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On the Relationship between Inflation and Nominal Government Liabilities

The Role of the Independence of the Central Bank

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1. Introduction

It is widely recognized that discretionary monetary policies suffer from an inflation bias (Kydland and Prescott (1977), Barro and Gordon (1983a, 1983b)). In the absence of rules, monetary authorities are tempted to produce surprise inflation in order to boost economic activity or to reduce the real value of nominal government liabilities like debt and money. Rational economic agents will recognize this temptation and adjust their expectations accordingly. Hence, inflation will be higher than in the case of rules without having any positive effects upon output or the costs of debt servicing.

As the size of the inflation bias depends on the stock of nominal liabilities, an increase in the latter is predicted to lead to higher average inflation.[1] Indeed, nominal government liabilities make surprise inflation beneficial, as their real rate of return varies with the rate of inflation. The scatter diagram in Figure 1 illustrates the point. The figure plots the rate of inflation against the total of public debt and M1 in terms of GNP for a number of OECD countries. As the predicted inflation effect holds for the average rate of inflation, we have averaged both variables over the period 1970-'89.[2] The figure clearly suggests a positive relationship between inflation and nominal liabilities.

Despite the sound theoretical basis of the Barro-Gordon model of inflation, its explanation of the impact of nominal government liabilities upon average inflation is only partial. The reason is that it assumes that the independence of the central bank is a constant and does not depend on the stock of nominal public debt and money. The large diversity in monetary institutions across countries however suggests otherwise.

[1] There are several other factors that give rise to an inflation bias, the most well-known of which is the output gap or the level of underemployment. Next, uncertainty about policy effects on money growth is relevant as it may lead to a conservative use of the policy instrument, thereby reducing the inflation bias (Swank (1994)). Furthermore, nominal wealth inequality will be a factor to the extent that it renders price inflation an effective instrument for redistributing wealth to the median voter (Beetsma and Van der Ploeg (1996)). In addition, the central banker's inflation preferences play a role. Inflation-averse central bankers will be able to achieve low inflation by keeping down inflationary expectations. The attractiveness of inflationary policies depends on how distortionary are alternative methods of government finance (Barro and Gordon (1983a)).

[2] The data used in Figure 1 are taken from Grilli *et al.* (1991) and from various issues of the International Financial Statistics. The sample countries in Figure 1 are indicated as follows:
AS = Austria, AU = Australia, BE = Belgium, CA = Canada, DE = Denmark, FR = France, GE = Germany, GR = Greece, IR = Ireland, IT = Italy, JA = Japan, NE = Netherlands, NZ = New Zealand, PO = Portugal, SP = Spain, SW = Switzerland, UK = United Kingdom, US = United States.

Figure 1 Inflation and nominal government liabilities

In addition, also over time, changes occur in the way monetary policies are organised (Cukierman (1994)). These changes may very well be the response to changes in the stock of nominal government liabilities. In order to combat the inflation bias that corresponds with high public debt, countries have the choice between reducing the debt or appointing more conservative central bankers. Presumably, the latter type of policy change involves smaller political costs. Therefore, it is unnatural to think that changes in the stock of nominal government liabilities will not affect the organisation of monetary policies, at least on a long-term basis.

This paper explores whether society can improve its inflation performance by using the independence of its central banker (CB) as an instrument to combat the inflation bias from nominal debt and money. The paper models a stochastic world, in which the degree of CB independence that maximizes the welfare of households is a function of the variability of output and the average rate of inflation. It thus reflects a trade-off between credibility and flexibility, as in the analyses of Rogoff (1985) and Alesina and Grilli (1991). Furthermore, the optimal degree of CB independence is a function of nominal government liabilities which this paper will show to have a U-shaped form, reflecting two counteracting effects. First, nominal liabilities reduce the central banker's credibility, making it attractive for society to invest in more conservative monetary policies. Second, they increase the effectiveness of monetary stabilization policies, making it attractive for society to invest in flexibility, or a less inflation-averse central banker. Since the former effect dominates for high levels of nominal assets and the latter for low levels of nominal liabilities, the degree of CB independence curve has the claimed U-shape.

In a model with endogenous CB preferences, nominal liabilities influence the rate of inflation both directly and indirectly, by changing the optimal degree of independence. For low levels of debt and money, both effects work in the same direction. An increase in liabilities increases inflation directly, by boosting inflationary expectations, and indirectly, as society will be induced to appoint a less inflation-averse central banker to exploit the stabilization properties of nominal liabilities. For high liability levels, the indirect effect works in the opposite direction. Then, an increase in nominal liabilities leads society to appoint a more independent central banker to combat the inflationary effects of the increase in liabilities. Combined, average inflation turns out to be a hump-shaped function of nominal liabilities.

Our extension of the theory of inflation thus predicts that highly indebted countries combat their inflation bias by appointing more independent central bankers. The same effect does not arise for low asset levels, since debt and money also render stabilization policies more effective. This demonstrates that the assumption of stochastic output is crucial for obtaining the hump-shaped relationship. As Poterba and Rotemberg (1990) demonstrate, the relationship between inflation and nominal liabilities can take a variety of forms, even when the degree of CB independence is exogenous, depending on the form of the banker's utility function. However, the slope of the inflation-nominal liabilities curve cannot be negative when CB preferences are exogenous, whereas negativity of this slope is a robust result when CB preferences are endogenous.

Empirically, our model outperforms the Barro-Gordon model in which CB preferences are independent of the stock of nominal government liabilities. On the one hand, it supports the prediction of the latter model that inflation is a positive function of nominal liabilities for low liability levels. On the other hand, it outperforms the Barro-Gordon model which predicts too much inflation for those countries with a high level of public debt. Consequently, our model better explains why countries like Greece and Portugal have relatively high inflation rates and why a highly indebted country like Belgium has a relatively low rate of inflation.

The rest of the paper is structured as follows. Section 2 develops a model of household portfolio behaviour. Section 3 integrates this model with a stochastic Barro-Gordon model of monetary policies. Section 4 analyses optimal monetary policies and section 5 examines the role of nominal government liabilities. Section 6 provides some cross-country evidence for the propositions derived. Section 7 concludes.

2. The Portfolio Model

In order to make explicit the welfare costs and benefits of inflationary policies, we adopt a portfolio model to describe the behaviour of households. As we will see, in this model the welfare of households depends negatively upon output variability and anticipated inflation. As such, the model is able to demonstrate the trade-off between flexibility and credibility, as the first implies low output variability and the second is reflected in a low average rate of inflation.[3]

We consider an economy that consists of an infinite number of households. The representative household derives utility from the consumption of goods and liquidity services. The latter are provided by money which we denote in terms of the consumption good. As we will see below, the consumption of goods is stochastic, and we represent the household's preferences by a mean-variance utility function:

$$u = E(c) - \frac{1}{2}\beta Var(c) - \exp(-\alpha m) \qquad \alpha,\ \beta > 0 \qquad \textbf{(1)}$$

In (1), u denotes utility and c measures the consumption of goods. *E(.)* and *Var(.)* are the expectations and variance operator respectively. β measures the households' risk aversion, α measures the liquidity services per unit of money, and m stands for real money holdings. The third term at the RHS of (1) measures the value of liquidity services. These liquidity services are increasing in real money holdings, but at a diminishing rate, *i.e.* $\partial u/\partial m > 0$, $\partial^2 u/(\partial m)^2 < 0$.[4]

The problem of the household is to maximize (1) by allocating a given amount of wealth over four different assets, namely capital, indexed government bonds, nominal government bonds and money. The model is entirely static, so that the consumption of

[3] The derivation of a welfare function from the micro-founded behaviour of economic agents may be a very important feature of the analysis. Calvo and Leiderman (1992) show that deriving the welfare costs of inflation from an explicit money demand produces conditions that are different from those obtained for ad hoc welfare functions. Fischer and Summers (1989) give some examples of how the functional form of the welfare function can affect the effects of inflation policies.

[4] See Feenstra (1986) for the equivalence between using real money balances as an argument of the utility function and entering money into liquidity costs which appear in the budget constraint.

the household coincides with its after-tax portfolio returns.[5] The latter are defined as the sum of the returns on capital, the interest on nominal and indexed government debt, and the returns on money, net of taxes:

$$c = \left[q y + q_N (i - \tilde{p}) + q_I r - q_m \tilde{p} \right] w - t \tag{2}$$

Here, q, q_N, q_I and q_m stand for the portfolio shares of equity, nominal government bonds, indexed government bonds, and money. w is the household's portfolio wealth. Through the budget constraint, $q + q_N + q_I + q_m = 1$. The return on capital equals the output per unit of capital, y, as capital is the only production factor and firms cannot increase their capital stock through investment. Next, i stands for the nominal interest rate on nominal bonds and r for the real interest rate on indexed bonds. p is the price of goods in terms of money and, using tildes to represent rates of change, $\tilde{p}$ refers to the rate of inflation. t refers to the level of taxation. Output, inflation and taxes are all stochastic, whereas the two interest rates i and r are deterministic.

Maximizing utility with respect to the portfolio shares of capital and indexed bonds gives rise to the following portfolio demand equations:

$$\begin{aligned} q w = {} & \frac{Var(\tilde{p})}{\beta (Var(y)\, Var(\tilde{p}) - Cov(y,\tilde{p})^2)} \left[E(y) - (i - E(\tilde{p})) \right] \\ & - \frac{(Var(\tilde{p}) + Cov(y,\tilde{p}))}{\beta (Var(y)\, Var(\tilde{p}) - Cov(y,\tilde{p})^2)} [r - (i - E(\tilde{p}))] \\ & + \frac{(Cov(y,t) Var(\tilde{p}) - Cov(y,\tilde{p})\, Cov(\tilde{p},t))}{(Var(y)\, Var(\tilde{p}) - Cov(y,\tilde{p})^2)} \end{aligned} \tag{3}$$

[5] Since the model focuses on the portfolio-allocation aspects of output and inflation variability and the credibility aspects of average inflation, nothing is gained by making the model intertemporal through including a consumption-saving decision.

$$q_I w = \frac{-(Var(\tilde{p}) + Cov(y,\tilde{p}))}{\beta(Var(y)\,Var(\tilde{p}) - Cov(y,\tilde{p})^2)}\left[E(y) - (i - E(\tilde{p}))\right]$$

$$+ \frac{Var(y + \tilde{p})}{\beta(Var(y)\,Var(\tilde{p}) + Cov(y,\tilde{p})^2)}\left[r - (i - E(\tilde{p}))\right] \qquad \textbf{(4)}$$

$$+ w + \frac{[Cov(\tilde{p},t)(Var(y) + Cov(y,\tilde{p})) - Cov(y,t)(Var(\tilde{p}) + Cov(y,\tilde{p}))]}{Var(y)Var(\tilde{p}) - Cov(y,\tilde{p})^2}$$

where *Cov(.,.)* denotes the covariance between two variables. According to (3) and (4), households exert speculative demands for capital and indexed bonds that are positive functions of the excess of the expected real rates of return on capital and indexed bonds over that on nominal bonds. The remaining terms at the RHS of (3) and (4) are minimum variance portfolio components.

In order to elaborate (3) and (4), we make use of the result that shocks in taxes and inflation are perfectly negatively correlated, a result that follows from the government budget constraint. Throughout the analysis, we will assume that the stock of government debt is a constant that cannot be manipulated by the government. Hence, the budget constraint of the government cum central banker can be written as follows:

$$t = (i - \tilde{p})b_N + rb_I - \tilde{p}m \qquad \textbf{(5)}$$

Here, b_N and b_I denote the stock of nominal and indexed bonds respectively, measured in terms of the consumption good. The three terms on the RHS of (5) refer to the interest payments on nominal bonds, indexed bonds and money respectively. Alternatively, (5) states that the government levies taxes to pay for that part of its debt service that is not covered by seigniorage revenues.

The marginality condition for money holdings implies a negative relation between the portfolio share of money and the nominal interest rate on nominal bonds:

$$\alpha\exp(-\alpha m) = i \qquad \textbf{(6)}$$

Let us now define the portfolio equilibrium as the equality of demand and supply on the four asset markets:

$$q w = k \tag{7}$$

$$q_I w = b_I \tag{8}$$

$$q_N w = b_N \tag{9}$$

$$q_m w = m \tag{10}$$

The portfolio equilibrium solves for the real interest rates on nominal and indexed government bonds and the price level, given the levels of nominal and indexed debt, capital, and portfolio wealth, which are all exogenous, and given the nominal money supply which is predetermined in the portfolio equilibrium (the nominal supply is solved in the second-period goods markets equilibrium, specified in the following section). Furthermore, expected output which coincides with the expected return on equity and the expected rate of inflation can be taken as predetermined in the portfolio equilibrium. The portfolio equilibrium thus specifies the equality of demand and supply on four markets, one of which has endogenous supply (real money holdings) and two of which have endogenous prices (the real interest rates on nominal and indexed bonds). The fourth asset market is in equilibrium due to Walras's law.

Substitution of the portfolio demand equations (3) and (4) into (7) and (8) yields expressions that solve for the risk premia on capital and nominal bonds:

$$E(y) = r + \beta Var(y) k \tag{11}$$

$$i - E(\tilde{p}) = r - \beta Cov(y,\tilde{p}) k \tag{12}$$

(11) states that in equilibrium the expected real rate of return on equity equals the real interest rate on risk-free bonds plus an equity premium. This equity premium is a positive function of the risk aversion of households, the variance of output, and the capital stock. Analogously, (12) expresses the risk premium on nominal bonds. As in Fischer (1975), the sign of the correlation between output and inflation determines whether nominal bonds sell at a higher rate of return than indexed bonds. If output and inflation are uncorrelated, the two types of bonds sell at the same real rate of return.

Substitution of r as implied by (11) into (12) yields a reduced-form solution for the nominal interest rate on nominal bonds:

$$i = E(\tilde{p}) + E(y) - \beta(Var(y) + Cov(y,\tilde{p}))k \qquad \textbf{(13)}$$

This solution features the Fisherian proposition that expected inflation will translate one-to-one into a higher nominal interest rate.

Combining (13) with (6) and (10) and using the definition of the real money supply $m = M/p$, we arrive at the solution for the price level:

$$p = -\alpha M\left[\log\left(\frac{1}{\alpha}\left(E(\tilde{p}) + E(y) - \beta(Var(y) + Cov(y,\tilde{p}))k\right)\right)\right]^{-1} \qquad \textbf{(14)}$$

For p to be positive, the inequality $i/\alpha < 1$ must hold, which we will assume to be the case.

Having characterized the portfolio equilibrium, we can now derive its welfare properties. We define welfare as the maximum of utility and denote it with v. The expression for v derives from filling in (5), using (8), (9), and (10), into (2) and substituting the result and (6) into (1):

$$v = E(y)k - \frac{1}{2}\beta Var(y)k^2 - \frac{1}{\alpha}i \qquad \textbf{(15)}$$

The RHS of (15) consists of three terms. The first one refers to average output, the second one to the variability of output and the third one to the utility loss that derives from a lack of liquidity services. Inflation variability and variability of taxes do not enter the welfare expression. The reason is that the government balances its budget so that the variability of household income is not affected through inflation or taxation policies, while households can diversify all inflation and taxation risk by appropriate reallocation of their portfolios.

The expression in (15) includes the nominal interest rate on nominal bonds. Substituting expression (13) into (15) yields a reduced-form solution for welfare:

$$v = E(y)k - \frac{1}{2}\beta Var(y)k^2 - \frac{1}{\alpha}E(\tilde{p}) - \frac{1}{\alpha}E(y) + \frac{\beta}{\alpha}(Var(y) + Cov(y,\tilde{p}))k \qquad \textbf{(16)}$$

This expression demonstrates that welfare depends negatively upon the average rate of inflation. It raises the nominal interest rate, which increases money transaction costs. More generally, (16) specifies that welfare depends on the means and the variances of output and inflation.[6] In a model of inflation, output and inflation are the outcome of a game between the central banker and the public. Therefore, in order to elaborate (16), the next section develops a stochastic version of the Barro-Gordon model of inflation.

3. A Stochastic Barro-Gordon Model

Although our model is static, it contains two periods. In the first period, the realizations of output, inflation and taxes are unknown and the household decides on his portfolio allocation on the basis of the second-period probability distributions of these variables. This first-period equilibrium has been discussed in the previous section. In the second period output, inflation and taxes are determined, possibly in reaction to a productivity shock. This second-period equilibrium will be described in the present section.

If we based the central banker's objective function that underlies stabilization policies upon the household utility function, as for example in Calvo (1978) or Calvo and Guidotti (1993), the central banker could not play a role in the stabilization of output shocks. Indeed, household's welfare depends upon the means and variances of inflation and output and not upon actual realizations. To include stabilization policies in the model, we therefore base the behaviour of the government cum central banker upon a Barro-Gordon type of objective function with inflation and output as arguments (Barro (1983), Barro and Gordon (1983a, 1983b)). This type of utility function can be motivated by noting that in the real world, central bankers' statutes often emphasize price stability as well as output considerations. In addition, this Barro-Gordon type of objective function is widely used in the literature, which allows a comparison between our results and those of others.

In the model of Barro and Gordon (1983b), inflation is produced by a central banker who trades off the costs and benefits of a higher rate of inflation. Here, we postulate that the government cum central banker minimizes a loss function L with the rate of inflation and the deviation of the output-capital ratio y from a target level $\hat{y}$ as arguments:[7]

[6] In the real world, both anticipated and unanticipated inflation affect the economy through many more channels than are being modelled here (Fischer and Modigliani (1978)). Combined, the two effects modelled in this paper capture the trade-off between credibility and flexibility aspects of monetary policies, as we will see below.

[7] An alternative specification replaces the deviation of the level of output from a target level with the deviation of the rate of output growth from a target rate (Barro and Gordon (1983a), Rogoff (1985)). The two

$$L = \tilde{p}^2 + \delta(y - \hat{y})^2 \qquad \delta \geq 0 \tag{17}$$

The parameter δ, which denotes the relative weight the central banker places on output, is usually interpreted as a measure of central bank independence (Cukierman (1992)). As pointed out by several authors, in settings where the central banker and the government make separate decisions, δ measures the inflation aversion of the central banker, which may be different from its degree of independence.[8] Here, we take the government and the central banker as one entity and use the terms independence and conservatism alternately. Next, we assume that $\hat{y} > y_n$, which says that there are distortions on output and labour markets that lead the policymaker to view the level of output that is realized in the absence of shocks as too low.

With respect to output, we assume that it increases when taxes are lowered or when there is a stochastic output shock. The tax term summarizes the negative effects that redistribution policies may exert upon output through distorting labour supply decisions, investment decisions etc.. Moreover, we assume that only taxes in deviation from their average affect output. This very crudely represents the notion that permanent increases in taxation have smaller effects than temporary increases. Here, we take the extreme position that only temporary tax changes matter as effects of permanent taxes complicate the analysis unnecessarily. Summarizing, we postulate the following supply function:

$$y = y_n - \gamma(t - E(t)) + \mu \qquad \gamma \geq 0 \tag{18}$$

Here, $y_n > 0$ denotes the normal level of output, and μ represents an error term, drawn from a distribution with zero mean and strictly positive variance *Var(μ).*

The level of unexpected taxation derives from combining the government budget constraint with the assumption that the central banker cannot change the stocks of indexed and nominal government bonds:

$$t - E(t) = -(\tilde{p} - E(\tilde{p}))(b_N + m) \tag{19}$$

specifications are equivalent if the level of output of one period earlier is known at the time the target is formulated.

[8] See for example Lohmann (1992), Lippi and Swank (1994), and Beetsma and Bovenberg (1995).

Combining (18) and (19), we can write the output supply equation as a Lucas-type surprise inflation equation:

$$y = y_n + \epsilon(\tilde{p} - E(\tilde{p})) + \mu \qquad \textbf{(20)}$$

where $\epsilon = \gamma(b_N + m)$.

(20) indicates why stabilization policies are effective in raising output. Inflation erodes the value of nominal debt and money and allows the government to lower taxes, thereby raising output growth. Of course, there are alternative explanations for the effectiveness of stabilization policies, the most familiar probably being the wage-contract version of the Lucas supply equation. In this specification, monetary policies can boost output by eroding real wages. In a sense, the two specifications are similar. Both specifications stress that the policy effectiveness derives from nominal rigidities. In the former case, the nominal returns to financial capital (the interest rate) are fixed, while in the latter case the nominal returns to human capital (the wage rate) are fixed. To derive a money demand function, note that the level of real money holdings is solved in the first-period portfolio equilibrium and acts as a predetermined variable in the second-period goods markets equilibrium.[9] Hence, any change in M will change p proportionally, or

$$\tilde{p} = \tilde{M} \qquad \textbf{(21)}$$

The central banker now chooses the rate of growth of the nominal money supply, M, and the level of taxes, t, such as to minimize (17) under the budget constraint (19). The solution to this problem follows from elaborating the first-order conditions of the problem, the supply function (20), the money demand function (21) and the assumption that households have rational expectations. The following expressions for the rate of inflation and the level of output characterize the solution of the model:

[9] Note that (14) solves the real money supply or, given the nominal money supply, the level of prices. (22) defines the rate of price inflation. If a system change occurred, like for example a change in the variability of inflation, the price defined in expression (14) would jump to a new level, without affecting the rate of inflation in (22).

$$\tilde{p} = \delta\epsilon(\hat{y} - y_n) - \frac{\delta\epsilon}{1+\delta\epsilon^2}\mu \tag{22}$$

$$y = y_n + \frac{1}{1+\delta\epsilon^2}\mu \tag{23}$$

(22) and (23) can be used to derive the average output-capital ratio and the inflation bias from nominal government liabilities:

$$E(y) = y_n \tag{24}$$

$$E(\tilde{p}) = \delta\epsilon(\hat{y} - y_n) = \delta\gamma(\hat{y} - y_n)(b_N + m) \tag{25}$$

Average inflation is linear in the stock of nominal liabilities. This linearity might depend upon the functional form of the central bankers' objective function (Poterba and Rotemberg (1990)). More importantly, the slope of the average inflation curve is positive for every level of (b_N+m).

(22) and (23) can also be used to derive the variances of inflation and output and their covariance:

$$Var(\tilde{p}) = \frac{\delta^2\epsilon^2}{(1+\delta\epsilon^2)^2}\, Var(\mu) \tag{26}$$

$$Var(y) = \frac{1}{(1+\delta\epsilon^2)^2}\, Var(\mu) \tag{27}$$

$$Cov(y,\tilde{p}) = \frac{-\delta\epsilon}{(1+\delta\epsilon^2)^2} Var(\mu) \tag{28}$$

Output variability is a negative function of total nominal liabilities. Inflation variability depends positively (negatively) upon the level of nominal liabilities if $1 - \delta\epsilon^2 > 0$ (< 0). Furthermore, (28) demonstrates that unexpected inflation and output are negatively correlated. The central banker produces inflation when the economy is in recession and the marginal value of output is high. Empirical evidence for the G7 countries in the period 1960-1989 confirms the countercyclical nature of prices (Fiorito and Kollintzas (1994)). (28) also implies that this correlation is perfect. This result, which is not that realistic, is due to the assumption that policymakers can perfectly monitor the money supply. Extending the model with imperfect monitoring would produce a correlation coefficient that can take any value between minus and plus one. As the assumption of imperfect monitoring is of no further relevance for the analysis, we will maintain the simple assumption of perfect monitoring.

The model specification furthermore implies that the inflation tax is negatively correlated with the conventional tax. This reflects that an optimizing government equates the marginal costs of the inflation tax and the conventional tax.[10] Exogenous output shocks change the marginal cost of the conventional tax. Specifically, a drop in output raises the marginal cost of the conventional tax. To equate the marginal cost of the inflation tax to that of the conventional tax, it is necessary to increase inflation and to lower the conventional tax.

As output variability is decreasing in nominal assets, nominal bonds may dominate indexed bonds in terms of stabilization properties. This relates to Bohn (1988), who analyses a model in which distortionary tax rates move opposite to output in order to finance a given level of government spending. In his model, nominal bonds allow for tax smoothing if inflation moves opposite to output, which gives nominal bonds better stabilization properties than indexed bonds.

4. Optimal Monetary Policies

[10] In Mankiw's (1987) analysis, shocks in government expenditure imply a positive correlation between the inflation tax and the conventional tax. This illustrates that the sign of the correlation coefficient between the two policy instruments depends upon the type of shock that is being analysed. Calvo and Guidotti (1993) adopt a setting in which the welfare cost of unexpected inflation is zero. In their model, the government should use only the inflation tax and not conventional taxes to finance temporary changes in public expenditure. This illustrates that optimizing government behaviour does not necessarily imply the simultaneous adjustment of all government instruments in response to an exogenous shock.

Given the first and second moments of the probability distributions for output and inflation, we can characterize optimal monetary policies for a typical case. Let us therefore restate the welfare function which we defined in section 2:

$$v = E(y)k - \frac{1}{2}\beta Var(y)k^2 - \frac{1}{\alpha}E(\tilde{p}) - \frac{1}{\alpha}E(y) + \frac{\beta}{\alpha}(Var(y) + Cov(y,\tilde{p}))k \qquad \textbf{(29)}$$

Suppose that output risk is near to zero. Optimal monetary policies imply the minimization of the average rate of inflation. The Friedman full liquidity rule - the optimal rate of inflation is the negative of the real interest rate - does not apply here as the marginal utility of real money balances is positive everywhere and, as a result, there is no finite satiation level of real money balances (Abel (1987)). From expression (25), which relates the average rate of inflation to the degree of CB independence, it can be derived that the average rate of inflation cannot be negative. The optimal average rate of inflation that is feasible is therefore zero. Obviously, zero average inflation can be obtained by requiring the central banker to be ultra-conservative ($\delta = 0$).

In a risky economy, welfare depends on output variability and the average inflation rate. It can be maximized by letting the central banker stabilize the economy when the economy is hit by output shocks and otherwise follow a zero-inflation rule. However, it is well-known that this solution is time-inconsistent (Calvo (1978)). Let us therefore explore the nature of the suboptimal time-consistent solution that results when society chooses that degree of CB independence that maximizes its welfare. In this solution, society precommits to the chosen institutional setting: it cannot overrule the central banker in the conduct of monetary policies.

In characterizing the solution, we make use of the expressions for $E(y)$, $E(\tilde{p})$, $Var(\tilde{p})$, $Var(y)$ and $Cov(y,\tilde{p})$ in (24) to (28). After substituting these expressions into (29), differentiation of the resulting expression with respect to δ produces the following expression for the marginal welfare gain from a shift in policy preferences towards output:

$$\partial v/\partial\delta = \frac{\beta\epsilon Var(\mu)k}{(1+\delta\epsilon^2)^3}\left\{\epsilon k - \frac{2\epsilon}{\alpha} - \frac{(1-\delta\epsilon^2)}{\alpha}\right\} - \frac{\epsilon(\hat{y}-y_n)}{\alpha} \qquad \textbf{(30)}$$

The RHS of (30) consists of four terms. The first term represents the welfare gain from the reduction in output variability that occurs when the central banker becomes more concerned with output. The second term measures the higher money transaction costs that derive from an increase in the nominal interest rate. That the interest rate increases is because the reduction in output variability lowers the equity premium, while any change in the equity premium, given that the expected return on capital is exogenous, falls upon the nominal interest rate. The third term measures the impact of the covariance of inflation and output upon money holdings. As inflation variability goes up and output variability goes down when δ increases, this term may have either sign. Finally, the fourth term measures the loss from the increase in the nominal interest rate that is due to the increase in expected inflation.

Unfortunately, putting $\partial v/\partial\delta$ in (30) to zero yields a third-order polynomial. However, if the parameter α has high value, then the contribution of the second and third term between accolades in (30) to the solution of $\partial v/\partial\delta = 0$ is small. This case, in which money yields high liquidity services, might be very relevant in many modern, industrialized economies. Therefore, we approximate the term between accolades in (30) by ϵk. In addition, in selecting the optimal value of δ, we assume society to regard ϵ a constant - which means that it abstracts from changes in m that stem from changes in δ.[11] Again, this approximation is quite innocent when α is high. Approximating the term between accolades in (30) by ϵk means that we abstract from the fifth term at the RHS of (29).[12] In this case, the welfare function reads as follows:

$$v = E(y)k - \frac{1}{2}\beta Var(y)k^2 - \frac{1}{\alpha}E(\tilde{p}) - \frac{1}{\alpha}E(y) \qquad \textbf{(31)}$$

Elaborating the first-order condition $\partial v/\partial\delta = 0$ and denoting its solution as δ^*, we have the following result:

[11] Alternatively, if we had used a Cagan-type of specification for the demand of money, as in Calvo (1978), such approximation would not have been necessary. In this specification, the demand for money is a function of the expected rate of inflation, rather than the nominal interest rate. However, it is difficult to motivate why the demand for money would not be part of the more general problem of choosing the optimal portfolio-allocation.

[12] This suggests that the approximation in question will be little problematic, if the standard deviations of price inflation and output are of the same order and if prices and output are negatively correlated. Fiorito and Kollintzas (1994) find that the standard deviations of price and output are indeed of the same order, whereas they find prices to be countercyclical to output in the G7 countries.

$$\delta^* = \frac{1}{\epsilon^2}\left[\left(\frac{\alpha\beta\epsilon k^2 Var(\mu)}{\hat{y}-y_n}\right)^{1/3} - 1\right] \tag{32}$$

Restricting δ^* to be non-negative, (32) states that δ^* is increasing in β and $Var(\mu)$ and decreasing in $\hat{y}$-y_n. At the optimum, monetary policies thus trade off credibility against flexibility. Intuitively, high risk aversion and high output variability require a lot of stabilization or a high δ^*. Similarly, large distortions on output markets require monetary policies to be credible, which means a low δ^*.

The conclusion about the trade-off between credibility and flexibility repeats the earlier findings of Rogoff (1985) and Alesina and Grilli (1991). They derive that optimal monetary institutions are characterized by a δ that is lower than the one that reflects society's (or the median voter's) preferences, but that is higher than zero. Noting that the δ that reflects society's preferences is the one that maximizes the gains from stabilization and that zero is the value of δ that minimizes the time-consistency losses, this optimum reflects a mix between reputational and stabilization considerations. The difference between (32) and the results in Rogoff (1985) and Lohmann (1992) is that (32) provides a closed-form solution for the optimal central banker's preferences, whereas Rogoff and Lohmann only specify upper and lower bounds. (32) differs from the results obtained by Alesina and Grilli (1991) and Van der Ploeg (1995) in that it does not relate the central banker's preferences to those of the median voter, but to the parameters that characterize the underlying household behaviour. In particular, a society with households that are highly risk averse (β high) will favour a central banker that gives proper weight to output considerations. In contrast, if money provides few liquidity services (α low), households will hold large stocks of money and society will favour a more inflation-averse central banker.

5. The Hump-Shaped Pattern of the Relationship Between CB Independence and the Level of Nominal Liabilities

What role do nominal liabilities play in the determination of optimal monetary policies? As (32) shows, nominal liabilities enter the expression for δ^* through ϵ, the slope of the Phillips curve. As noted in section 3, this slope is a positive function of the total of nominal government bonds and money: $\epsilon = \gamma(b_N + m)$. (32) indicates that ϵ may increase or decrease δ^*. The reason is that nominal liabilities have two effects that work in opposite directions. On the one hand, they create an incentive for the central banker to cheat the public and wipe out the real value of nominal liabilities. On the other hand, they contribute to the effectiveness of stabilization policies. Depending on which of these two effects dominates, an increase in the amount of nominal liabilities will then increase or decrease δ^*.[13]

To illustrate this proposition, Figure 2 portrays the relation between δ^* and ϵ that can be derived from (32).[14] As values for ϵ below ϵ_i produce a negative interior solution for δ^*, only the region $\epsilon \geq \epsilon_i$ is relevant. For $\epsilon_i \leq \epsilon < \epsilon_{ii}$, δ^* is a positive function of ϵ. In this region, the stabilization argument dominates, so that society will find it worthwhile to invest more in stabilization polices when the total of nominal debt and money increases. For $\epsilon > \epsilon_{ii}$, δ^* is a negative function of ϵ. In this region, the time-consistency problem dominates and an increase in nominal liabilities leads society to appoint a more conservative central banker. Our analysis thus predicts a hump-shaped pattern for δ^* as a function of ϵ. Figure 3 depicts $1/\delta^*$, which measures the degree of CB independence and which is a U-shaped function of ϵ.

[13] Similar effects might be obtained by using the wage-contract specification of the Lucas supply curve. Wage indexation not only removes the inflation bias, but also worsens the stabilization properties of monetary policies. See Devereux (1989), Ball and Cecchetti (1991) and Milesi-Ferretti (1994) on wage indexation in a model of discretionary monetary policies.

[14] The values ϵ_i, ϵ_{ii} and ϵ_{iii} in Figures 2 to 6 are defined as the values for ϵ for which $\delta^* = 0$, $\partial\delta^*/\partial\epsilon = 0$ and $\partial^2\delta^*/(\partial\epsilon)^2 = 0$ respectively. They can be calculated as $\epsilon_i = (\hat{y}-y_n)/(\alpha\beta Var(\mu)k^2)$, $\epsilon_{ii} = (6/5)^3\epsilon_i$, and $\epsilon_{iii} = (27/20)^3\epsilon_i$.

Figure 2 *The degree of CB unemployment aversion*

Having derived the relation between δ^* and ϵ, it is interesting to see what this relation implies for average inflation, output variability and welfare. First, note that average inflation is proportional to $\delta^*\epsilon$. As shown in Figure 4, the shape of $\delta^*\epsilon$ is similar to that of δ^*.[15] Both $\delta^*\epsilon$ and ϵ cross the horizontal axis at $\epsilon = \epsilon_i$. Different however is that $\delta^*\epsilon$ is more stretched than δ^*: δ^* has its maximum at $\epsilon = \epsilon_{iv}$, which is higher than ϵ_{ii}. Similarly, $\delta^*\epsilon$ has its point of inflection at a higher value of ϵ: $\epsilon_v > \epsilon_{iii}$. Consequently, for $\epsilon_i \leq \epsilon < \epsilon_{iv}$, average inflation is increasing in nominal liabilities, while it is decreasing for $\epsilon > \epsilon_{iv}$. This suggests that the intuition that nominal liabilities are an incentive to monetary authorities to cheat the public and thus will lead to a higher average rate of inflation, is only partially correct. Indeed, for $\epsilon > \epsilon_{iv}$, society "overreacts" to an increase in nominal liabilities by appointing a central banker that is so conservative that average inflation drops. On the other hand, for $\epsilon_i \leq \epsilon < \epsilon_{iv}$, nominal debt increases inflation, first because it makes cheating more attractive and, second, because it induces society to appoint a less inflation-averse central banker.

[15] ϵ_{iv} and ϵ_v in Figure 4 are defined as those values for which $\partial(\delta^*\epsilon)/\partial\epsilon = 0$ and $\partial^2(\delta^*\epsilon)/(\partial\epsilon)^2 = 0$ respectively. They can be calculated as $(3/2)^3\epsilon_i$ and $(9/5)^3\epsilon_i$ respectively.

Figure 3 *The degree of CB independence*

Figure 4 *The average rate of inflation*

Figure 5 *Output variability*

Figure 6 *Welfare*

Figure 5 depicts the relation between the variability of output and ϵ. For $\epsilon = \epsilon_i$, $\delta^* = 0$ and *Var(y)* equals *Var(μ).* For all $\epsilon \geq \epsilon_i$, the relation is downward sloping. Changes in ϵ thus dominate the response from δ^*: irrespective of the institutional response to increases in ϵ, increases in nominal assets increase the effectiveness of stabilization policies to such an extent that output variability is reduced.

The level of welfare that results when the degree of CB independence responds optimally to changes in ϵ, is also a function of ϵ. Denoting the value of v in (31) after δ has been replaced by its optimal value δ^* as v^*, we can find the form of this function by deriving an expression for $\partial v^*/\partial\epsilon$:

$$\partial v^*/\partial\epsilon = \frac{(\hat{y}-y_n)}{\alpha\epsilon^2}\left[\left(\frac{\alpha\beta\epsilon k^2 Var(\mu)}{\hat{y}-y_n}\right)^{1/3} - 1\right] \qquad \textbf{(33)}$$

This expression is proportional to that for δ^* as a function of ϵ. This implies that welfare has a minimum at $\epsilon = \epsilon_i$ and is a positive function of ϵ for $\epsilon > \epsilon_i$ (see Figure 6). The implication is that nominal liabilities allow for an increase in welfare, which can also be seen from the expressions for average inflation and output variability. If society responded to an increase in nominal liabilities by lowering δ proportionally, average inflation would remain unaffected, but output variability would drop. Alternatively, society could lower δ to such an extent that output variability would remain constant, but average inflation would drop. As is demonstrated in Figures 4 and 5, society responds to an increase in nominal assets by choosing δ such that output variability falls. In addition, for $\epsilon > \epsilon_{iv}$, average inflation also drops.

The analysis thus far suggests that countries can improve the efficiency of monetary policies further by optimally choosing between nominal and indexed bonds as means of financing the public deficit. Indeed, given the amount of money in circulation and given the total of government debt, countries can increase their welfare by replacing indexed with nominal bonds. If we exclude the possibility of holding indexed bonds by the government, the optimum involves that all public debt is financed by issuing nominal bonds. Obviously, this prediction corresponds quite well with reality: across countries and over time, the instrument of indexing bonds (indexing it to the domestic price level or denominating the bonds in foreign currency) has seldom been used.

6. Some Cross-Country Evidence

This section explores the empirical relevance of the results derived in the previous sections. In particular, it analyses whether endogenizing monetary institutions changes the model such that it provides a better explanation of average inflation than does the model with exogenous CB preferences.

Table 1 summarizes a series of regression results. It contains estimates of the coefficients of the relationship between average inflation and the total of public debt and money (in the definition of M1) in terms of GNP for a number of OECD countries.[16] The estimates refer to the periods 1970-1979, 1980-1989 and 1970-1989 respectively. The last group of estimates pools the data that refer to the periods 1970-1979 and 1980-1989.[17]

[16] It would be interesting to exclude from the data on public debt those bonds that are indexed to prices and those bonds that are issued in foreign currency. Cross-country data on these two types of bonds are scarce however. Moreover, indexed debt is usually only a small proportion of outstanding debt so that the error from not excluding indexed bonds may be not too large.

[17] See Beetsma and Van der Ploeg (1996) for evidence on the relationship between public debt and inflation for a number of OECD and non-OECD countries.

The first of each set of three estimates pertains to the model with exogenous CB preferences. It tests whether a linear specification fits the data well. The coefficient estimates turn out to be positive in all cases - as predicted by theory - and highly significant. The coefficient estimates lie in the range 0.12-0.17, suggesting that if public debt and money holdings add up to ten percent of GNP, this raises the average inflation rate with about one and a half percentage points.

The second and third regressions of each set of estimates test the model with endogenous CB preferences. They refer to a quadratic and third-order specification respectively. We have chosen these two functional forms as both of them imply concavity of the average inflation curve as well as a negative slope for large values of (B + M1)/GNP - as predicted by the theoretical model with endogenous CB preferences. Except for two, all coefficient estimates differ significantly from zero at the 1% level. Next, the addition of the second and third power of (B + M1)/GNP to the equation raises its explanatory power and reduces the standard error in all cases. Graphically, the new specifications pick up more easily the countries with intermediate debt positions and high inflation like Greece and the countries with high levels of debt and moderate inflation like Belgium.

This does not mean that the new specifications improve the statistical performance of the model in every respect. Their prediction of the average inflation rate in the Netherlands, for example, is worse than the prediction based on the old model. To give a better explanation of the average inflation performance of countries that combine intermediate debt positions with low inflation, the analysis might be extended with other explanatory variables, like for example the degree of price indexation of wages.[18] However, such an analysis falls outside the scope of this paper.

Table 1 *Empirical estimates of the relationship between average inflation and the stock of nominal government liabilities*[1]

	(B + M1)/GNP	$[(B + M1)/GNP]^2$	$[(B + M1)/GNP]^3$	R^2 adj.	SE*10^2
(1)[2]	0.17 (10.28)			−0.35	3.92
(2)[2]	0.32 (6.69)	−0.22 (3.19)		0.12	3.16
(3)[2]	0.26 (8.33)		−0.17 (3.05)	0.09	3.21

[18] Equation (32) suggests that the average inflation rate depends on a number of parameters that may have different value for different countries. We have made some estimations that included the rate of unemployment as explanatory variable. As these estimations only produced insignificant coefficients, we did not include them in Table 1.

(4)[3]	0.12 (7.03)			0.04	4.94
(5)[3]	0.21 (4.23)	−0.10 (1.92)		0.17	4.59
(6)[3]	0.18 (5.69)		−0.07 (2.15)	0.21	4.48
(7)[4]	0.14 (9.15)			−0.05	4.11
(8)[4]	0.26 (5.75)	−0.15 (2.67)		0.23	3.52
(9)[4]	0.21 (7.66)		−0.11 (2.85)	0.26	3.45
(10)[5]	0.14 (11.14)			−0.19	4.69
(11)[5]	0.26 (7.91)	−0.15 (3.80)		0.14	3.99
(12)[5]	0.21 (10.27)		−0.09 (3.90)	0.15	3.96

[1] $E(\dot{p})$ and (B + M1)/GNP are defined as percentages. *t*-values are shown beneath the coefficient estimates between parentheses.

[2] Cross-section regression with variables defined over 1970-1979.

[3] Cross-section regression with variables defined over 1980-1989.

[4] Cross-section regression with variables defined over 1970-1989.

[5] Combined cross-section time-series regression with variables defined over 1970-1979 and 1980-1989.

7. Summary and Conclusions

This paper has endogenized the degree of central bank independence along the lines of Rogoff (1985) and others and examined its implications for the relationship between inflation and nominal government liabilities. The optimal degree of independence trades off credibility aspects that derive from an exogenous output distortion against flexibility aspects that are due to stochastic output shocks. Nominal liabilities exert two effects upon the optimal degree of independence. As in the Barro-Gordon model, they erode the credibility of monetary policies, making it optimal for society to appoint a more conservative central banker. However, they also render stabilization policies more effective, requiring less inflation-averse central bankers. Since for low liability levels, the latter argument dominates and the former does for high liability levels, it follows that the optimal degree of independence is a U-shaped function of nominal liabilities.

This result on the optimal degree of CB independence implies that average inflation is a hump-shaped function of nominal liabilities. For low liability levels, increasing amounts of nominal liabilities fuel inflation, both directly and indirectly, as they induce society to invest in less inflation-averse central bankers to exploit their stabilization properties. For high liability levels, increasing amounts of nominal liabilities reduce inflation. Here, the direct effect of fuelling inflation expectations is dominated by the indirect effect of moving to more inflation-averse monetary policies. This has the effect of bending downwards the inflation-nominal liabilities relationship for high levels of nominal liabilities.

Our extension of the theory of inflation improves the fit of cross-country data for the OECD area. The relation between inflation and nominal liabilities to GDP fits the data better when a specification is being used that allows for a negative slope for high liability levels. For countries with small amounts of nominal liabilities, the Barro-Gordon model of inflation provides a reasonable fit. However, our theory gives a better explanation for the relatively low inflation rates of high-debt countries and relatively high inflation rates of some countries in an intermediate position.

The analysis can be extended in several directions. As mentioned above, the analysis might also be applicable to the case of wage indexation. Indeed, nominal wage rigidity and nominal interest rate rigidity are equivalent as both render stabilization policies effective while at the same time introduce a time-consistency problem. It would therefore be an interesting extension to see whether central bank preferences and the average rate of inflation can also be related to the incidence of wage indexation.

It is also interesting to see whether our theory can be helpful in explaining institutional changes over time. In recent years, many countries have adopted changes in their central bank institutions (Cukierman (1994)). EC countries are increasing the independence of their central banks in order to qualify for EMU. Next, the governments of some Latin-American countries have increased the independence of their central banks to curb their high inflation. It is an intriguing question whether these institutional changes are optimal responses to changes in fundamentals like the levels of nominal liabilities or whether they can more fruitfully be explained from historical inflation experiences.

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On the Relationship between Inflation and Nominal Government Liabilities:
The Role of the Independence of the Central Bank

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Abstract

It is well-known that discretionary monetary policies suffer from an inflation bias. In the absence of rules, monetary authorities are tempted to produce surprise inflation in order to reduce the real value of nominal government liabilities like debt and money. As rational economic agents will adjust their expectations accordingly, inflation will be higher than in the case of rules.

According to this theory of inflation, inflation is a positive function of nominal government bonds. Still, the theory may overlook an important aspect of reality. In particular, it takes the degree of central bank (CB) independence as given but in the real world the degree of CB independence varies across countries and over time. These differences may very well be related to differences in the stocks of government debt and money. Indeed, a rise in government indebtedness may very well lead society to vote for a more conservative central banker in order to combat its inflationary bias.

This paper explores the implications for the relationship between inflation and nominal government liabilities when society chooses the degree of CB independence such that it maximizes its welfare. The paper finds that the degree of CB independence is a U-shaped function of nominal government debt and money. This particular shape reflects the interaction of a credibility effect and a flexibility effect. First, nominal liabilities reduce the central banker's credibility, making it attractive for society to invest in more conservative monetary policies. Second, nominal government liabilities increase the effectiveness of monetary stabilization policies, which also increases the attractiveness of investing in more flexible monetary policies. Since the former effect dominates for high levels of nominal liabilities and the latter for low levels of nominal liabilities, the relationship between the degree of CB independence and the stock of nominal government liabilities has the claimed U-shape.

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As a consequence, the average inflation rate is a hump-shaped function of nominal liabilities. An increase in nominal public debt thus does not necessarily fuel inflation, but may give rise to lower inflation as it induces society to appoint a more conservative central banker. Empirical estimates for the OECD area suggest that the model with endogenous CB preferences outperforms the model in which CB preferences are exogenous. In particular, the model with endogenous CB preferences outperforms the latter model which predicts too much infation for those countries with high levels of public debt.