe a menu-cost model of pricing behaviour where positive shocks to firm's desired prices generate faster adjustment than negative shocks, since in the latter case the adjustment of relative prices can be at least partially achieved by the presence of trend inflation."

Asymmetric or non-linear effects from demand on inflation do not, however, feature strongly in most empirical macroeconometric models.[12] An exception is the Bank of Canada model, following the work by Laxton et a/. (1993*b*), which found evidence of such asymmetry when estimating a reduced form inflation equation on annual data for Canada, see Coletti et a/. *(1994)*. The findings of Laxton *et al.* (1993*b*) suggest that the inflationary effects of a positive output gap are more than five times as great as the deflationary effect from a similar negative output gap and that, in addition, inflation responds more quickly to a positive gap. Recent work by Laxton et a/. *(1994)*. discussed further below, also finds evidence of such asymmetric non-linearities using a pooled estimation technique for the major seven economies. The restrictions necessary to transform their preferred non-linear asymmetric model of inflation to a more standard linear model are overwhelmingly rejected.[13]

In the present paper, the hypothesis of asymmetric gap effects is initially investigated by allowing differences between the effects of positive and negative output gaps in the estimated equations discussed in previous sections (this is similar to the approach followed by Laxton *et al.,* 1993*b*). Positive and negative output gap terms are retained in the equation, as before, providing that they have a t-ratio of at least unity. The resulting equations (tabulated in the second column of

Table **2.** **The inflationary effect of the output gap in the asymmetric models**

	Positive gaps		Negative gaps	
	Impact effect	Long-run effect	Impact effect	Long-run effect
United States	0.73 **	0.32*	a	a
Japan	0.74***	0.64***	a	a
Germany	0.37**	0.23 **	0.18	0.11
France	0.32	0.70 **	a	0.47
Italy	0.76*	0.35	0.80'	0.80'
United Kingdom	a	0.44'	0.65**	0.65**
Canada	0.96***	0.96***	a	a

a) Denotes that there is no effect due to the exclusion of the relevant coefficients.
*, ** and *** denote the coefficient is significant at the 10, **5** and I per cent significance level respectively
Source: See equations in second column of Tables A1 to **A7** in Annex **2.**

Tables A1 to **A7** in the ***Annex*** 2) generally have larger and statistically better determined coefficients on the positive gap terms than the negative gap terms, as summarised in Table 2. It is difficult to reliably quantify the extent to which long-run positive gap coefficients are greater than the negative gap coefficients because the latter are so poorly determined or even wrongly signed, but (with the exceptions of the United Kingdom and Italy) the positive gap effects are at least two to three times greater. The larger magnitude of the coefficients on short-run positive gap terms compared with the negative gap terms (again with the exceptions of the United Kingdom and Italy) implies that inflation also reacts more quickly to the opening up of a positive gap than a negative gap. The revised equations lead to an improvement in goodness-of-fit (as measured by a lower standard error of the equation) in three countries (United States, Japan and Canada). In two of these cases, the United States and Canada, the set of linear restrictions necessary to transform the equation into the corresponding linear equation discussed earlier are rejected by an F-test at the 1 per cent and 5 per cent significance level, respectively. However, in each of these cases, while there is some statistical improvement in fit, the resulting models have the implausible property that there is no disinflationary effect from a negative output gap.

Allowing for possible mismeasurement of the gap

While the results summarised in Table 2 are at least suggestive of inflation responding more to positive gaps than to negative gaps, the results are far from being conclusive. One reason why the results are perhaps not more convincing is the problem of measuring the output gap. In particular, if positive output gaps have a greater effect on inflation than negative gaps, then it may be reasonable to assume that on average actual output is below potential output, a point emphasised by Laxton *et al.* (1994).[14] This in turn would mean that standard

methods of estimating potential output (such as the Hodrick-Prescott filter adopted here), which typically produce some smoothed trend of actual output, may be systematically over-estimating potential output. Laxton *et al.* (1993) present Monte-Carlo evidence which shows that if the true data generation process does have asymmetric effects from inflation, a failure to allow for this mismeasurement strongly biases tests towards the acceptance of a linear approximations. However, given the limited span of time series data typically being worked with, it is difficult to simultaneously identify the bias in the gap as well as a non-linear relationship between the gap and inflation. In order to overcome this problem Laxton et a/. (1994) adopt a pooled estimation technique in which common parameters across the major seven OECD countries are imposed. The use of a pooled estimation approach, however, clearly relies on the assumption of similarity in the processes generating inflation across economies with widely different institutional frameworks and widely different histories of macroeconomic performance.[15]

An alternative approach which is adopted here is to assume a simple relationship between the mismeasurement of the output gap and the form of the non-linear relationship between inflation and the output gap. Thus if, for example, it is assumed that a positive gap has an effect on inflation which is **double** the effect of a negative gap, then the output gap derived from the Hodrick-Prescott filter is adjusted by subtracting a constant to give the result that over the full sample period the sum of all negative output gaps is **double** the sum of all positive gaps.[16] More formally, if a constant 6, is subtracted from the Hodrick-Prescott gap measure, GAP, so that the cumulative negative output gap is « n » times the cumulative positive gap, then the form of the gap which is included in the reduced form inflation equation is $f_n(GAP)$, where :

$$f_n(GAP) = n \ (GAP - 6) \quad \text{if} \quad (GAP - 6) > 0 \quad\quad [5]$$
$$= \ (GAP - 6) \quad \text{if} \quad (GAP - 6) < 0.$$

Thus 6 is calculated, dependent on n, to ensure that the weighted sum of positive and negative gap terms is zero (*i.e.* $\Sigma \ f_n(GAP) = 0$, where Σ denotes the sum over the entire sample period). For each country $f_n(GAP)$ is calculated for values of n of 2, 3, 4 and 5 and the value of n chosen according to which $f_n(GAP)$ gives the greatest goodness-of-fit when substituted For the linear GAP variables (which correspond to the case n = 1) in the estimated reduced form inflation equations.[17]

The results from following this estimation procedure are summarised in Table 3 with full details of the equations (for the optimal value of n) detailed in the third column of Tables A1 to A7 in the Annex 2. For five of the seven countries some improvement in goodness-of-fit (as measured by a lower standard error to the equation) is achieved relative to the linear model. The values of n which maximise the goodness-of-fit are **4** for the United States, Japan and Canada, 2 for Germany and France, whereas for both the United Kingdom and Italy the transformed gap measures do not give any improvement in goodness-of-fit over the linear model. In three of the fives cases (the United States, Canada and Japan) where there is some improvement over the linear model, the linear model is rejected at least at the 5 per

Table **3.**   **Tests for alternative asymmetric models**

	Value of "n" for $f_n(GAP)$ giving greatest goodness-of-fit[1]	Magnitude of adjustment (δ) to the output gap (per cent of GDP)	F-test versus linear Model[2]
United States	4	0.89	Linear model rejected at 1 per cent level
Japan	4	1.11	Linear model rejected at 5 per cent level
Germany	2	0.71	Not possible to reject linear model
France	2	0.47	Not possible to reject linear model
Italy	1		Not applicable
United Kingdom	1	_	Not applicable
Canada	4	0.92	Linear model rejected at 5 per cent level

1.   Greatest goodness-of-ht is judged by lowest standard error for the equation. A value of "n" of I signifies the linear model is preferred.

2.   The test is carried out by constructing a composite equation of the linear model and the asymmetric model with $f_n(GAP)$ and then conducting an F-test to see whether the linear model is a valid restriction of the composite model.

cent significance level as a restriction of the more general composite model which includes both the linear and transformed gap terms. This is, however, quite a strict test of the asymmetry. because there is a high degree of collinearity between the alternative measures of the output gap |*i.e.* GAP and $f_n(GAP)$] in the composite equation, which will tend to bias against rejection of the linear model.

The magnitude of the constant adjustment, δ, to the Hodrick-Prescott measure of the gap is between 0.9 and 1.1 per cent for the United States, Japan, and Canada, and 0.5 to 0.7 per cent for France and Germany. The magnitude of these adjustments can be compared with the constant adjustment of 0.6 per cent which Laxton et a/. (1994) estimate for the major seven countries using a pooled estimation technique.

The two countries, Italy and United Kingdom, where the linear model is favoured over asymmetric alternatives are also those (together with japan) where the standard error of the equation is largest. They are also the two countries where, arguably, structural reform, particularly in the labour market, has had most influence in changing the processes which determine inflation. Barrell (1990) finds evidence of a structural break in estimated wage equations for Italy in the early 1980s. which is attributed to the gradual dismantling of wage fixing agreements under the Scala Mobile. If the reduced form inflation equation is estimated for Italy. but only using data from 1980 onwards, then an asymmetric model is preferred to linear alternatives.

An illustrative example

In order to demonstrate the importance of these asymmetries, the behaviour of inflation in various recovery scenarios from a hypothetical recession are considered, using the US equations as an illustrative case, with the predictions from the linear model being compared with those of the asymmetric model. The recession is assumed to take place following a period of stable inflation (assumed to be 5 per cent per annum) where output has coincided with potential output. In the first, second and third years of the recession output is assumed to be 1, 2 and 3 per cent below potential output, respectively. Three alternative recovery scenarios are considered : ((gradual recovery,, whereby the gap is closed to −2, −1 and zero in successive years; ((fast recovery,, whereby the gap is closed immediately, but thereafter output does not rise above potential; and an ((over-shooting), scenario whereby the gap is closed immediately, and output then over-shoots potential giving a positive gap of +2 and then +1 before the gap is finally closed.

The results of applying these three scenarios to the linear US model are shown in Figure 2a. In all cases, the post-recovery inflation rate is lower than the pre-recession inflation rate and the reduction in inflation is proportional to the loss of output (relative to potential). Thus, in the gradual recovery scenario the total cumulative output loss is three times greater than in the over-shooting scenario and the reduction in inflation is similarly three times greater (*i.e.* the sacrifice ratio is constant across the recovery scenarios). Differences between these scenarios illustrate that, to the extent that this simple linear model is appropriate, mistakes in macroeconomic policy-making are not very costly. For example, if following the over-shooting scenario the inflation rate is judged to be unacceptably high, then this could be subsequently remedied by running a negative output gap for a sufficiently long period – the cumulative output loss/gain of achieving any given steady-state inflation target at some point in the future is identical no matter what time path the output gap follows.[18]

The asymmetric ((shifted, output gap equation for the United States (see third column of Table A1 in the *Annex* 2) has the property that the magnitude of the long-run inflationary effect from a given positive gap is four times the magnitude of the response to the same negative gap and also about double the magnitude of the effect (of either sign) in the linear equation. The results of the same three scenarios on the asymmetric model are very different from those of the linear model, see Figure *2b.* Firstly, the reductions in inflation achieved in the gradual recovery and fast recovery scenarios are smaller than those implied by the linear model. The most striking difference, however, is that the inflation rate at the end of the over-shooting scenario is actually **higher** than the pre-recession rate, despite a cumulative output loss relative to potential of 3 percentage points over the course of the entire cycle (*i.e.* the sacrifice ratio has a perverse sign). Furthermore, correcting for past mistakes is much more costly than implied by the linear model. In this case, the inflationary effect of every percentage point of output above potential requires four percentage points to be spent below potential to produce a corresponding

A. Linear model¹

Sacrifice ratio = **4.3** in all cases

Trough

Over-shoot

Fast recovery

Gradual recovery

B. Asymmetric model¹

Trough

Over-shoot,
perverse sacrifice ratio

sacrifice ratio = 9.1

Gradual recovery,
sacrifice ratio = 9.1

Year
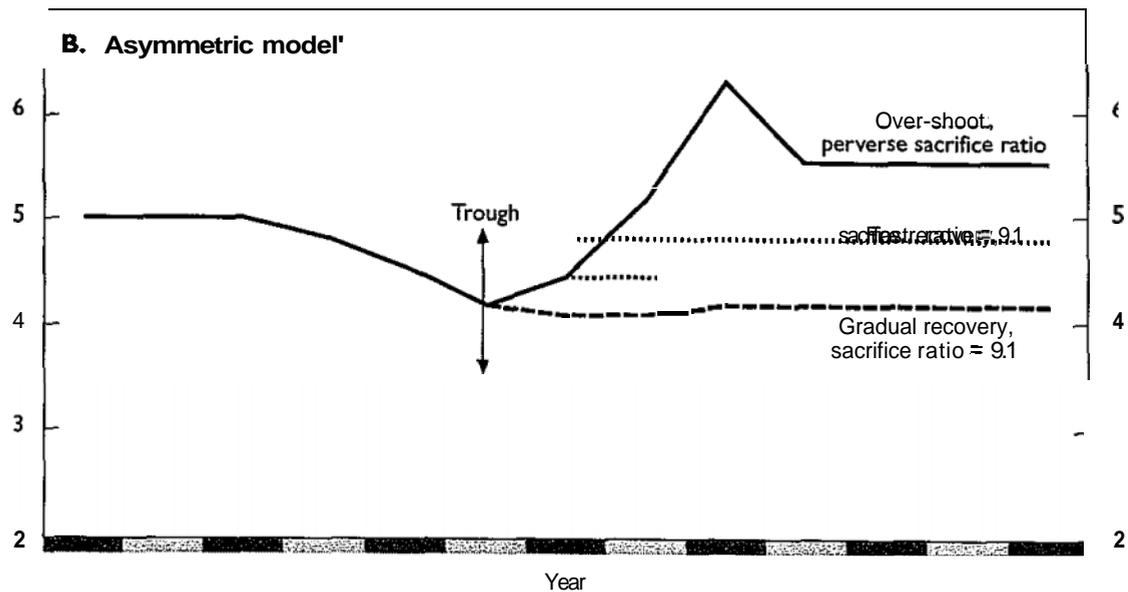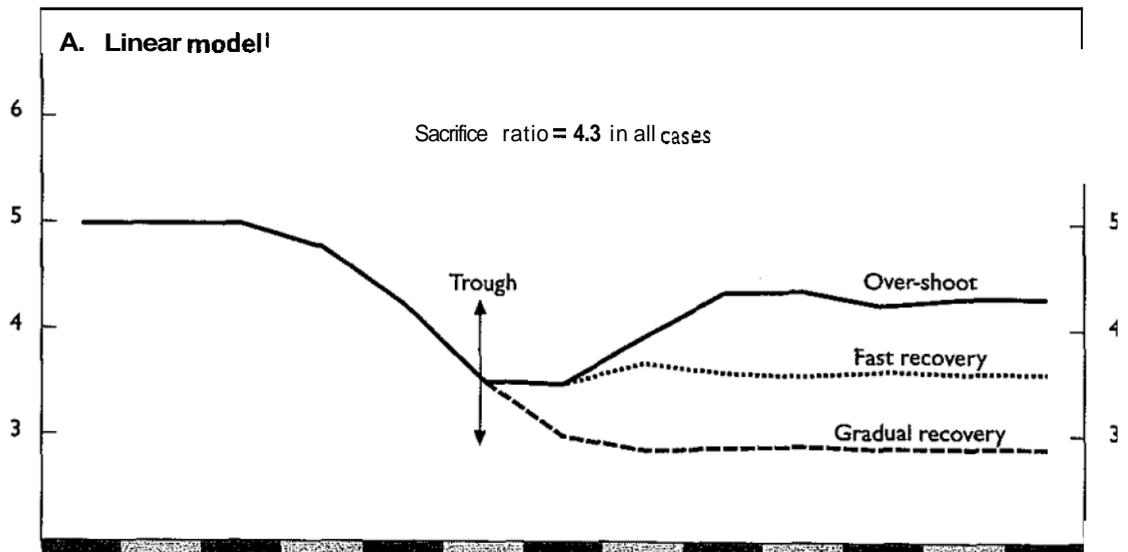
1. Inflation is determined according to the equation:

$$An = b_0 {}^*GAP + b_1 GAP_{-1} + \alpha_1 \Delta\pi_{-1} + \alpha_2 \Delta\pi_{-2}$$

where α_1 = -0.483, α_2 = **-0.266**. b_0 = **0.234** and b_1 = 0.174 are based on the estimated parameters of the linear model for the United Sates (first column of Table A I in the Annex 2).

2. Inflation is determined according to the equation:

$$\Delta\pi = b_0 f_4(GAP) + b_1 f_4(GAP)_{-1}$$

where b_0 = 0.183. and b_1 = **-0.093** are based on the estimated parameters of the asymmetric model for the United Sates

(third column of Table A I in the Annex 2)

deflationary effect. Thus, following the over-shooting scenario, in order to return to the inflation rate that would have prevailed following the fast recovery scenario, a further 12 percentage point cumulative loss in output would be required (whereas in the case of the linear model it would only require the over-shoot to be reversed with a further **3** percentage point cumulative loss in output).[19]

This is one example of the more general proposition highlighted by Laxton *et al.* (1994), that in an economy where there are important non-linear inflation effects «by adopting rules that minimise the variance of output, policy makers can raise the average level of output of the economy over time». The extent of the output loss implied by the volatility in output can be readily evaluated for the estimated asymmetric equations (see*Annex 1).* For the three countries (the United States, Japan and Canada), where evidence of such asymmetries has been found to be strongest, the volatility in output over the entire sample estimation period implies an average output loss of about 1 per cent of GDP. However, over the course of particularly pronounced cycles, the output cost has on occasions been more than double this.

While the gains from active macroeconomic policy are in principle much greater with asymmetric inflation effects, judging the appropriate time to intervene can be more problematic. Thus, in the over-shooting scenario the upturn in inflation, is very sudden compared with the more gentle upturn in inflation predicted by the linear model. This suggests that changes in inflation may only act as a very late warning signal to tighten policy.

SUMMARY AND POLICY IMPLICATIONS

Some evidence has been found to support the notion of speed limit effects in the context of a linear model underlying the inflation process for three of the major seven OECD economies. However, the extent of such effects are more limited than has been found in previous work which has focused on the labour market. Nevertheless, an awareness of speed limit effects may be important for forecasting purposes, particularly if the authorities are committed to maintaining inflation within a target range. However, speed limit effects do not fundamentally alter the questionable property of linear models of inflation that macroeconomic policies can have no first order effect on output without changing inflation.

For three of the major seven economies it is possible to significantly improve on linear models of inflation by allowing for asymmetric effects from the output gap which suggest that the inflationary effects of positive gaps are up to four times larger than the deflationary effect of negative gaps. One reason why the results are not more convincing may be the difficulty of simultaneously estimating the form of the non-linear relationship between inflation and the output gap as well as the size of the output gap. An important implication of asymmetric inflation effects is that conventional ((trend» methods of deriving the output gap are likely to be systematically biased.

In the presence of asymmetric inflation effects, of the form explored in this paper, the main inflationary risks come not from closing the gap quickly *per* se, but rather from overshooting potential output. In practice, the problem of judging the right moment for policy action to prevent over-shooting is likely to be difficult for a number of reasons : uncertainty about where potential output is; inertia behind movements in the real economy and lags in the operation of policy instruments; as well as the possibility that inflation may only act as a late warning signal. These considerations all suggest that a prudent policy approach would be one that ensures that the output gap is not closed too quickly during recovery. Such a policy conclusion seems to capture the sentiments expressed in the advice from *The Economist* magazine quoted in the introduction. Moreover, it represents one example of how a non-linear model of inflation provides a clear rationale for the importance of timeliness in macroeconomic policy actions, which is otherwise absent in linear models.

NOTES

1. The «excessive» and ((reduction)) in output both being measured relative to some notion of ((actual output)), a concept which is explained further in the section on ((Estimation of reduced form equations to explain inflation».

2. For a recent example where output gaps are used as a means of assessing inflationary risks, see OECD (1994b).

3. See Giorno et al. in this issue for a comparison of alternative methods of deriving the output gap.

4. A convention which will be followed throughout this paper is that if output is above potential this will be defined as being a **positive** output gap, whereas if output is below potential there is a **negative** output gap.

5. A Hodrick-Prescott filter is used to provide the proxy for potential output, rather than use a framework with a more theoretical basis, such as that detailed in Torres and Martin **(1990)** and Giorno et al. **(1995)**, for two reasons. Firstly, because of the relative ease of deriving a long sample of data. Secondly, both sources estimate potential output based on theoretical frameworks implicitly assuming symmetrical effects of positive and negative output gaps on inflation – exactly the assumption which is questioned in the third section.

6. The wedge is the difference between workers' take home pay deflated by consumption prices and firms' real wage costs deflated by output prices. An increase in the wedge will be inflationary if workers attempt to maintain their real consumption wage.

7. There was some form of incomes policy in operation throughout much of the 1960s and 1970s in the United Kingdom. However, the period in which it exercised the greatest restraint on wages is generally regarded to be in 1976 and 1977 (see a comparison of alternative measures of incomes policy in Turner et al, 1989). The "strength of incomes policy" variable devised by Lawson **(1981)** was also tested in the equation, but the dummy variable for 1976 and 1977 was preferred.

8. The inclusion of a variable which has a coefficient with a t-ratio of at least unity will reduce the overall equation standard error. The size of the equation standard error is subsequently used as a model selection criteria.

9. In a linear model the presence of a speed limit, by symmetry, also implies that a reverse speed limit will be present whereby a fall in output can lead to a fall in inflation despite output being above potential.

10. Similar tests comparing the rate of change and levels effect of unemployment in wage equations in a number of OECD economies by Elmeskov (I 993) imply a higher incidence of speed limit effects in the labour market.

I I. The theory described by Ball and Mankiw implies that the extent of the asymmetry will be related to the prevailing level of general inflation: at low levels of inflation the asymmetry will decline and at zero inflation the asymmetry would disappear. However, no attempt has been made to model such a form of asymmetry here.

12. A common departure from strict linearity in modelling the inflation process is the inclusion of the **logarithm** of the unemployment rate in estimated wage equations. Nevertheless, in all but the most extreme of circumstances, the extent of the non-linearity introduced in this way is likely to be quite modest, particularly in comparison with the the scale of the non-linearities implied by the work of Laxton et a/. (I9934 1994). This point is illustrated by means of a numerical example in Annex 1.

13. The work by Laxton et al. (I 994) makes use of a variant of the non-linear form of the output gap (a "modified hyperbola") first proposed by Chada et al. (I 992).

14. If negative output gaps are not more predominant than positive gaps then asymmetric inflation effects would imply a trendwise rise in inflation over time, unless on average the effect of supply shocks is to reduce inflation (an assumption which seems difficult to justify).

15. Some doubt is cast on the validity of this assumption by, for example, the very differing degrees to which the major seven economies appear to vulnerable to different supply shocks, as suggested by the results in the Annex 2.

16. This approach relies on the assumption that the effect of supply shocks over the full estimation period are not biased so as to significantly raise or lower inflation, on average.

17. The form of the non-linear relationship adopted here is criticised by Laxton et al. (I 994) for implying an abrupt change, or "kink", in the inflationary effect of the gap as it changes sign, which may be difficult to rationalise given that the gap reflects the average of conditions in many markets. This form of relationship does have the advantage here, however, of providing a natural assumption regarding the extent of the adjustment to the gap.

18. This is the reverse of the case criticised by De Long and Summers (1988) where the linear model predicts that "Excess unemployment incurred today because of policy 'mistakes' allows a larger boom tomorrow".

19. The example considered above can be adapted (see Annex I) to demonstrate that the extent of the non-linearity implied by having inflationary pressure related to the logarithm of the unemployment rate is comparatively modest: in the over-shooting scenario, for example, it is unlikely that there would be a perverse sacrifice ratio.

ALGEBRAIC PROOFS

Proof of expressions for the speed limit effect

Assume inflation is determined according to the expression:

$$\Delta\pi = \beta_0 \text{ GAP} + \beta_1 \text{ GAP-,} + \alpha_1 \Delta\pi_{-1} + \alpha_2 \Delta\pi_{-2} \qquad [A1]$$

Now suppose that in period 1 output is below potential, GAP, $= \text{GAP*} < 0$, and that in period 2 a proportion, θ, of this gap is closed, *i.e.* GAP, $= (1 - \theta)\text{GAP*}$. If, in order to prevent inflation rising in period 2, θ must be less than one, then a speed limit effect is in operation. Expressions for θ are derived for three cases.

Case (i) – No lagged inflation terms ($\alpha_1 = a, = 0$)

To derive the proportion of the gap which can be closed while keeping inflation in period 2 unchanged, substitute **An** $= 0$, GAP-, $= \text{GAP*}$, GAP $= (1 - 9)\text{GAP*}$ in [A1] to give:

$$0 = \beta_0(1 - 9) \text{ GAP*} + \beta_1\text{GAP*} \qquad [A2]$$

Solving for θ gives:

$$\theta = (\beta_0 + \beta_1)/\beta_0 \qquad [A3]$$

as per expression [2] in the section on "speed limit effects in the linear model".

Case (ii) – Lagged inflation terms are present in [A1] and prior to period 1 the output gap was zero and inflation stable

In this case the fall in inflation in period 1 is given by [A1] as An, $= \beta_0 \text{ GAP''}$. Then to derive the proportion of the gap which can be closed while keeping inflation in period 2 unchanged, substitute An $= \Delta\pi_{-2} = 0,$ **An-,** $= \beta_0 \text{ GAP''}$, GAP-, $= \text{GAP*}$, GAP $= (1 - \beta) \text{ GAP*}$, in [A1] to give:

$$0 = \beta_0(1 - \theta) \text{ GAP*} + \beta_1 \text{ GAP*} + \alpha_1\beta_0 \text{ GAP*} \qquad [A4]$$

Solving for θ gives:

$$\theta = (\beta_0\alpha_1 + P_0 + \beta_1)/\beta_0 \qquad [A5]$$

as per expression [3] in the section cited above

Case (iii) – Lagged inflation terms are present in [A1] and prior to period 1 the output gap has been at GAP* for a sufficient number of periods that inflation is falling at a steady state rate

In this case the fall in inflation in period 1, as well as in periods prior to it, is given by the steady state solution of [A1] to gap of GAP*, namely $(\beta_0 + \beta_1)GAP^*/(1 - \alpha_1 - \alpha_2)$. Then to derive the proportion of the gap which can be closed while keeping inflation in period 2 unchanged, substitute $\mathbf{A\pi} = 0$, $\mathbf{A\pi_{-1}} = \Delta\pi_{-2} = (\beta_0 + \beta_1)GAP^*/(1 - \alpha_1 - \alpha_2)$, GAP$_{-1}$ = GAP*, GAP = $(1 - \theta)$ GAP*, in [A1] to give:

$$0 = \beta_0(1 - \theta)\, GAP^* + \beta_1\, GAP^* + (\alpha_1 + \alpha_2)(\beta_0 + \beta_1)GAP^*/(1 - \alpha_1 - \alpha_2) \qquad [A6]$$

Solving for θ gives:

$$\theta = [(\beta_0 + \beta_1)/(1 - \alpha_1 - \alpha_2)]/\beta_0 \qquad [A7]$$

as per expression [4] in the section cited above.

Proof of an expression for the sacrifice ratio

A derivation of the sacrifice ratio is as follows.

Consider the change in inflation over the course of a recession between periods 0 and period T, where GAP$_0$ = GAP$_T$ = 0 and inflation is determined by:

$$\mathbf{A\pi} = \beta_0\, GAP + \beta_1\, GAP_{-1} + \alpha_1\, \Delta\pi_{-1} + \alpha_2\, \Delta\pi_{-2} \qquad [A8]$$

Denoting the sum over all periods between 0 and T by Σ, it follows that:

$$\Sigma\Delta\pi = (\beta_0 + \beta_1)\, \Sigma GAP + (\alpha_1 + \alpha_2)\, \Sigma\Delta\pi \qquad [A9]$$

But, $\Sigma\Delta\pi = (\pi_T - \pi_0)$. Substituting in [A2] gives:

$$(\pi_T - \pi_0) = (\beta_0 + \beta_1)/(1 - \alpha_1 - \alpha_2)\, \Sigma GAP \qquad [A10]$$

But the sacrifice ratio is defined as $\Sigma GAP/(\pi_T - \pi_0)$, hence from [A3] it is equal to $(1 - \alpha_1 - \alpha_2)/(\beta_0 + \beta_1)$. Note in particular that the sacrifice ratio is independent of expressions [A3], [A5] or [A7] and therefore independent of the presence or scale of a speed limit effect.

The extent of the non-linearity implied by having inflation dependent on the logarithm *of* unemployment

This example repeats the over-shooting scenario used in the section on "asymmetric effects from positive and negative output gaps on inflation", but on the assumption that inflation is related to the logarithm of the unemployment rate.

Assume that inflation is dependent on the logarithm of the unemployment rate, U, according to the following reduced form relationship:

$$\mathbf{A\pi} = -\lambda\, (\ln U - \ln U^*),\ \lambda > 0, \qquad [A11]$$

where U^* is the natural rate of unemployment which, based on Giorno et *al.,* is assumed to be 6 per cent for the United States. It is further assumed that there is an Okun coefficient of two, so that an increase in the output gap of 2 percentage points reduces the unemployment rate by 1 percentage point.

With an Okun coefficient of two, the profile of the output gap in the over-shooting scenario implies a profile for the unemployment rate which initialy rises to 6½, 7 and 7½ per cent during the recession phase and then falls during the recovery phase to 6, 5, and 5½ per cent, before finally settling at the natural rate of 6 per cent (consistent with a zero output gap).

The change in inflation over the course of the scenario is given by the expression:

$$\Delta\pi = -\lambda \, \Sigma(\ln U - \ln U^*), \qquad [A12]$$

where Σ denotes the sum over all periods of the entire scenario. Substituting in the values for the unemployment rate given above, gives:

$$\Delta\pi = -\lambda \, [\ln(6½ + 7 + 7½ + 6 + 5 + 5½) - 6 \ln(6)] \qquad [A13]$$

Evaluating this expression implies:

$$\Delta\pi = -0.19 \, \lambda < 0 \qquad [A14]$$

Thus inflation **falls** over the course of the entire scenario (regardless of the magnitude of λ) and so the sacrifice ratio is "correctly" signed, in contrast to the example illustrated in Figure 2 in the main text where the US equation with an asymmetric output gap effect predicted a perverse sacrifice ratio for the same scenario.

Evaluating the cost of volatility in output where there are asymmetric effects from the output gap on inflation

Suppose inflation is determined according to:

$$\Delta\pi = \beta \, f_n(GAP), \qquad [A15]$$

where lags of $\Delta\pi$ and $f_n(GAP)$ are ignored for simplicity of exposition. Over the course of a full cycle, if inflation is to be the same rate at the end of the cycle as at the beginning of the cycle then:

$$\Sigma\Delta\pi = \beta \, \Sigma f_n(GAP) = 0, \qquad [A16]$$

where Σ denotes the sum over all periods of the cycle. Let a true measure of the output gap, GAP, be defined as $GAP = (GAP - 6)$ and $POSGAP = GAP$ if $GAP > 0$ and $NEGGAP' = GAP$ if $GAP < 0$. Thus, [A16] can be rewritten as:

$$\beta \, [\Sigma POSGAP' + \Sigma NEGGAP'] = 0. \qquad [A17]$$

However, the cumulative output loss (relative to a situation where output remains at potential) is given by:

$$\text{Output Loss} = -(\Sigma\text{POSGAP}' + \text{CNEGGAP}).$$ [A18]

Combining [A17] and [A18] gives:

$$\text{Output Loss} = (n-1)\,\text{CPOSGAP},$$ [A19]

or alternatively:

$$\text{Output Loss} = -[(n-1)/n]\,\text{CNEGGAP}'$$ [A19']

Note that in either case if $n=1$, corresponding to the linear model, the output loss is always zero. However if n is greater than one then the output loss will increase with the size of n and with the volatilty in output (relected in larger values of ΣPOSGAP' and CNEGGAP).

Annex 2

ESTIMATION RESULTS

All equations are estimated by OLS unless otherwise noted. The tests used to evaluate the estimated equations were as follows:

Serial Correlation: A Lagrange multiplier test for up to second order serial correlation.

Functional Form: Ramsey's RESET test using the square of the fitted values

Normality: Jarque-Bera test of skewness and kurtosis of residuals

Heteroscedasticity: Based on the regression of squared residuals on squared fitted values.

The distribution of the test statistics is given in the tables. In the case tests for serial correlation and functional form, the degrees of freedom of the denominator of the F-distribution is given for the equation in the first column of each Table. To the extent that equations in subsequent columns have more/(less) explanatory variables the number of degrees of freedom of the denominator is reduced/(increased).

A failure of the test at the 10, 5 and 1 per cent levels of significance being denoted by "*", "**" and "***" respectively.

Table A1. Reduced form inflation equations for the **USA**

Dependant variable: Δn (mean = 0.032). estimation period: 1962-93

	Linear model	Asymmetric model	Asymmetric and shifted gap model
Constant	−0.2561 (−1.41)	−0.4782 (−2.10)	−0.2568 (−1.57)
$\Delta\pi_{-1}$	−0.4831 (−3.55)	−0.5535 (−5.08)	−0.5071 (−4.21)
$\Delta\pi_{-2}$	−0.2664 (−2.15)		
$\Delta\pi_{c-1}$	−	0.5421 (3.36)	0.5067 (2.74)
GAP	0.2340 (2.52)	−	−
GAP_{-1}	0.1741 (1.72)	−	
POSGAP	−	0.7277 (5.83)	−
$POSGAP_{-1}$	..	−0.4063 (−2.28)	
$f_4(GAP)$	−		0.1829 (5.74)
$f_4(GAP)_{-1}$	−	−	−0.0927 (−1.63)
$w\Delta\pi_m$	−	0.9954 (3.84)	0.8180 (2.80)
$w(\Delta\pi_m-\pi)_{-1}$	1.3286 (5.00)	0.8722 (2.46)	0.8763 (3.25)
$(pc-p)_{-1}$	18.966 (2.54)	16.876 (2.61)	16.911 (2.40)
SE of regression	0.7780	0.6087	0.6763
R−sqd	0.6651	0.8032	0.7571
Autocorrelation. $F(1,23)$	0.67	0.85	0.24
Functional form, $F(1,23)$	1.22	0.73	0.08
Normality, $\chi^2(2)$	1.17	0.67	1.64
Heteroscedasticity. $F(1.30)$	0.10	1.02	0.00

Table A2. **Reduced form inflation equations for japan**

Dependant variable: **A n** (mean $= -0.181$), estimation period: 1966-93

	Linear model	Asymmetric model	Asymmetric and shifted gap model
Constant	−0.3458 (−1.04)	−0.9094 (−2.34)	-0.3537 (−1.13)
$\Delta \pi_{-1}$	-0.8396 (−2.82)	-0.8541 (−2.98)	-0.8420 (−3.03)
GAP	0.4548 (2.61)	–	–
POSGAP		0.7427 (3.00)	–
$f_4(GAP)$		–	0.2333 (3.32)
$\Delta \pi_{a-1}$	0.6700 (2.49)	0.6881 (2.65)	0.6746 (2.68)
$\Delta \pi_{So}$	0.0534 (7.93)	0.0549 (8.52)	0.0542 (8.66)
SE of regression	1.7477	1.6857	1.6362
R-sqd	0.7859	0.8009	0.8124
Autocorrelation. $F(1,22)$	0.39	0.54	0.35
Functional form, $F(1,22)$	0.64	0.72	0.58
Normality. $\chi^2(2)$	1.37	0.33	0.40
Heteroscedasticity. $F(1,26)$	0.00	0.17	0.09

Table A3. **Reduced form inflation equations for Western Germany**

Dependant variable: An (mean = −0.033), estimation period: 1963-93

	Linear model	Asymmetric model	Asymmetric and shifted gap model
Constant	-0.3679 (−2.50)	4.5157 (−1.97)	4.3192 (−2.20)
$\Delta\pi_{-1}$	4.2858 (−3.66)	-0.2724 (−2.52)	-0.2203 (−2.53)
$\Delta\pi_{-2}$	-0.3921 (−3.66)	−0.3880 (−4.17)	−0.3836 (4.45)
GAP	0.2248 (2.41)	−	−
GAP_{-1}	0.1211 (1.02)	−	−
POSGAP		0.3687 (2.40)	
NECGAP		0.1805 (1.11)	−
$f_2(GAP)$		−	0.2031 (3.75)
$w\Delta\pi_{m-1}$	0.1967 (1.47)	0.2634 (2.21)	0.2696 (2.33)
D70	6.6794 (8.34)	6.7184 (8.26)	6.7614 (8.60)
SE of regression	0.7752	0.7851	0.7638
R-sqd	0.8412	0.8371	0.8388
Autocorrelation. $F(1.24)$	2.53	4.02'	2.00
Functional form. $F(1,24)$	0.06	0.88	0.19
Normality, $\chi^2(2)$	0.91	3.14	1.72
Heteroscedasticity. $F(1.29)$	0.42	0.51	0.21

Table **A4.** Reduced form inflation equations for France

Dependant variable: Δn (mean = -0.062). estimation period: 1965-93

	Linear model	Asymmetric model	Asymmetric and shifted gap model
Constant	-0.2391 (-1.24)	-0.3744 (-1.11)	-0.1822 (-0.97)
GAP	0.1584 (0.96)	–	-
GAP_{-1}	0.4443 (2.61)	–	–
POSGAP		0.3247 (1.16)	-
$POSGAP_{-1}$		0.3727 (1.34)	-
$NEGGAP_{-1}$	–	-0.4699 (1.52)	–
$f_2(GAP)$	–	–	0.1399 (1.21)
$f_2(GAP)_{-1}$	–	–	0.2733 (2.35)
$w\Delta\pi_m$	0.1045 (2.88)	0.1047 (2.92)	0.1026 (2.86)
$(\pi_c-\pi)_{-1}$	0.7239 (3.30)	0.7449 (3.35)	0.7522 (3.45)
D6869	2.3717 (3.26)	2.4034 (3.24)	2.2973 (3.19)
SE of regression	0.9490	0.9606	0.9473
R–sqd	0.6421	0.6496	0.6437
Autocorrelation. $F(1,22)$	1.29	1.29	1.25
Functional form, $F(1,22)$	0.98	1.77	0.37
Normality, $\chi^2(2)$	0.97	0.78	0.98
Heteroscedasticity $F(1.27)$	1.57	1.40	0.93

Table A5. **Reduced form inflation equations for Italy**

Dependant variable: **An** (mean = –0.086). estimation period: 1963-93

	Linear model	Asymmetric model	Asymmetric and shifted gap model
Constant	0.1169 (0.48)	0.4466 (0.68)	0.1228 (0.49)
GAP	0.7774 (3.59)	.	—
GAP$_{-1}$	–0.2008 (−1.03)	—	-
POSGAP	—	0.7600 (1.80)	—
POSGAP$_{-1}$	—	–0.4063 (−1.20)	—
NEGGAP	—	0.7994 (1.98)	
f_2(GAP)	—	—	0.5575 (3.44)
f_2(GAP)$_{-1}$	—	—	−0.1524 (−1.05)
w$\Delta\pi_m$	0.7098 (3.42)	07139 (3.37)	0.6845 (3.13)
w(π_m-π)$_{-1}$	1.2052 (5.20)	1.2433 (4.42)	1.1241 (4.65)
SE of regression	1.3338	1.3487	1.3563
R–sqd	0.7526	0.7567	0.7179
Autocorrelation, $F_{(1,25)}$	0.01	0.00	0.04
Functional form, $F_{(1.25)}$	0.38	0.71	1.41
Normality. $\chi^2(2)$	2.37	2.67	4.34
Heteroscedasticity. $F_{(1,29)}$	0.02	004	0.00

Table **A6.** Reduced form inflation equations for United Kingdom

Dependant variable $\Delta\pi$ (mean = 0.026). estimation period: 1960-93

	Linear model	Asymmetric model	Asymmetric and shifted gap model
Constant	0.87I4 (2.21)	1.0932 (1.82)	0.9097 (2.29)
GAP	0.21I6 (1.01)	–	–
GAP_{-1}	0.3405 (1.59)	.	....
$POSGAP_{-1}$	–	0.4427 (1.76)	–
NEGGAP		0.6450 (2.08)	–
$f_2(GAP)$		–	0.1318 (0.98)
$f_2(GAP)_{-1}$	–	–	0.2335 (1.72)
$w(\pi_m - \pi)_{-1}$	2.1840 (6.86)	2.0965 (6.93)	2.2023 (6.77)
D7677	-6.9352 (−4.51)	−7.3961 (−4.75)	-6.7946 (−4.37)
SE of regression	2.0830	2.0554	2.1048
R–sqd	0.7766	0.7825	0.7719
Autocorrelation. $F_{(1,25)}$	0.64	0.68	0.56
Functional form, $F_{(1,25)}$	0.66	0.47	0.53
Normality, $\chi^2(2)$	1.25	0.50	0.98
Heteroscedasticity. $F_{(1,32)}$	0.05	0.68	0.38

Table A7.   **Reduced form inflation equations for Canada**

Dependant variable: **Ax** (mean = 0.015). estimation period: 1962-93

	Linear model	Asymmetric model	Asymmetric and shifted gap model
Constant	1.0887 (3.52)	0.3386 (1.13)	1.1731 (4.10)
GAP	0.4123 (3.64)	–	–
POSGAP	–	0.9588 (4.85)	–
$f_4(GAP)$	–	–	0.2512 (4.56)
$w\Delta\pi_m$	1.8420 **(5.02)**	2.0749 **16.31)**	2.0306 (6.02)
$w(\pi_m-\pi)_{-1}$	1.8525 (4.36)	2.4000 (5.93)	2.2469 (5.53)
$(\pi_a-\pi)_{-1}$	0.6496 (3.80)	0.5376 (3.71)	0.5980 (3.95)
AIB	−4.4692 (−4.32)	−4.6872 (−5.08)	−4.4311 (−4.74)
SE of regression	1.4091	1.2550	1.2903
R−sqd	0.7190	0.7771	0.7644
Autocorrelation. $F(1.25)$	2.22	0.00	0.90
Functional form, $F(1,25)$	0.33	0.56	0.43
Normality. $\chi^2(2)$	0.69	0.40	1.95
Heteroscedasticity. $F(1,30)$	0.16	0.66	0.16

Key to variables

All data is annual and is taken from the OECD's Analytical Data Base (ADB), except where explicitly noted otherwise. Lower case denote logs. Subscripts denote lags and "A' the first difference operator.

π = Annual rate of inflation, measured according to the non-oil GDP deflator. For those countries without significant oil production sectors (France, Italy. Germany and Japan) the non-oil GDP deflator is assumed to be the same as the GDP deflator. For the United States, Canada and the United Kingdom the necessary adjustment to GDP deflators were calculated using national sources. The data for this latter adjustment was unavaliable for the United States and the United Kingdom for 1993 and unavailable for Canada for 1992 and 1993. However, given that there was little change in real oil prices in these years, the adjustment was assumed to be zero rather than lose these years as observations.

GAP = a measure of the output gap derived as the difference between real GDP and trend real GDP (both logged), where trend GDP is measured using a Hodrick-Prescott filter on actual GDP. The value of the filters chosen are the same as those chosen by Giorno *et al.* (1985). namely 25, except for France and the United Kingdom (100) and Canada (200). A positive value of GAP implies actual GDP is above trend GDP.

POSGAP = GAP if GAP > 0 and zero otherwise

NEGGAP = GAP if GAP < 0 and zero otherwise

$f_n(GAP)$ = n (GAP − 6) if (GAP − 6) > 0
= (GAP − 6) if (GAP − 6) < 0
where n takes the value 2, 3, 4 or 5 and 6 is a constant adjustment such that the cumulation of all negative gaps over the sample period is n times the cumulation of all positive gaps.

π_m = Import price inflation rate.

π_a = Absorption price inflation rate.

π_c = Consumer price inflation rate.

$\pi_{\$o}$ = Dollar oil price inflation rate.

$(pc − p)$ = Ratio of consumer price level to GDP deflator (logged).

w = Weight of imports in total final expenditure.

Dyyxx   =   Dummy variable taking the value unity in years 19yy and 19xx and zero elsewhere.

AIB   =   Dummy for operation of Anti-Inflation Board [Canada).

BIBLIOGRAPHY

B. LL and MANKIW **(1994)**, "Asymmetric Price Adjustment an Economic Fluctuations", *Economic Journal,* 104 (March), **247-261.**

BARRELL R. (I **990),** "Has the EMS Changed Wage and Price Behaviour in Europe ?",*National Institute Economic Review,* November.

CHADA, B, P. MASSON and G. MEREDITH **(1992),** "Models of inflation and the costs of Disinflation", *IMF Staff Papers,* Vol. **39,** No. **2.**

COLETTI, D., B. HUNT, D. ROSE and R. TETLOW **(1994),** "Some Dynamic Properties of QPM", *Bank* of *Canada,* mimeo.

DE LONG, J.B. and L.H. SUMMERS **(1988),** "How does Macroeconomic Policy Effect Output", *Brookings Papers on Economic Activity, 2,* pp. **433-494.**

ELMESKOV, J. **(1993),** "High and Persistent Unemployment: Assessment of the Problem and its Causes", *OECD Economics Department Working Paper,* No. **132,** Paris.

GIORNO, C., P. RICHARDSON, D. ROSNEARE, P. VAN DEN NOORD **(1995),** "Estimating Potential Output, Output Gaps and Structural Budget Balances", *OECD Economics Department Working Papers,* No. **152,** Paris.

LAXTON, D., D. ROSE, and R. TETLOW **(1993a),** "Problems in Identifying Non-Linear Phillips Curves: Some Further Consequences of Mismeasuring Potential Output", *Bank* of *Canada, Working Paper* **93-6.**

LAXTON, D., D. ROSE, and R. TETLOW **(1993b),** "Is the Canadian Phillips Curve Non-Linear?", *Bank of Canada, Working Paper* **93-7.**

LAXTON, D., G. MEREDITH and D. ROSE, **(1994),** "Asymmetric Effects of Economic Activity on Inflation: Evidence and Policy Implications", *IMF Working Paper.*

OECD **(1991),** *OECD Economic Outlook,* No. *50,* Paris, December.

OECD **(1994a),** "The OECD Jobs Study, Part I, Labour Markets and Underlying Forces of Change", Paris.

OECD **(1994),** *OECD Economic Outlook,* No. **56,** Paris, December.

TORRES, R. and J.P. MARTIN **(1990),** "Measuring Potential Output in the Seven Major OECD Countries", *OECD Economic Studies,* No. **14,** Paris.

TURNER, D, K.F. WALLIS and J.D. WHITLEY, "Using Macroeconometric Models to evaluate Policy Proposals", in "Policymaking with Macroeconomic Models", ed. A. Britton, Gower.