1 Theory

1.1 The Friedman hypothesis

Friedman (1977) outlined an informal argument regarding the real effects of inflation. Friedman's point comes in two parts: In the first leg of the Friedman hypothesis, an increase in inflation may induce an erratic policy response by the monetary authority and therefore lead to more uncertainty about the future rate of inflation.

In the second leg of the Friedman hypothesis, the increasing uncertainty about inflation distorts the effectiveness of the price mechanism in allocating resources efficiently, thus leading to negative output effects. Friedman's argument represents one of the few existing arguments on the rationalisation of the welfare effects of inflation. The informal ideas advanced by Friedman were subsequently presented with the use of elegant theoretical models.

Demetriades (1988) shows that in the presence of asymmetric information between the policymaker and the public and asymmetric stabilisation policies (i.e., greater policy response to negative than to positive shocks), a positive correlation between inflation and its variance applies. However, the direction of causality between inflation and inflation uncertainty is not addressed by Demetriades (1988).

Ball (1992) focuses on the first leg of the Friedman hypothesis. He analyses an asymmetric information game where the public faces uncertainty regarding the type of policymaker in office. Two types of policymakers are considered: a weak type that is unwilling to disinflate and a tough type that bears the cost of disinflation. The policymakers alternate stochastically in office. When current inflation is high, the public faces increasing uncertainty about future inflation, as it is not known which policymaker will be in office in the next period and consequently what the response to the high inflation rate will be (i.e., what the money supply growth will be). Such an uncertainty does not arise in the presence of a low inflation rate.

It is also possible that more inflation will lead to a lower level of inflation uncertainty. The argument advanced by Pourgerami and Maskus (1987) is that in the presence of rising inflation agents may invest more resources in forecasting inflation, thus reducing uncertainty about inflation. A formal analysis of this effect is presented in Ungar and Zilberfarb (1993).

The second part of Friedman's hypothesis predicts that increased inflation uncertainty would increase the observed rates of unanticipated inflation and hence will be associated with the costs of unanticipated inflation.[1] Such costs arise from the effect of inflation uncertainty on both the intertemporal and intratemporal allocation of resources.

Nominal uncertainty affects interest rates (the inflation premium) and hence all decisions relating to the intertemporal allocation of resources. In a world of nominal rigidities, inflation uncertainty also affects the real cost of the factors of production and the relative prices of final goods, and therefore, the intratemporal allocation of resources.

The effect of inflation uncertainty on output has been addressed formally by Dotsey and Sarte (2000). In a cash-in-advance model that allows for precautionary savings and risk aversion, they show that more inflation uncertainty can have a positive output growth effect.

According to the authors' argument, an increase in the variability of monetary growth, and therefore inflation, makes the return to money balances more uncertain and leads to a fall in the demand for real money balances and consumption. Hence, agents increase precautionary savings, and the pool of funds available to finance investment increases. This result is analogous to the literature's finding that fiscal policy uncertainty is conducive to growth by encouraging precautionary savings.

[1] This part draws on Huizinga (1993).

1.2 The impact of inflation uncertainty on inflation

The opposite direction of causality to that examined by Friedman in the inflation/inflation uncertainty relationship has also been addressed by the theoretical literature. This literature examines the impact of a change in inflation uncertainty on the average rate of inflation.

Cukierman and Meltzer (1986) employ a Barro-Gordon model, where agents face uncertainty about the rate of monetary growth and therefore, inflation.[2] In the presence of this uncertainty, the policymaker applies an expansionary monetary policy in order to surprise the agents and enjoy output gains.

This argument implies a positive causal effect from inflation uncertainty to inflation and has been dubbed by Grier and Perry (1998) the Cukierman-Meltzer hypothesis.

Holland (1995) has supplied a different argument based on the stabilisation motive of the monetary authority, the so-called 'stabilising Fed hypothesis'.

He claims that, as inflation uncertainty rises due to increasing inflation, the monetary authority responds by contracting money supply growth, in order to eliminate inflation uncertainty and the associated negative welfare effects. Hence, Holland's argument supports the opposite sign in the causal relationship, i.e., a negative causal effect of inflation uncertainty on inflation.

The theoretical ambiguity surrounding this causal relationship necessitates an empirical investigation of the sign of the effect.

[2] Ball (1992) and Cukierman and Meltzer (1986) assume inflation uncertainty is caused by uncertainty about the rate of money growth. In contrast, Holland (1993a) assumes that inflation uncertainty arises from the uncertain effect of money growth on the rate of inflation. He provides US evidence in support of his prediction.

1.3 The effects of output uncertainty on inflation and output growth

The effect of output growth uncertainty on inflation has been examined by Devereux (1989). Devereux (1989) extends the Barro-Gordon model by introducing wage indexation endogenously. He considers the impact of an exogenous increase in real (output) uncertainty on the degree of wage indexation and the optimal inflation rate delivered by the policymaker. He shows that more real uncertainty reduces the optimal amount of wage indexation and induces the policymaker to engineer more inflation surprises in order to obtain favorable real effects.

The prediction of Devereux's theory regarding the positive causal effect of output uncertainty on the inflation rate is borne out also in a recent paper by Cukierman and Gerlach (2003). They show that, even if policymakers target the potential rate of unemployment, inflation bias a la Barro and Gordon obtains in the presence of more uncertainty about the level of output. This result hinges on the assumption that central banks are more sensitive to employment below than above its normal level.

From a theoretical point of view, it is possible for more output uncertainty to reduce inflation. Higher output uncertainty reduces inflation uncertainty[3] and, therefore, the rate of inflation, according to the Cukierman-Meltzer hypothesis. Hence, the testable implication of these two effects combined is that more output growth uncertainty should lead to a lower rate of inflation.

[3] The negative association between inflation and output variability is known in the literature as the Taylor effect.

The effect of output uncertainty on output growth has received considerable attention in the theoretical macroeconomic literature. However, there is no consensus among macroeconomists on the direction of this effect.

Macroeconomic theory offers three possible scenarios regarding the impact of output variability on output growth. First, there is the possibility of independence between output variability and growth. In other words, the determinants of the two variables are different from each other.

For example, according to some business cycle models, output fluctuations around the natural rate are due to price misperceptions in response to monetary shocks. On the other hand, changes in the growth rate of output arise from real factors such as technology (Friedman, 1968).

The scenario of a negative association between output variability and average growth goes back to Keynes (1936), who argued that entrepreneurs, when estimating the return on their investment, take into consideration the fluctuations in economic activity. The larger the output fluctuations, the higher the perceived riskiness of investment projects and, hence, the lower the demand for investment and output growth.

A similar result is obtained by the literature on sunspot equilibria (Woodford, 1990). According to Bernanke (1983) and Pindyck (1991), the negative relationship between output volatility and growth arises from investment irreversibilities at the firm level. Ramey and Ramey (1991) show that in the presence of commitment to technology in advance, higher output volatility can lead to suboptimal ex post output levels by firms (due to uncertainty-induced planning errors) and hence, lower mean output and growth.

Finally, the positive impact of output variability on growth can be justified by the following two economic theories: First, more income variability (uncertainty) would lead to a higher savings rate (Sandmo, 1970) for precautionary reasons, and hence, according to Solow's (1956) neoclassical growth theory, a higher equilibrium rate of economic growth. This argument has been advanced by Mirman (1971).

The alternative explanation is due to Black (1987) and is based on the hypothesis that investments in riskier technologies will be pursued only if the expected return on these investments (average rate of output growth) is large enough to compensate for the extra risk. As real investment takes time to materialize, such an effect would be more likely to obtain in empirical studies utilizing low-frequency data. All the theories presented in section 2 are summarised in the following Table.

Testable hypotheses-Theories	Sign of the effect
1) **Inflation Granger-causes inflation uncertainty.**	
Friedman (1977), Ball (1992)	+
Pourgerami-Maskus (1987), Ungar-Zilberfarb (1993)	-
2) **Inflation uncertainty Granger-causes output growth**.	
Friedman (1977)	-
Dotsey and Sarte (2000)	+
3) **Inflation uncertainty Granger-causes inflation.**	
Cukierman-Meltzer (1986)	+
Holland (1995)	-
4) Output uncertainty Granger-causes inflation.	
Devereux (1989), Cukierman-Gerlach (2003)	+
Taylor effect and Cukierman-Meltzer (1986)	-
5) Output uncertainty Granger-causes output growth.	
Business cycle models	zero
Keynes (1936), Bernanke (1983), Woodford (1990), Pindyck (1991), Ramey-Ramey (1991)	-
Mirman (1971), Black (1987)	+

1.4 The relationship between inflation and output growth

Mean inflation and output growth are interrelated. Whereas the traditional short-run Phillips curve implies that an increase in output above its natural level would result in inflationary pressures, another strand of the literature asks how a rise in the output growth can affect the rate of inflation. Briault (1995) argues that there is a positive relationship between growth and inflation, at least over the short run, with the direction of causation running from higher growth (at least in relation to productive potential) to higher inflation. For simplicity, in what follows we will refer to this positive effect as the 'Phillips curve' effect.

Useful summaries of the macroeconomic literature on the inflation-growth relationship can be found in Briault (1995), Bruno and Easterly (1996), Haslag (1997), Temple (2000) and Klump (2003). Economists in the structuralist tradition have sometimes argued that moderate inflation rates are potentially beneficial for growth.

Overall, it would now be hard to find much support for the view that inflation can raise growth (Temple, 2000). The theoretical studies generally find that a rise in inflation either results in slower growth or has no impact on the growth rate. Some models have produced insignificant long-run inflation-output growth effects (for example, Dotsey and Sarte, 2000), while at least an equally diverse group of models have produced significant and negative inflation-growth effects.

In particular, Gylfason and Herbertsson (2001) present a simple model of the interaction of inflation and output growth. Their model indicates that, although a wide variety of outcomes is possible, inflation via saving, financial development and the government budget deficit tends to deter growth in the long run.

Klump (2003) points out that inflation can lead to a reduction of the aggregate elasticity of factor substitution. He suggests several microeconomic justifications for such an influence, which in turn can help to explain the negative link between inflation and growth.

Gillman and Kejak (2005) show that a broad array of endogenous growth models, with different usage of physical and human capital and different exchange technologies, can all generate significant negative effects of inflation on growth.

1.5 Output uncertainty and inflation uncertainty

There is a consensus among macro theorists to express the ultimate objectives of the monetary authority in terms of deviations of inflation and output from their target levels. Nevertheless, one may argue that Central Banks are also interested in minimising the variability of inflation and output around their target levels (see for example, Cecchetti and Krause, 2001).

Taylor (1979) shows that a trade off between the two variabilities exists, it is consistent with rational expectations and sticky prices, and implies no long-run trade off between the levels of inflation and unemployment (the Taylor effect).

Fuhrer (1997) employs a structural model of optimal monetary policy chosen by minimising a loss function that depends on the variances of inflation and output (expressed as deviations from their targets) and derives the variance trade off. Cecchetti and Ehrmann (1999) show that aggregate supply shocks create a trade-off between nominal and real variability. Policymakers, depending on their preferences, i.e., their degree of aversion towards inflation and output variability, can choose a point along this trade-off. Clarida et al. (1999) also derive a short-run inflation-output variability trade off that represents an efficient frontier.

In contrast to the Taylor effect, Logue and Sweeney (1981) claim that nominal uncertainty can have a positive impact on real uncertainty. A higher inflation rate makes it more difficult for producers to distinguish between nominal and real demand shifts, thus leading to more relative price variability. Assuming this relative price variability leads to more producer uncertainty, the upshot will be more variability in real investment and economic activity. Finally, in Devereux's (1989) model, inflation uncertainty and the mean rate of inflation are positively correlated because the variability of real shocks is the predominant cause of nominal uncertainty. In particular, more variable shocks cause a reduction in the degree of indexation and increase the benefits to the government of creating surprise inflation.

1.6 The impact of output growth and inflation on the uncertainty about inflation and output growth

The causal effects of inflation and output growth changes on nominal and real uncertainty can be examined according to the theories outlined in sections 2.1-2.3 above.

Friedman (1977) argues that during high-inflation periods it is more likely that the monetary authority will instigate an erratic policy response, and therefore, uncertainty about the future inflation rate increases (the so-called Friedman hypothesis).

The informal argument presented by Friedman (1977) was subsequently formalised by Ball (1992), who analyses an asymmetric information game where the public faces uncertainty about the type of the policymaker in office. Policymakers alternate stochastically in office and can be of two types: a weak type that is unwilling to disinflate and a tough type that is prepared to bear the costs of disinflation. In periods of high inflation, uncertainty about the type of policymaker that will be in office in the next period increases uncertainty about the rate of money growth and hence the future inflation rate. In periods of low inflation, such uncertainty does not arise.

Opposite to the Friedman-Ball hypothesis, Ungar and Zilberfarb (1993) show formally that as inflation increases, agents may invest more resources in forecasting inflation, thus curtailing nominal uncertainty. In summary, theoretically speaking, the effect of inflation on its uncertainty is ambiguous.

Similarly, the effect of inflation on output uncertainty is ambiguous. In particular, a rising inflation rate would be expected to have a negative impact on real uncertainty via a combination of the Friedman and Taylor effects. However, this impact could be positive: higher inflation reduces its uncertainty (Ungar and Zilberfarb effect) and increases output uncertainty (Taylor hypothesis).

The sign of the effect of output growth on macroeconomic uncertainty is also ambiguous. Consider first the effect of higher real growth on nominal uncertainty. A higher growth rate will raise inflation according to the 'Phillips curve' effect and, therefore, inflation uncertainty, as predicted by the Friedman hypothesis. Hence, the impact of output growth on nominal uncertainty is positive.

On the other hand, the increased inflation rate arising from more real growth might reduce rather than increase inflation uncertainty (Ungar and Zilberfarb hypothesis). In this case the effect will be negative.

Two more theories predict a negative effect. First, Brunner (1993) claims that a decline in economic activity generates uncertainty about the response of the monetary authority and hence the average rate of inflation. Second, if more output growth leads to less inflation due to the inflation-stabilizing actions of the monetary authority, inflation uncertainty also falls (Friedman hypothesis).

Finally, consider now the effect of growth on real uncertainty. An increase in real growth, given that the 'Phillips curve' and Friedman effects hold, pushes nominal uncertainty upward and output uncertainty downward (Taylor effect). However, if the impact of inflation on its uncertainty is negative, the opposite conclusion applies.