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**THE STEADY INFLATION RATE
OF ECONOMIC GROWTH**

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ABSTRACT

This paper considers the existence of a path of GDP corresponding to steady inflation in the prices of domestic goods. We estimate the steady inflation rate of growth, denoted the SIRG, at a little over 4 per cent per annum in the post-float period. Changes in inflation are modelled as a nonlinear combination of growth and changes in import price inflation. Because import price inflation is more volatile than overall inflation, policy that targets overall inflation may require growth to fluctuate considerably, whereas growth can be steady if the target is steady inflation of domestic goods' prices.

Keywords: inflation, growth , import prices, monetary policy

JEL Classifications: E31, E52

There would probably be widespread agreement on the proposition that an economy that attempts to grow 'too fast' is likely to experience a rise in its inflation rate and that low or negative growth will imply falling inflation. The reason is that higher growth rates of real output are likely to be associated with higher excess demand and other pressures for costs and prices to rise. Our paper investigates this relationship between inflation and growth and finds it a satisfactory alternative to the labour market focussed Phillips curve approach. The policy implications are first, that although there is a short run trade-off between inflation and growth, in the long run there is an equilibrium rate of growth consistent with steady inflation of the prices of domestic goods. Secondly, where import prices fluctuate substantially as in Australia's case, attempts to stabilise the overall inflation rate including import price inflation will require substantial fluctuations in real growth.

It would be entirely conventional to argue that prices will rise if, in some sense, there is demand pressure relative to supply for the products concerned. Also they will rise if for some reason, usually based on past and present economic behaviour, there is the expectation that prices will be higher in the future. In this paper we examine the proposition that there is some path of GDP that would correspond to steady, including zero, inflation for domestic goods. Although not the only approach, this again is not particularly controversial in that potential output could well be defined in this manner and then deviations from potential output would measure pressures that generate rising or falling inflation.

The most popular way of explaining inflation is to use the Phillips curve which employs a measure of the state of the labour market as a key variable for explaining wage inflation. The wage inflation results are then often extended by some means to the generation of inflation in the goods market. Alternatively, price inflation is sometimes related directly to unemployment. This usually involves estimating the NAIRU, or non-accelerating inflation rate of unemployment, which can be interpreted as that rate of unemployment which yields equilibrium in the labour market (in that any wage changes occurring are compatible with zero excess demand for labour). However, the large movements in actual unemployment that many countries have experienced suggest that finding a reliable set of estimates of the path of the equilibrium unemployment rate could well be a difficult task and empirical results

seem to bear this out. The Australian literature on the Phillips curve will be examined in section II.

A further problem for some standard explanations of inflation is the method of moving from a theory of wage changes in the labour market context to explaining how prices change. A 'mark up' process whereby wages and other variable costs per unit of output are marked up by a constant profit margin to yield price is often the implicit or explicit mechanism used. However, such price setting does not contain any process by which the goods market might be brought to equilibrium, other than by chance. This can be accommodated by allowing profit markups to vary with excess demand or supply of goods and services. But if profit margins are to move when there is disequilibrium in the goods markets it is a small but reasonable step simply to suppose that price movements are driven by the state of the goods markets.

The approach in this paper then has three distinguishing features. First, prices are taken to respond to some concept of market pressure such as excess demand in the goods markets, just as the Phillips curve approach allows wages to move with unemployment, usually regarded as a proxy for excess demand for labour. Secondly, we are concerned to investigate the concept of the rate of growth of real GDP that is consistent with steady inflation. We call this the SIRG or steady inflation rate of growth. It could be investigated indirectly by estimating a relationship between inflation and some measure of excess demand, such as the output gap, and then examining the connection between excess demand and growth. Alternatively, there is some theoretical justification for the hypothesis that the rate of inflation could be closely associated with the rate of growth itself and this is the approach we shall take. Relating inflation to growth yields estimates of the SIRG for the period since the exchange rate was floated (1983-98). Many recent investigations of the NAIRU have had to allow for the possibility of its varying over time. By contrast, our investigation of the SIRG does not suggest that a time varying approach is crucial.

The third feature is the inclusion of import prices in the regressions. Of course, this is not that unusual, particularly in the case of pegged exchange rate systems, but we find that they also add considerably to the explanation of inflation for the period since Australia's exchange rate was floated. Including import prices when the exchange rate floats raises issues about whether the system insulates from foreign inflation, which we discuss in section III, the nature of import price and real exchange rate movements

and whether monetary policy has been compatible with insulation. Although the addition of import price inflation to explanations of Australian inflation is not new in the Australian literature (eg de Brouwer and Ericsson (1998), Gruen, Pagan and Thompson (1999)) some studies, such as Ng (1998), omit it and it has only recently been included in a panel study of the Phillips curve for a selection of open economies in DiNardo and Moore (1999) where import price inflation is proxied by US inflation for all other countries.

A preliminary version of our model was presented in the Reserve Bank conference volume for 1998 as part of an attempt to assess the potential for GDP growth to ameliorate unemployment.¹ This paper expands on the inflation section of that work, covering further functional forms and test statistics, elaborating on the role of import prices and drawing out implications for inflation that were not appropriate in a work on unemployment. Section I sets out the model of inflation which we use and outlines its theoretical and policy implications. The nature of the data employed and some recent work on the Phillips curve is discussed in section II. Section III contains the empirical results and an examination of the relationship between inflation and growth that the results imply. The issue of the contribution of import prices to inflation is treated in section IV. Section V deals with policy implications and other conclusions.

I. A model of inflation involving growth and import prices

Unlike Phillips curves, which relate the divergence between actual and expected inflation to unemployment, the hypothesis we examine is that this divergence depends on conditions in product markets. A simple case of price determination through the goods markets could involve inflation being determined by excess demand for goods and expectations of future inflation. However, if imported goods and domestically produced importables are close substitutes and if the prices of imports are determined in world markets, there will be no excess demand for importables. Imports can enter the market to the extent necessary for it to clear. Importables prices will then be given by foreign currency world prices translated to domestic currency by the appropriate exchange rates.² Hence, *prima facie*, importables prices need separate treatment.

¹ Dungey and Pitchford (1998).

² This assumes that importables are available immediately in quantities that will clear markets, an assumption that is unlikely to be fulfilled in Australia's case. Hence there can be temporary excess demand for importables and their prices can temporarily differ from world prices.

It is assumed that there is an index of local consumption prices P such that the prices of domestically produced goods P and of imports M (in domestic currency) enter into the index with constant geometric weights a and $(1-a)$.³ Lower case is used to represent the proportional rate of change in a variable, so that the inflation rate of the index, p , is

$$p = ap + (1-a)m \quad (1)$$

Domestic goods prices are supposed to adjust to a measure of market pressure x (such as, but not necessarily, excess demand) according to

$$p - p^e = p - p_{-1} = y(x), \quad y' > 0, \quad y(0) = 0 \quad (2)$$

where -1 stands for the previous period.⁴ In the absence of data on the price expectations of those who determine prices, the expected rate of price change p^e is taken to be determined by the rate of change in the previous period. This simple mechanism for expectations has been used for instance by Ball (1997) and is not without plausibility. Another option would be to base expectations on weighted backward and forward inflation rates (Chadha, Masson and Meredith (1992) and Clark, Laxton and Rose (1996)). However, hypotheses using actual values of information unknown at the time seem inappropriate and are also not useful for policy purposes. Survey data on expectations is another option. For a range of US inflationary expectation surveys Englander and Stone (1989) demonstrated that in general these indices were highly correlated with immediate past inflation, and in periods where they were not there was no clear direction of expectations between the surveys. Research on recent Australian expectations data by Brischetto and de Brouwer (1999) shows a consistent margin between lagged actual and expected inflation, implying that changes in inflationary expectations can be extracted from lagged changes in the inflation rate itself. This study was performed only over the period 1995 to mid-1998, but is supported by evidence from an alternative series of inflationary expectations based on *The Economist* survey of banks. Using this series, Skilos (1999) found that the relationship between realised and expected inflation in

³ In principle prices of exports should enter these equations. However, for Australia the proportion of exports that directly enter the price index is small. Also, empirical results do not justify their inclusion.

⁴ Note that we could have made the demand for home goods and hence their inflation rate also depends on the relative price of imports to home goods. However, it is not necessary to do this explicitly as it will be seen that the estimated equation for overall inflation can be interpreted as possessing such a component.

Australia had not been changed by the introduction of inflation targeting in 1993.⁵ In any case our test will be a joint test of our assumption about expectations as well as the other aspects of our hypothesis. Moreover, when we use the Melbourne Institute expectations survey data for our expectations variable we find that the coefficient on the term measuring the difference between this variable and the past inflation rate is insignificant and that the resulting coefficients are not significantly changed from those found using last period's inflation as the expectations proxy.⁶ Combining (1) and (2),

$$p - p_{-1} = \Delta p = aY(x) + (1 - a)\Delta m \quad (3)$$

where we also assume for imports that the expected inflation rate is given by last period's inflation rate. We later estimate the price equation in the form (3), though it should be noted that almost nothing about lag structures has been decided by theoretical considerations.⁷

Assume there is some equilibrium (potential) rate of growth of the output of domestic goods in the absence of unforeseen output shocks $\tilde{g}$ determined by the growth rate of the supply of inputs. When the economy is in equilibrium, demand for domestic goods grows at the same rate as potential output. One way in which growth might be thought to affect the inflation rate of domestic goods p is through the adjustment cost effect of faster growth on costs. Thus prices could rise, other things being equal, when growth was above potential growth and fall when it was below. The inflation rate of domestic goods prices p , neglecting expectational effects for the moment, would then be given by

$$p = c(g), \quad c(\tilde{g}) = 0, \quad c' > 0, \quad c'' \geq 0 \quad (4)$$

⁵ Skilos (1999) also found that the persistence of Australian inflation was unchanged since the 1970s. In contrast, in other industrialised nations that have adopted inflation targeting he found evidence of changes in both the persistence and formation of inflationary expectations since the adoption of targeting.

⁶ If survey material on inflationary expectations p^e is used the expression $p - p^e = Y(x)$ can be reformed so that $\Delta p = (p^e - p_{-1}) + Y(x)$. This can be combined with (1) to produce an expression $\Delta p = a(p^e - p_{-1}) + aY(x) + (1-a)\Delta m$. Inflationary expectations data is available for p not p^e . However, assuming that expected import price inflation is equal to last period's import price inflation, $\Delta p = a(p^e - p_{-1}) + aY(x) + (1-a)\Delta m$, (3'). The empirical results obtained with this form, using the median Melbourne Institute Series on inflationary expectations, were little different from those obtained using the lagged inflation rate and are given, for the SIRD only, in footnote 14.

⁷ Strictly, the m in (1) and (3) are different variables, the first being the import component of the CPI (on which there is no data) and the second the import price deflator from the National Accounts. Import

(4) by itself gives a justification for growth affecting the inflation rate.

As well, or alternatively, another hypothesis under which growth could affect the inflation rate could arise from both growth and prices being sensitive to excess demand. Suppose that growth remains at its potential level unless there is excess demand or supply. However, if excess demand develops, suppose that planned growth will be set above potential. Further, assume that when actual growth is not sufficient to eliminate excess demand there will be a tendency for prices to rise. This sequence of responses will ensure that prices rise at the time when or after actual growth is in excess of potential.⁸

Adding inflation expectations and allowing for import prices yields an equation of the form of (3) with the divergence between actual and potential growth the measure of market pressure for domestic goods, so that

$$p - p_{-1} = F(g) + (1 - a)\Delta m \quad (5)$$

where when growth is at potential, $F(\tilde{g}) = 0$. The theoretical relationship between inflation and growth implied by this model is similar to that between inflation and unemployment in analyses of the Phillips curve. The curve $F(g)$ in figure 1 illustrates the overall inflation rate resulting when the inflation rate of both domestic and imported goods has initially been zero. Assume for the moment that the inflation rate of imports remains at zero. If growth continues at $\tilde{g}$ (which we call the steady inflation rate of economic growth, or SIRG) the inflation rate continues to be zero, but if g rises to $g' > \tilde{g}$ the inflation rate becomes positive. In turn expected inflation becomes positive and actual and expected inflation continue to increase while growth exceeds the SIRG. If growth is now reduced to the SIRG, the inflation rate will then remain steady but positive. A period of inflation with growth below the SIRG is necessary to restore the initial (zero) rate of inflation. In short, the inflation rate rises if growth is higher than the SIRG and falls if it is lower. A non-linear form has been chosen to depict the function $F(g)$ to reflect the possibility that the marginal impact of an increment of growth on inflation may be higher the higher the growth rate and that some very high growth rates are technically unobtainable. However, in the range of

prices are measured at the time of entry of goods to the country, so that in practice there would be significant lag before such goods are sold.

⁸ This hypothesis depends critically on timing in that a more rapid response of prices than growth would lead to a situation where current inflation is associated with planned future growth.

actual growth rates experienced the question of the appropriate form of this function is not easily determined theoretically and we do not rule out the possibility that the relationship in this range may be approximately linear.

Figure 1

A number of studies of Australian inflation include import price inflation as an explainer of the overall inflation rate, though without justifying why this should hold in a floating rate regime. We will discuss the major questions that such an approach to import price inflation raise and give our justification for using it in detail in section IV. However, some preliminary analysis of these issues can illustrate the questions involved and so is appropriate here. First, suppose that inflation insulation works perfectly, in that a 'neutral' domestic monetary policy (such as a constant level or growth rate of the money supply) insulates the domestic inflation rate against foreign inflation (foreign currency import price rises) without leading to any real effects such as changes in the growth rate. The simplest case, and that usually assumed in examinations of insulation, is that in which there are no forces making for a change in the real exchange rate, which we shall here measure as the ratio of domestic currency import prices to the prices of home goods, and real interest rate. In this world there is no need to consider import prices separately. Foreign currency import price inflation produced by foreign monetary expansion which has no effect on real variables (such as foreign real interest rates) will lead to an appreciation of the domestic exchange rate which will just offset the import price rise, so insulating from such foreign inflation. The conditions which produce these results do not necessarily apply to our model or data. In particular, a floating rate system does not necessarily insulate from

import price rises which are part of a real exchange rate change.⁹ In such a situation there are two basic options. One is to take no policy action so that the change in the real exchange rate occurs as a rise in the domestic currency import price and in the overall price index with the price of domestic goods and the growth rate remaining unchanged.¹⁰ The second is to use contractionary monetary policy to hold the overall price index constant so that the domestic currency import price rises by less than before because the exchange rate appreciates, and the price of domestic goods falls. This last outcome requires a period in which growth is lower than the SIRG.

We shall see that steady rates of change of the real exchange rate are not a common occurrence in Australian data. Nevertheless, consider the case of a steady positive inflation rate of import prices. For the simple lag structure in (3) the inflation rate is determined, using (5) and (1) by

$$p = p_{-1} + (1 - a)\Delta m + F(g) = ap_{-1} + (1 - a)m + F(g) \quad (6)$$

so that the past inflation rate of home goods and the current rate of inflation of import prices determine the intercept of the inflation response curve on the vertical from $\tilde{g}$. Hence import price inflation will tend to raise or lower the overall inflation rate in an obvious way and unless chance or other circumstance ensure $p = m$ the real exchange rate will be changing. Offsetting the effect of import prices on the overall inflation rate would require growth being held lower than the SIRG.

II. Preliminaries

This section treats several preliminary issues such as the time period relevant for our investigation, the nature of the data which we use and some recent inflation studies which adopt the Phillips curve approach relating inflation to unemployment.

The period since Australia adopted a floating rate in December 1983 requires separate treatment from earlier episodes when several different types of pegged and managed exchange rate systems were in operation. The reason is that as noted above foreign sourced import price movements could affect inflation differently depending on the exchange rate regime. Added to this, the seventies were a time of considerable

⁹ Insulation against foreign inflation involving relative price shifts is shown to be possible in Pitchford (1993). However, the result requires continual clearing of the home goods market and so avoids the issue of growth fluctuating about its potential level.

turbulence for import prices because of the oil price shocks with, for example, import prices in domestic currency rising by 36% in the year to December 1974. Hence we examine inflation and growth from 1970, but concentrate mainly on the period 1983:4 – 1998:2.

Full data definitions and sources are given in Appendix A. Data on the variables is illustrated in graphs 1, 2 and 7.

Our dependent variable, the overall inflation rate (graphs 1,2), had a mean of 4.75% pa for the period and was mainly falling from about 1986. Over the whole period the average quarter on quarter change in the inflation rate was a fall of one tenth of a percentage point. Although much of the fall occurred in the 1990-92 recession, there was also a substantial decline from the mid to the late eighties. For imports (graph 2), the inflation rate was much more variable than overall inflation and averaged 2.24%.

¹⁰ There will be substitution effects in demand and production from this relative price change. These can be accommodated in the argument, but are secondary to the issues discussed here.

The mean annual real GDP growth rate (graph 2) for the period was 3.6% with a range of –1.6% to 8.7%. Defining the real exchange rate for practical purposes as the ratio of import prices to the Treasury underlying index, it is clear from graphs 2 and 7 that it fluctuated substantially in the period, and this was mainly due to the fluctuations in import prices.

The standard approach to inflation, as noted, has been the Phillips curve relating wage or price inflation to unemployment. In its early form this hypothesis predicted that high unemployment should be accompanied by rapidly falling inflation. However, attempts to fit Phillips curves in the context of the large and sustained rises in unemployment since the mid seventies have led to the hysteresis proposition that the steady inflation rate of unemployment or NAIRU is endogenous, rising in association with actual unemployment. Gruen, Pagan and Thompson (1999) have recently reviewed the Phillips curve literature as applied to Australia, with particular emphasis on its historical policy relevance. The intricacies inherent in estimating the NAIRU are evident in the contemporary Australian literature. For example, the estimates made in Debelle and Vickery (1999) are questioned in Gruen, Pagan and Thompson. The difficulties in providing plausible interpretations of applications of approaches used successfully overseas to Australian data are apparent in Groenewold and Hagger (1998) (see also McDonald (1999), Debelle and Lowe (1999) and Groenewold and Hagger (1999)). Other examples of the problems inherent in estimating this concept are apparent in the range of results presented in Borland and Kennedy (1998), including those from the Treasury Model (TRYM) and Murphy Model (MM2), and the range estimated in Lye, McDonald and Sibly (1999). A number of these are shown in figure 3 in Borland and Kennedy (1998, p.71). These, and work by Crosby and Olekalns (1998) and Debelle and Vickery (1999), suggest that the natural rate in the eighties and nineties was much higher than in the seventies. Finally, note that the aspect of the Phillips curve which we wish to question and replace is the hypothesis on price inflation and unemployment and not that between wage inflation and labour market conditions.

III. Empirical results

Now consider the results that may be obtained when inflation is related to growth. The form of the encompassing equation for our general to specific approach is

$$\Delta p_t = c + \sum_{i=1}^h a_i \Delta p_{t-i} + \sum_{i=0}^k b_i f(g_{t-i}) + \sum_{i=0}^j g_i \Delta m_{t-i} + e_t, \quad (7)$$

Here, p is the annual Treasury underlying consumer price inflation rate, g is the annual percentage growth rate in real GDP(A), f is some function of g , and m is import price inflation. Lagged values of the dependent variable are included to allow for a possibly dynamic adjustment process both to demand pressure and to import price effects. Using the standard ADF tests we accepted that the inflation rate, output level and import price inflation were I(1) in nature. Estimation was carried out on quarterly data for the period 1983:4 to 1998:2.

A linear relationship between inflation and growth was found to fail the RESET test for functional form, leading us to consider non-linear relationships.¹¹ The non-linear forms considered were the quadratic, a 'modified quadratic' ($f(g) = (\text{sign}(g))g^2$) as in Dungey and Pitchford (1998), and an hyperbolic form $f(g) = 1/(k-g)$ where k is an asymptote such that the inflation rate increases without limit as g approaches k . Dupasquier and Ricketts (1998) discuss theoretical aspects of several of these forms of the inflation/output gap relationship. Similar arguments can be constructed for the linear, quadratic and hyperbolic functional forms investigated here. The modified quadratic form was examined in Dungey and Pitchford (1998).¹² Its formulation gives an higher marginal response to higher growth rates and an increasingly deflationary response to negative growth. The fact that there are relatively few periods of negative growth in the sample period results in very similar estimates for both the quadratic and modified quadratic forms.

Table 1 presents the estimates for each of the linear, quadratic, modified quadratic and hyperbolic forms. The first four columns represent estimations over the post-float period from 1983:4 to 1998:2 and the final column gives the pre-float estimates for the hyperbolic form. The linear and quadratic forms were estimated using OLS. We were unable to reject the hypothesis in each case that the coefficients on changes in import price inflation were insignificantly different across the lags, and that the coefficients on g_{t-1} and g_{t-2} were equal but opposite in sign, as were the coefficients on g_{t-2} and g_{t-3} . These latter restrictions mean that the system could be re-parameterised

¹¹ For the case of the inflation-output gap relation this result was also found by Laxton, Meredith and Rose (1995), and Dupasquier and Ricketts (1998).

in terms of both a change and levels of growth rate effect. This makes little difference to our current analysis so we do not present the results here.

Table 1: Estimation Results

variables	linear	modified quadratic	quadratic	hyperbolic	hyperbolic pre-float
constant	-0.3473* (0.0923)	-0.2667* (0.0669)	-0.2563* (0.0729)	-1.0989* (0.5509)	-0.2939* (0.1620)
k	n.a	n.a.	n.a.	15.277* (4.5190)	7.4085* (0.1159)
$\Delta\pi_{t-1}$	0.3195* (0.0950)	0.3811* (0.0865)	0.4081* (0.0897)	0.3698* (0.0868)	0.4911* (0.1129)
g_{t-1}	0.0983* (0.0367)	0.0157* (0.0044)	0.0134* (0.0045)	14.1735 (12.9261)	-0.0125 (0.1353)
g_{t-2}	-0.1427* (0.0516)	-0.0214* (0.0060)	-0.0169* (0.0061)	-20.1192 (18.8706)	0.2595* (0.1926)
g_{t-3}	0.13226* (0.0347)	0.0200* (0.0043)	0.0168* (0.0045)	18.0816 (16.7205)	0.5155* (0.2867)
Δm_{t-1}	0.0267* (0.0082)	0.0304* (0.0076)	0.0329* (0.0080)	0.0297* (0.0077)	0.1005* (0.0232)
Δm_{t-2}	0.0226* (0.0084)	0.0209* (0.0080)	0.0206* (0.0085)	0.0209* (0.0077)	0.0086 (0.0288)
Δm_{t-3}	0.0318* (0.0086)	0.0287* (0.0081)	0.0266* (0.0086)	0.0298* (0.0077)	-0.0429 (0.0241)
Serial cor. (LM)	1.5036	1.2835	1.3577	5.5571	2.5285
RESET test	4.7211*	0.6435	1.5267	1.2699	0.0156
Normality	0.2721	0.4509	0.7733	0.1677	3.9531
Hetero (LM)	1.6959	0.9440	0.0363	1.2386	0.0154
$\bar{R}^2$	0.6428	0.6770	0.6824	0.6645	0.7258
AIC	-15.2846	-12.3167	-15.6055	-18.6570	-66.9013
SBC	-23.5948	-20.6269	-23.9156	-26.9680	-74.9306

* significant at 5% level, ⁺ pre-float 1983:4, post-float 1970:1 to 1983:3.

The hyperbolic form was estimated using maximum likelihood to allow for joint estimation of the asymptote parameter k , in conjunction with the other parameters. Starting values were formed via a 2-step procedure, involving an initial estimation of the function $f(g)$ prior to estimating the final equation by OLS. In a similar result to the earlier forms the preferred lag length was found to be from one to three inclusive, using the LR test. In the estimation of the hyperbolic system the lags of the growth terms $f(g)$ are individually statistically insignificant, however a LR test of joint

¹² In that paper the point of inflection of $F(\cdot)$ is shown incorrectly to be at the intercept with the g -axis in figure 1, rather than the p -axis.

significance rejects the hypothesis of excluding these lags from the estimation at all conventional levels of significance.¹³ Hence a common lag structure results across all the functional forms investigated.

The SIRGs resulting from these forms and their standard errors are presented in Table 2. The confidence intervals for the SIRGs have been calculated in two ways. Firstly using the standard delta approach (Greene (1993)), and secondly, to take into account that the SIRD is a construction of two parameter estimates, using a Fieller statistic approach (see for example Staiger, Stock and Watson (1997) and Ericsson, Jansen, Kerbeshian and Nymoen (1997)). The results reflect the impact of estimating the hyperbolic limiting parameter, k , on the standard errors.

Table 2: SIRGs and confidence intervals: post-float¹⁴

form	SIRD	standard error (delta method)	90% confidence interval (delta method)	90% confidence interval (Fieller statistic)
linear	3.95%	0.8987	2.45 to 5.45%	3.07 to 5.09%
modified quadratic	4.32%	0.2319	3.93 to 4.71%	3.00 to 5.57%
quadratic	4.39%	0.2778	3.93 to 4.86%	3.00 to 5.56%
hyperbolic	4.23%	4.6727	-3.58 to 12.04%	3.89 to 5.33%

The calculated SIRGs using the different functional forms are not significantly different from one another. However, they are above the observed average real growth rate for the sample period of 3.6%, statistically significantly so for some forms. The explanation for this lies in the growth performance of the period. In the sample period there was a significant slowdown in 1986 and recession in 1990-92. During both periods inflation was falling, consistent with growth below SIRD and over the period as a whole the inflation rate fell (see graph 1). However, some of this could have been due to the behaviour of import prices. Hence it is necessary to look at what the model implies the inflation rate would have been if import prices had contributed to inflation at the same rate as home goods prices. Our estimate of this is discussed in section IV.3 and shown in graph 8, from which it is evident that inflation without import

¹³ The joint test of $\mathbf{b}_i=0$ for all i yields an LR statistic of 23.09 which is distributed χ^2_3 with a critical value of 7.815 at the 95% level.

¹⁴ The estimated SIRGs (and standard errors) for these functional forms using the Melbourne Institute series of inflationary expectations as outlined in footnote 6 are: linear 3.90% (0.8945), modified quadratic 4.30% (0.2351), quadratic 4.38% (0.2810) and hyperbolic 4.20% (4.8594). Full details of these results are available from the first author on request.

inflation effects showed the same pattern of an early rise followed by sustained falls as the actual series. The implication that the period was predominantly one of falling home goods inflation explains why the SIRD could be higher than the observed average growth rate of the period. Further, during recent periods growth has been relatively rapid by historical standards without an accompanying increase in inflation. For example, from 1997:2 to 1999:2 the growth rate has been above 4%, while the inflation rate has fallen or registered only small rises.

Using the hyperbolic form, recursive estimates of the SIRD (graph 3) suggest that it has been relatively stable over the post-float period. While the economy's potential growth rate is likely to vary in the longer run, the recursive estimates suggest that the SIRD has not been subject to the same degree of variation as has been revealed in studies of the NAIRU for similar periods.

While the linear form gives results similar to the others its failure on the RESET test make it less acceptable. In terms of SIRD outcomes there seems little basis in the results in table 1 for preferring one of the non-linear forms over the others. However, the AIC and SBC criteria both support the hyperbolic function. For the purposes of analysis the remaining discussion in this paper focuses on the SIRD estimates using the hyperbolic form.

When estimated over the pre-float period (1970:1 – 1983:3) the hyperbolic form of the equation (7) yields the coefficients shown in the final column of Table 1 and produces a SIRD of 4.8% (with a standard error of 0.9720 calculated by the delta

method). The lag structure for the pre-float period was again unable to be reduced further on the basis of joint tests of significance of the coefficients presented here¹⁵.

III.1 The size and timing of the growth/inflation effect

The magnitude of the effect of growth on inflation implied by the estimated coefficients has been discussed for a similar system in Dungey and Pitchford (1998). Consider a sustained rise or fall in g when the system has been at the SARG for a long period. Using the post-float SARG, starting from a steady state with zero inflation and then setting a steady GDP growth rate of 5.5% pa means that the system would reach about 1.2% annual inflation after 18 months and 2.5% after 3 years. By comparison, with a 5% real growth rate inflation will take almost twice as long to reach 1.2% pa. All this assumes that import prices are not contributing to inflation. Notice also that the non-linear functional form implies that higher growth has a greater marginal impact on inflation than lower.

The dependence of the change in the inflation rate on growth involves three lags, the second with a negatively signed coefficient. One way of interpreting this is that a rise in the growth rate that is not sustained will raise the inflation rate with a lag of one period. However, this will be reversed if the higher growth rate does not last. As was shown earlier, the proposition that the absolute value of the coefficients of $f(g_t)$ are equal cannot be rejected.

Hence, when the economy is in a downswing with growth falling, a continuing reduction in inflation will occur as long as growth continues to fall. This is in addition to the effect on inflation arising from the difference between the actual growth rate and the SARG. Such a lag pattern hastens the fall in inflation in the downswing. The opposite occurs in the upswing, with additions to the inflation rate coming from each rise in growth. Hence, the temporary effects from the lag structure can be thought of as speeding up the adjustment of inflation over the each phase of the cycle.

III.2 Inflation when growth is at the SARG

To further illustrate the consequences of import price fluctuations, suppose that growth had been set at the SARG (4.32%) during the period 1983:4 to 1998:2. Domestically sourced inflation will have an effect on the exchange rate and so on the

¹⁵ A joint test of the significance of the coefficients on g_{t-1} , Δm_{t-2} and Δm_{t-1} yields an LR statistic of 20.015 which is distributed χ^2_3 with a critical value of 7.815 at the 95% level.

growth rate of import prices. We assume that if there were no domestically sourced inflation the rate of growth of import prices would have been lower by the rate of inflation of the CPI.¹⁶ The initial inflation rate is taken to equal the actual inflation rate, which to the December quarter 1983 was 7.27% pa. The resultant inflation rate is generated from

$$p_t = p_{t-1} + a\Delta p_{t-1} + \sum_{i=1}^3 b_i \Delta \tilde{m}_{t-i} \quad (8)$$

where $\tilde{m}_{t-i}$ is import price inflation less the actual CPI inflation rate and the effects of g are taken to be zero.

Graph 4 shows that if the SIRC had been maintained, the lower import price inflation would have ensured that inflation declined slowly to reach 4.8% pa by the June quarter 1998. By comparison, actual inflation declined rapidly due to the 1990-92 recession. However, if inflation had started at the Reserve Bank's (average) target level of 2.5% the graph shows that maintaining growth at the SIRC would have been compatible with inflation below 2% over the nineties. This is due to the behaviour of import prices which will be discussed in section IV.

The 1990-92 recession had the effect of bringing the inflation rate down to levels that are regarded as more acceptable. A measure of the cost of this exercise and of other

¹⁶ It can be seen from graph 6 that this assumption makes very little difference to the numerical results

departures from the SIRG is given in graph 5, the shaded areas being the log of foregone output. The high cost of the 1990-92 recession is evident, and raises the question of whether disinflation could have been achieved with less foregone output.

IV. Inflation and import prices

In the post-float period, import prices can be seen to affect inflation in all cases with lags of one, two and three quarters. Having no land borders, it is reasonable that imports would arrive in Australia a significant time after ordering and that the time needed to sell stock, and for imported producer goods, the time needed to bring them into production would occasion lags in the effect of import prices on the general price level. While this seems to make the results in Table 1 reasonable there is a question as to whether import prices measured in domestic currency should have any impact on the inflation rate in a floating exchange rate system. In this section we shall first attempt to justify why import prices could well have an important independent role in the generation of inflation. In part this justification is based on the type of movements in import prices and the real and nominal exchange rate movements that Australia faces. This experience is set out and examined in section IV.2. The results of our regressions are used to analyse the quantitative contribution of import prices to inflation in section IV.3. Fluctuations in import prices arising largely from external sources raise fundamental issues about the consequences of attempting to target overall inflation. We shall argue in section V that the appropriate objective for inflation policy should usually be the domestic goods inflation rate.

because movements in Dm are very similar to those of Dr , where R is the real exchange rate.

IV.1 Inflation and import prices with a floating exchange rate

Consider first the way in which a flexible exchange rate system might insulate from foreign inflation. To illustrate this suppose the domestic economy produces a single commodity that it consumes and exports, whose price is P . It imports a different commodity that is the sole output of the rest of the world (price $M = EM^*$, nominal exchange rate E and price in foreign currency M^*). From a situation of zero inflation everywhere, suppose there is then continuing monetary expansion abroad which generates uniform inflation for the two goods consumed there. With a pegged inflation rate, this foreign inflation would be imported, but with a floating rate it is possible in principle in a well-behaved economy for the domestic authorities to avoid inflation by not expanding the domestic money supply.¹⁷ As a consequence the exchange rate will appreciate at the rate of foreign inflation as this is necessary to preserve the relative price of foreign to domestic goods (which is the measure of the real exchange rate that is relevant for our purposes, $\tilde{R} = EM^*/P$). But what if inflation is not uniform, that is there are forces making for changes in the real exchange rate? It turns out that it still can be shown that in principle insulation is possible, that is there is a monetary policy that will allow an index of prices of imports and home goods to be held constant.¹⁸

The real issue is whether in a less than ideal world the outcome of attempts at insulation would be desirable. Take the case of a once-off real depreciation (fall in the relative price of home goods to foreign goods) which arises from foreign sources. Supposing for simplicity that all prices and the exchange rate are initially unity, then the price index can be written

$$P = aP + (1-a)EM^* = (a + (1-a)\tilde{R})P \quad (9)$$

Now suppose that monetary policy in the rest of the world is set so that M^* remains constant. This example is different from the foreign inflation example we started with, but involves the same principles. It is taken because, as will be shown in the next section, it is typical of Australian experience in the eighties and nineties. One option for monetary policy is to attempt to hold P constant which must involve a fall in P and a rise in E . Real depreciation is accomplished by a combination of nominal

¹⁷ An additional condition that needs to be satisfied is that the Fisher Effect works abroad. In some systems uncovered interest parity also needs to be satisfied.

depreciation and domestic deflation. In practice this is liable to involve a fall in the growth rate. Indeed, our earlier results suggest that a fall in the growth rate is necessary to accomplish a fall in domestic goods prices from a situation of zero inflation. Another option is for monetary policy to aim to hold P constant, in which case the relative price change will be accomplished wholly by nominal depreciation. There will be a rise in the price index, but unless the real depreciation continues it will not be a continuing rise. If the authorities take the option of not deflating to offset the effects of real depreciation and not inflating to offset real appreciation, import price movements will affect the overall inflation rate, even though some or all of the conditions, except the appropriate monetary policy, that make insulation possible are satisfied. To ensure inflation insulation when there are relative price shifts, the real economy will be required not to respond to the monetary policy needed to produce changes in the domestic price level. It is unlikely that this condition will be fulfilled.

IV.2 The behaviour of import prices

In the preceding section two questions were raised about the behaviour of various prices, namely

1. In practice in the post-float period, have domestic currency import prices largely reflected exchange rate fluctuations with changes in foreign currency import prices and other factors being relatively minor influences on their movements?
2. Were real exchange rate fluctuations in the post-float period largely accomplished by changes in domestic currency import prices with domestic prices having a relatively minor contribution to their movements?

It was asserted in section II that the answer to the first question was yes and we now proceed to provide the evidence for that answer. An affirmative answer to the second question would support the view that the authorities were not effectively taking action to prevent real exchange rate movements from affecting the domestic inflation rate and hence would justify having import price effects in our regressions.

In regard to the first question for the post-float period, the contemporaneous correlation coefficient between m and e is 81% so that domestic currency import price

¹⁸ See Pitchford (1993).

changes have been closely associated with nominal exchange rate variations.¹⁹ Hence, foreign currency import price movements have been a relatively minor contributor to domestic currency import price fluctuations.

To answer question 2 it is necessary to use a workable definition of the real exchange rate. Define it as²⁰

$$R = EM^*/P, \text{ so } r = m - p, \quad Dr = Dm - Dp \quad (10)$$

where E is the nominal exchange rate and M^* the foreign currency import price.²¹

Further, using (1)

$$r = a(m-p) = a(e + m^* - p) \quad (11)$$

Over the post-float period the correlations between m and r , Δm and Δr , and r and e are 94%, 99% and 82% respectively.

Hence, in the 1983–98 period much of the fluctuation in domestic currency import prices has come from exchange rate movements. Moreover, real exchange rate movements have been largely accomplished by nominal exchange rate fluctuations. It is also clear from graphs 6 and 7 that real exchange rate fluctuations have been substantial in the period since the float and hence could have had a significant influence on real growth had the policy of attempting to insulate the domestic inflation rate from foreign inflation been followed. Also, for our purposes it would seem that there is ample justification for the inclusion of import prices as an explanator of domestic inflation.

Some of these issues are illustrated by graphs 6 and 7. The first shows the annual rate of change of the real exchange rate. A major source of these fluctuations is thought to be foreign commodity price movements and graph 6 also illustrates the RBA index of commodity prices measured in SDRs. Notice that commodity price movements affect foreign currency export prices and hence are thought to change the nominal exchange rate.²² The existence of such considerable and frequent external shocks to the relative price of imported to domestic goods backs up our view that monetary policy

¹⁹ An incidental consequence of this is that information on exchange rate movements, being available almost immediately may be useful in predicting import price movements which are available only with a considerable lag.

²⁰ R is a linear transformation of $\tilde{R}$.

²¹ This assumes that the law of one price $M = M^*E$ holds.

²² See Pitchford (1993).

necessary to produce insulation would probably be costly and therefore unlikely.

The actual variables that enter into the estimated equations are the changes in import price inflation rates. This variable behaves in a very similar fashion to changes in the inflation rate of the real exchange rate, the difference $Dm - Dr$, being the change in the domestic inflation rate, can be seen to be minor relative to real exchange rate movements. Rises follow falls in Dm with cycles lasting about two to three years. The evidence is strong that most of the variation of Dm is accounted for by the variation associated with the real exchange rate.

IV.3 The contribution of import prices to inflation

One way of appreciating the influence of import prices on inflation is to ask what inflation would have been if import prices had contributed to inflation to the same extent as domestic goods prices? This can be determined by substituting p for m in (7) and calculating the consequent inflation from a base date, December 1983. The results

are summarised in graph 8 for the hyperbolic form, showing by how much, according to our model, the overall inflation rate has been altered by import price movements. It can be seen that import price inflation held down the overall inflation rate by between one and two percentage points in the period since 1987. Depreciation in the mid-80s added to inflation, but from about 1987 the contribution of import prices has been steadily negative. Anti-inflation policy has benefited considerably from these import price movements.

From (1) and (2), if import price inflation rises, the curve $y(g)$ rises (figure 1) but it keeps moving up only if import price inflation continues to increase. It is important to note that this is different from the case of growth, where if g rises above g^* and stays there, inflation will perpetually rise. A period of falling import price inflation will cause the curve to fall.

The implication for policy is that steady growth at the SIRG could allow the overall inflation rate to drift up and down with fluctuations in import price inflation without causing a rise in domestically generated inflation. In addition, when import inflation is decelerating, perhaps growth could exceed the SIRG without causing overall inflation to rise. Notice that this result stems from the generation of import price fluctuations by the movements in the real exchange rate, a real variable. Hence, it holds irrespective of the way in which domestic goods prices are thought to be determined. The policy implications of these issues are considered further in section V.

Another aspect of the contribution of import prices to inflation can be investigated if the hyperbolic form results are regarded as representing the equation (3), which was constructed by combining (1) and (2). In that case, the weight of import prices in the

price index is given by the sum of the coefficients on the various lags of Dm . This calculation suggests that the weight on import items in the CPI is 8% and on home goods 92%.²³

V. Conclusions

V.1 Import prices and the inflation target

It has been seen that import prices fluctuate quite widely. The effect of this on the overall price index is moderated by the small size of their marginal impact on overall inflation. Nevertheless, our results suggest that an inflation target specified in terms of the overall price index, that is including import prices as well as domestic goods prices, may require considerable swings in the growth rate. One way of showing this is to assume that the overall price index remains steady at some target value reflecting perfect achievement of an overall inflation target.

Thus set $\Delta p = \Delta p_{-1} = 0$ in the hyperbolic form so that

$$ghk_t - 1.42ghk_{t-1} + 1.28ghk_{t-2} - .08 + f(t) = 0 \quad (12)$$

where the $f(t)$ term represents the effect of import price changes. Neglecting this non-autonomous term, (12) is a second order difference equation in ghk_t and may readily be shown to yield oscillatory and unstable behaviour. By contrast, holding growth at the SIRG yields, by definition, a steady rate of growth of GDP and an overall inflation rate which fluctuates with import prices in a way illustrated in section IV.

Another way of looking at this issue is to ask how growth in period t would need to change if it were to offset the effect of the period t change in import prices. This would not lead to steady overall inflation because of the lagged effects of both growth and import prices on inflation, but it would be one component of this process. Substituting for $f(t)$ in (12) it can be shown that $\partial g_t / \partial \Delta m_t = 0.26$. Hence, applying a reduction of about a quarter to the scale of graph 6 and referring to the graph of Δm_t gives the growth changes necessary to effect this partial offset of import prices on inflation.

These considerations strongly support the position that targeting domestic rather than

²³ Rearranging (1) and (2), this estimate could be used to construct a series for changes in the domestic

overall inflation will normally be a preferable approach. When import prices rise by very large amounts, such as was the case with the oil price shocks of the 1970s, the overall inflation rate may, temporarily, rise very considerably. On the other hand the cost of offsetting this in terms of foregone growth would also be considerable. Policy toward such rare special events would need to be formulated with these trade-offs clearly recognised.²⁴

V.2 Targeting the SIRD

If the concept of the SIRD were accepted, the long run objective of economic management would be to achieve this rate of growth combined with some steady home goods inflation rate. In theory the transition path to this goal would involve a trade-off between lower inflation of domestic goods prices and lower real output which would reflect the costs of each. While the cost of foregone output is not so hard to calculate, it is doubtful that our knowledge of the cost of inflation as well as of the transition dynamics of the economy allows such fine-tuning. Because it involves adjusting to inflation and output, a Taylor rule would be an appropriate way of thinking about such issues. In practice such exercises are a guide to policy principles rather than an aid to precise monetary settings.

Of course, use of the SIRD as a guide to policy would require caution. In common with any such policy relevant parameter, the confidence intervals imply that care and experience in its use would be needed. Obviously, if growth at or less than the SIRD appeared to produce increasing domestic goods' price inflation there would be grounds for reducing the growth target and the opposite case would suggest increasing it.

IV.3 Concluding remarks

This paper has proposed an alternative way of examining the relationship between economic activity and inflation outcomes. While the traditional approach using the Phillips curve seems logical in the case of wage inflation such analyses of both wage and price inflation are complicated by the necessity of estimating a variable equilibrium unemployment rate. For price inflation our approach takes a more direct

goods' inflation rate.

²⁴ Cecchetti (1998) discusses some of the problems of dealing with such events.

path, reasoning that inflation in the goods market should be related to an index of excess demand in that market.²⁵ Our work gives rise to the SIRG as a possible guide to inflation policy and our empirical results suggest that it has been comparatively stable in the post-float period.

We also found that import price inflation contributes to an understanding of overall inflation. For Australia, world commodity price fluctuations are thought to give rise to real and nominal exchange rate movements which in turn are found to be a dominant source of variations in import prices. We argue that attempts to control overall inflation rather than inflation of home goods prices might lead to considerable fluctuations in rates of economic growth.

²⁵ In this sense our work is complementary to that which uses the output gap as a measure of market pressure in the goods markets. (Laxton, Meredith and Rose (1995), Ng (1998), Dupasquier and Ricketts (1998)).

Appendix A: Data definitions

- M: quarterly implicit price deflator for imports from the TSS database on dX (NPDQ.AD90IMP#)
- π : quarterly Treasury underlying Consumer Price Inflation rate taken from the TSS database on dX (RSR.U190C9211001).
- R: the exchange rate – from the RBA database on dX (FXRTWI). Quarterly data derived as the average of the end-month figures.
- Y: quarterly Australian real GDP (A) (seasonally adjusted) taken from the ABS TSS database on dX. (NPDQ.AK90GDP#A)

Capital letters denote data in levels and lower case denotes logged series.

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