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An Empirical Analysis of the Effect of Growth on Inflation, Australia, Canada and the United States

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ABSTRACT

Economists often comment that inflation will tend to increase (or decrease) if growth is higher or lower than the 'potential' growth rate of the economy. After setting out a theoretical justification for such a relationship we estimate equations relating the change in inflation to growth rates for the US, Canada and Australia. Our system also allows for the possibility that traded goods price inflation will influence the inflation rate of consumer prices. The estimates yield 'steady inflation rates of economic growth' of close to 3% pa for the US and Canada and 4% for Australia. These estimated potential growth rates vary little over a variety of sub periods from the 1960s to 2000. Inflation rates of import and export prices also contribute to the explanation of inflation in some but not all sub periods.

Keywords: Inflation, growth, potential growth, monetary policy

JEL Classifications: F43 - Economic growth of open economies, E31 - Price level, inflation, deflation

An Empirical Analysis of the Effect of Growth on Inflation, Australia, Canada and the United States

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1. Introduction

How fast can an economy grow? The question needs close definition because the answer will depend on many influences such as the stage of the cycle, the myriad of factors envisaged by old and new growth theory, and on what happens to inflation. There seems little doubt that at any time there will be a growth rate beyond which the inflation rate will start to rise. This rising inflation is a signal that the growth rate is unsustainable and the authorities in many countries will react by tightening monetary policy to reduce growth. It is our purpose in this paper to investigate this relation between inflation and growth, to give it a simple theoretical explanation and to see what can be learnt about it empirically. What we put forward is both an examination of the practical limits to growth and a way of thinking about inflation. Our purpose is to investigate empirically whether a path of growth exists at which the inflation rate an economy generates could remain stable.

While we attempt to do this systematically, we are not alone in taking this view of inflation. Such observations are often informal and, of course, may be mixed with conventional explanations of inflation. Economists and economic commentators commonly make observations to the effect that inflation is likely to increase (decrease) when an economy is growing rapidly (slowly). Central Bankers, charged with the responsibility for controlling inflation, frequently justify their monetary policy actions on the basis of what such actions will do to economic growth and hence to inflation. For example, during 2001 official statements accompanying the easing of monetary policy in each of Australia, Canada and the US have associated the earlier high growth with

increasing inflation and/or the subsequent lower growth with falling inflation. For example on 13 February 2001 the Federal Reserve Board explained recent monetary policy in the following terms.

> "After having increased the interest rate on federal funds through the spring to bring the growth of aggregate demand and potential supply into better alignment and thus contain inflationary pressures, the Federal Reserve had stopped tightening as evidence of an easing of economic growth began to appear." (Federal Reserve Board, February 13, 2001, p.1)

This suggests a belief that growth above the economy's potential had raised inflationary pressures which could be contained by slower growth. Similar associations of output and inflation can be found in statements from the Bank of Canada about the easings in May, July and August 2001, in the February 2001 Monetary Policy Report to US Congress and attached to the April 2001 easing in Australian monetary policy. Some quotes from these statements are given in Appendix A. If for no other reason, the prevalence of such statements suggest that it would seem worthwhile to investigate the relation between inflation and growth.

Building on work derivative from Phillips (1958), Friedman (1968) and Phelps (1968) the conventional approach to inflation specifies that changes in the inflation rate will be induced by deviations in real variables from equilibrium levels. The relevant real variable conventionally is the unemployment rate, and inflation is thought to increase when unemployment is less than the equilibrium or natural rate or NAIRU.[1] However, because of wide variations in the unemployment rate, particularly since the 1970s, without concomitant changes in the inflation rate, the equilibrium unemployment rate has become

[1] Inflation would change relative to its expected level and this would result in a change in the actual inflation rate in the absence of policy to prevent it. Of course, behind the changes in real variables would be appropriate monetary adjustments.
With respect to the NAIRU, when the unemployment rate is less than the NAIRU the inflation rate would not necessarily "accelerate". The use of the term denoting the second derivative of the inflation rate where the first derivative is what is meant is avoided in this paper except where it is necessary to refer to work which uses it.

a somewhat dubious indicator of changes in inflation. US experience may be an exception, though even there doubts exist about the stability of the natural rate.[2]

In a growth context, conventional theories of inflation would argue that if growth is in some sense high, the demand for labour would be high resulting in falls in unemployment and the bidding up of wages which, by some means, is supposed to induce higher price inflation. We do not follow this usual route with its dependence on a critical path or rate of unemployment (NAIRU), though our approach is not necessarily inconsistent with some such labour market developments. Instead, we hypothesise that *price* pressures should be thought of as generated by conditions in the *goods* markets and that the difference between the actual and the 'potential' growth rate may be an indicator of such pressures.[3] This approach has much in common with that which relates inflation to the gap between actual and potential output.[4] One major difference is that while the output gap approach requires a guess to be made of potential output, our work yields an estimate of potential growth. Thus a central concept in our investigation is the 'steady inflation rate of economic growth' or SIRG which will be seen to be akin to potential growth.

Another feature of our study is the inclusion of the behaviour of tradeables prices in the explanation of inflation. These were found to be significant additional explanators of the inflation rate of the consumer price index which usually will contains such goods, for at least for some periods in each of the three countries. In consequence the notion of the SIRG given above must be amended to that of the 'steady domestic goods inflation rate of economic growth'.

Our earlier investigations of these issues were for the Australian economy.[5] Here we use a somewhat different treatment of the dynamics and of traded goods prices to examine and compare the relationship between inflation and growth in the US, Canada and Australia. As the usefulness of the SIRG for policy purposes would be enhanced if it

[2] See, for instance, Gordon (1997,1998), Stiglitz (1997), Staiger, Stock and Watson (1997).
[3] Of course, conditions in other markets, measured by variables such as unemployment and the rate of investment, will affect the state of the goods market.
[4] For example, Laxton, Meredith and Rose (1995), Clark, Laxton and Rose (1996) for the US, Dupasquier and Ricketts (1998) for Canada, and Ng (1998) for Australia. These papers used a closed economy framework.
[5] Dungey and Pitchford (1998, 2000).

were found to be reasonably steady, we attempt to assess the stability of our estimates. The problem is not properly identified for estimation of the time varying type typically applied to the NAIRU[6]. Instead we have estimated our equations over a number of time periods in order to check the extent to which the SIRG changes over time. The results suggest that it has been relatively stable for Canada and the US even over long periods. With the exception of the decade of the 1960s this is also true for Australia. We estimate that for the US the SIRG appears to have been steady at about 3% pa over long periods, and that the Canadian SIRG has also been relatively stable at about 3% pa. For Australia we find a figure a little over 4% for most periods, contrasting with 5% for the sixties.

A theoretical justification for relating inflation to growth is given in section 2 and the model to be tested is set up. Sections 3 and 4 deal with the data and results and section 5 conducts some simulation experiments. Section 6 discusses various implications including those for policy.

2. Theory

The notion that the inflation rate is influenced by the growth rate seems intuitively appealing. Thus, in a growing economy there will be two sources of pressure on prices. First, past actions conducive to growth will result in increasing factor supplies and this, by itself, will put downward pressures on prices. To the extent that there is actual growth for any *given* supply of factors there will be upward pressure on prices. Whether price and/or the inflation rises or falls depends on the outcome of these two forces.[7]

To give precision to these ideas suppose an economy produces a single good in quantity Y sold competitively under marginal cost which rises with output, *other things being equal*. P is the price of the domestic good. Lower case indicates proportional rates of growth. Allowing for growth, increasing supplies of factors ensure that for some initial level of output there will be a growth rate g^* at which marginal cost C' will not rise when the consequent output is produced and that marginal cost will rise (fall) when actual growth g

[6] Specifically, the variance properties of the independent and dependent variables are such that it is not possible to find a global solution to a Kalman filter form of the problem (see for example, Gruen, Pagan and Thompson (1999)).
[7] It is assumed that appropriate monetary conditions exist.

is such that $g > g^*$ ($g < g^*$). For reasons such as hysteresis, adjustment costs etc, this growth rate would usually not be the one that would bring an economy that is, say, in recession to full employment immediately for to do this could raise marginal cost. Too large a jump in actual output will raise marginal cost as it requires a bidding up of factor prices and real costs. No increase or a small increase in output in an economy which has growth potential will lead to a bidding down of factor prices and a usage of inputs such that marginal cost declines. Hence, at any time and for any initial output there will be a 'potential' output Y^* such that if actual output growth just absorbs factor supplies so as to equal potential output growth, marginal cost will not change. That is, writing total cost as,

$$C(Y/Y^*), \quad C'>0, \quad C''>0, \tag{1}$$

so that the rate of change of marginal cost is

$$\left(\frac{dC'}{dt}\right)\frac{1}{C'} = \frac{C''Y}{C'Y^*}\{g - g^*\} \geq (\leq)\ 0 \quad as \quad g \geq (\leq)\ g^*, \tag{2}$$

An individual firm will attempt to set its *relative* price equal to marginal cost. Suppose this is the case here, while the situation in which it takes time to close the gap between price and marginal cost is derived in Appendix B. Extending this argument to the economy and making usual aggregation assumptions, this price will be the ratio of actual price ($P(t)$) to prices in the rest of the economy. This will be represented by a price index, and for the moment is taken to be an index of expected prices ($P^e(t)$), so that

$$P(t)/P^e(t) = C'(Y(t)/Y^*(t)) \tag{3}$$

Differentiating with respect to time

$$p - p^e = \left(C''Y \big/ C'Y^*\right)(g - g^*) \tag{4}$$

where p and p^e are proportional rates of change of P and P^e, respectively. $g^*(t)$ can be thought of as the potential growth rate *at any time*. In this sense it may well be heavily dependent on the actual output level and its deviation from an equilibrium level where factors are fully employed. Thus in a recession the potential growth rate may well be

higher than at full employment because of unemployed factors and it is well known that at the start of a boom quite high growth rates are possible without substantial increases in inflation.[8] In practice what we estimate is a figure, which though influenced by the experience of boom and recession in any sample, will be an average pertinent to that sample. In this sense it is akin to the growth rate of a full employment model, differing to the extent that the sample contains significant departures from full employment. It may well be possible to find an index of the state of economic activity that will indicate the variation in the SIRG over the cycle. However, we have tried to allow in our testing for this influence on potential growth, but so far have not been able to detect a significant effect.

Now introduce discrete time so that

$$p - p^e = p - p_{-1} = \psi(g - g^*), \quad \psi' > 0, \quad \psi(0) = 0 \tag{5}$$

where we work with the case where in the absence of appropriate data on expected inflation this is approximated by last period's inflation rate.[9]

If there is an adjustment process of price to marginal cost an alternative equation, derived in Appendix B, is

$$\Delta p - \Delta p^e = \Delta p - \Delta p_{-1} = \beta_0 + \beta_1 L_1 g + \beta_2 L_2 \Delta p \tag{5a}$$

where L_1 and L_2 are lag operators $\beta_i L_i x = \sum_{j=1}^{n} \beta_i^j x_{-j}$ and Δ the difference operator.

Now assume that our economy also consumes a foreign good, price M, and a good it also exports, price X, so that the inflation rate of a consumer price index is given by[10]

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[8] Hence, while the elasticity $C''(Y/Y^*)/C'(Y/Y^*)\,(Y^*/Y)$ could be taken as a constant at a first approximation, it may well vary over the cycle.

[9] The use of expectations data in our earlier (2000) paper did not alter the results. However, there we were working with annual rates of inflation. Expectations data on quarterly inflation rates are harder to find. Simple adaptive expectations have been used in the past, for example by Ball (1999).

[10] It would be necessary to invert the input/output matrix to discover the level of output and price of the home or domestic good.

$$\pi = (1-h-k)p + hm + kx \qquad (6)$$

Combining (5) and (6)

$$\pi - \pi_{-1} = (1-h-k)\psi(g-g^*) + h\Delta m + k\Delta x \qquad (7)$$

where it is assumed that expected import and exportable price inflation is given by last period's inflation rate for those prices.

Equation (7) explains the change in inflation in terms of growth and the change in the inflation rates of export and import prices. An alternative arrangement of (7) can be obtained in which the inflation rates of tradeables are replaced by the rates of change of the prices of tradeables relative to home goods.[11]

Thus (6) can be rewritten as

$$\pi = p + h(m-p) + k(x-p) \qquad (8)$$

and so

$$\pi - \pi_{-1} = \psi(g-g^*) + h\Delta(m-p) + k\Delta(x-p)x \qquad (9)$$

This is the version which we prefer for our empirical work because it highlights the role of relative price changes in changing the inflation rate. As there are no direct estimates of the price of domestic goods we will approximate *M/P* and *X/P* by *M/Π* and *X/Π* , repectively. These approximations are better the smaller and more similar are *h* and *k*. Using (7) instead of (9) does not greatly change results, particularly with respect to the value of the SIRG.

Growth at the SIRG ($g = g^*$) implies that changes in the inflation rate arise only from changes in the relative inflation rates of tradeables to domestic goods. Alternatively, from (7) if $\Delta m = \Delta x = 0$, growth at the SIRG implies a steady inflation rate.

[11] These relative price are candidates for the concept of real exchange rates.

The transmission of inflation in a fixed exchange rate regime from traded to domestic goods prices would seem to be rather direct. However, in theory, a floating rate insulates from foreign inflation and it would appear that movements in traded goods prices should not explain domestic inflation. Moreover, with a floating rate a domestic monetary expansion should in principle, perhaps after some initial overshooting, depreciate the exchange rate in the same proportion that it raises domestic prices, so that for this reason also it could be argued that traded goods prices should not appear in an equation to explain inflation. Against these arguments it should be noted that the standard deviations of inflation rates of import and export prices in the three countries are of the order of 2 to 3 times that of the domestic consumer price inflation rate, and that the sorts of uniform changes that the above theoretical propositions envisage are rare. Hence, fluctuations in the relative prices of tradeables to domestic goods are the rule and the importables and exportables component of these changes are the dominant varying force. In these circumstances, it is these relative price effects which will affect domestic inflation in either a fixed or flexible rate regime and are thus included in our regressions.[12]

If we base the theory on equation (5) the form in which we estimate the inflation equation is

$$\Delta\pi_t = \alpha + \sum_{i=1}^{L} \beta_i \Delta\pi_{t-i} + \sum_{i=1}^{L} \delta_i g_i + \sum_{i=1}^{L} \phi_i (\Delta m_i - \Delta\pi_i) + \sum_{i=1}^{L} \gamma_i (\Delta x_i - \Delta\pi_i) + \varepsilon_t \qquad (10)$$

where lagged values of the dependent variable represent the possibility that its adjustment may take time. Holding inflation rates and the growth rate steady

($\Delta\pi = 0 = \Delta m_i = \Delta x_i;\ g_{t-i} = g^*,$ constant for all i)

the SIRG is given by

$$g^* = -\alpha / \left(\sum_{i=1}^{L} \delta_i \right) \qquad (11)$$

[12] See Dungey and Pitchford (2000) for further discussion of this issue.

If, instead the case where the adjustment of price to marginal cost takes time is explicitly modelled (equation (5a)), the estimation is based on

$$\Delta^2\pi_t = \alpha + \sum_{i=1}^{L}\beta_i\Delta\pi_{t-i} + \sum_{i=1}^{L}\delta_i g_i + \sum_{i=1}^{L}\phi_i(\Delta^2 m_i - \Delta^2\pi_i) + \sum_{i=1}^{L}\gamma_i(\Delta^2 x_i - \Delta^2\pi_i) + \varepsilon_t \qquad (10a)$$

3. Data

To estimate the relationship between inflation and output growth developed in Section 2 we use selected data on inflation rates, output growth, import prices and export prices in each of the US, Canada and Australia. In the US literature several inflation rates are commonly investigated, here we choose the "CPI without shelter" inflation rate (CPIS). A number of alternatives were investigated with little difference in results.[13] In Canada the standard CPI was examined, while in Australia we worked mainly with the underlying inflation rate series. This series was the target variable for Australian monetary policy from the early 1990s until 1999, when the target shifted to the published CPI, known as headline inflation. The reason for this shift is that a substantial period in our data over which the headline CPI includes mortgage costs which overstates the cost of interest rate rises on consumer prices.[14] This is the same reason that we choose to remain with the underlying inflation series and is also why we use the 'CPI without shelter series' to generate US inflation. Definitions of the import and export prices and the output series used in each case are given in Appendix C.

The time series properties of prices and output are still the subject of some debate in the empirical literature. However, our theoretical formulation concerns inflation rate changes and output growth both of which are clearly stationary in nature.

[13] The alternative price series were the total urban CPI and the Personal Consumption Expenditure deflator. The use of these series, and the CPIS is consistent with that of Gordon (1998) and Staiger, Stock and Watson (1997). The various calculated SIRGs were little different.

[14] An alternative would be the Acquisition CPI compiled by the Reserve Bank which adjusts the headline CPI for this subperiod, but we have preferred to use the underlying rate series because it was, until recently, the series targeted by the Reserve Bank.

4. Estimation and Results

In this section we present the results of estimating the SIRG in each of the US, Canada and Australia. Each case relates the quarterly change in the quarterly inflation rate with the quarterly growth rate, and quarterly changes in quarterly import and export price inflation. Unlike our previous work (Dungey and Pitchford (2000)), which examined the behaviour of quarterly changes in the annual inflation rate, we do not find that non-linearities are dominant in the relationship. In each case we are able to establish a linear relationship between inflation and the independent variables using the standard general to specific approach. Estimates of the SIRG are then obtained using equation (11) and 90% confidence bands constructed via the delta method.

The SIRG appears to be a reasonable alternative to the NAIRU approach as a way of explaining price inflation.[15] This is partly due to the attractive logic of working with a goods market variable as an explanator of goods market price inflation and partly due to the relative stability of the estimated SIRG compared with the time varying NAIRU. We estimate the inflation/growth relationship over a number of sub-samples in each country. While there is evidence of shifts in the lag structure over time, the SIRGs are relatively stable across time periods in each economy.

(Tables 1, 2, 3, 4 [now at end of text] to be placed here.)

Tables 1, 2 and 3 show the outcomes of estimation using equation (10). Table 4 shows the alternative estimates from equation (10a), but as the resulting SIRGs are similar to those from equation (10) our discussion applies to both cases. Some general comments applicable to more than one of the countries may be made. As noted, for most periods growth was found to be a significant explanator of changes in inflation and there was little variation in the value of the SIRG for each country across periods. The decade of the 1970s, containing, as it did, considerable oil price shocks was difficult to fit for the US and Australia, but less so for Canada.[16] The upheaval of this period seems to have made the connection of growth to inflation less significant in the first two countries. In

[15] We do not pass judgement on the NAIRU approach as a way of explaining wage movements.

general, the Canadian and US SIRGs are about a percentage point lower than those estimated for Australia. Import and export prices were often significant explanators of inflation, but not always. Export prices were not significant for Canada in any period. There is a folk economics view that Australia, being a large exporter of commodities and farm products, will find its consumer prices independent of export prices. Contrary to this view, export prices are significant for some periods in the inflation equation.

Our results show only weak evidence to support the proposition prevalent in the nineties that in that decade the potential growth rate for Australia shifted up. For Canada our results suggest a lower SIRG for the nineties and perhaps weak evidence of a higher one for the US. However, these observations are based on differences in point estimates which are generally not statistically significantly different across periods.

4.1 US

For the US, twenty year sub-periods yielded SIRGs of about 3%, which is close to the long term average growth rate. Three periods of estimates of the SIRG are given in Table 1. For the two decades covering 1960 to 1980 the SIRG is estimated at about 2.8% with a fairly tight confidence band. For the period from 1970 to 1990 the SIRG increases slightly to 3.1%, although these numbers are statistically indistinguishable. Likewise for the final decade from 1990 to 2000 the SIRG rises again slightly to 3.3%, but is again statistically insignificantly different to the two other time periods.

The estimated equations consistently show an AR(2) process for the quarterly inflation changes.[17] The growth structure does not seem to be as consistent across the sub-periods, with the structure of the dynamics tending to shorten over history. Relative import price inflation does not seem to have a consistent effect at a particular time horizon. However, relative export price inflation is important at three lags (18 months) in two periods. As

[16] The work of Robert Gordon on the US NAIRU has developed a comprehensive set of dummy observations to cope with various supply shocks throughout the period. References are given in Gordon (1998) for example.

[17] The 1990s also exhibit a significant effect of the fourth lag of inflation. Functional form problems are evident with only an AR(2) structure. The inclusion of the fourth lag dominates the alternative of including the third lag of changes in inflation.

US exports include highly manufactured goods likely to be also heavily consumed at home, the effect of export prices on consumption prices is not unexpected.

In summary, the US SIRG is estimated at around 3%. Point estimates for various sub periods do not vary significantly across the sample. Very similar results are obtained using equation (10a) and are shown in table 4.

4.2 Canada

The Canadian SIRG is also estimated to be around 3% for most periods since 1973. The Canadian results suggest a rate of 3.1% for the entire sample period, but a slightly higher rate for the 1980s of 3.3%. In the recent period, from 1990 to 2000 the SIRG is estimated at only 2.5%. This is in line with the historical experience of Canada, with low growth and low inflation for a substantial part of the 1990s. This period incorporates the episode dubbed the 'Great Canadian Slump' by Fortin (1996) (see also Freeman and Macklem (1998) and Fortin (1999)) involving Canada's prolonged recovery from the recession of the early 1990s.

Across the Canadian results we see that the structure of the changes in inflation are generally represented as an AR(3) process. For most periods growth enters with a lag of around 18 months. Canada is a small open economy exporting primary products and importing transformed goods, and the contribution of relative import price inflation has been recognized in empirical work (see for example Kichian (2001) and Lafléche (1996-97)). The results in Table 2 show relative export price inflation as having no effect while import price inflation is significant for regressions using post 1980s data. Again table 4 gives similar outcomes.

4.3 Australia

Like Canada, Australia is a small open economy exporting commodities, primary products, services and manufactured goods and importing transformed goods. Folk theory and results from working with the inflation rate of tradeables as per equation (7) suggest that export price inflation will be insignificant (see for example studies such as Gruen, Pagan and Thompson (1999), de Brouwer and Ericsson (1998)). Using the relative

inflation rate of tradeables this is the case for the 1960s and 1980s but not for longer periods. Table 3 gives the results of estimating the SIRG for Australia over various sub-periods.

The first column of table 3 presents estimates of the relationship for the 1960s. In this period we use the headline CPI inflation rate due to the unavailability of the underlying series. The estimated SIRG of 5% p.a. is substantially higher than for later periods. This fits in with the view that that decade was particularly good for growth because of the substantial discoveries of and investment in the extraction of minerals and oil that occurred at the time.

The estimated SIRG for the post-float period is 4.4%, compared with 4.2% in our earlier work based on a non-linear specification (Dungey and Pitchford (2000)). If, in deference to folk theory, export price inflation is excluded, the point-estimate of the SIRG is again 4.2%. This is the same rate we obtain for the most recent decade of observations.

More unusually, for the 1980s and 1960s, shown in columns 2 and 3 of Table 3, we find no significant influence of import price inflation. The relationship found was between changes in inflation and growth alone.

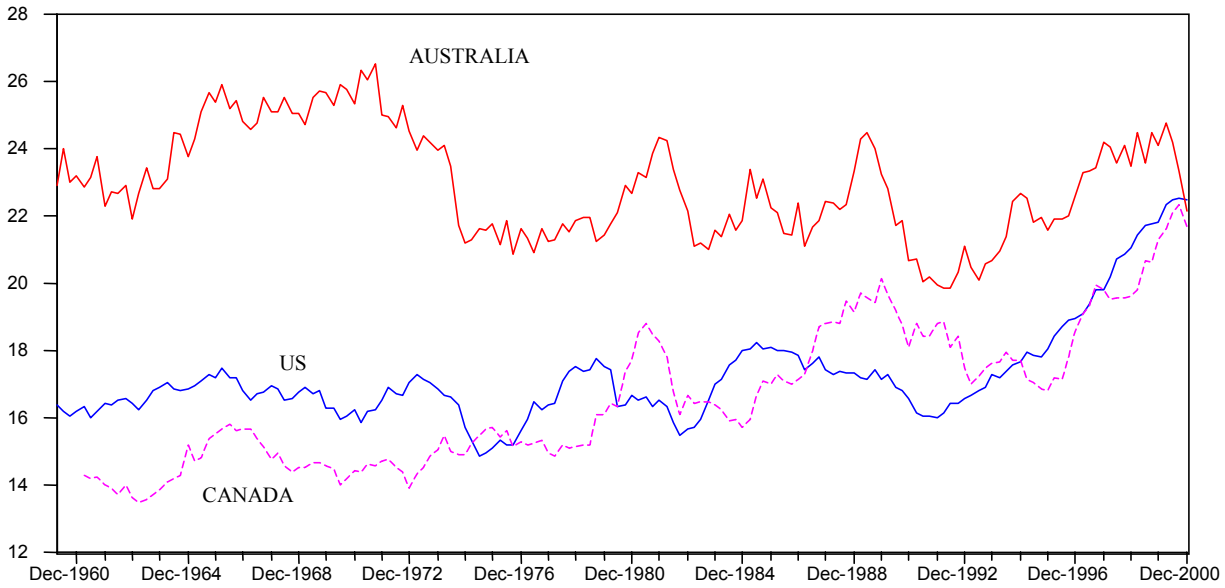
4.4 Differences in SIRGs Across Countries

Substantial investigation of why SIRGs may differ between countries is not appropriate here, but a few brief remarks on some differences can be made. Australia's SIRG turns out to be higher than those of the US and Canada by about one percentage point. This is consistent with the fact that the average growth rate for Australia in 1980Q1 to 2000Q1 was 3.4% compared with 2.5% for Canada and 3.1% for the US, but this does not fully account for the differences, especially with respect to the US. One factor behind growth levels, the percentage of gross fixed capital formation to GDP for each country, is shown in Chart 1. It is notable that Australia's percentage was highest in the 1960s and this was the period for which its estimated SIRG was 5%. Also its percentage was considerably higher than those of the US and Canada for almost the whole period from 1960 to 2000. Another interesting aspect of this data is that both Canada and the US experienced a

significant rise in the investment/GDP ratio during the 1990s. This experience is consistent with speculation that potential growth in these economies had risen in this decade. Nevertheless, our estimates of the SIRG do not identify such a shift.

Chart 1:

PERCENTAGE OF GROSS FIXED CAPITAL FORMATION TO GDP
US, CANADA,



SOURSE: OECD ECONOMIC INDICATORS

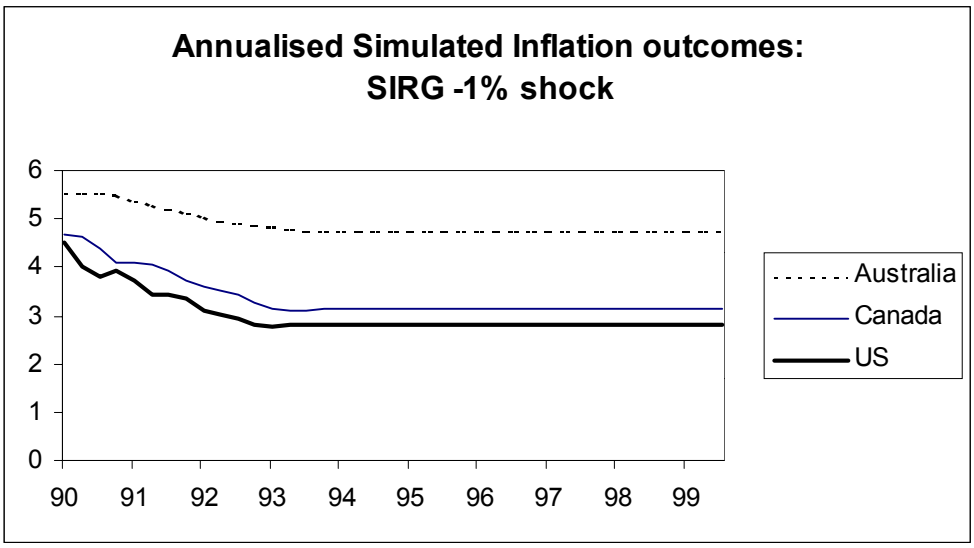
5. Simulation Experiment

In order to illustrate the dynamics of our estimated relationship between inflation and growth consider the effects of a temporary shock to the growth rate in each of the three countries. The estimates for the decade of the 1990s from Tables 1 to 3 are used to benchmark the models and relative import and export price inflation are assumed to be zero.

The scenario is set as the starting value of actual inflation in the December quarter for 1989 in each country. If the SIRG were attained in each quarter for the following years, and no import or export price inflation occurred, the inflation rate converges rapidly to a level dependent on its initial values. Consider instead a negative shock of 0.25 of a percentage point per quarter, approximately equivalent to an annual one percentage point

to the growth rate, sustained for a period of 3 years and then removed. The effects of this are shown as the simulated line for each country. The quarterly inflation rates at the starting point of December 1989 for each country were 0.90%, 0.67% and 1.64% for the US, Canada and Australia, respectively.[18] The first observation shown on each chart is for December 1990.

Chart 2:



The impact of the experiment on the inflation rates in the three countries is reasonably similar in the US and Canada but different for Australia. In the US the inflation rate falls by around 1.7 percentage points over the period to the end of 1993 before stabilising. In Canada, the fall is about 1.4 percentage points over the period to mid-1994 and in Australia stability is reached around the end of 1994 after a fall of approximately 0.8 percentage points The differences in the time taken to approximately stabilise reflect the differing lag structures in the estimations. The Australian case clearly responds less to the growth rate shock than the US (as reflected in the parameter estimates).[19] We can show that a reduction in growth below the SIRG of about 1 percentage point *per quarter* would have produced an outcome very similar to that actually observed in the 1990s.

[18] The annual inflation rates for the December quarter of 1990, ie corresponding to the first observation shown on chart 2, are 6.3%, 4.8% and 5.3% for the US, Canada and Australia respectively. The extent to which the 'actual' inflation line deviates from the starting point for the SIRG experiments on the graphs is the result of two things. The first is how well the estimated equation fits the data, and the second is the extent to which the actual growth rate deviated from the SIRG in the first four observations used to make up the annual inflation rate.

[19] On the other hand a growth rate beyond the SIRG would have conversely small effects on inflation.

We have demonstrated that the dynamics of the system is such that in the absence of effects from traded goods prices, the inflation rate can converge to a steady value provided growth is held at the SIRG.

6. Discussion and Conclusions

This paper has tested our concept of the SIRG for three countries and found that it appears to have relevance in each and that estimates of its value remain relatively stable. Here we find that a simple linear relationship exists between changes in inflation and output growth rates, augmented by import and export price inflation. This relationship provides a useful means of encapsulating information on domestic price formation in a direct way, rather than the traditional indirect route via the labour market. Further, despite speculation to the contrary, we have not found convincing evidence of much change in potential growth in the 1990s for any of the countries examined. With the exception of the 1960s for Australia and the 1990s for Canada the estimated value of the SIRG in Tables 1-4 remain remarkable steady in each country.

We have noted that the value of the SIRG will also be influenced by the stage of the cycle as well as long run factors, though we have been unable to find indicators of the cycle that are significant and/or are not highly correlated with growth. Define the long run equilibrium SIRG as that appropriate to an economy that has been at full employment for a long period. It is this growth rate which has been the subject of many growth models. The short run SIRG is that growth rate which over our unit time period would keep the inflation rate of domestic goods prices constant. The disruption of a significant recession, leading as it does to a reduction in investment, obsolescence of and physical depreciation of capital, and unemployment and loss of labour skills is likely to mean that potential growth in the intermediate period may be slower than that for the long run equilibrium.

Because most decades contain recessions and booms, what we have estimated above is an intermediate period SIRG whose value will be influenced by the history of the cycle in the period studied. It will be some form of average of short run SIRGs. If, for instance, very conservative monetary policy kept growth well below the long run SIRG for a considerable time the economy could well adjust to a much lower SIRG with low

investment and high long run unemployment. Hence, the actual growth rate may well influence the intermediate SIRG.

Many commentators would seem to have based their assessments of steady inflation potential growth on past average obtained growth, without taking into account the historical performance of inflation or cyclical effects. So, for example, in the Australian case 3.5% was seen as a reasonable level of growth in the mid-1990s. By the late-1990s, however, after sustained periods of historically high growth *without* increasing inflation these estimates had been revised upwards by most participants (see for example the Semi-Annual Monetary Policy Statements by the Reserve Bank of Australia over the period). Estimated values of the SIRG suggest that the potential for growth was higher than inferences about the average suggested.

If the SIRG is attained the inflation rate that will then remain steady is the domestic goods component of the price index. When inflation arises from the effects on the consumer price index of traded goods price inflation, our results require that the authorities must attempt to reduce growth to offset this if they wish to hold the inflation rate of this index steady. To the extent that import price inflation represents a temporary shock there seems little to be gained from adjusting the domestic economy. Of course, the judgement as to which shocks are temporary and which are not is a difficult one for policy makers. However, a glance at the data on the inflation rate for tradeables for all three countries shows that it consists to a considerable degree of changes in one direction which are soon reversed. Hence, stabilisation of an index of overall prices could well require continual fluctuations in growth.

Our results, taken together with the comments by Central Bankers on potential inflation such as those in Appendix A, suggest that information on the value of the SIRG could well assist in managing inflation. The possibility that the short run SIRG varies over the cycle would mean that the intermediate value SIRG which we have estimated would be most relevant in periods when recession is absent. It is clear that *like any such concept* its use could be as a general guide only and that the authorities would need to apply it on a

trial and error basis. For instance, the view that the average growth rate represented an upper limit to what the authorities could allow would seem to require revision.

Finally, our analysis has been constructed for and applied to economies with moderate inflation. Its application to economies with high rates of inflation such as have been experienced in Latin America and to hyperinflations has not been considered or implied.

Table 1: Results for the dependent variable $\Delta\pi$ for the United States – various subperiods from 1960 to 2000

variable	1960Q1-1980Q1	1970Q1-1990Q1	1990Q1-2000Q2
constant	-0.144*	-0.150*	-0.235*
	(0.066)	(0.065)	(0.0763)
$\Delta\pi_{-1}$	-0.384*	-0.360*	-0.499*
	(0.107)	(0.098)	(0.134)
$\Delta\pi_{-2}$	-0.354*	-0.383*	-0.673*
	(0.098)	(0.100)	(0.106)
$\Delta\pi_{-4}$			-0.228**
			(0.122)
g_{-1}	0.094*		
	(0.041)		
g_{-2}			0.287*
			(0.080)
g_{-4}	0.116*	0.199*	
	(0.040)	(0.051)	
Δxr_{-3}	0.068**	0.081**	
	(0.038)	(0.046)	
Δxr_{-4}	0.148*	0.133*	
	(0.038)	(0.046)	
Δxr_{-5}	0.069**		
	(0.038)		
$Rbar^2$	0.324	0.323	0.590
AIC	-33.975	-55.137	-8.349
annual SIRG	2.8%	3.1%	3.3%
90% intervals			
Delta method	2.10-3.42	2.18-3.92	1.76-4.87

All regressions passed the tests of Serial Correlation, Functional Form, Normality and Heteroskedasticity in Microfit Version 4.0.
** significant at 10% * significant at 5%

Table 2: Results for the dependent variable $\Delta\pi$ for Canada: various subperiods from 1973Q1 to 2000Q2

variables	1973Q1 – 2000Q2	1973Q1 – 1982Q2	1980Q1 – 1990Q1	1980Q1 – 1995Q1	1990Q2 – 2000Q2
c	-0.165**	-0.424*	-0.328*	-0.168*	-0.182**
	(0.061)	(0.144)	(0.089)	(0.077)	(0.106)
$\Delta\pi_{-1}$	-0.388**	-0.475*	-0.412*	-0.331*	-0.543*
	(0.090)	(0.133)	(0.137)	(0.131)	(0.148)
$\Delta\pi_{-2}$	-0.413**	-0.477*	-0.350*	-0.258*	-0.410*
	(0.090)	(0.137)	(0.138)	(0.129)	(0.154)
$\Delta\pi_{-3}$	-0.294**	-0.372*		-0.345*	-0.523*
	(0.085)	(0.128)		(0.127)	(0.167)
g_{-1}		0.199*	0.212*		
		(0.086)	(0.064)		
g_{-4}				0.214*	0.295*
				(0.076)	(0.141)
g_{-6}	0.215**	0.366*	0.193*		
	(0.057)	(0.094)	(0.065)		
Δmr_{-1}	0.061**			0.089*	
	(0.021)			(0.030)	
Δmr_{-4}					0.100*
					(0.038)
$Rbar^2$	0.303	0.434	0.379	0.306	0.310
AIC	-74.328	-25.272	-18.798	-43.847	-34.551
annual SIRG	3.1%	3.0%	3.3%	3.2%	2.5%
90% intervals					
Delta method	2.40-3.78	2.58-3.48	2.79-3.77	2.18-4.17	1.60-3.38

All regressions passed the tests of Serial Correlation, Functional Form, Normality and Heteroskedasticity in Microfit Version 4.0.
** significant at 10% * significant at 5%

Table 3: Results for the dependent variable $\Delta\pi$ for Australia: various subperiods 1961Q1 to 2000Q2

variables	1961Q1-1971Q1[a]	1981Q1 – 1991Q1[b]	1983Q4-2000Q2[b,c]	1983Q4-2000Q2[b]	1990Q1-2000Q2[b]
c	-0.264*	-0.261*	-0.121*	-0.209*	-0.242*
	(0.117)	(0.089)	(0.042)	(0.056)	(0.062)
$\Delta\pi_{-1}$	-0.794*	-0.418*	-0.400*	-0.373*	-0.732*
	(0.113)	(0.147)	(0.106)	(0.103)	(0.123)
$\Delta\pi_{-2}$	-0.500*		-0.148	-0.167	-0.455*
	(0.119)		(0.109)	(0.104)	(0.145)
$\Delta\pi_{-3}$			-0.270*	-0.305*	-0.444*
			(0.104)	(0.102)	(0.133)
g_{-1}	0.100*	0.142*		0.070**	0.112*
	(0.034)	(0.054)		(0.037)	(0.048)
g_{-2}	0.138*				
	(0.035)				
g_{-4}	0.104*				
	(0.036)				
g_{-5}	-0.127*				
	(0.033)				
g_{-6}		0.116*	0.112*	0.131*	0.113*
		(0.051)	(0.033)	(0.032)	(0.048)
Δmr_{-1}			0.017*		
			(0.008)		
Δmr_{-2}			0.026*		
			(0.010)		
Δmr_{-3}			0.032*		
			(0.010)		
Δmr_{-4}			0.027*	0.019*	
			(0.008)	(0.007)	
Δxr_{-2}					0.027**
					(0.014)
Δxr_{-3}				0.029*	0.033*
				(0.010)	(0.015)
Δxr_{-4}					0.049*
					(0.014)
$Rbar^2$	0.669	0.254	0.366	0.372	0.561
AIC	-22.129	-16.372	-3.987	-3.242	4.091
annual SIRG	5.0%	4.1%	4.4%	4.2%	4.4%
90% intervals Delta method	4.06-5.94	3.36-4.87	3.51-5.31	3.73-4.73	3.86-4.87

All regressions passed the tests of Serial Correlation, Functional Form, Normality and Heteroskedasticity in Microfit Version 4.0.

** significant at 10% * significant at 5%

a. Inflation is measured as headline inflation.
b. Inflation is measured as underlying inflation.
c. Excluding export price inflation.

Table 4: Results for the dependent variable $\Delta^2\pi$ for United States, Canada & Australia – various subperiods

	United States		***Canada***		***Australia***	
variable	1970Q1-1990Q1	1990Q1-2000Q3	1973Q2-2000Q2	1980Q1-1990Q1	1983Q4-2000Q2	1981Q1-1991Q1
constant	-0.156* (0.067)	-0.217* (0.079)	-0.237* (0.068)	-0.328* (0.089)	-0.183* (0.060)	-0.262* (0.084)
g_{-1}				0.212* (0.064)	0.077** (0.040)	0.148* (0.051)
g_{-2}		0.269* (0.083)				
g_{-4}	0.206* (0.052)		0.138* (0.060)			
g_{-6}			0.169* (0.058)	0.193* (0.065)	0.110* (0.035)	0.112* (0.049)
$\Delta\pi_{-1}$	-1.326* (0.102)	-1.640 (0.117)	-1.404* 0.091	-1.412* (0.137)	-1.346* (0.115)	-1.382* (0.138)
$\Delta\pi_{-2}$	-0.337* (0.102)	-0.636* (0.109)	-0.457* (0.090)	-0.350* (0.138)		
$\Delta\pi_{-3}$			-0.339* (0.086)			
$\Delta^2 mr_{-1}$			0.055* (0.021)			
$\Delta^2 mr_{-3}$					0.014* (0.007)	0.013** (0.008)
$\Delta^2 mr_{-4}$					0.027* (0.010)	0.018* (0.008)
$\Delta^2 mr_{-5}$					0.019* (0.010)	
$\Delta^2 mr_{-6}$					0.012* (0.007)	
$\Delta^2 xr_{-4}$	0.044* (0.027)					
$Rbar^2$	0.702	0.840	0.733	0.746	0.715	0.739
AIC	-57.197	-9.354	-71.885	-18.798	-8.607	-15.46
annual SIRG 90% intervals	3.1%	3.3%	3.1%	3.3%	4.0%	4.1%
Delta method	2.19-3.93	2.69-3.84	2.65-3.60	2.79-3.77	3.41-4.55	3.40-4.79

All regressions passed the tests of Serial Correlation, Functional Form, Normality and Heteroskedasticity in Microfit Version 4.0.
** significant at 10% * significant at 5%

7. Appendix A: Quotes on growth and inflation

Relevant statements are italicised.

The Federal Reserve Board

"When the Federal Reserve Board submitted its previous Monetary Policy Report to Congress, in July of 2000, tentative signs of a moderation in the growth of economic activity were emerging following several quarters of extraordinarily rapid expansion. *After having increased the interest rate on federal funds through the spring to bring the growth of aggregate demand and potential supply into better alignment and thus contain inflationary pressures, the Federal Reserve had stopped tightening as evidence of an easing of economic growth began to appear*." (Federal Reserve Board, February 13, 2001, p.1)

"….. the very rapid pace of economic growth over the first half of 2000 was threatening to place additional strains on the economy's resources, which were already stretched thin. Private long-term interest rates had risen considerably in response to the strong economy, and, *in an effort to slow the growth of aggregate demand and therefore prevent a buildup of inflationary pressures, the Federal Reserve had tightened its policy settings substantially through its meetings in May 2000*." (Federal Reserve Board, February 13, 2001, p.2)

Bank of Canada

"….. *the Bank now expects economic growth in the third and fourth quarters of this year to be below potential, resulting in a lower level of activity than earlier expected. This implies reduced pressures on production capacity and inflation through the rest of this year and into 2002*." (Bank of Canada, "Bank of Canada lowers key policy interest rate by 1/4 percentage point to 4 per cent, 28 August", 2001. p.1)

"*Overall, the pace of expansion in the first half of this year has fallen below the growth rate of potential output, leading to some slack in the economy. These conditions should put downward pressure on core inflation.*" (Bank of Canada, "Bank of Canada lowers key policy interest rate by 1/4 per cent", 29 May, 2001. p.1

Reserve Bank of Australia

"Real GDP fell in the December quarter, resulting in a small net decline in activity over the second half of 2000. ….. *Hence, overall growth is well below longer-run potential, which is likely to keep inflationary pressures controlled in the short term*, even though the exchange rate has fallen further in recent months and wages growth has edged higher."(Reserve Bank of Australia, Press Release, 4 April, 2001.)

8. Appendix B: Derivation of equation (5)

Suppose prices to be adjusted to the gap between marginal cost and price so that[20]

$$\frac{dP}{dt}\frac{1}{P}-\frac{dP^e}{dt}\frac{1}{P^e}=p-p^e=\lambda\left(\frac{C'}{P/P^e}\right),\quad \lambda(1)=0$$

Differentiating with respect to time

$$\frac{dp}{dt}\frac{1}{p}-\frac{dp^e}{dt}\frac{1}{p^e}=\lambda\left(\frac{dC'}{dt}\frac{1}{C'}-[p-p^e]\right)=\lambda(\frac{C''Y}{C'Y*}\{g-g^*\}-[p-p^e])$$
$$=\lambda(\frac{C''Y}{C'Y*})g-\lambda(\frac{C''Y}{C'Y*})g^*-\lambda[p-p^e]$$

If the inflation rate is steady ($p = p^e = p_{-1}$) the growth rate will be at the SIRG ($g = g^*$).

Working with discrete time and using $p^e = p_{-1}$ this may be written

$$\Delta p-\Delta p_{-1}\frac{p}{p_{-1}}=\lambda p\{\alpha_0+\alpha_1 g+\alpha_2\Delta p\}$$

Δp_{-1} is a good approximation for $\Delta p_{-1}\frac{p}{p_{-1}}$ in practice so that we estimate the equation, with the addition of lags, in the form

$$\Delta p-\Delta p^e=\Delta p-\Delta p_{-1}=\Delta^2 p=\beta_0+\beta_1 L_1 g+\beta_2 L_2\Delta p$$

where L_1 and L_2 are lag operators $\beta_i L_i x=\sum_{j=1}^{n}\beta_i^j x_{-j}$ and Δ the difference operator.

[20] A more complex equation, for instance, involving the adjustment of prices to the gap between marginal cost and price may well be appropriate in practice and indeed the lags found in our empirical relations support this.

9. Appendix C:

USGDP	Real, seasonally adjusted, chained GDP, 1996=100	BEA website www.bea.gov.doc downloaded October 2000
USCPIS	All urban consumer price index less shelter, 1982-84=100 quarterly average of monthly data	BLS website www.bls.gov CUSR0000SAOL2
USIPD	Import Price Deflator, chain-weighted prices	BEA website, file czw Table 9, line 19, code PMC0000 www.bea.gov.doc
USXPE	Export Price Deflator, chain-weighted prices	BEA website, file czw Table 9, line 13, code PMX0000 www.bea.gov.doc
CGDP	Real, seasonally adjusted	Datastream
CI	Quarterly CPI	Datastream
CIPD	Quarterly implicit price deflator	Datastream
CXPE	Quarterly implicit price deflator	Datastream
AGDP	Real, seasonally adjusted, chained GDP	DX database
AI	Quarterly headline CPI	DX database: TSS (RSRQ.UI90C90110001)
AUI	Quarterly Treasury Underlying CPI	DX database: TSS (RSRQ.UI90C92110001)
AIPD	Quarterly implicit price deflator for imports	DX database: TSS (SNAQ.AD####99MGS)
AXPE	Quarterly implicit price deflator for exports	DX dabase: TSS (SNAQ.AD####99XGS)

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