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# Non-neutrality and Uncertainty in a Model of Growth<sup>‡\*</sup>

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#### Abstract

The paper develops a model that examines the effects of monetary policy uncertainty on trend growth. It is assumed that the provision of potentially productive public goods and services is financed by money creation (seignorage). Uncertainty derives from stochastic fluctuations in money supply. It is found that money is not neutral and that higher variability in money growth affects the choices of individuals on how to allocate their time between different activities. Depending on the underlying mechanism through which improvements in productivity occur, a greater degree of monetary policy uncertainty (higher monetary variability) can have either positive or negative effects on the average rate of growth.

*Keywords:* Volatility, Growth, Seignorage JEL classification: E32; E60; O42

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#### **1. Introduction**

The emergence of the new growth literature, pioneered by Romer (1986) and Lucas (1988), has stimulated renewed interest in an almost forgotten area of macroeconomics. By endogenising the process of technological change, this literature has enabled economists to address fundamental issues in the long-run growth and development of economies. Included among these are the relationships between growth and inequality, between growth and financial development, between growth and population, and between growth and government policy. The upshot has been a much better understanding of the forces that drive growth and the factors that cause growth rates to differ across countries.

In addition to the above, one recent strand of research has been concerned with examining how long-run growth may be affected by uncertainty arising from cyclical fluctuations. This research has been motivated, in part, by a growing body of empirical evidence indicating a relationship between growth and volatility. Significantly, the sign of this relationship varies across studies, being reported as negative in some cases (e.g., Ramey and Ramey 1995; Martin and Rogers 2000; Kneller and Young 2001) and positive in others (e.g., Caporale and McKiernan 1996; Kormendi and Meguire 1985; Grier and Tullock 1989). The same conflict in results appears at the theoretical level, where it has been shown that growth and volatility may be negatively or positively correlated depending on a number factors. One of these, identified by de Hek (1999), Jones et al. (1999) and Smith (1996), is the degree of relative risk aversion displayed by agents (i.e., whether agents have a high or low elasticity of intertemporal substitution). A second, observed in Aghion and Saint-Paul (1998) and Blackburn and Galindev (2003), concerns the underlying mechanism of technological change (i.e., whether this is based on deliberate, purposeful actions that substitute for production activity, or serendipitous learning-by-doing that complements such activity). A third, reported by Blackburn and Pelloni (2004),

relates to the impulse sources of fluctuations (i.e., whether these take the form of real shocks or nominal shocks).<sup>1</sup>

It is generally accepted that one of the major sources of uncertainty for agents is the variability of government policies. The potential for both fiscal and monetary policies to have important effects on growth is now well-established.<sup>2</sup> Uncertainty about such policies may arise for a number reasons: policy makers may change their behaviour in response to changes in the environment (e.g., due to exogenous shocks) and changes in policy objectives (e.g., due to the election of a new government); policy makers may alter their choices of policy instruments and may have imperfect control over these instruments; policy makers may even deliberately try to create policy surprises as a means of achieving their targets. Whatever the reason, uncertainty about macroeconomic policy is an important consideration for agents when making their optimal plans. Such uncertainty can distort these plans and have profound effects on individual welfare and aggregate outcomes.

There are a number of existing analyses which illustrate precisely how policy uncertainty can affect long-run growth. Aizenman and Marion (1993) develop a model in which firms are subject to a tax on profits that fluctuates randomly between low and high values, the difference between which is used as a measure of policy variability. It is shown that an increase in such variability may either increase or decrease growth (depending on how it affects the marginal product of capital) by an amount that depends on the degree of persistence in policy. In a similar vein, Hopenhayn and Muniaguria (1996) present a model in which firms receive randomly either positive or zero subsidies to their investments. It is shown that more frequent changes (i.e., more variability) in policy lead to lower growth by lowering the return on investment. Arguably, uncertainty about fiscal policy is less important than uncertainty about monetary policy.<sup>3</sup> An analysis of the latter is conducted by Dotsey and Sarte (2000) using an "AK" model with a cash-in-advance constraint on consumption and investment. Greater variability of monetary shocks is shown to have a positive effect on growth as individuals respond to the increased uncertainty by

<sup>&</sup>lt;sup>1</sup> Other analyses of the relationship between growth and volatility include Canton (1996) and Martin and Rogers (2000).

 $<sup>^{2}</sup>$  See, for example, Barro (1990), Rebelo (1990) and Easterly (1992) for analyses of the growth effects of fiscal policy, and van der Ploeg and Alogoskoufis (1994) and Roubini and Sala-i-Martin (1995) for analyses of the growth effects of monetary policy.

<sup>&</sup>lt;sup>3</sup> According to Drazen (2000), for example, "the political mechanism by which taxes are chosen means that the imposition of a wealth tax is rarely a surprise" (p.125). The same could be said about other instruments of fiscal policy.

increasing their precautionary savings (which raises capital accumulation). Blackburn and Pelloni (2004) develop an endogenous monetary growth model based on learning-by-doing with nominal rigidities. According to their analysis, an increase in monetary volatility has a negative effect on growth through a reduction in average employment. A similar result is established in Evans and Kenc (2001) and Turnovsky (1996), though for different reasons. In these studies greater nominal variability leads to lower long-run growth through portfolio reallocation effects (a shift by individuals away from productive assets, such as capital, towards unproductive assets, such as government bonds).<sup>4</sup>

This paper presents a further investigation into the effects of monetary policy uncertainty on long-run growth. It does so within the context of a stochastic endogenous growth model in which the accumulation of knowledge, or human capital, is the mechanism through which technological improvments and productivity gains occur. In contrast to the above analyses, where monetary injections take the form of randomly distributed lump-sum transfers, I consider the case in which the seignorage revenues generated by stochastic fluctuations in the money supply are used to finance the provision of potentially productive public goods and services. These goods are productive if they contribute to human capital accumulation and are wasteful otherwise.<sup>5</sup> Human capital may also be accumulated through purposeful actions (the deliberate, but costly, acquisition of skills and expertise) on the part of agents. Limiting cases of interest are a "Barrotype economy", where productivity improvements depend solely on the external effects of public goods provision, and an "Uzawa-Lucas-type economy", where technological change is driven purely by the internal efforts of individuals.<sup>6</sup> I show that the relationship between growth and volatility is negative in the former case, but positive in the latter. For the general scenario in which learning reflects both external and internal forces, the sign of the relationship is almost certain to be negative. An implication of this is that changes in policy designed to enhance productivity are likely to do more harm than good if such changes create additional uncertainty. Except under very special circumstances, growth is reduced by an increase in policy uncertainty.

The model produces a strong non-neutrality result in the sense that it does not rely on any kind of nominal rigidity (such as wage or price stickiness) to generate real effects of changes in

<sup>&</sup>lt;sup>4</sup> Gomme (1993) and Ozlu (1998) also consider stochastic monetary endogenous growth models, though their focus is on the business cycle properties of these models, rather than on the relationship between growth and volatility.

<sup>&</sup>lt;sup>5</sup> Another assumption could be that individuals derive utility from government consumption. With logarithmic preferences, as I assume in the model, the results will be identical to the case where the public good is wasted.

<sup>&</sup>lt;sup>6</sup> The terminology I use is based on the contributions of Barro (1990), and Uzawa (1965) and Lucas (1988).

the money supply. Rather, these effects arise for two quite different reasons. First, since the government acquires a fraction of real resources by providing agents with money balances, monetary growth acts like a tax on real income and affects individuals' decisions - in particular, decisions concerning the optimal allocation of time between employment, leisure and learning. In this way, money has an indirect effect on both the level and growth rate of output. Second, since seignorage is used to finance the provision of public goods, changes in monetary growth impact on the process of knowledge accumulation whenever this process depends on such goods. In this other way, money has a direct effect on both the level and growth rate of output. It is because these effects are non-linear that the variability of money growth influences the average (trend) growth rate of output as well.

Seignorage is generally considered as a method of expenditure finance most appealing to governments of less developed countries.<sup>7</sup> The commonly accepted arguments in favour of the above statement concern the insufficient revenues from taxation (due to the low tax base for example) or the poor credit ratings that prevent some developing countries from borrowing in world financial markets. Given this model's implications for the relationship between policy variability and growth when public investment is financed with money creation, it is appropriate to have some evidence supporting the idea of seignorage as a mean of productive spending. Indeed, Agbonyitor (1997) argues that structural economic reforms in several Sub-Saharan African countries were undermined by reductions in the provision of public services and poor maintenance of public infrastructure as a result of shortages in local funds due to reduced seignorage. Basu (2001) reports the results of a cross-sectional study, indicating a positive and statisticaly significant correlation between the average seignorage rate and the public investment rate. Theoretical models that address the growth implications of the use of seignorage for public investment have been developed by Krolzig and Wrohmann (1996), Ferreira (1999) and Basu (2001), among others, however none of these papers considers the implications of policy variability under such assumptions.

The remainder of the paper is organised as follows. Section 2 presents the model. Section 3 contains the solution of the model. Section 4 studies the growth effects of monetary shocks. Section 5 attends to the growth effects of monetary uncertainty. Section 6 concludes.

<sup>&</sup>lt;sup>7</sup> Click (1998) presents evidence that, for a large number of developing countries, revenues from money creation account for almost 30% of total government revenues.

#### 2. The Model

Time is discreet and indexed by  $t = 0, 1, ...\infty$ . The economy is populated by a unit mass of identical, infinitely-lived agents who are both producers and consumers of a single commodity. The lifetime utility of the representative agent is given by

$$V_t = \sum_{t=0}^{\infty} \beta^t \left[ \log(c_t) + \log\left(\frac{M_t}{P_t}\right) + \delta \log(l_t) \right], \quad \beta \in (0,1), \ \delta, \zeta > 0 \tag{1}$$

where  $c_t$  denotes consumption,  $M_t$  denotes real money balances,  $P_t$  is the price level and  $l_t$  denotes leisure. As in other models, the inclusion of money in the utility function is meant to capture the idea that money serves to facilitate exchange and transactions (e.g., by reducing the time spent on these activities).<sup>8</sup> Leisure is the amount of time left after the agent has devoted  $n_t$  units of time to producing output and  $s_t$  units of time to acquiring human capital. Normalising total available time to one, it follows that

$$n_t + s_t + l_t = 1.$$
 (2)

The budget constraint facing the agent is

$$c_{t} + \frac{M_{t}}{P_{t}} = y_{t} + \frac{M_{t-1}}{P_{t}},$$
(3)

where  $y_t$  denotes output. The agent produces output under a constant returns to scale technology using her own labour,  $n_t$ , and her own stock of human capital (or technological knowledge),  $x_t$ , which determines her level of productivity. That is,

$$y_t = An_t x_t, \quad A > 0 \tag{4}$$

There are two possible ways in which the agent can learn and accumulate human capital. The first is by combining  $s_t$  units of her own time with her own existing stock of knowledge,  $x_t$ , to acquire further skills and expertise for herself (e.g., through formal education, training and research). This way of learning is internal to the agent's decision problem of maximising her utility. The second is by exploiting publicly provided goods and services, denoted by  $g_t$ , that

<sup>&</sup>lt;sup>8</sup> This type of short-cut for generating a money demand function originates from the work of Sidrauski (1967) and has been widely used by monetary economists.

improve the productivity of all agents equally (e.g., the provision of social infrastructure, public education, and law and order). This way of accumulating human capital is external to the agent's maximisation problem.<sup>9</sup> Formally, I assume the following specification for the process governing the evolution of  $x_t$ :

$$x_{t+1} = B(s_t x_t)^{\varepsilon} g_t^{1-\varepsilon}, \quad B > 0, \quad \varepsilon \in (0,1)$$
<sup>(5)</sup>

The relative importance of the two mechanism of growth is captured by the parameter  $\varepsilon$ . The limiting cases of interest, alluded to earlier, are when  $\varepsilon = 1$  and  $\varepsilon = 0$ . In the case of the former - what one may refer to as an "Uzawa-Lucas economy" - human capital is accumulated solely on the basis of agents' own actions. In the case of the latter - what one may characterise as a "Barro economy" - improvements in productivity are purely the result of public goods provision.

The government finances its expenditures on public goods through money creation. I assume that it takes one unit of expenditure to produce one unit of public good, and that the total amount of public expenditure is a (random) fraction,  $\gamma_t$ , of output. Thus

$$g_t = \gamma_t y_t. \tag{6}$$

Denoting by  $H_t$  the nominal supply of money, the government's budget constraint is

$$g_{t} = \frac{H_{t} - H_{t-1}}{P_{t}}.$$
(7)

The growth rate of the money supply is stochastic. Following others (e.g., Rankin 1998a, 1998b), it is convenient to work in terms of the monetary contraction rate, defined as  $\phi_t$  such that

$$H_{t} = \frac{1}{\phi_{t}} H_{t-1}.$$
 (8)

I assume that  $\{\phi_t\}_{t=0}^{\infty}$  is a sequence of independently and identically distributed random variables with mean  $\mu < 1$  and variance  $\sigma^2$ . In the analysis that follows  $\sigma^2$  is used as a measure of policy variability or policy uncertainty.<sup>10</sup>

<sup>&</sup>lt;sup>9</sup> Several other authors have developed models in which productivity improvements depend on externality effects associated with public policy (e.g., de la Croix 2001; Glomm and Ravikumar 1992). In addition to formal education and training, governments may provide a host of other services (e.g., transport and communication networks) that contribute to the accumulation of human capital and that raise efficiency in the private sector.

<sup>&</sup>lt;sup>10</sup> According to this formulation, monetary growth is the underlying source of stochastic fluctuations which imply fluctuations in the provision of public goods. A reinterpretation of the model is to think of  $\gamma_t$  as being the initial source of randomness which induces randomness in  $\phi_t$ .

Equations (1) to (8) describe the complete set-up of the model. Before proceeding to the solution of the model, it is worth describing briefly the sequence of events that characterise individual and government behaviour. At the beginning of each period, an agent is endowed with unit of time and posseses money carried over from the previous period. The government procures seigniorage revenues by increasing the supply of money and uses these revenues to provide public goods. Based on the realisation of the monetary growth rate, together with expectations about future outcomes, the agent decides how to allocate her time between different activities, taking public goods provision as given. She then chooses how much of her wealth to consume and how much to hold in the form of money balances.

#### **3. Solution of the Model**

An individual's objective is to choose sequences for  $c_t$ ,  $n_t$ ,  $s_t$ ,  $M_t$  and  $x_{t+1}$  so as to maximize the expected value of (1) subject (2), (3), (4) and (5), taking as given  $g_t$ ,  $H_t$  and  $P_t$ . Denoting by  $E_t$  the conditional expectations operator, the first-order conditions for this maximization problem may be written as

$$\lambda_t = \frac{1}{c_t},\tag{9}$$

$$\frac{\delta}{1 - n_t - s_t} = A\lambda_t x_t,\tag{10}$$

$$\frac{\delta}{1-n_t-s_t} = \frac{\varepsilon \xi_t x_{t+1}}{s_t},\tag{11}$$

$$\xi_{t} x_{t+1} = \varepsilon \beta E_{t} (\xi_{t+1} x_{t+2}) + A \beta E_{t} (\lambda_{t+1} n_{t+1} x_{t+1}), \qquad (12)$$

$$\frac{\lambda_t M_t}{P_t} = \beta E_t \left( \frac{\lambda_{t+1} M_t}{P_{t+1}} \right) + \zeta, \qquad (13)$$

where  $\lambda_t$  and  $x_t$  are the Lagrange multipliers associated with (3) and (5), respectively. Equation (9) gives the marginal utility of consumption. Equations (10) and (11) are the static optimality conditions for the allocations of time towards working,  $n_t$ , and learning,  $s_t$ , respectively. Each

of these conditions equates the marginal cost and marginal benefit of an addition unit of time spent on each activity. The marginal cost of each activity is the same, being a reduction in leisure. The marginal benefit of working is extra current consumption. The marginal benefit of learning is extra future consumption associated with an improvement in future productivity. This is captured in equation (12) which gives the dynamic optimality condition for  $x_t$ . Equation (13) is the dynamic optimality condition for money,  $M_t$ , equating the marginal costs and benefits of an additional unit of cash balances.

A complete characterisation of the general equilibrium of the economy is obtained by combining the relationships obtained so far with the appropriate market clearing conditions. Clearing of the goods market requires  $y_t = c_t + g_t$ , while clearing of the money market requires  $M_t = H_t$ . Thus, using (6), (7) and (8),

$$c_t = (1 - \gamma_t) y_t, \tag{14}$$

$$\gamma_t y_t = \frac{(1 - \phi_t)M_t}{P_t}.$$
(15)

It is straightforward to verify that equation (13) has the following solution:

$$\frac{M_t}{P_t c_t} = \frac{\zeta}{1 - \beta \mu} \equiv z.$$
(16)

Accordingly, the demand for real money balances is simply proportional to consumption which is (stochastically) proportional to output.<sup>11</sup> In turn, (14), (15) and (16) may be combined to obtain

$$\gamma_t = \frac{z(1-\phi_t)}{1+z(1-\phi_t)} \equiv \gamma(\phi_t), \tag{17}$$

which satisfies  $\gamma_t \in (0,1)$ . Evidently,  $\gamma'(\cdot) < 0$ , implying that the government's share of total output (and therefore the provision of public goods) is an increasing function of the monetary growth rate (i.e., a decreasing function of  $\phi_t$ ).<sup>12</sup> Given these results, together with (4), it is

<sup>&</sup>lt;sup>11</sup> That (16) is a solution to (13) is verified by direct substitution. This solution also satisfies the transversality condition on money balances.

<sup>&</sup>lt;sup>12</sup> Observe also that  $\gamma_t$  increases with an increase in the value of z (which corresponds to an increase in money demand, allowing the government to extract more revenues from seignorage).

possible to write (12) as  $\xi_t x_{t+1} = \varepsilon \beta E_t (\xi_{t+1} x_{t+2}) + \beta [1 + z(1 - \mu)]$ . The solution to this expectations difference equation is<sup>13</sup>

$$\xi_t x_{t+1} = \frac{\beta [1 + z(1 - \mu)]}{1 - \varepsilon \beta} \equiv Z.$$
(18)

Equations (10) and (11) may now be used to derive the equilibrium allocations of time towards working and learning as

$$n_t = \frac{1 + z(1 - \phi_t)}{1 + z(1 - \phi_t) + \delta + \varepsilon Z} \equiv n(\phi_t), \tag{19}$$

$$s_t = \frac{\varepsilon Z}{1 + z(1 - \phi_t) + \delta + \varepsilon Z} \equiv s(\phi_t).$$
<sup>(20)</sup>

The solutions in (19) and (20) show how an agent would re-allocate her time in response to changes in the monetary growth rate. Specifically,  $n'(\cdot) < 0$  while  $s'(\cdot) > 0$ . In words, an increase in monetary growth causes agents to devote more time to producing output and less time to accumulating human capital. These responses reflect the fact that, *ceteris paribus*, an increase in monetary growth increases the amount of output absorbed by the government and reduces the amount of output available for private consumption. In order to mitigate the effects on consumption, agents work harder to produce more output and therefore spend less time on accumulating knowledge. The opposite occurs when monetary growth decreases: since more output becomes available for private consumption, the opportunity cost of not working is lower and agents devote relatively more time to improving their future productivity.

#### 4. Growth and Non-neutrality

The results obtained above may be used to derive an expression for the equilibrium growth rate of productivity,  $x_{t+1}/x_t$ .<sup>14</sup> Substituting (6) and (4) into (5) gives an initial expression for this growth rate as

<sup>&</sup>lt;sup>13</sup> As before, the solution may be verified by direct substitution and is consistent with the transversality condition on human capital.

$$\frac{x_{t+1}}{x_t} = BA^{1-\varepsilon} s_t^{\varepsilon} n_t^{1-\varepsilon} \gamma_t^{1-\varepsilon}.$$
(21)

This expression shows that productivity growth depends on three factors: the first,  $s_t$ , is the amount of time that agents, themselves, devote to acquiring knowledge; the second,  $n_t$ , is the amount of time that agents allocate to producing output; and the third,  $\gamma_t$ , is the fraction of output appropriated by the government. The last two terms enter through their influence on the provision of public goods which contribute to productivity. *Ceteris paribus*, a higher value of  $n_t$  means that more output is available to both agents and the government, while a higher value of  $\gamma_t$  means that more output is available exclusively to the latter. In both cases the government acquires more resources with which to provide more public goods.<sup>15</sup>

A final expression for equilibrium productivity growth is derived by substituting into (21) the relationships obtained previously for  $\gamma_t$ ,  $n_t$  and  $s_t$ . These relationships - given in (17), (19) and (20) - show that each of these variables is a function of the stochastic policy variable,  $\phi_t$ . Accordingly, productivity growth is also a function of this variable. That is,

$$\frac{x_{t+1}}{x_t} = \frac{BA^{1-\varepsilon} (\varepsilon Z)^{\varepsilon} [z(1-\phi_t)]^{1-\varepsilon}}{1+z(1-\phi_t)+\delta+\varepsilon Z} \equiv f(\phi_t).$$
(22)

The precise way in which monetary growth influences productivity growth depends essentially on the underlying mechanism of technological change. To be sure, consider each of the limiting cases, alluded to earlier, where the parameter  $\varepsilon$  is assigned either its maximum or minimum permissable value. For the case in which  $\varepsilon = 1$  (an "Uzawa-Lucas economy"), equation (22) becomes

<sup>14</sup> The growth rate of output is related to the growth rate of productivity according to  $\frac{y_{t+1}}{y_t} = \left(\frac{x_{t+1}}{x_t}\right) \left(\frac{n_{t+1}}{n_t}\right)$ . For

simplicity, I focus on the latter since there is one less extra term,  $\frac{n_{t+1}}{n_t}$ , to deal with. This is inconsequential for the

analysis that follows as one arrives at the same conclusions irrespective of which measure of growth is used.

<sup>&</sup>lt;sup>15</sup> With the exclusion of  $\gamma_t$ , equation (21) becomes similar to the growth equation derived by Blackburn and Galindev (2003). In their model, growth is driven through learning-by-doing (captured by the average level of employment) and the deliberate accumulation of knowledge, with stochastic fluctuations originating from real (preference) shocks.

$$\frac{x_{t+1}}{x_t} = \frac{B\hat{Z}}{1 + z(1 - \phi_t) + \delta + \hat{Z}} \equiv f_1(\phi_t),$$
(23)

where  $\hat{Z} = \{\beta[1+z(1-\mu)]/(1-\beta)\}$ . Thus  $f'_1(\cdot) > 0$ , implying that an increase in monetary growth (a reduction in  $\phi_t$ ) leads to a decrease in productivity growth. This is because of a decrease in  $s_t$ , the amount of time that agents devote to learning (which is the only channel through which productivity improvements occur). For the case in which  $\varepsilon = 0$  (a "Barro economy"), equation (22) reduces to

$$\frac{x_{t+1}}{x_t} = \frac{BAz(1-\phi_t)}{1+z(1-\phi_t)+\delta} \equiv f_2(\phi_t).$$
(24)

In contrast to the above,  $f'_{2}(\cdot) < 0$ , implying that an increase in monetary growth causes an increase in productivity growth. This is because of an increase in both  $n_{t}$ , the amount of time that agents devote to working, and  $\gamma_{t}$ , the share of output taken by the government, both of which imply an increase in public goods provision (which is the only channel through which productivity is improved).

It is worth emphasising that the real effects of money in this model do not reflect the existence of any nominal rigidities. Rather, they arise for two other reasons: the first is that changes in monetary growth are associated with changes in the provision of public goods and services which contribute directly to productive efficiency; the second is that changes in monetary growth imply changes in the amount of resources available to private agents who respond by re-allocating their time between different activities. These channels of non-neutrality are quite separate from each other: as shown above for the case of  $\varepsilon = 1$ , even if public goods were completely unproductive (so that the revenues from seignorage are effectively thrown away), the allocation of time between working and learning would still be affected by changes in money growth which would still have an impact on productivity growth.

### 5. Growth and Uncertainty

The foregoing analysis reveals how actual productivity growth is affected by monetary shocks. The main concern of this paper is to investigate how the average (or trend) rate of productivity growth is influenced by the volatility of these shocks. The general approach to doing this is summarised as follows.

Consider the general case in which actual productivity growth is determined according to (22). An approximation of the average growth rate may be computed by taking the expected value of a second-order Taylor series approximation of  $f(\cdot)$ . This yields

$$Mean\left(\frac{x_{t+1}}{x_t}\right) \cong f(\mu) + \frac{1}{2}f''(\mu)\sigma^2, \qquad (25)$$

where it is recalled that  $\sigma^2$  is the variance of  $\phi_t$ . Thus, whether  $Mean\left(\frac{x_{t+1}}{x_t}\right)$  is positively or negatively related to  $\sigma^2$  depends solely on the sign of  $f''(\mu)$  which reflects the curvature properties of  $f(\cdot)$ . This is merely an example of the well-known result that the expected value of

a convex (concave) function of a variable is increased (decreased) by a mean-preserving spread of that variable. For the two limiting scenarios of  $\varepsilon = 1$  and  $\varepsilon = 0$ , average growth is approximated via approximations of the functions  $f_1(\cdot)$  and  $f_2(\cdot)$  in (23) and (24), respectively.

The correlation between  $Mean\left(\frac{x_{t+1}}{x_t}\right)$  and  $\sigma^2$  is then determined by the signs of  $f_1''(\mu)$  and

 $f_2''(\mu)$ . It is instructive to consider these scenarios first.

For the case in which 
$$\varepsilon = 1$$
, one finds that  $f_1''(\mu) > 0$ , implying that  $Mean\left(\frac{x_{t+1}}{x_t}\right)$  is increased

by an increase in  $\sigma^2$ . In other words, there is a positive correlation between average growth and monetary volatility. The reason for this is as follows. Human capital accumulation depends solely on agents' own efforts to learn and acquire new skills. According to (20), the time spent on doing this is an increasing, convex function of the policy shock (i.e.,  $s'(\cdot), s''(\cdot) > 0$ ). This indicates a precautionary motive for investing in human capital. Given this, then agents respond to greater policy uncertainty by undertaking, on average, more of this investment. As a result, there is an increase in the average growth rate of productivity.

For the case in which  $\varepsilon = 0$ , one observes that  $f_2''(\mu) < 0$ , meaning that  $Mean\left(\frac{x_{t+1}}{x_t}\right)$  is a

decreasing function of  $\sigma^2$ . Accordingly, there is now a negative correlation between average

growth and policy variability. In this case human capital accumulation depends solely on public goods provision which increases with the total amount of output produced by agents and the share of output taken by the government. From (19) and (17), both of these variables are seen to be decreasing, concave functions of the policy shock (i.e.,  $n'(\cdot) < 0$ ,  $n''(\cdot) < 0$  and  $\gamma'(\cdot) < 0$ ,  $\gamma''(\cdot) < 0$ ). This means that, on average, both variables are lowered by higher policy uncertainty, implying lower average growth as well.

Given the above, it is natural to surmise that, in general, the correlation between average growth and policy variability will depend on the relative extent to which productivity improvements are the result of agents' own actions or the result of publicly-provided inputs. Interestingly, this conjecture proves to be misguided. An indication of this is given by the expression for  $f''(\mu)$  in (25), the sign of which appears unlikely to be ever positive, except for extremely high values of  $\varepsilon$ . This is confirmed by the results of numerical computations under various configurations of other parameter values. For all cases,  $f''(\mu)$  remains negative unless  $\varepsilon \cong 1$ . In summary, the model predicts that growth and volatility will be positively correlated only when productivity improvements depend almost exclusively on agents' own efforts. Even if public policy contributes only a small amount to productivity, the relationship will be negative.

#### 6. Conclusions

This paper has presented a model in which output and productivity growth are affected by the variability of monetary policy. Money is not neutral in this model for two reasons: first, money is used to finance public goods and services which contribute to human capital accumulation; second, the use of seignorage as a means of raising revenue impacts on agent's choices between different activities. The precise way in which growth is influenced by policy uncertainty differs according to the underlying mechanism through which productivity improvements occur. If this mechanism is based solely on agents' own actions, then growth is stimulated by uncertainty; if the mechanism relies purely on public goods provision, then growth is impeded by uncertainty. In general, when both forces are at work, the latter tends to dominate the former.

The model used in this paper is stylised in a number of respects which allow one to obtain analytical solutions. It would be interesting to develop a more general model and to conduct the same type of analysis using numerical simulations. Such a model could be used to allow for more general assumptions about preferences and technologies, more general assumptions about the stochastic processes governing shocks and more general assumptions about the government's financing decisions. Based on the results of the present analysis, this seems to be an avenue of research worth pursuing.

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