The Price of Low Inflation

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Any society that desires to lower the inflation rate may suffer output losses in the interim period. Even independent central banks have to contend with such output losses, given the inertia in inflation expectations and credibility constraints. Presenting estimates of the sacrifice ratio for India, this paper argues that the slope of the aggregate supply curve in India is flattening and this may raise the output costs of reining in inflation when the upturn of overall economic activity takes root. Accordingly, estimates of the sacrifice ratio are going to become more valuable than before. A low inflation regime may have continuous benefits which may be enough to offset the initial output losses. This is the relevant trade-off that society faces: whether the present generation is willing to suffer some hardships for the benefits that will accrue to future generations.

Introduction

Currently, inflation in many parts of the world is lower than in half a century. In crisis-affected Asia, economies continue to contend with disinflation and hesitant recovery. In the last bastions of growth in Asia - China and India - there is a clear slackening of momentum. Consumer price inflation which turned negative in China in 1998 and 1999 is expected to remain negative in 2002 (-0.4 per cent); in India, year-on-year changes in wholesale prices – the official measure of inflation – were trailing a little above 1 per cent in early 2002 with inflation in terms of manufactured product prices touching zero. Over the rest of 2002, inflation has remained weak, with average inflation rate sliding downwards from its level a year ago.

Recent evidence from industrial countries, particularly from the US in the 1970s, 1980s and early 1990s, suggests that disinflation has been a major cause of recession. The decade-long co-existence of near zero growth and falling prices in Japan has raised the spectre of deflation over the global economy. In industrial countries, policy interest rates have eased to levels which seem to indicate that monetary policy is approaching a zone of ineffectiveness. In the Euro area, sentiment has begun to flag and apprehensions of a moderation in the strength of the anticipated recovery are beginning to surface. There is the growing danger that even if economies continue to expand over the next year, growth may not be strong enough to prevent the onset of deflation in several countries including the world's three biggest economies (The Economist, 2002).

This paper undertakes an assessment of the lessons gathered from this close encounter with the threat of deflation. Although fears of deflation and its extreme manifestation – depression – receded in the second half of the twentieth century, the paper argues that it is unwise to disregard Keynes' pronouncement on the inexpediency of deflation being worse than the injustice of inflation (Keynes, 1932). In particular, the paper cautions against a generalised easing of the resistance to deflation which has occurred in the closing decades of the twentieth century as price stability (in terms of keeping inflation permanently low) gained primacy as an objective of monetary policy. The commitment to price stability has been reinforced by radical changes in the institutional apparatus of monetary policy through legislative empowerment and institutional reform. While the benefits of price stability are well known, it is important to recognise that there may be some sacrifice in the movement from high/medium inflation to a low inflation on a permanent basis. Just as inflation in the higher reaches has harmful effects on growth, monetary policy action moving inflation to lower levels inevitably involves a cost in terms of output foregone. The slope of the aggregate supply curve has a crucial bearing on the magnitude of the output cost of disinflation. The flattening out of the aggregate supply curve which has occurred in this unprecedented era of low inflation, coupled with the presence of nominal wage rigidities, has tended to enhance the output costs of lowering inflation. This is because economic agents are forced to adjust to slowing output, not through reduction in nominal wages which are particularly rigid during low inflation, but through cutbacks in employment and sacrifice of potential output. Therefore, a tightening of monetary policy, should it become necessary, would have stronger real effects than in the past.

Estimation of the sacrifice ratio – the loss of output (or employment) due to a lowering of trend inflation – is the main objective of this paper. In recent years, there has been a proliferation of empirical estimates of the sacrifice ratio, mainly following the seminal contribution of Okun (1978). Interest in the subject has spurred the employment of alternative methodologies which are dealt with in this paper. Furthermore, estimation of sacrifice ratios has generally been confined to industrial countries. For developing countries, and particularly India, estimation of sacrifice ratios is rarely attempted, the only known effort being the work reported in the Report on Currency and Finance (RBI, 2002a).

The rest of the paper is organised into four sections. The following section addresses definitional issues and select contributions to the literature on the sacrifice ratio with a view to shedding light on common grey areas in the interpretation of sacrifice ratio estimates. Section II sets out the methodology adopted in this paper and the analytical refinements necessary in the conventional approach to make the sacrifice ratio meaningful in the context of a country like India. Section III presents an analysis of the results. The final section contains concluding observations.

Section I

Sacrifice Ratio in the Literature

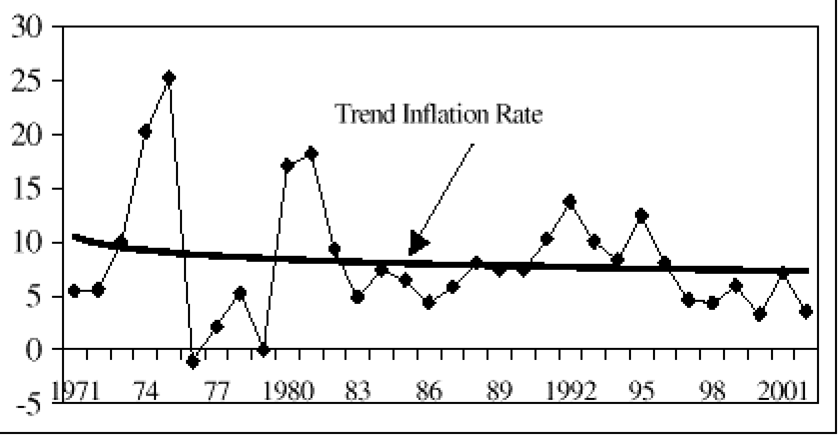
Since the 1950s, the debate on the trade-off between inflation and growth has arguably focused on higher inflation as the cost of higher growth and reduction in unemployment. Even the Friedman (1968)-Phelps (1969) critique on the trade-off in the long-run pointed to the inflation consequences of attempting to lower unemployment below its natural rate. In large measure this was the consequence of the Keynesian-type conduct of monetary policy and its institutional framework which imparted a bias towards inflation. Before the Great Depression, however, inflation and deflation were treated as roughly symmetric; the conventional wisdom of the 1920s, exemplified in Keynes early writings, warned that ‘the fact of falling prices injures entrepreneurs; consequently the fear of falling prices causes them to protect themselves by curtailing their operations’ (Keynes, 1923). After the Great Depression, a near consensus emerged that the effects of inflation and deflation were asymmetric and that it was deflation which had led to an unprecedented macroeconomic holocaust. The fear of deflation in the literature of the 1930s was stoked by the monetary policy ineffectiveness produced by the zero bound on the nominal interest rate – deflation can generate further increase in real interest rates and cause perverse wealth transfers – and the danger of financial fragility turning systemic due to the impairment of debtors' portfolios. The international effects of the threat of deflation were drawn out in terms of competitive deflationary policies, including exchange rate depreciation spirals (De Long, 1999).

Back to the present. Why has the disinflation since the late 1990s resurrected the spectre of deflation? This is mainly on account of a dissipation of the inflation bias associated with monetary policy as well as rising output gaps in the major economies. In significant measure, the easing of the inflation bias reflects the reforms that have occurred in the institutional framework of monetary policy. Following the seminal work of Kydland and Prescott (1977), the issue of time-inconsistency of monetary policy and proximate resolutions has proliferated in the literature, mainly focusing on the reputational constraints on monetary policy – the preference for rules over discretion (Friedman, 1977); appointing a conservative central banker with a relatively low (or no) time preference and a high preference for price stability (Rogoff, 1985) which provides a rationale for an independent central bank; contracts between the principal (government) and the agent (monetary authority) with the tenure of the contract linked to the performance of the agent in delivering low inflation (Walsh, 1995); constrained discretion through target and instrument rules (Taylor, 1993; Svennson, 1999); and reforms in monetary-fiscal coordination emphasising clarity of roles, responsibilities and objectives, open processes of policy formulation and public accountability (IMF, 1999). These developments have had a fundamental impact on the institutional infrastructure of monetary policy and improved the technical skill with which monetary policy is being conducted, even to the extent of eliminating the inflationary bias. Indeed, this has led to an extreme view that the probability of deflation is so small that worrying about it is a waste of time (Perry, 1998). On the other hand, it can be argued that the risks of deflation have increased significantly, in view of the widening output gaps coupled with the fact "many of today's central bankers, brought up to believe that their job is to fight inflation, seem to be underplaying the risk" (The Economist, 2002a).

The fear of disinflation turning into deflation is fuelled by the limits it imposes on the effectiveness of monetary policy. Too low inflation is not just a disincentive for production decisions; it can also delay consumer spending in anticipation of further fall in inflation and damp demand at a time when its revival could have been critical for triggering the upturn. Low inflation also imparts inflexibility to nominal wages and labour markets, causing higher unemployment and deepening the recession. Signals from financial prices turn ineffective and with the real burden of debt increasing, financial distress can threaten the health of the financial system. Systematic evidence turned in on the presence of downward rigidity in wages indicates that in a period of falling inflation the ability of firms to make adjustment in real wages is severely constrained and this leads to inefficiency in the allocation of resources and a rise in unemployment (Akerlof, Dickens and Perry, 1996). The ability of the monetary policy to counter deflation is also exacerbated by the long time lags – at least 18 months or so – in its taking effect on its final targets. This weakness is further compounded by the failures to produce consistent and reliable forecasts of inflation over a time horizon that correspond with the effective range of monetary policy (DeLong 1999); this view is, however, contradicted by others (Sims, 1999). Simulations for Japan to assess the impact of a zero interest rate floor show that the probability of a deflationary spiral which is nil for an inflation target of two per cent and above increases to 11 per cent when the inflation target is zero (IMF, 2002). This leads up to the diagnosis that good monetary policy should aim for a rate of change in the price level consistently on the high side of zero (DeLong, 1999) or an inflation target in the range of 1.5-4.0 per cent (Akerlof *et al* 2000). A more radical view is that strict inflation targeting is not the promised panacea as fixation with short-term price stability can lead to neglect of important signs of financial imbalances which can cause deeper recessions and even a future risk of deflation (The Economist, 2002b).

In the Indian context, the average inflation rate (on the basis of movements in the wholesale price index, WPI), has been around 8 per cent per annum over the last three decades. A decade-wise comparison reveals that the inflation rate has been quite stable: it averaged 9.0 per cent per annum during the 1970s, 8.0 per cent during the 1980s and was 8.1 per cent during the 1990s (Chart 1). Since the latter half of the 1990s, however, there is a perceptible lowering of the trend inflation, abstracting from the supply shocks. The current low inflation reflects both demand and supply factors; accordingly, periods of low inflation for a year or so may not break public's inflation expectations, given the role of adaptive expectations. Moreover, recent monetary policy statements have projected indicative targets for money supply based on an assumption of the inflation rate in the vicinity of 4-5 per cent. Against this background, the costs of a further permanent reduction in inflation rate to the levels prevailing in industrialised nations may need careful consideration. Furthermore, the edging down of trend inflation suggests a flattening of the aggregate supply curve in India as in many other countries bound by the downturn. The stance of monetary policy in India has been accommodative with policy interest rates at their three decade lows. There are indications that the inevitable tightening of monetary policy to stabilise the upturn will be postponed well in to 2003. Given the shape of the aggregate supply curve, the output effects of the imminent change in the stance of the monetary policy may warrant a close scrutiny.

Chart 1: Wholesale Price Index: Inflation Rate



Some Conceptual Issues

The sacrifice ratio encapsulates the output costs of lowering inflation. It has generally been employed in the recent literature in association with disinflationary settings of monetary policy – the US disinflation overseen by the Fed Chairman Paul Volcker in the early 1980s is viewed as the best episode for testing the validity and information content of the sacrifice ratio. The sacrifice ratio has been described as one of the subjects in macroeconomics that is at the heart of many practical policy discussions but, at the same time, rarely finds its way into serious academic publications (Mankiw, 1994). The size of the sacrifice ratio has been regarded as a guidepost in determining the speed of disinflation to be engineered by monetary policy action. The potential costs include lost output, higher unemployment, and related social ills. Only with accurate measures of both can monetary policy in the quest of price stability be assessed (Filardo, 1998). In this sense, the sacrifice ratio becomes relevant not merely in assessing policy effectiveness in a one-time transition from high inflation to low inflation but also in the context of the ongoing policy rule.

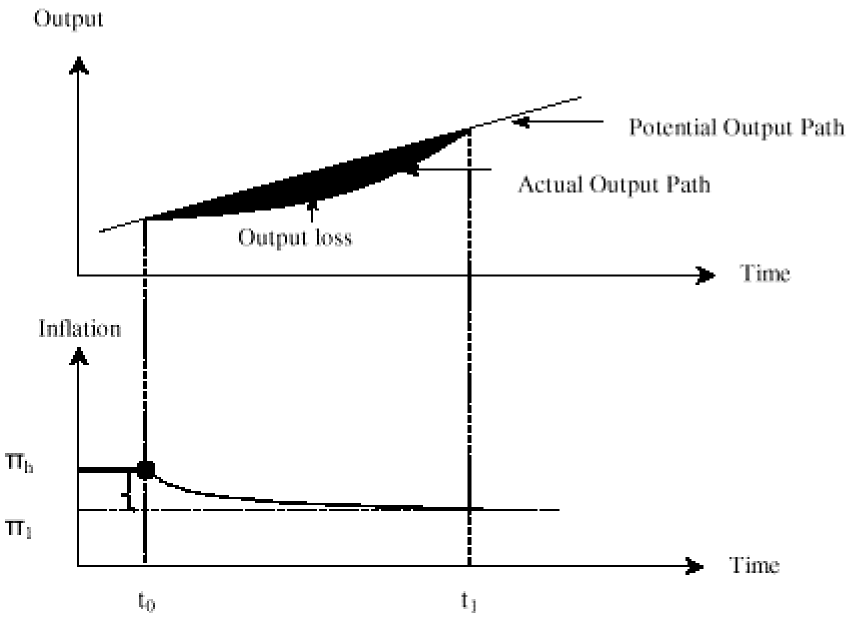
The concept of sacrifice ratio quantifies in a single number the extent of the output-inflation trade-off and, as such, distils complex economic phenomenon into a fairly simple, yet informative, cost measure (Filardo 1998). The sacrifice ratio is defined as the cumulative output losses that an economy must endure to reduce average inflation, on a permanent basis, by one percentage point. A few aspects of the definition are worth underscoring. First, the focus of sacrifice ratio estimations so far is on reducing inflation on a permanent basis as a deliberate strategy by the monetary authority; temporary reductions in inflation on account of other reasons, say, beneficial supply shocks are not the focus of the exercise. Secondly, the concept of sacrifice ratio is relevant for all values of inflation. Thus, although there are long-term gains from inflation reduction for an economy whose inflation rate is above its ‘threshold’, the process of reducing the inflation towards the threshold would nonetheless involve output sacrifice since inflation expectations will continue to be dominated heavily by the immediate past behaviour of inflation. Hence, the concept of sacrifice ratio is consistent with the concept of threshold inflation. Thirdly, the sacrifice ratio refers to cumulative output losses, *i.e.*, output losses occur over time and not in a single period and the output losses are measured as deviations from potential output. The output losses decay over time and are not recurrent for a given disinflation episode. Over time, the actual output approaches its potential level in a gradual manner. At the same time, the concept of sacrifice ratio is consistent with a long-run Phillips curve. Once the lower inflation target has been achieved, the economy gradually returns to its potential output path; in the long-run, the natural rate of unemployment (or potential output) can be associated with any average rate of inflation.

The nature of the output-inflation trade-off and the concept of sacrifice ratio can be easily illustrated in an expectations augmented Phillips curve:

$$\pi_t = \pi^e + a(y_t - y_t^*) \qquad (1)$$

where, π_t , π^e, and y_t^* denote actual inflation, expected inflation, potential output and actual output, respectively. Equation (1) indicates that, given the potential output level, any attempt to reduce inflation requires either a reduction in expectations or a reduction in current period output. Available evidence strongly suggests that inflation expectations exhibit inertia, being largely adaptive (Mankiw 2001). Consequently, a tighter monetary policy can reduce inflation only by depressing economic activity (a lower y_t). Over time, as inflation starts falling, inflation expectations also adjust downwards and the output approaches its potential level. In the long-run, therefore, monetary policy reduces inflation through a lowering of expectations and, hence, the Phillips curve is vertical in the long-run. The concept of sacrifice ratio is illustrated in Chart 2; the shaded area in the chart represents output losses associated with disinflation and the sacrifice ratio may be calculated as the shaded area divided by the size of disinflation.

Chart 2 : Sacrifice Ratio



Source **:** Filardo (1998).

One of the factors determining the size of the sacrifice ratio is the shape of the Phillips curve. If the Phillips curve is linear, then the slope of the Phillips curve is constant and, therefore, independent of the business cycle and the speed of disinflation (Filardo, *op cit*). In contrast, a non-linear Phillips curve would imply that the sacrifice ratio would depend upon the current stage of the business cycle and the aggressiveness of the disinflation. For instance, a concave Phillips curve would be flatter and, hence, the sacrifice ratio would be higher as compared with that computed from a linear one. The opposite will hold in the case of a convex Phillips curve. Theoretically, a concave Phillips curve would be consistent with an economy where firms have pricing power (*i.e.,* not purely competitive) and the convex curve with an economy subject to capacity constraints.

Sacrifice Ratio versus Benefits of Low Inflation

The concept of sacrifice ratio does not dispute the need for a low and stable inflation rate. Lower inflation is beneficial to growth as it may, over a period of time, offset the output losses suffered in the process of disinflation (Mayes and Chapple, 1994). Disinflation produces a net benefit and the output losses associated with a typical US disinflation are made up in 10-20 years, *i.e.,* output losses can be recovered in less than one generation (Neely and Waller, 1996). What the concept of sacrifice ratio stresses is that attempts to reduce the inflation rate will inevitably involve output losses in the interregnum or 'painless disinflation is impossible' (Buiter and Grafe, 2001). The question, therefore, is whether gain from reducing inflation to zero is worth the sacrifice in output and employment that would be required to achieve it (Feldstein, 1996). Some studies suggest that low to moderate inflation of about 10 per cent or less does not have any adverse impact on growth (Barro, 1995 and Fischer, 1993). Other studies suggest that there may be welfare losses even under low inflation and, therefore, favour price stability. These studies have, in particular, focused and quantified the distortions under an imperfect indexed tax system and distortions to money demand even when inflation is low. For the US, reduction in inflation by 2 percentage points could generate welfare benefits of 1 per cent of GDP per year forever (Feldstein, *op cit*). For the UK, the benefits from a same order of reduction in inflation are estimated at 0.2 per cent of GDP per annum forever (Bakshi *et al.* 1997). All studies of this genre, however, obtain their estimates of benefits under a number of *ad hoc* assumptions. Moreover, these distortions can be eliminated by changes in the tax code and, therefore, there is no strong case for a zero long-run inflation target (Mishkin and Schmidt-Hebbel, 2001).

Sacrifice Ratio: Estimates for Industrial Countries

The literature on the sacrifice ratio owes its origins to Okun (1978) who examined a family of Phillips curve models for the US to find that 'the average estimate of the cost of a 1 per cent reduction in the basic inflation rate is 10 per cent of a year's GNP, with a range of 6 per cent to 18 per cent'. Gordon and King (1982) refined Okun's methodology, using traditional and vector autoregression models within the assumption of a linear Phillips curve model, to obtain estimates of the sacrifice ratio in the range of 0 to 8 per cent.

These early efforts assumed a linear Phillips curve. This constrains the output-inflation trade-off to be the same during disinflation as during increases in trend inflation or temporary fluctuations in demand. Accordingly, Ball (1994) employed an atheoretical approach to estimating the sacrifice ratio by circumventing the assumption of linearity. The procedure consisted of identifying disinflation episodes and measuring the sacrifice ratio as the sum of output losses over the episode divided by the change in trend inflation. The estimate of the sacrifice ratio at 3.1 was in reasonable proximity of the earlier work. Ball's episodic approach has a reasonable following (Debelle 1996, Zhang 2001).

Intuitively, it is argued that Ball's method of focussing only on disinflationary episodes is acceptable only if there were a well-established asymmetry in the impact of monetary policy on output and prices (Cecchetti and Rich, 2001). Non-linear Phillips curve models were employed by Filardo (1998) to estimate sacrifice ratios which were sensitive to the initial strength of the economy, the intended timing of monetary policy action – whether preemptive or disinflationary - and the size of the potential inflation change. Accordingly, the output cost and the stance of policy have to be evaluated on a case-by-case basis. On the other hand, Gordon (1997) did not find any empirical evidence for a non-linear Phillips curve. Cecchetti and Rich (*op cit*) estimated a generalised Phillips curve relationship through structural vector autoregression models to get estimates of the sacrifice ratio for the US in the range of 1.3 to 10 per cent of a year's GDP for a permanent one percentage point reduction in inflation. The need for subjecting the estimates of the sacrifice ratio to robustness tests for statistical precision was emphasised, the underlying economic relationships being somewhat uncertain.

Andersen and Wascher (1999) represent an important contribution to the empirical literature on the sacrifice ratio in the context of the conduct of monetary policy in an environment of low inflation. Employing several methods of estimating sacrifice ratios, *i.e.,* slope of the aggregate supply curve, structural wage and price equations as well as actual developments in output and inflation, sacrifice ratios were found to have risen from 1.5 during 1965-85 to 2.5 during 1985-98 for 19 industrial countries. This suggested inflation inertia paradoxically stemming from enhanced credibility of monetary policy in conjunction with real and nominal wage-price rigidities. Consequently, lower rates of inflation have been accompanied by a flattening of aggregate supply curves. This leads to the key proposition that a tightening of monetary policy would henceforth have stronger effects on real output than in the past, with price adjustments occurring over a longer time span. At the same time, the cross-country evidence of sacrifice ratios being lower for countries that have flexible and competitive markets suggests that countries can undertake structural measures in their markets to offset the increasing sacrifice ratios.

Cross-country evidence corroborate these findings. The average sacrifice ratio for OECD countries, based on single equation estimates, was 3.2 with a range of 2-4, although outliers of 1.6 (Japan, Italy and the Netherlands) and 7 (Norway) were also observed. System estimates yielded a common sacrifice ratio of 3.7 for 15 out of the 17 sample countries (Turner and Seghezza, 1999). The key characteristics emerging from sacrifice ratio literature (summarised in Table 1) is that estimates of sacrifice ratios are highly sensitive to the estimation methodology.

Table 1 : Estimates of Sacrifice Ratios

Study	Methodology	Coverage and Study Period	Estimates of Sacrifice Ratio (%)
1	2	3	4
Okun (1978)	Aggregate supply curve	USA	6-18
Ball (1993)	Actual developments in output and inflation	19 industrial Countries; 1960-92.	Average 5.8 per cent for quarterly data and 3.1 per cent for annual data. For annual data, the range was 0.9 (France) – 10.1 (Germany).
Debelle (1996)	Actual developments in output and inflation	Australia, New Zealand and Canada	0.4-3.5
Filardo (1998)	Aggregate supply curve (non-linear) in a VAR framework	USA	5.7 for a linear specification; 5.0 for a weak economy and 2.1 for an overheated economy[@] for a non-linear specification.
Anderson and Wascher (1999)	Aggregate supply curve; structural wage and price equations; actual developments in output and inflation	19 OECD countries; 1965-98.	Average of 1.5 (1965-85) and 2.5 (1985-98).
Turner and	Aggregate supply	21 OECD coun-	Average of 3.2 with a

Seghezza (1999)	curve	tries; 1963-97.	range of 1.6 (Japan, Italy and the Netherlands) – 7.0 (Norway).
Hutchison and Walsh (1998)	Aggregate supply curve	New Zealand; 1983:2-1994:2	4.5-6.0 for the entire sample.@@
Zhang (2001)	Actual developments in output and inflation	G-7; 1960:1-1999:4	1.4 (without any long-lived effects); 2.5 (with long-lived effects)
Cecchetti and Rich (2001)	Structural VAR models	US; 1959:1-1997:4	1-10
RBI (2002)	Aggregate supply curve	India; 1971-2000.	2.0
Current Study	Aggregate supply curve: alternative specifications	India; 1971-2001	0.3-4.7

Note:
@ : Weak (overheated) economy defined as one with output 0.9 per cent or more below (above) the potential.
@@ : 2.7-3.4 for the first sub-sample (1983:2-1989:4, the period before central bank independence); and, 14.2-18.9 (albeit not significant) for the second sub-sample (1990:1-1994:2, the post-reform period).

The sacrifice ratio is influenced by a number of factors like credibility/independence of the central bank, the speed of disinflation, the initial level of inflation, persistence/hysteresis of output path, the approach to disinflation (deliberate versus opportunistic) and openness of the economy.

Central Bank Independence

An issue debated animatedly in the context of central bank independence (CBI) in an inflation targeting framework is the impact of credibility of the central bank on the sacrifice ratio, *i.e.*, whether increased CBI lowers the sacrifice ratio. In other words, is there a credibility bonus associated with independent central banks? *A priori* the public is expected to more readily believe the anti-inflationary pronouncements of an independent central bank and this, in turn, should lower output losses. The empirical results, however, do not support the theoretical prediction of a credibility bonus (Debelle and Fischer, 1994; Fischer, 1994; and, Posen 1998).

Debelle (1996) compared the experience of New Zealand (where the central bank was provided legal independence) with that of a control set (Australia and Canada, *i.e.*, countries with a similar inflation history but with the central banks not having explicit independence at the time of the study). The results suggest that costs of disinflation were not lower in New Zealand as compared with the control set; moreover, the sacrifice ratio increased from 0.3 in the 1980-83 disinflation episode (period before central bank reform) to 2.6 in the 1989-93 disinflation which followed central bank reform (Table 2). "It is less clear that the adoption of an inflation target was in fact successful in reducing the costs of disinflation by reducing the inflation expectations of financial markets and the public – and this despite the fact that my senior colleagues and I devoted an enormous amount of effort to convincing the public of the seriousness of our effort" (Brash, 2002). Even the Deutsche Bundesbank and the Swiss National Bank, whose pursuit of low inflation over the last two decades has presumably given them maximum credibility, have been able to achieve inflation reductions only at high costs in lost output and employment (Bernanake and Mishkin, 1997). A comprehensive evaluation of the experience of 17 OECD countries did not yield any evidence that the costs of disinflation were lower in countries with independent central banks (Posen, 1998). On the contrary, the coefficient on CBI is found to be positive and highly significant. Moreover, the effect is also large: "going from a dependent central bank like the Bank of Belgium (central bank independence score of 0.19) to one like the Bundesbank (0.66) adds around 1.25 point-years of unemployment to the sacrifice ratio of an average disinflation" (Posen 1998). The available evidence, therefore, suggests that independent central banks, on an average, pay a higher output price per percentage point of inflation reduction.

Table 2 : Central Bank Independence and Sacrifice Ratios

Country	Disinflation Episode	Sacrifice Ratio
Australia	1974:2-1978:1	0.4
	1982:1-1984:1	1.6
	1989:2-1992:1	1.7
New Zealand	1980:2-1983:4	0.3
	1985:4-1993:1	1.2
	1989:4-1993:1	2.6
Canada	1974:2-1976:4	0.4
	1981:2-1985:2	2.0
	1990:1-1993:2	3.5

Source: Debelle (1996).

The observed increase in sacrifice ratio in the context of independent central banks may, however, be reflecting other offsetting phenomena. For instance, in the context of New Zealand, the CBI and structural reforms were initiated around the same time as is most likely to be the case in many other countries. Accordingly, the stance of fiscal policy and the loss in employment due to such concomitant reforms in public sector and privatisation could have been among the factors leading to an increase in the sacrifice ratio in New Zealand (Debelle, *op cit).* Another reason for the observed positive correlation between CBI and higher sacrifice ratios could be the possibility that the wage setting behaviour may be endogenous to the CBI. In a model with competitive firms, a monopoly labour union and a central bank, Hutchison and Walsh (1998) show that the degree of wage indexation chosen by workers' unions is inversely proportional to the weight put by the central bank on inflation in its loss function. Since increased CBI implies greater weight on inflation stabilisation by the central bank, it may lead to relatively longer nominal wage contracts, *i.e.,* a decline in the degree of indexation in the economy. This would increase the nominal rigidities in the economy and which, as empirical studies show, would be reflected in a higher sacrifice ratio. Hutchison and Walsh find empirical support for this proposition: while the estimated inflation-output trade-off for New Zealand increased between the pre-reform and post-reform period, the increase in the trade-off was not discrete at the time of the Act providing independence; rather, the trade-off (*i.e.,* the sacrifice ratio) remained virtually unchanged for more than a year following the implementation of the Act and then rose steadily over a two year period.

As for the critical issue of disentangling the effect of CBI *per se* and the increased nominal rigidities induced by the CBI, Hutchison and Walsh find that greater CBI reduces the sacrifice ratio but the reduction is more than offset on account of higher nominal rigidity. On the other hand, Posen (*op. cit.*) does not find any statistically significant relationship between CBI and nominal wage rigidity in the cross-section study covering 17 OECD countries. Thus, central bank independence increases the costs of disinflation irrespective of wage-setting arrangements (Posen, *op cit*). It needs to be recognised, however, that accurate measures of CBI are difficult to obtain. The existing measures of CBI based on codings of legal provisions are believed to be imperfect and unreliable; the usual approach of relying on different measures of CBI is not helpful as "any combination of unreliable measures, no matter how elaborate, is still an unreliable measure itself" (Mangano, 1998). If this measurement error in CBI is not accounted for by the econometric methodology employed, then anomalous results can be obtained; with measurement errors in CBI, covariance structure analysis rather than OLS should be used (Brumm 2000).

In contrast to these studies, Chortareas *et al* (2002) examine a related aspect of central bank institutional design, *viz.,* monetary policy transparency and its influence on sacrifice ratio in a cross-section study covering 44 countries (comprising the OECD as well as the non-OECD countries). Focussing on two types of transparency, *viz.,* transparency in forecasting and transparency in decisions, for the sample as a whole, the sacrifice ratio with unemployment as the indicator of economic activity is lower for countries whose central banks are more transparent in their forecasts. The evidence, though, is weaker for non-OECD countries. When output is used as an indicator for activity, the result is not robust even for the OECD countries.

Speed of Disinflation

An important influence on the sacrifice ratio is the speed of disinflation. One view stresses that gradualism is preferable so that wages and prices, which exhibit an inertial behaviour, can adjust smoothly to the tighter monetary policy (Taylor 1983). The opposing view holds that gradualism raises the probability of future reversals and may have no favourable impact on inflationary expectations; therefore, a cold turkey approach is less costly because expectations adjust sharply (Sargent 1983). A number of empirical studies support the latter view, *i.e.,* gradual disinflation leads to a higher sacrifice ratio compared to a cold turkey approach although it turns out that the results are sensitive to the shape of the Phillips curve (Ball, 1993; Filardo, 1998; Zhang, 2001). For G-7 countries, the sacrifice ratio was 3.8 if the reduction in inflation rate was 0.25 percentage points per quarter; the ratio would be almost one-half (1.8) if the speed of disinflation were to be increased to 0.5 percentage points per quarter (Zhang 2001). Similarly, estimates by Filardo for the US suggest that, with the economy at its potential output, the sacrifice ratio would be 9.8 if the objective of disinflation were to reduce inflation by one percentage point; the (average) sacrifice ratio would be lower at 7.0 if the disinflation objective were a reduction of two percentage points in inflation (Table 3). The preference for cold turkey reflected in these estimates is related to the Phillips curve being concave. If the Phillips curve turns out to be convex, gradualism could be the optimal approach.

Table 3 : Average Sacrifice Ratio and Speed of Disinflation

	Initial Strength of the Economy		
Size of Disinflation	**0.45 per cent below trend**	**At trend**	**0.45 per cent above trend**
1 per cent	7.0	9.8	12.6
2 per cent	5.6	7.0	8.1

Source: Filardo (1998).

Initial Inflation Rate

The sacrifice ratio may be inversely related to the initial inflation level. Higher initial inflation is expected to be associated with a lower sacrifice ratio due to lower nominal rigidities. For 19 industrial countries for which inflation rates had fallen from 8 per cent (1965-85) to 3.5 per cent (1985-98), an increase of almost 75 per cent in the sacrifice ratios from 1.5 to 2.5 was observed (Anderson and Wascher, 1999). The average sacrifice ratio for G-7 countries increased from 1.3-2.0 (1960-90) to 5.9 during the 1990s (Zhang, 2001) and, *a la* Ball (1994), the relationship between initial inflation and sacrifice ratio was found to be negative and statistically significant. Thus, if initial inflation decreases from 5 per cent to 4 per cent, the sacrifice ratio increases by 0.59 per cent; if initial inflation falls from 20 per cent to 19 per cent, the increase in sacrifice ratio is almost one-fourth (0.14 per cent). A negative relationship between inflation and slope of the Phillips curve is also documented by Dupasquier and Ricketts (1998) for Canada with the slope more than doubling between episodes of low/moderate and high inflation; the results are, however, sensitive to the measure of potential output.

Hysteresis

The sacrifice ratio may also depend upon the degree of hysteresis or persistent effects of monetary policy on potential output. Since the disinflation process forces the economy to deviate from its potential output path, the deviation itself may have an adverse effect on the economy's potential output path. The 'persistence' hypothesis holds that that the economy may take a fairly long time to return to its potential output path; in the extreme case, disinflation may have a permanent effect on output and the economy may display 'hysteresis', *i.e.*, the potential output path may itself undergo a parallel downward shift (Blanchard and Summers, 1986). The method of Ball (1994) which assumes that output returns to potential after a trough over some quarters may thus underestimate the sacrifice ratio. Studies that estimate sacrifice ratios from the slope of the Phillips curve are less susceptible to this criticism although all type of methodologies may be subject to the hysteresis critique. Zhang (2001), who makes a correction for the possible persistence in output, estimated that the average sacrifice ratio for G-7 countries to be about 2.5, almost double that of 1.4 by the conventional method.

Deliberate Disinflation versus Opportunistic Disinflation

Once the transitional costs of disinflation are accepted, an important issue would be how to minimise such losses. A strand in the literature stresses an opportunistic approach to disinflation as opposed to a deliberate disinflation. The opportunistic approach waits for recessions and favourable supply shocks to lower inflation and hence, would take a longer time. The opportunistic approach is less costly only if credibility is exogenous (Bomfim and Rudebusch 1997); however, credibility is more likely to be endogenous to the performance of the policy maker. Once this endogeneity is taken in to account, deliberate disinflation is found to be preferable.

Openness

Another factor that can influence the sacrifice ratio is the openness of the economy. In a more open economy, a tighter monetary policy will tend to appreciate the exchange rate and this will lower imported inflation, thereby reinforcing the reduction in inflation. Thus, for a given monetary policy shift, the fall in inflation will be larger for a more open economy (Romer 1991); in other words, sacrifice ratios should be lower for more open economies. Using imports/GDP ratio as a measure of trade openness, Ball (1994) did not find any support for this proposition. Loungani, Razin and Yuen (2002), however, argue that sacrifice ratio should be higher for more open economies; the preliminary empirical evidence, using an index of openness of current and capital account, supports their proposition.

Section II
Methodology and Data

In the literature, three methodologies have generally been used to calculate the sacrifice ratio. One approach focuses on historical episodes of disinflation and calculates the sacrifice ratio as the output losses during that particular episode (Ball 1994; Zhang 2001). This approach has the advantage of not constraining the sacrifice ratio to be the same for all disinflation episodes. On the other hand, it focuses only on episodes of disinflation rather than both inflation and disinflation episodes and thereby ignores correlations at other points in the business cycle. The approach also does not provide for any controls for supply shocks. Moreover, it makes an *ad hoc* assumption that output returns to its potential within a few quarters (for instance, four quarters in Ball, 1994) of inflation recording a trough; this assumption may underestimate the sacrifice ratio if the output path indicates persistence and takes a longer time to return to the potential path. The second approach derives estimates of sacrifice ratios from a vector autoregression framework (Cecchetti and Rich, 2001); however, sacrifice ratios obtained from structural VARs are highly sensitive to the size of the model and the identification restrictions. The estimated effects of shocks can vary substantially as a result of slight changes in identifying restrictions. The degree of imprecision of the estimates of sacrifice ratios is found to increase with the complexity of the model used.

The third approach estimates sacrifice ratios from the slope of the aggregate supply curve, *i.e.*, the Phillips curve. This method avoids *ad hoc* assumptions of output returning to trend in some specified quarters; treats inflation and disinflation episodes symmetrically; and can control for supply shocks. Moreover, the data requirements are less intensive than a VAR-based framework and the problem of sensitivity to identifying restrictions is also avoided.

This paper estimates the sacrifice ratio using the Phillips curve approach from reduced-form specifications of the aggregate supply curve. Within this framework, alternative specifications based on different underlying theoretical models are attempted. The simple expectations augmented Phillips Curve (Equation 1) can be reformulated to include supply shocks and adaptive expectations to obtain the 'triangle model of inflation' (Gordon, 1997). The phrase 'triangle' stresses that inflation depends on a tripartite set of basic determinants: inertia (in inflation), demand and supply shocks, *i.e.*,

$$\pi_t = a(L)\ \pi_{t-1} + b(L)Dt + c(L)\ zt$$

where, π_t Dt, and zt denote inflation, a measure of excess demand (unemployment gap or output gap) and supply shocks (foodgrains prices or imported inflation), respectively and L is the lag operator. Excess demand is proxied by output gap (deviation of actual output from its trend). In view of substantial evidence on a possible unit root in inflation, the equation can be modified to take inflation in first difference form, following Turner and Seghezza (1999). Accordingly, the equation used for estimation is as follows:

$$\triangle\pi_t = a(L)\ \triangle\pi_{t-1} + b^*ygap_{t-1} + c(L)^*\ \triangle\pi s$$

where, $\triangle$ is the difference operator, ygap is the output gap and πs is inflation due to supply shocks. The specification implies no long-run trade-off between the level of output and the level of inflation: a temporary increase in the output gap will lead to a permanent increase in inflation. The sacrifice ratio is computed as [(1-coefficients of lagged inflation)/coefficient of output gap].

The inflation-output trade-off, as stressed in the "new classical" literature, can also arise from misperceptions of agents in regard to relative prices. Based on a Lucas framework, the inflation-output trade-off can be obtained from the decomposition of changes in nominal income and its impact on inflation and real output. Following Hutchison and Walsh (1998), the aggregate short-run supply curve can be formulated as:

$$\pi_t = \lambda dx_t + \beta E_{t-1}\ \pi_t + \alpha(ygap)_{t-1} + \mu z_t$$

where, dx is growth rate of nominal output and other variables are as defined before. The coefficient λ measures the proportion of the change in nominal aggregate demand that affects inflation in the short-run, given expected inflation, the state of the business cycle and supply shocks. The lagged output gap allows for the delayed effects of business cycle conditions on inflation. Since λ measures the change in prices, the term (1-λ), therefore, captures the effect of the change in nominal demand on real output. The sacrifice ratio is then calculated as [(1-λ)/λ]. In the absence of explicit survey data on inflationary expectations, expected inflation can be proxied by lagged inflation (Andersen and Wascher 1999); this appears to be a reasonable assumption in the context of the observations of Mankiw (2001). Equation (3) can, therefore, be re-specified as:

$$\pi_t = \lambda dx_t + \beta\pi_{t-1} + \alpha(ygap)_{t-1} + \mu z_t$$

The definition of sacrifice ratio used by Hutchison and Walsh is, however, not the only possible alternative since lagged inflation as well as the lagged output gap in the equation could also be sources of nominal rigidity. In that case, the sacrifice ratio could be calculated as α/λ or β/α. To remove these ambiguities, Anderson and Wascher suggest a constrained version of (4) by making use of the nominal income identity which imposes the homogeneity restriction $\alpha = \lambda$ (Equation 4a). In order to remove further ambiguity, they impose an additional restriction i.e., $\beta = (1-\lambda)$ for both 4 and 4a. The sacrifice ratio is then calculated, as before, as $[(1-\lambda)/\lambda]$.

$$\pi_t = \lambda(dx_t + (ygap_{t-1}) + \beta\pi_{t-1} + \mu z_t$$

Finally, aggregate supply curve can also be derived directly from the explicit nominal income identity (Chand 1997). By definition, nominal income growth (dx) is the sum of the inflation rate (π_t) and the growth rate of real output (dq) as:

$$dx_t = \pi_t + dq_t$$

Let dq* be growth rate of potential output. Adding this term and re-arranging, we get

$$dx_t = \pi_t - \pi_{t-1} + \pi_{t-1} + dq_t + dq^* - dq^*,$$

or,

$$(\pi_t - \pi_{t-1}) + (dq_t - dq^*) = dx_t - (\pi_{t-1} + dq^*) \qquad (5)$$

The first term on the left hand side of equation (5) is the acceleration in the inflation rate while the second term captures deviations of real output growth from its potential growth path. The term within parentheses on the right side can be interpreted as the potential rate of growth valued at preceding period's rate of inflation. The right side of (5), therefore, denotes excess income gap (EIG), *i.e.*, excess of nominal income growth over the potential rate of growth valued at preceding period's rate of inflation. While (5) is an identity, economic theory can be used to postulate acceleration in inflation and the deviation of output - the left hand side terms of (5) - as dependent upon EIG to form behavioural equations:

$$\pi_t - \pi_{t-1} = a[dx_t - (\pi_{t-1} + dq^*)] \qquad (6)$$
$$(dq_t - dq^*) = (1-a)[dx_t - (\pi_{t-1} + dq^*)] \qquad (7)$$

The estimated coefficients 'a' and (1-a) will depend upon the structure and behavioural characteristics of the economy and should add up to unity to satisfy the nominal income accounting constraint. While the estimates of sacrifice ratio require estimation of 6 alone, we estimate (7) as well to see whether the adding up requirement is satisfied. As in previous cases, the equations 6 and 7 can be augmented to include supply shocks. The sacrifice ratio can be calculated as [a/(1-a)].

Data

Equations (2), (3), (4), (4a), (6) and (7) are estimated over the period 1970-71 to 2000-01 using annual data. Inflation is measured from the average wholesale price index. To test for robustness, an alternative indicator of inflation, *viz.*, the GDP deflator is also used for Equations 3-5. On the other hand, for Equations (6) and (7), given the explicit derivation from national income accounting and the adding up constraint, only the GDP deflator is used. Output gap is defined as the deviation of actual real output from potential real output (as percent of potential output) where potential (trend) real output is the Hodrick-Prescott filtered real output. The supply shocks are captured by foodgrains prices in the WPI or imported inflation, the latter proxied by unit import values. A weighted measure of the import price inflation, *i.e.*, unit import prices weighted by the openness (imports as a ratio of GDP) is also tried. The inflation rate of these supply shocks enter the specification either in first differences or as relative to the overall inflation. The oil price shocks are controlled through the use of dummies. In view of significant structural changes in the Indian economy since the 1990s, all the equations are also estimated over the second half of the sample period (1984-85 onwards) to check the robustness of the estimates.

Section III

Estimates of Sacrifice Ratio for India

The definition of the sacrifice ratio assumes that inflation is not mean reverting, *i.e.*, non-stationary while output gaps are stationary. Examination of the stationarity properties of the variables employed becomes necessary for determining the appropriate model specification. Unit root properties are tested using the Augmented Dickey-Fuller (ADF) tests as well as the Phillips-Perron (PP) test. For the ADF tests, lag selection using both Akaike Information Criteria (AIC) and Schwartz-Bayesian Information Criteria (BIC) criteria was undertaken. By the AIC criteria, all variables, excepting inflation and nominal GDP growth, turned out to be stationary. As regards inflation, its first difference was stationary. By the BIC lag selection criteria, all variables entering the regressions were found to be stationary. Similarly, by PP tests too, all variables indicate stationarity. In brief, the various tests indicate that all series are I(0), except for some ambiguity on WPI inflation (Table 4). This ambiguity is addressed by testing alternative specifications with either inflation or its first difference as the dependent variable.

The estimates based on alternative supply equation specifications are set out in Tables 5-9. The estimated equations have a satisfactory fit and explain a substantial amount of variation in the dependant variable (with R-bar*2 usually in the range of 70-80 per cent and even more which can be considered satisfactory in view of the dependant variable being in first difference). The Jarque-Bera (JB) normality tests on residuals indicate that all residuals have normal disturbances. Based on the Ramsay RESET test of errors in specification, almost all equations appear to be specified correctly.

The results of the basic specification (equation 2) using WPI inflation rate (in first differences) as the dependant variable are in Table 5. The lagged inflation variables are significant indicating the presence of inflation inertia. The demand variable, proxied by output gap, is also significant and estimates suggest that, other things remaining constant, real output one per cent above potential output in the current year pushes up the inflation rate by around 60 basis points in the next year. Supply shocks emanating from variations in foodgrains prices are an important determinant of the inflationary process and are significant in all specifications. On the other hand, imported inflation is not significant in all specifications. Based on these specifications, the estimates of sacrifice ratio lie in the range of 1.9 to 2.7 for the full sample period. The estimates are fairly close to that of 2.0 in RBI (2002).

With GDP deflator as the measure of inflation, the estimates of sacrifice ratio are somewhat higher at 2.6-3.5 (Table 6). As another robustness check, we restrict the sample size to the period 1984-85 onwards; in view of the sample size and lower degrees of freedom, the results should be interpreted as only indicative. The sacrifice ratio is estimated at 2.0 when the WPI inflation is used and 4.7 when the GDP deflator is used for the truncated sample period. This can be seen as evidence of the flattening of supply curve.

The results for WPI inflation under specifications 4, 4a and 4b are in Table 7. Based on unconstrained specification (i.e., Equation 4), the estimated sacrifice ratio is 1.9 (but not significant) for the full sample period when computed solely from the coefficient of the change in nominal GDP; however, as indicated earlier, alternative measures of sacrifice ratio are possible from this specification with widely varying results, including estimates as low as 0.5. The results are broadly the same when GDP deflator is used as a measure of inflation (Table 8). As in the case of the specification 2, the sacrifice ratio estimates based on the period 1984-2000 turn out to be higher; for the constrained specification, the estimated sacrifice ratio is 1.1 (with WPI inflation) and 1.0 (with GDP deflator).

Finally, the results of the specification 6 derived from explicit nominal income accounting and using the GDP deflator inflation are presented in table 9. The table provides estimates of the responsiveness of the inflation acceleration term as well as the cyclical output growth to the excess income gap. The coefficients sum to unity, satisfying the adding up requirement with minor shortfalls as in Chand (1997). The sacrifice ratio is estimated to be 0.7 for the full sample.

Robustness Tests

One area of concern in the literature is the stability of the Phillips curve specifications from which the estimates of sacrifice ratios have been obtained. In the context of the US, a number of studies have documented instability in the coefficients of the estimated Phillips curve and, in particular, in the coefficients on lagged inflation. Although statistically significant, this instability does not seem to be quantitatively large, particularly in its effects on 12-month ahead forecasts (Stock and Watson, 1999). In view of such concerns, this paper undertakes and reports a variety of stability diagnostics and their probability values (Tables 5-9). A well-known test of parameter stability is the Chow's F-test; for this purpose, the paper breaks the sample period into two equal halves. The p-values in all tables are above 0.05 suggesting that the null hypothesis of parameter stability cannot be rejected. A weakness of the Chow test is that it requires definite knowledge of the break point, which is often difficult to know. This can be overcome by CUSUM and CUSUM sum of squares (CUSUMSQ) techniques to detect gradual changes based on recursive residuals. While the usual approach to these tests is to examine their plots, a compact alternative is regression diagnostics based on the maximum values of the CUSUMs relative to their bounds or mean and the associated p-values. For example, if a p-value is less than 0.05, the CUSUM crosses the bound. As may be seen from Tables 5-9, almost all specifications (27 out of 32) have fairly high p-values supportive of parameter stability. Thus, based both on the CHOW tests and the CUSUM and CUSUMSQ tests, it can be concluded that the specifications are generally stable.

Another area of concern is that most studies have ignored the issue of statistical significance of the estimated sacrifice ratios. The only study that undertook such an exercise found the sacrifice ratio estimates to be imprecise, with the degree of imprecision increasing with the complexity of the VAR model used and forcing the authors to conclude that the estimates provide a very unreliable guide for assessing the output costs of a disinflation policy (Cecchetti and Rich, *op cit*). We, therefore, report the significance of the estimated sacrifice ratio (Tables 5-9). In contrast to Cecchetti and Rich, the sacrifice ratio estimates in this paper are generally highly significant statistically although it may be noted that the methodologies of the two papers are not comparable.

In sum, the estimates of the sacrifice ratio for India depend upon the theory underlying the specification, the measure of inflation used and the period of estimation. For most of the specifications, the estimates of sacrifice ratio based on the GDP deflator are higher than those derived from WPI inflation. The estimates are highly significant statistically and the wide range of estimates appears to be consistent with the existing studies in the literature. As noted earlier in the section, the unit root tests were somewhat ambiguous about the stationarity of the WPI inflation rate; amongst the various specifications, perhaps those using the first-difference of inflation as the dependent variable could be considered as more robust. Furthermore, as noted above, within the Lucas supply curve, alternative estimates of sacrifice ratio are possible.

Section IV
Concluding Observations

This paper has argued that any society that desires to lower the inflation rate may suffer output losses in the interim period. These output losses may arise on account of nominal and real rigidities in the system or on account of misperceptions of economic agents in distinguishing relative from aggregate price changes. A review of the literature reveals that even independent central banks may have to undergo such output losses, given the inertia in inflation expectations and doubts about the credibility. This paper presents estimates of sacrifice ratio for India which turn out to be in a wide range based on alternative short-run aggregate supply specifications, a feature consistent with empirical studies on the subject.

The estimated sacrifice ratio warrants a number of caveats in its analytical interpretation. The output losses, following the definition noted earlier, refer to cumulative output losses spread over a number of years associated with decline in trend inflation and not episodic fluctuations. The relevant rate of inflation used in the computation, as pointed out earlier, is the average annual rate of inflation. Thus, computation of output losses with respect to the prevailing point-to-point inflation rate is inconsistent with the underlying framework. For instance, during 2001-02, the average rate of inflation was 3.6 per cent as compared with 1.6 per cent based on a point-to-point inflation rate; the use of the latter measure obviously exaggerates the output losses. It is also crucial to understand the dynamics and sources of inflation; for instance, the low WPI inflation during 2001-02 was significantly enabled by the decline in international crude oil prices and the base effect of the sharp increase during 2000-01. The methodology adopted in this paper controls for such supply shocks and a distinction needs to be made between low inflation driven by positive supply shocks and that due to a tight monetary policy. As stressed in RBI (2002b), current liquidity and monetary conditions suggest clearly that the recent deceleration in inflation cannot be attributed to a tight monetary policy; rather, it reflects favourable supply shocks and global disinflationary trends. In brief, the estimates of sacrifice ratio cannot be applied mechanically to the existing inflation rate and it is necessary to take into account the sources of inflation, the stance of monetary policy and the role of imported inflation. It needs to be recognised that the slope of the aggregate supply curve is flattening and this may raise the output costs of reining in inflation when the upturn of overall economic activity takes root. Accordingly, estimates of the sacrifice ratio are going to become more valuable than before.

The concept of sacrifice ratio argues neither the case for high inflation nor for low inflation and is in no way inconsistent with the views favouring a lower inflation rate in the economy. What the concept of the sacrifice ratio stresses is that there could inevitably be output losses in the process of transition from high inflation to low inflation, when such a low level of inflation is due to tight monetary policies rather than favourable supply shocks. As against these transitional one-time (though spread over a number of periods) output losses associated with a deliberate disinflation, a low inflation regime may have continuous benefits and which may be enough to offset the initial output losses. Perhaps, this is the more relevant trade-off that society faces: whether the present generation is willing to suffer some hardships for the benefits that will accrue to future generations.

Table 4 : Unit Root Tests *(t-values)*

Variable	**Augmented Dickey-Fuller Test**		**Phillips-Perron (PP) test**
	AIC Lag Selection Criteria	BIC Lag Selection Criteria	
INFLX	-2.50 [7]	-4.94* [3]	-3.89
INFGDP	-4.16* [3]	-4.61* [0]	-4.47
WPIFG	-4.67* [0]	-4.67* [0]	-4.49
DGDPN	-1.37 [7]	-3.97* [0]	-3.55
DINFLX	-4.11* [5]	-6.22* [3]	-6.59
DINFGDP	-4.24* [5]	-4.24* [5]	-8.32
DWPIFG	-5.95* [2]	-5.95* [2]	-7.66
UVMRELG	-3.89* [0]	-3.89* [0]	-3.94
DUVMGB	-7.19* [2]	-5.96 * [0]	-7.20
WPIFGRELG	-4.91* [2]	-4.91* [2]	-6.44
YGAP	-4.45* [3]	-4.45* [3]	-4.37

Note : For ADF tests, critical t-values are: 3.58 (1%), 2.93 (5%) and 2.60 (10%).
For PP tests, window size of 4 was used and critical value is 3.41 (5%).

Figures in square brackets indicate the number of lags used.
*, ** and *** indicate significant 1%, 5% and 10% level.

INFLX	=	WPI Inflation Rate
INFGDP	=	GDP Deflator
WPIFG	=	Foodgrains Inflation Rate
DGDPN	=	Growth in Nominal Income
DINFLX	=	First-difference of WPI Inflation Rate
DINFGDP	=	First-difference of GDP Deflator
DWPIFG	=	First-difference of Foodgrains Inflation
UVMRELG	=	Import Unit Values less WPI Inflation
DUVMGB	=	First-difference of change in import-weighted unit import values
WPIFGRELG	=	Foodgrains Inflation less WPI Inflation
YGAP	=	Output Gap (Actual output less Potential Output)

Table 5 : Estimates using WPI Inflation

	1976-2001	**1976-2001**	**1973-2001**	**1985-2001**
$\triangle\pi_{t-1}$			-0.28 (-2.9)	-0.28 (-2.4)
$\triangle\pi_{t-2}$	-0.22 (-1.8)	-0.43 (-5.5)		
$\triangle\pi_{t-4}$	-0.27 (-2.0)	-0.23 (-2.2)		
YGAP(-1)	0.56 (2.2)	0.87 (3.2)	0.47 (1.9)	0.63 (3.7)
DWPIFG	0.28 (4.0)	0.47 (8.5)	0.46 (8.0)	0.19 (6.0)
DUVMGB		0.55 (1.5)*	1.9 (3.9)	
DUM76	-13.2 (-5.0)			
DUM78		-13.3 (-5.4)		
DUM8081			7.29 (5.6)	
DUM83			-6.49 (-6.7)	
DUM88				3.71 (12.9)
DUM94		6.3 (6.9)		

DUM95				4.20 (6.5)
DUM97				-4.24 (-8.5)
Durbin's h/h-alt	-0.3	-1.0	-0.1	-0.7
R*2	78.4	81.0	80.4	76.1
Sacrifice ratio				
(1-a(L))/b	2.7	1.9	2.7	2.0
t-statistic	2.1	2.8	1.8	3.7
p-value	0.04	0.006	0.08	0.00
Diagnostic tests		P-values		
CSMAX	1.0	0.76	0.88	1.00
CSQMAX	0.01	0.71	0.34	0.28
CHOW	0.99	0.48	0.21	0.62
JB	0.59	0.57	0.55	0.94
RESET2	0.26	0.49	0.35	0.93

Figures in brackets are t-statistics.
*: not significant.
Note:
The table presents estimates for the specification (2)
$\triangle \pi_t = a(L) \triangle \pi_{t-1} + b*ygap_{t-1} + c(L)* \triangle \pi s$ where,
$\triangle\pi_t$ = First-difference of inflation rate,
For variables list, see Table 4.
Diagnostic tests CUSUM, CUSUMSQ and CHOW test for stability of parameters. CUSUM diagnostics are based on the maximum values of the CUSUMs relative to their bounds or mean; they provide a compact alternative to the plot; for example, if a P-value is less than 0.05, the CUSUM crosses a bound. For CHOW test, the sample is split in to two equal halves.
JB test (Jarque-Bera normality test) is a joint LM test of the residuals' skewness and normality.
RESET2 is Ramsey's RESET test, where the residuals are regressed on the original RHS variables and powers of the fitted values to check for missing quadratic terms and interactions for the RHS variables.
For diagnostic tests, p-values have been indicated; p-values higher than 0.05 suggest that the null hypotheses of parameter stability, misspecification and normal disturbances can not be rejected at the 5 per cent probability level.

Table 6 : Estimates using GDP Deflator Inflation
(*Specification As in Table 5)*

	1973-2001	1973-2001	1973-2001	1985-2001

$\triangle\pi_{t-1}$	-0.53 (-7.7)	-0.42 (-6.2)	-0.42 (-5.7)	-0.41 (-2.1)
YGAP(-1)	0.44 (2.4)	0.53 (2.5)	0.54 (2.7)	0.30 (2.2)
DWPIFG	0.37 (6.8)			
WPIFGRELG		0.61 (5.9)	0.61 (6.1)	0.27 (4.1)
DUVMGB	1.05 (3.3)			
UVMGRELG		0.006 (0.2)*		
DUM74	3.77 (4.0)			
DUM8081	4.46 (6.4)	5.69 (8.4)	5.70 (8.8)	
DUM00	-2.18 (-3.7)			-3.12 (-7.2)
Durbin's h/h-alt	-1.2	1.3	1.2	-0.7
R*2	85.4	80.1	80.8	58.5
Sacrifice ratio				
(1-a(L))/b	3.5	2.7	2.6	4.7
t-statistic	2.2	2.3	2.5	2.4
p-value	0.03	0.02	0.01	0.01
Diagnostic tests		**P-VALUES**		
CSMAX	0.96	0.97	1.00	0.57
CSQMAX	1.00	0.80	0.94	0.36
CHOW	0.09	0.15	0.14	1.00
JB	0.52	0.43	0.41	0.76
RESET2	0.07	0.02	0.03	0.22

See notes to Table 5.

Table 7 : Estimates with WPI Inflation

	1971-2001	**1971-2001**	**1971-2001**	**1971-2001**	**1985-2001**	**1985-2001**	**1985-2001**	**1985-2001**
Specification	4	CE	4a	CE	4	CE	4a	CE
Constant	-2.94 (-1.3)	-7.26 (-10.2)	-5.32 (-2.0)	-7.11 (-8.5)	-2.17 (-1.3)	-4.79 (-7.0)	-2.05 (-1.2)	-5.18 (-7.0)

dx_t	0.34				0.29			
	(2.1)				(2.7)			
		0.67				0.44		
		(6.9)				(4.9)		
dx_t +			0.55				0.30	
$Ygap_{t-1}$			(2.9)				(2.7)	
				0.68				0.48
				(7.8)				(5.1)
π_{t-1}	0.23		0.27		0.45		0.38	
	(1.9)		(2.2)		(3.3)		(2.7)	
YGAP(-1)	0.71	1.11			0.47	0.63		
	(2.4)	(5.2)			(2.6)	(3.6)		
WPIFG	0.46	0.35	0.40	0.35	0.25	0.20	0.29	0.24
	(3.9)	(2.9)	(3.9)	(3.7)	(4.5)	(5.7)	(4.1)	(5.0)
DUM74	3.99	3.15						
	(2.6)	(2.2)						
DUM80			11.4	11.7				
			(10.7)	(13.2)				
DUM8081	9.08	8.79						
	(12.5)	(8.7)						
DUM95					4.25	4.44		
					(5.3)	(4.9)		
DUM97					-3.63	-3.69	-4.08	-4.17
					(-9.0)	(-7.9)	(-9.6)	(-9.2)
DUM01	3.84	4.73	4.90	5.33	3.88	4.74	4.04	5.09
	(4.8)	(7.3)	(4.8)	(7.2)	(5.2)	(13.8)	(6.0)	(19.4)
DW/Durb-in's h/h-alt	0.5	1.7	-0.06	1.9	0.3	2.0	-1.1	2.6
R*2	77.8	83.9	72.3	81.5	76.8	73.2	66.2	61.6
Sacrifice ratio								
$(1-\lambda)/\lambda$	1.9	0.5	0.8	0.5	2.4	1.3	2.3	1.1
t-statistic	1.4	2.3	1.3	2.4	1.9	2.8	1.9	2.6
p-value	0.16	0.02	0.18	0.02	0.05	0.01	0.06	0.01
β/λ	0.7		0.5		1.6		1.3	
t-statistic	1.4		2.2		2.1		2.0	
p-value	0.15		0.03		0.04		0.05	
β/α	0.3				1.0			

t-statistic	2.9				2.8			
p-value	0.003				0.006			
Diagnostic tests				P-VALUES				
CSMAX	0.51	0.86	0.40	0.41	0.20	1.00	0.81	1.00
CSQMAX	0.16	0.43	0.05	0.09	0.04	0.24	0.11	0.10
CHOW	0.77	0.52	0.73	0.65	0.60	0.93	1.00	0.99
JB	0.44	0.45	0.53	0.55	0.98	0.65	0.77	0.73
RESET2	0.02	0.51	0.02	0.17	0.76	0.80	0.85	0.23

Note:
* = not significant; CE = constrained estimates
The table presents estimates for the specifications (4,4a)

$$\pi_t = \lambda dx_t + \beta\pi_{t-1} + \alpha(ygap)_{t-1} + \mu z_t \qquad (4),$$

$$\pi_t = \lambda(dx_t + (ygap_{\ t-1}) + \beta\pi_{t-1} + \mu z_t \qquad (4a),$$

dx = Growth rate of nominal GDP; other variables as before. Both 4 and 4a are also estimated with the constraint $\lambda = (1 - \beta)$ and these estimates are shown under the column CE.
Also, see notes to Table 5.

Table 8 : Estimates using GDP deflator
(*Specification As in Table 7)*

	1972-2001	1972-2001	1972-2001	1972-2001	1985-2001	1985-2001	1985-2001	1985-2001
Specification	4	CE	4a	CE	4	CE	4a	CE
Constant	0.10 (0.1)	-3.84 (-7.8)	0.61 (0.3)	-4.08 (-9.2)	-1.30 (-0.8)	-2.96 (-4.4)	-1.24 (-0.8)	-3.23 (-6.0)
dxt	0.43 (4.1)				0.40 (3.8)			
		0.65 (5.7)				0.46 (4.5)		
$dx_t + ygap_{t-1}$			0.45 (3.9)				0.43 (4.6)	
				0.75 (7.4)				0.50 (6.9)
π_{r-1}	0.24 (1.8)		0.17 (2.0)		0.43 (3.2)		0.39 (5.4)	
YGAP(-1)	0.60 (2.9)	1.02 (7.9)			0.50 (3.0)	0.60 (5.0)		

WPIFGRELG	0.35 (5.5)	0.27 (4.0)	0.27 (5.0)	0.18 (2.6)	0.22 (3.5)	0.21 (4.0)	0.21 (3.2)	0.19 (3.2)
UVMGRELG			0.04 (2.4)	0.02 (1.1)*				
DUM79			-3.08 (-5.0)	-2.52 (-3.7)				
DUM80			5.61 (6.5)	6.88 (9.5)				
DUM8081	4.43 (5.5)	4.22 (4.0)						
DUM94	3.71 (5.8)	4.07 (6.2)			2.99 (4.6)	3.11 (5.3)	2.70 (7.0)	2.67 (6.8)
DW/Dur-bin's h/h-alt	-0.4	2.0	0.1	2.1	-0.7	2.3	-0.7	2.4
R*2	81.3	87.4	82.2	87.4	66.5	60.7	68.8	62.3

Table 8 : Estimates using GDP deflator (Contd..)
(*Specification As in Table6)*

	1972-2001	**1972-2001**	**1972-2001**	**1972-2001**	**1985-2001**	**1985-2001**	**1985-2001**	**1985-2001**
Sacrifice ratio								
$(1-\lambda)/\lambda$	1.3	0.5	1.2	0.3	1.5	1.2	1.3	1.0
t-statistic	2.3	2.0	2.1	1.9	2.3	2.4	2.7	3.4
p-value	0.02	0.04	0.03	0.07	0.02	0.02	0.01	0.00
β/λ	0.6		0.4		1.0		0.9	
t-statistic	1.6		1.9		2.1		3.8	
p-value	0.11		0.06		0.03		0.00	
β/α	0.4				0.9			
t-statistic	2.3				4.5			
p-value	0.02				0.00			
Diagnostic tests				**(**P-VALUES)				
CSMAX	0.69		0.87		1.00	0.73	1.00	0.86
CSQMAX	0.03		0.49		0.89	0.69	0.90	0.80
CHOW	0.91		0.59		0.57	0.52	0.62	0.39
JB	0.65		0.69		0.99	0.80	0.94	0.89
RESET2	0.33		0.75		0.60	0.29	0.63	0.33

See notes to Table 5.

Table 9 : Estimates using GDP Deflator
(Using Specification 6and 7)

	1972-2001	1972-2001	1985-2001	1985-2001
	Dependent Variable			
	$(\pi_t - \pi_{t-1})$	$(dq_t - dq^*)$	$(\pi_t - \pi_{t-1})$	$(dq_t - dq^*)$
CONSTANT	-0.92	0.50	0.01	-0.42
	(-2.4)	(1.4)	(0.001)	(-1.4)
$dx_+ - (p_{t-1} + dq^*)$	0.58	0.35	0.63	0.32
	(4.3)	(2.7)	(3.8)	(2.1)
WPIFGRELG	0.30	-0.29	0.17	-0.16
	(3.7)	(-3.7)	(1.8)	(-1.8)
DUM72	4.15	-3.69		
	(8.8)	(-8.1)		
DUM77	6.68	-5.92		
	(6.0)	(-5.5)		
DUM80	10.3	-8.99		
	(17.4)	(-15.4)		
DUM89			-4.04	3.81
			(-5.1)	(5.2)
DUM97			-2.43	2.31
			(-6.0)	(6.1)
DW	2.3	2.3	2.2	2.1
R*2	84.4	53.0	57.1	55.3
Sacrifice ratio				
(1-a)/a	0.7		0.6	
t-statistic	1.8		1.4	
p-value	0.07		0.16	
Diagnostic tests				
CSMAX	0.14		0.03	
CSQMAX	0.002		1.00	
CHOW	0.95		0.17	
JB	0.72		0.78	
RESET2	0.01		0.01	

Note
The table presents estimates for the specifications:

$(\pi_t - \pi_{t-1}) = c + a[dx_t - (\pi_{t-1} + dq^*)] + b(WPIFGRELG)$ (6)

$dqt - dq^* = c + (1-a)[dxt - (\pi_{t-1} dq^*)] - b(WPIFGRELG)$ (7)

dqt = growth rate of actual real output;
dq* = growth rate of potential real output; other variables as before.
Also, See notes to Table 5.

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