THE MONETARY POLICY EFFECTS ON SEIGNORAGE REVENUE IN A SIMPLE GROWTH MODEL

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Abstract

Monetary policy has two levers with which to manipulate seignorage revenue collection. Generally speaking, the inflation rate affects the tax rate while reserve requirements affect the size of the tax base. In this paper, I ask how seignorage revenue responds to changes in these two levers, both separately and together. Because both monetary policy variables affect the growth rate, the tradeoff is whether the growth-rate effects dominate the policy impact. I begin with an examination of statistical regularities between seignorage revenue and these two monetary policy measures, using cross-country data.

How do changes in monetary policy affect the seignorage revenue collected by the government? Lowering the inflation rate reduces the tax rate so that for a given tax base, revenue would fall. Lowering the reserve requirement ratio reduces the tax base so that for a given inflation rate, revenue would fall. These simple answers become less clear, however, if these policy actions result in faster growth.

The purpose of this paper is to investigate the impact that movements in both the inflation rate and reserve requirements have on the present value of seignorage revenue. The experiments considered here are of the following type: Will an anticipated change in the policy variable(s) permit the government to fund, in present-value terms, the same stream of expenditures under the new policy setting as under the initial setting.

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A substantial literature exists which studies the effects of the inflation tax on economic activity. Most of this literature, however, focuses on the business cycle behavior related to movements in the inflation rate.[1] Milton Marquis and Kevin Reffert (1995) examine the effects that changes in the inflation rate have on the growth rate in a version of Stockman's model in which cash-in-advance constraint applies to gross investment purchases. The upshot is that the inflation rate has implications for the growth rate. Philip Brock (1989) looks at how changes in the inflation rate and reserve requirement ratio can be used together to obtain the maximum steady-state level of seignorage revenue. Peter Ireland (1994) studies a similar question, but in terms of changes in fiscal policy; specifically, Do the growth-rate increases more than offset a reduction in income tax rates? Thus, the main contribution of this paper is to investigate the possibility that a dynamic Laffer curve exists for monetary policy.

The paper is organized as follows. In Section 1, I look for statistical regularities in seignorage revenue and monetary measures. The data are cross-country and the methods are similar to those used in looking at the relationship between output growth and its determinants. I specify a general equilibrium model in Section 2. The model specifies that seignorage revenue is the only source of government revenue. What is really important is that at least some capital purchases are financed via the intermediary. In Section 3, I calibrate the model and investigate the seignorage revenue impacts for the policy experiments. I modify the basic model to consider the seignorage revenue impacts for a model in which both income taxes and unintermediated capital are present. Section 5 offers a brief summary of the findings.

1. Data Analysis

In this section, I use *International Financial Statistics* data to examine low frequency co-movements between seignorage revenue and monetary policy measures. These results will be useful for calibrating the model in the experiments later on. Moreover, it will be interesting to identify some, if any, empirical regularities that exist between seignorage revenue and monetary policy variables.

Table 1 presents summary statistics for the 82 countries included in this sample. The data are averages of annual values of the ratio of seignorage revenue to GDP, real, per-capita GDP growth, the inflation rate, and the ratio of bank

[1] See, for example, Jeremy Greenwood and Gregory Huffman (1987) and Thomas Cooley and Gary Hansen (1989).

reserves to deposits.[2] The data span the period 1975-93.[3] Most noteworthy is the statistics presented in row 1 of Table 1, indicating seignorage revenue relative to GDP. On average, the 82 countries use seignorage revenue to generate slightly less than 0.9% of GDP.[4] New Zealand generates the smallest percentage of seignorage revenue relative to GDP while seignorage revenue accounts just over 4% of GDP in Malaysia.

The relationships between the monetary policy variables and seignorage revenue are summarized in Tables 2 and 3. Table 2 produces the simple correlation coefficients between seignorage revenue-to-GDP ratio and both inflation and the reserves-to-deposit ratio. There is a significant positive correlation between the reserves-to-deposit ratio and seignorage revenue relative to GDP. The coefficient between inflation and the seignorage revenue measure is small and negative, but not statistically significant. It is interesting to note that per capita output growth is positively related to the seignorage revenue-to-GDP ratio. Table 3 applies a nonparametric approach. Countries are identified as "high" ("low") seignorage revenue countries by adding (subtracting) 1/2 standard deviation to the mean ratio of seignorage revenue-to-GDP. Once identified, I then calculate the mean inflation rate and reserve ratio for the set of high and low countries. As Table 3 shows, high reserve requirement countries tend to be associated with high seignorage revenue countries. Similarly, the mean inflation rate is higher for those countries that rely most heavily on seignorage revenue.

Perhaps the finding that countries with a relatively high seignorage revenue-to-GDP ratio tend to have somewhat higher inflation rates than low seignorage-dependent countries is present because there is a nonlinearity in the inflation rate-seignorage revenue relationship. I consider a regression to determine if there

[2]The reserve requirement involves one of the more difficult data decisions in this paper. In general, reserve requirements are nonlinear functions of deposits in virtually every country. Ideally, a researcher would want the average marginal reserve requirement ratio. Unfortunately, the data necessary to construnt such a series are not readily available. My solution was to use the ratio of bank reserves-to-deposits, thinking that this ratio would serve as a rough measure of the reserve requirement. Here, deposits are defined as checking deposits and savings accounts. In most countries, these are the deposits against which reserves must be held.

[3]In the country tables in *International Financial Statistics,* banks reserves are item 24, deposits are the sum of items 24 and 25, real GDP is item 99, population is item 99z, and consumer prices are item 64.

[4]Stanley Fischer (1982) also examined the reliance on seignorage revenue by country. Compared with Fisher's data, the range of seignorage tax rates is a bit lower in the sample of countries. For a more detailed look, a list of the countries and mean values of several variables are included in the Data Appendix.

is curvature in the either the inflation-rate effect that are not picked up in the linear correlation coefficients. For symmetry, I also consider potential curvature in the relationship between the reserve ratio and the seignorage-GDP ratio. Such curvature could, for example, indicate either a hump- or U-shape in the relationship between the ratio of seignorage revenue to GDP and the monetary policy measures. Because I am using the ratio of seignorage revenue-to-GDP, however, the curvature implied by the regression does not imply anything about the relationship between the level of seignorage revenue and the inflation rate; that is, the Laffer curve. I run the following regression with a quadratic term to look for the curvature

$$s_i = \alpha_0 + \alpha_1 \pi_i + \alpha_2 (\pi_i)^2 + \alpha_3 \gamma_i + \alpha_4 (\gamma_i)^2 \tag{1.1}$$

where s denotes the ratio of seignorage revenue to GDP, π is the inflation rate, and γ is the reserve ratio. The results from equation (1) can be used to identify whether there is one turning point in the relationships between either the inflation rate- or reserve ratio-seignorage revenue ratio. If α_1 is positive and α_2 is negative, then there exists an inflation rate for which there is a maximum value for the ratio of seignorage revenue to GDP. Conversely, if α_1 is negative and α_2 is positive, there is a minimum value for the seignorage-GDP ratio associated with a particular inflation rate. The same holds for the reserve ratio, depending on the signs of α_3 and α_4. The maximum or minimum occurs for the inflation rate that solves $\pi^* = -\frac{1}{2}\frac{\alpha_1}{\alpha_2}$ and for the reserve-ratio that solves $\gamma^* =.-\frac{1}{2}\frac{\alpha_3}{\alpha_4}$.

The results of the regression are presented in Table 4. The quadratic form is useful in the sense that there is a nonlinearity present in the relationship between s and π. Indeed, the coefficients on both the inflation rate and its squared term are both statistically significant. Moreover, the sign on the inflation rate coefficients indicate that ratio of seignorage revenue-to-GDP is U-shaped in $s - \pi$ space. Indeed, the minimum s-value occurs at an inflation rate of 317%. For the range of inflation rates we observe in this sample, the regression results would be associated with the ratio of seignorage revenue-to-GDP as a decreasing function of the inflation rate. For the reserves-to-deposit ratio, the evidence suggests that a hump-shape is present in $s - \gamma$ space. The s-value maximum occurs at a reserve ratio approximately equal to 62%.

2. The Model

In this section, the model is presented. Initially, I assume that seignorage revenue is the only source of funding. This assumption will be relaxed in later sections.

2.1. Model specification.

The economy has four types of decisionmakers: firms, households, banks, and the government. In each period, firms maximize profits in a perfectly competitive market, renting capital, K, to produce the single consumption good, Y. Input markets are also perfectly competitive. Because the firm rents capital from the bank, the maximization problem reduces to a series of static problems. The implication is that firms sell output at the price, p, and rent capital up until the point where the marginal product equals its rental rate, q.

Production is determined by the common-knowledge technology. Let t denote the period where t = 0, 1, 2, ...The date-t production function is represented by

$$Y_t = AK_t. \tag{2.1}$$

Over time, capital depreciates at the fixed rate, δ, and expands via investment, X. I assume that the consumption is costlessly transformed into the capital good at a one-for-one rate. The law of motion for capital is then expressed as

$$K_{t+1} = (1-\delta)K_t + X_t \tag{2.2}$$

Following John Bryant and Neil Wallace (1980), I assume that there is a minimum investment size, κ , with $\kappa > y$,where y is per-capita income. I further assume that κ is a linear function of per-capita output.[5] The role for the bank, therefore, is to pool together small savers to acquire capital.

Households are infinitely lived with preferences described by the following CES utility function

$$U = \sum_{t=0}^{\infty} \beta^t \frac{c_t^{1-\sigma} - 1}{1-\sigma}, \tag{2.3}$$

where c denotes the quantity of the consumption good, $0 < \beta < 1$ is the time rate of preference, and $\sigma > 0$ is a parameter such that $\frac{1}{\sigma}$ is the elasticity of intertemporal substitution. I assume population is constant such that there is no aggregation bias associated with treating movements in per-capita quantities as equivalent to movements in aggregate quantities.

The household's date-t budget constraint is

[5] The linearity assumption ensures that small savers do not grow rich enough to meet the minimum investment size condition. If so, the bank would be dispensible. One way to motivate this assumption is appeal to a legal restriction the keeps banks from making loans smaller than some fraction of output.

$$R_t d_t + g_t = c_t + d_{t+1} \tag{2.4}$$

where d_t denotes the deposits (measured in units of the consumption good) carried over from date t-1 to date t, R is the gross real rate of return on deposits, and g is the per-capita lump-sum transfer payment given to households. In this setup, deposits are simply the stored consumption good. As such, the same intuition applies here as for models in which capital is valued as a stored consumption good. In addition, the household faces a terminal constraint. The idea is that the household can sell claims against future deposits, but never at a value greater than the level that can be repaid. Formally, the terminal constraint is represented as

$$\lim_{T \to \infty} \left[\frac{d_T}{\prod_{s=0}^{T-1} R_s} \right] = 0, \tag{2.5}$$

which guarantees that the period budget constraints can be combined into an infinite horizon, present value budget constraint. The CES momentary utility function has the property that $U_c \to \infty$, $c \to 0$. Hence, an interior solution for c_t and d_{t+1} is guaranteed.

The bank accepts deposits, using the proceeds to purchase real money balances and capital. Capital is then rented to firms at date t. Banks maximize profits in a perfectly competitive environment and the cost of providing banking services is zero. Every unit of capital returns A + (1-δ) units of the consumption good next period. Capital rate of return dominates money, but banks hold fiat money to satisfy a reserve requirement, γ_t.

Finally, the government can commit to a sequence of (aggregate) lump-sum transfers equal to G_t units of the consumption good to households. The only means of financing the expenditure is through seignorage revenue. The government budget constraint is, therefore,

$$G_t = \frac{M_t - M_{t-1}}{p_t}. \tag{2.6}$$

Taking the sequence of gross real interest rates as given, committing to sequence of lump-sum transfer payments is consistent with a sequence of reserve ratios and fiat money stocks, taking a sequence of deposits as given. To determine the price level, it is necessary to state the money market equilibrium condition:

$$M_{t-1} = \gamma_t D_t p_{t-1} \tag{2.7}$$

where D is the aggregate level of bank deposit. Money carried over from date t-1 purchases $\frac{1}{p_t}$ units of the date-t consumption good. Thus, the gross real rate of return on fiat money is $\frac{p_{t-1}}{p_t}$. I assume that capital rate of return dominates fiat money so that $A + (1-\delta) > \frac{p_{t-1}}{p_t}$. The policy rule guiding money is as follows: $M_t = \theta_t M_{t-1}$

2.2. Equilibrium and the balanced-growth equations

An equilibrium in this model economy is a sequence of prices $\{p_t, q_t, R_t\}$, real allocations$\{c_t, x_t, k_t\}$, stocks of financial assets $\{M_t, d_t\}$, and monetary policy variables $\{\gamma_t, \theta_t\}$ such that

(i) Given prices and monetary policy, the real allocations and stock of financial assets solve the household's maximization problem (2.3) subject to (2.4) and (2.5);

(ii) Given prices and monetary policy, the allocations solve the firm's date-t profit maximization problem;

(iii) Given prices and monetary policy, the stock of financial assets solve the bank's date-t profit maximization problem;

(iv) $M_{t-1} = \gamma_t D_t p_{t-1}$, and $c_t + k_{t+1} - (1-\delta)k_t = Ak_t, \forall t \geq 0$.

In this model economy, balanced growth means that output, consumption, and deposits will grow at the same rate in the equilibrium defined above. With capital offering a higher rate of return than fiat money, the demand for money in equation (2.7) characterizes one part of the banks' asset allocation decision. Thus, $K_t = (1-\gamma_t)D_t$. Thus, the return to the banks' portfolio (and to depositors) is:

$$R_t = (1-\gamma_t)[A + (1-\delta)] + \gamma_t \tfrac{p_{t-1}}{p_t}. \tag{2.8}$$

The return on deposits is the weighted average of the return to the two assets held by banks, capital and fiat money. With $\frac{p_{t-1}}{p_t} < A + (1-\delta)$, equation (2.8) implies that the return on deposits is inversely related to movements in the reserve requirement ratio.

The agent's first-order condition implies that output, deposits, and consumption will grow at the rate ρ_t. The rate along the balanced-growth path will be

$$\rho_t = (\beta R_t)^{\frac{1}{\sigma}} = \{\beta[(1-\gamma_t)(A+1-\delta) + \gamma_t \frac{p_{t-1}}{p_t}]\}^{\frac{1}{\sigma}} \tag{2.9}$$

Equation (2.9) implies that the economy's growth rate is inversely related to the reserve requirement ratio and to the inflation rate.[6] In this growth setting, the reserve requirement crowds out capital accumulation in the sense that capital accumulates at a slower rate. In the limit, with $\gamma = 0$, monetary policy becomes divorced from the economy's growth rate. As Jones and Manuelli (1995) show in a model in which there is a cash-in-advance constraint on the consumption good, the rate of return on capital is independent of changes in money growth. Slightly different from Jones and Manuelli, when $\gamma = 0$, there is no monetary equilibrium in this economy. The intuition is the Keynes-Ramsey rule, a decline in the return to the agent's portfolio relative to the time rate of preference increases current consumption, depressing capital accumulation and reducing growth.

With $\gamma > 0$, the relationship inflation and money growth is the quantity theory. Equation (2.7) together with the balanced-growth condition that $\frac{D_{t+1}}{D_t} = \rho_t$ implies that $\theta_t = \rho_t \pi_t$. From equation (2.9) and the balanced-growth equation in the money market, it is trivial to show that economy's growth rate is inversely related to money growth. The intuition is exactly the same as that employed in the discussion of changes in the reserve requirement ratio. Faster money growth (hereafter, higher inflation) is inversely related to the gross real return on deposits.

In the remainder of this paper, I will focus on cases in which the reserve requirement ratio and inflation rate are constant over time. As Robert King and Sergio Rebelo (1990) note, the agent in this model economy has finite utility if and only if $\beta\rho^{1-\sigma} < 1$. This condition will hold in all the experiments considered throughout this paper.

3. Monetary Policy Experiments

In this section, I consider the impact of changes in monetary policy on seignorage revenue. In particular, I am interested in the following case: suppose that the present value of government expenditures is G_0 for the baseline setting of the monetary policy parameters, say γ_0 and π_0.[7] Can fund the same level of government spending, altering either the reserve requirement ratio, the inflation rate, or

[6]Both David Romer (1985) and Scott Freeman (1987) show how reserve requirements crowd out the level of private capital in a stationary economy.

[7]It is easier to pick the inflation rate and find the money growth rate that is consistent as defined by the moneygrowth-inflation relationship. For nonzero reserve requirements, money growth is a nonlinear function in the inflation rate. Thus, there are multiple inflation rates associated wtih a particular rate of money growth.

both?

3.1. Calibration

Obviously, to begin the experiments, it is necessary to select parameter values for the model. For this analysis, the model economy's period is assumed to correspond to one year. Following King and Rebelo, the growth rate of technology (ρ) is 2%. Following Jones and Manuelli, I choose $\sigma = 2$ and $\delta = 0.1$. For the inflation rate and reserve ratio, I use the average values reported in Table 1; that is, $\pi = 1.21$ and $\gamma = 0.17$. I choose $A = 0.165$, and $\beta = 0.95$.[8] Throughout, this analysis, I will set the initial capital stock, K_0, equal to 1.

3.2. Computational experiments

To characterize the present value of the government's budget constraint, I note that real government expenditures are growing at the same rate as the economy, so that the ratio of government spending to output will remain constant. Let $\alpha = G_t/Y_t$. Then, with $K_0 = 1$, the date-t value of government expenditures can be written as

$$G_t = \alpha A\{\beta[(1-\gamma)(A+1-\delta)+\frac{\gamma}{\pi}]\}^{\frac{t}{\sigma}}. \tag{3.1}$$

Substituting the money supply rule and equation (2.7) into equation (3.1) yields

$$(\theta-1)\frac{\gamma D_t}{\pi} = \alpha A\{\beta[(1-\gamma)(A+1-\delta)+\frac{\gamma}{\pi}]\}^{\frac{t}{\sigma}}. \tag{3.2}$$

Further substitution of the banks' asset allocation gives the date-t government budget constraint as a function of reserve requirement, money growth/inflation rate, and the capital stock; that is,

$$\frac{(\theta-1)\gamma}{(1-\gamma)\pi}K_t = \alpha A\{\beta[(1-\gamma)(A+1-\delta)+\frac{\gamma}{\pi}]\}^{\frac{t}{\sigma}}. \tag{3.3}$$

[8] An alternative method of choosing the time rate of preference is to find the gross-after-reserve requirement return and then calculate the ratio of the gross rate of technology change by the after-reserve requirement return. For these parameter settings, R= 1.0232, so that $\beta = 0.997$. This approach, used in King and Rebelo, would yield a discount factor that seems a bit high for a period as long as a year.

From equation (3.3), it is straightforward to show that date-t real seignorage revenue (the left-hand-side) is positively related to reserve requirement and to the inflation rate. Next, summing over all dates, the present value of the government budget constraint is represented as:

$$PVG = \sum_{t=0}^{\infty}(R)^{-t}[\frac{(\theta-1)\gamma}{(1-\gamma)\pi}K_t - G_t^0]. \tag{3.4}$$

The next step is to characterize the change in the present value government budget constraint for a given change in monetary policy.[9] For example, let the baseline reserve requirement-inflation combination be associated with the baseline present value of government expenditures; denoted, G_0. Let the baseline parameter settings be denoted γ^0 and π^0. Then, let the "new" parameter settings be denoted γ^1 and π^1. The object is to find the present-value of government revenue under different policy settings. Consider a case in which the reserve requirement ratio is the only policy parameter altered. With $K_0 = 1$, the government can fund the same sequence of transfer payments if and only if

$$d(PVG) = \sum_{t=0}^{\infty}\frac{(n^1-n^0)K_t}{[(1-\gamma^1)(A+1-\delta)+\gamma^1]^t} \geq 0 \tag{3.5}$$

where $n^1 \equiv \frac{(\theta-1)\gamma^1}{(1-\gamma^1)\pi}$, $n^0 \equiv \frac{(\theta-1)\gamma^0}{(1-\gamma^0)\pi}$, and $K_t = \beta[(1-\gamma)(A+1-\delta)+\frac{\gamma}{\pi}]^{\frac{t}{\sigma}}$. From equation (3.5), one can see that changes in reserve requirements affects the present value government budget constraint through three channels. First, seignorage revenue is positively related to changes in reserve requirements through the tax base effects. In short, the quantity of money agents will hold is positively associated with movements in reserve requirements. Second, the path of capital accumulation is inversely related to changes in reserve requirements; that is, the growth-rate effect. The Laffer-curve tension in the monetary policy experiments considered here are due to whether the tax base (or tax-rate effect in the case of a change in the inflation rate) dominates the growth-rate effect. Third, the discount factor present in the denominator of equation (3.5) is inversely related to the return on deposits, and thus the reserve requirement.

[9] Note that in these experiments, the question is posed in terms of the present value of government expenditures. It is likely that the path for seignorage revenue will not be identical for the two different economies being analyzed, even though the present value of government revenues are the same. The government might need to borrow or lend to smooth the period-by-period differences, but implicitly the present value of government debt is zero so that no wealth effects are present.

With $R > 1$, equation (3.5) can be further simplified to the following expression,

$$d(PVG) = \frac{n^1}{R^1 - (\beta R^1)^{\frac{1}{\sigma}}} - \frac{n^0}{R^1 - (\beta R^0)^{\frac{1}{\sigma}}} \tag{3.6}$$

where $R^1 = (1-\gamma^1)(A+1-\delta) + \frac{\gamma^1}{\pi}$; and $R^0 = (1-\gamma^0)(A+1-\delta) + \frac{\gamma^0}{\pi}$. Because monetary policy has an ambiguous effect, the next step is to apply numerical techniques to calculate the effects on $d(PVG)$; that is, using reasonable parameter values, can the same sequence of transfer payments be financed with a lower reserve requirement?

Figure 1 presents the change in PVG given a change in the reserve ratio from 17.3%.[10] According to Figure 1, then government can afford the same level of government spending if it raises the reserve ratio. Lowering the reserve ratio, however, results in a shortfall in the present value of seignorage revenue. Figure 1, therefore, indicates that there is no dynamic Laffer curve present in the model economy for changes in the reserve ratio. Note the curve present in $d(PVG)$ at reserve ratios greater than 22%. For these parameterizations, it is not possible to determine whether $d(PVG)$ would evenutally become negative because utility would be infinite.

Another question is, How does the ratio of seignorage revenue to output respond to changes in the reserve ratio? I calculate the date-1 levels of both seignorage revenue and output for this model economy. With $\gamma = 0.173$ and $\pi = 1.214$,real seignorage revenue was slightly more than 20% of output.[11] The ratio seignorage revenue to output is monotonically increasing the reserve ratio for this model economy, ranging from 0.011 when the reserve ratio is 1% to 0.3096 when the reserve ratio is 25%. Thus, the model is capable of accounting for the positive association between the seignorage revenue-to-GDP and reserve ratios present in the correlation coefficient. Because the relationship between the seignorage-to-GDP ratio is monotonically increasing in the reserve ratio, it is not clear whether the model economy can account for the hump-shape present in the data. Finally, note that the model economy's dependence on seignorage revenue is substantially larger than any we observe in the data.

[10] Note that $\gamma > 0.25$ was not considered in this case because of the finite utility restriction.

[11] This large seignorage tax rate owes mostly to the assumption that capital is intermediated. This means that the tax base is as large as possible. I relax the intermediation-only constraint in the next section.

The next experiment looks for the impact that changes in the inflation rate have on seignorage revenue. Here, I consider inflation rates from 0% to 80%. Figure 2 plots the change in PVG compared with the policy combination in which $\pi = 1.21$ and $\gamma = 0.17$. Figure 2a is dominated by a huge spike in $d(PVG)$. Figure 2b plots the case in the maximum inflation rate is 40% What the plot shows is that the change in PVG is small over most of the range of inflation rate values with a pronounced spike occurring between $\pi = 1.65$ and $\pi = 1.66$. At these two values, we see that the real return on deposits at the "new" policy setting (R^1 in equation (3.6)) is approaching $(\beta R^0)^{\frac{1}{\sigma}}$ from above. Consequently, at $\pi = 1.65$, the denominator in the second term in (3.6) is a large positive number, resulting in the first term in equation (3.6) nearly zero and $d(PVG)$ is negative. Then, at $\pi = 1.66$, the sign of the denominator in the second term switches, resulting in $d(PVG)$ becoming a large positive number. Even though $d(PVG)$ is negative for a higher inflation rate economy, this is not the growth-rate versus tax-rate opposition that is behind the Laffer curve. Figure 2b focuses on moderate inflation rates. For values of the inflation rate between 1.0 and 1.40, there is no evidence of a dynamic Laffer curve; that is, compared with $\pi = 1.214$, an increase in the inflation rate results in an increase in the present value of seignorage revenue while for a decrease in the inflation rate results in a decline in the present value of seignorage revenue. However, for $\pi > 1.45$, the amount of seignorage revenue falls compared with what one would obtain with $\pi = 1.214$. Thus, for a big enough change in the inflation rate, the model economies indicate that the tax-rate effect will be swamped by the growth-rate effect.

For the inflation rate experiments, the ratio of seignorage revenue-to-GDP ranges from 2.3% when the inflation rate is zero to over 96% for the case in which the inflation rate is 80%. Thus, the model economies indicate that seignorage revenue is quite a large proportion of output for the case in which the one calibrates the model using the mean values obtained in the cross-country sample. Moreover, the model economy cannot account for the U-shaped pattern in the cross-country relationship between the inflation rate and the ratio of seignorage revenue-to-GDP. There is, however, some evidence that a dynamic Laffer curve operates for cases in which the inflation rate changes.

4. A Model with unintermediated capital

I modify the economy such that there exists a substitute for intermediated capital. In words, the agents now have access to capital purchases that do not require an intermediary. The model has the feature that both intermediated and unintermediated capital can be held simultaneously. This specification also matches with Raymond Goldsmith's (1969) finding that the ratio of the intermediary's assets to output will increase over time. In addition, I include an income tax to the policy mix.

In this setup, the two types of capital are perfect substitutes in the production process. As such, firms will use each type of capital provided there are no arbitrage opportunities. In other words, both intermediated and unintermediated capital should offer the same gross real return. Unintermediated capital is not subject to a reserve requirement, but has a diminishing marginal product. Let the technology transforming unintermediated capital into the consumption good be described as

$$B(K^u)^\omega, \tag{4.1}$$

where K^u denotes the stock of unintermediated capital. With population constant, this the familiar Cobb-Douglas production technology. The arbitrage condition maintains that agents will purchase unintermediated capital up until the point at which its gross return is the same as the gross return on intermediated capital. Formally,

$$(1-\gamma)[A+(1-\delta)]+\frac{\gamma}{\pi}=\omega B(K^u)^{\omega-1}+1-\delta. \tag{4.2}$$

At date t=0, I assume that the two types of capital sum to one. Thus, equation (4.2) can be used to solve for K^u. Once we know K^u, then the stock of intermediated capital is simply 1-K^u.

In this setup, the limiting condition is that all capital will be intermediated. Thus, the presumption is that intermediation possesses an advantage over direct financing after a large enough capital stock has been accumulated. This assumption is partially supported by the stylized fact presented in Raymond Goldsmith's book. Goldsmith observed that the ratio of banks' asset to output had been rising over the period 1869-1963. With $A < 1$, balanced growth implies that the ratio of intermediated capital to output rises.

There are additional calibration issues associated with model extension. Specifically, the unintermediated capital productivity term, B, and the exponent on unintermediated capital, ω. For the computational experiments, I set $B = 0.25$ and $\omega = 0.35$.

Figure 3 plots $d(PVG)$ associated with a change in the reserve ratio. The experiment sets the "initial" policy combinations as before. The main result in

Figure 3 is that $d(PVG)$ increases (falls) for those cases in which the reserve ratio is lower (higher) than 17%. With unintermediated capital included in the model, the growth-rate dominates the tax-base effect for changes in the reserve ratio. Thus, with two types of capital in the model, the government can spend the same amount, in present-value terms, by lowering the reserve-requirement ratio because the additional growth more than offsets the reduction seignorage revenue that occurs because of a reduction in the tax base. In short, there is a dynamic Laffer curve operating in this model economy. The intuition behind this quantitative result is that there is substitution between the two types of capital. With unintermediated capital , a reduction in the reserve ratio makes intermediated capital relatively more attractive, which partially offsets the reduction in the tax base that accompanies the reduction in the reserve ratio. In this experiment, the elasticity of substitution between unintermediated and intermediated capital is large enough so that the growth-rate effect can dominate the net reduction in the tax base.

Introducing unintermediated capital into the model also affects the relationship between the ratio of seignorage revenue-to-GDP and the reserve ratio. First, the range of the ratio narrows dramatically when compared with the model economy in which only intermediated capital is available. At $\gamma = 0.01$, seignorage revenue is only 0.36%% of GDP at date 1. The maximum seignorage revenue-to-GDP ratio is 4.3% which occurs with $\gamma = 0.19$. This range of outcomes is well within the range we observe in the cross-country data. Second, there is a hump-shape exhibited in the relationship between seignorage revenue and the reserve ratio. Figure 4 shows this pattern in the model economy's data. Thus, there is date-specific Laffer curve operating on the seignorage revenue in response to movements in the reserve ratio. Here, an increase in the reserve ratio means that households substitute unintermediated capital for intermediated capital. Hence, the tax base can either rise or fall, depending on whether the stock of intermediated capital falls more or less than the reserve requirement ratio. Figure 4 shows that for this model economy, the decline in intermediated capital more than offset the increase in the reserve requirement ratio for reserve ratios above 19%.

Next, I run the inflation-rate experiments in the economy with two types of capital. Figure 5 plots the change in the present value of government revenues for different values of the inflation rate. Figure 5a plots the entire range of inflation rates considered while Figure 5b plots the outcomes for values of π between 1.0 and 1.4. Figure 5a is dominated by the spike that arises as R^1 approaches $(\beta R^0)^{\frac{1}{\sigma}}$ from above. As one can see, $d(PVG)$ is positive for case in which π is below its initial value of 1.214 and becomes negative for values above this initial setting. This evidence indicates that there is a dynamic Laffer curve. As π falls, the growth-rate effect on $d(PVG)$ is opposite to the impact corresponding to the lower tax rate. The results for this model economy indicate that the growth-rate effect dominates the tax-rate effect for $\pi \in [1.0, 1.45]$. For higher inflation rates, the reduction in the tax rate appears to be larger than the growth rate gains in that $d(PVG)$ is positive. As in the reserve-requirement experiments, an increase in the inflation rate results in households substituting for unintermediated capital and away from intermediated capital. In the case of higher inflation rates, real seignorage revenue is positively affected by the higher tax rate, but negatively affected by a reduction in the real reserves held by banks. On balance, the growth-rate is given greater weight when compared against the net change in date-t real seignorage revenue.

Finally, the question is whether the model with two types of capital can account for the U-shaped pattern present in the $s - \pi$ relationship. Interestingly, the ratio of seignorage revenue-to-GDP is negative in this model economy for very low inflation rates. For example, with zero inflation, $\theta < 1$, so that date-t seignorage revenue is negative. So, instead of seignorage revenue, the economy exhibits a seignorage subsidy at low inflation rates. Figure 6 plots the ratio of seignorage revenue-to-output for the range of inflation rates considered. There is pronounced hump-shaped pattern in s as the π increases, attaining a maximum of 0.0438 when $\pi = 1.25$.

Thus, the model economy with two types of capital is successful on two fronts, failing on a third. First, and not surprisingly, a model with unintermediated capital produces ratios of seignorage revenue-to-output that are closer to what we observe in the actual data across countries. Second, the model economy can account for the hump-shaped pattern in the relationship between the seignorage revenue-to-output ratio and the reserve ratio. The failure is that model cannot account for the U-shaped pattern in the relationship between seignorage revenue-to-output and the inflation rate.

One can break the ratio of real seignorage revenue-to-output down to better understand why s is positively related to inflation at low inflation rates. At low inflation rates, real seignorage revenue, the numerator in the ratio is positively related to inflation while the denominator, output, is negatively related to inflation. With low inflation rates, an increase π causes households at date-t to substitute unintermediated capital for intermediated capital, which in turn leads to a reduction in real money balances in the model economy. The tax rate increase more than offsets decline in the tax base, accounting for the rise in real seignorage revenue. Output declines as both types of capital become less productive. In the model economy, s reaches a maximum because real seignorage revenue begins to decline faster than output. Evidently, at high enough inflation rates the movement in the tax base becomes so small that higher tax rates no longer can offset the reduction in real money balances.

Suppose that the two monetary policy parameters move together. Table 5 reports the results in which the inflation rate is regressed on the reserve ratio, using the cross country data. The data show that every one-percentage-point increase in the reserve requirement is associated with a 1.2-percentage-point increase in the inflation rate. I run a set of experiments using the model economy with two types of capital, using the regression results to guide a coordination scheme. The results, plotted in Figure 7, show that the hump-shaped pattern prevails. this is not too surprising since the reserve requirement and inflation rate together have reinforcing effects on seignorage revenue and on output. The hump appears after the policy actions crowd out enough intermediated capital so that seignorage revenue responds to higher reserve requirements by falling at a faster rate than output.

5. Summary and conclusions

The purpose of this paper is to examine the relationships between seignorage revenue and two monetary policy parameters–reserve requirements and the inflation rate. I begin by reviewing some the evidence examined in Fischer's (1982) paper on seignorage revenue across countries. The data answer a basic question, What has happened since Fischer investigated this seignorage across countries. On the empirical side, the contribution of this paper is to look for correlations between seignorage revenue relative to GDP and the monetary policy variables. Interestingly, the cross-country evidence shows that seignorage revenue as a proportion of GDP exhibits a hump-shaped pattern with respect to reserve ratios; that is, starting from low reserve ratios, one sees that the ratio of seignorage revenue-to-GDP is positively correlated with reserve requirements. At some level, however, the seignorage revenue-to-GDP ratio reaches a maximum and falls as the reserve ratio rises further. With the respect to the inflation rate, the data indicate that the seignorage revenue-to-GDP ratio exhibits a U-shaped pattern

I specify a simple endogenous growth model to determine whether one can account for this stylized fact and to ask whether there is a Laffer curve for monetary policy actions. Including the reserve requirement means that the government can experiment with tax rates, the tax base, or both. In my experiment, the government can finance a stream of expenditures (read, lump-sum transfers) with known present value for a given monetary policy course. The computational experiment is to determine whether the government can finance the same present value of expenditures, changing either reserve requirements, the inflation rate, or both. I run this computational experiment for a member of the Ak-class of economies in which all capital is intermediated and also for a model economy in which there are two types of capital-intermediated and unintermediated. The tension arises in these models because while one can raise seignorage revenue directly by raising either the inflation rate or reserve requirement, both courses of action will depress growth.

The results of the experiments can generalized as follows. In the Ak model, there is no dynamic Laffer present. Moreover, the ratio of seignorage revenue-to-GDP in these model economies are both monotonically increasing in the monetary policy variables, thus failing to account for the stylized facts found in the cross-country data. Besides the growth-rate effects being swamped by the tax rate/base-effects in the model economies, the economies produce ratios of seignorage revenue-to-GDP that are roughly five times the *maximum* ratios found in the data.

There is some success in the models with two types of capital. These model economies obviously relax the assumptions that all capital is intermediated. With this feature, it is possible to match the seignorage revenue-to-GDP ratios as one introduces inter-capital substitution into the model. In this setup, a dynamic Laffer curve is present, the growth-rate effect dominates the tax rate/base effects. An increase in the monetary policy variables have the same growth-rate effects as in the Ak model. Here, however, an increase in either policy variable results in a substitution from intermediated capital to unintermediated capital, partially offsetting the positive effects that an increase in the inflation rate or reserve requirement has on seignorage revenue. In addition, the ratio of seignorage revenue-to-GDP exhibits the hump-shaped pattern in response to movements in reserve requirements. Unfortunately, the same pattern is present in the relationship between the seignorage revenue-to-GDP ratio and the inflation rate. At high-enough values for the policy variables, enough intermediated capital is crowded out so that seignorage revenue falls more than output falls, resulting in a decline in the seignorage revenue-to-GDP ratio. Can one account for different response patterns between the seignorage revenue-to-GDP ratio and the two monetary policy variables by coordinating monetary policy actions? The answer is no;

the cross-country data indicate that the policy variables are positively correlated with one another.

Though the model economies fails in attempting to account for the relationship between the seignorage revenue-to-GDP ratio and inflation, the results do point to some features that a model would have, thus providing a useful guide for future research. The seignorage revenue-to-GDP ratio will fall as long as growth falls at a slower rate than seignorage revenue. Hence, future research would aim for an approach in which the growth-rate effects are a bit smaller. The model economies studied in this paper possess growth-rate effects that are a bit too large compared with what we observe in actual cross-country data. In addition, it would seem useful to raise the sensitivity of the tax base to movements in the inflation rate in the model economies, such that real seignorage revenue decreases when the inflation rate rises even at moderate inflations. In these model economies, the interaction between the inflation and the reserve requirement means that real seignorage revenue is going to be about as sensitive to both monetary policy variables. The inability of model economies to account for the U-shaped pattern in the ratio of seignorage revenue-to-GDP and inflation rate data is not amenable to a quick fix. Preliminary experimentation with these model economies shows that seignorage revenue-to-GDP tends to have the same pattern response to a movement in reserve requirements as to a movements in the inflation rate.

Table 1
Summary Statistics
Sample period 1975-94
(N = 82)

Variable	Mean	Stnd Dev	Min	Max
s	0.0088	0.0088	0.0009 (N.Zealand)	0.0491 (Malaysia)
GDP_t/GDP_{t-1}	1.0211	0.0237	0.9717 (Rwanda)	1.0874 (Algeria)
P_t/P_{t-1}	1.214	0.643	1.0421 (Switzerland)	1.848 (Chile)
R_t/D_t	0.1734	0.1422	0.0065	0.7119

Table 2
Correlation with Seignorage revenue-GDP ratio
(N=82)

Variable	Corr Coeff
GDP_t/GDP_{t-1}	0.29*
P_t/P_{t-1}	-0.04
R_t/D_t	0.42*

Table 3
Country Characterics by
Seignorage revenue-GDP ratio
(N=82)

Variable	"High" ratio ($N_H = 14$)	"Low" ratio ($N_L = 27$)
P_t/P_{t-1}	1.2041	1.3124
R_t/D_t	0.2884	0.0967

Table 4
Regressions Results
Dependent Variable — s_i
(N=82)

Variable	Coeff	Stnd. Error
Intercept	0.024	0.01
π_i	-0.025	0.011
$(\pi_i)^2$	0.003	0.001
γ_i	0.069	0.018
$(\gamma_i)^2$	-0.056	0.028

S.E.E. = 0.0077

adj $R^2 = 0.23$

Table 5
Monetary Policy Coordination Tests

$\pi_i = 1.007 + 1.196\gamma_i$

Stnd. Errors: intercept = 0.108, γ_i = 0.485
S.E.E. = 0.623, adj R^2 = 0.06

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Figure 1

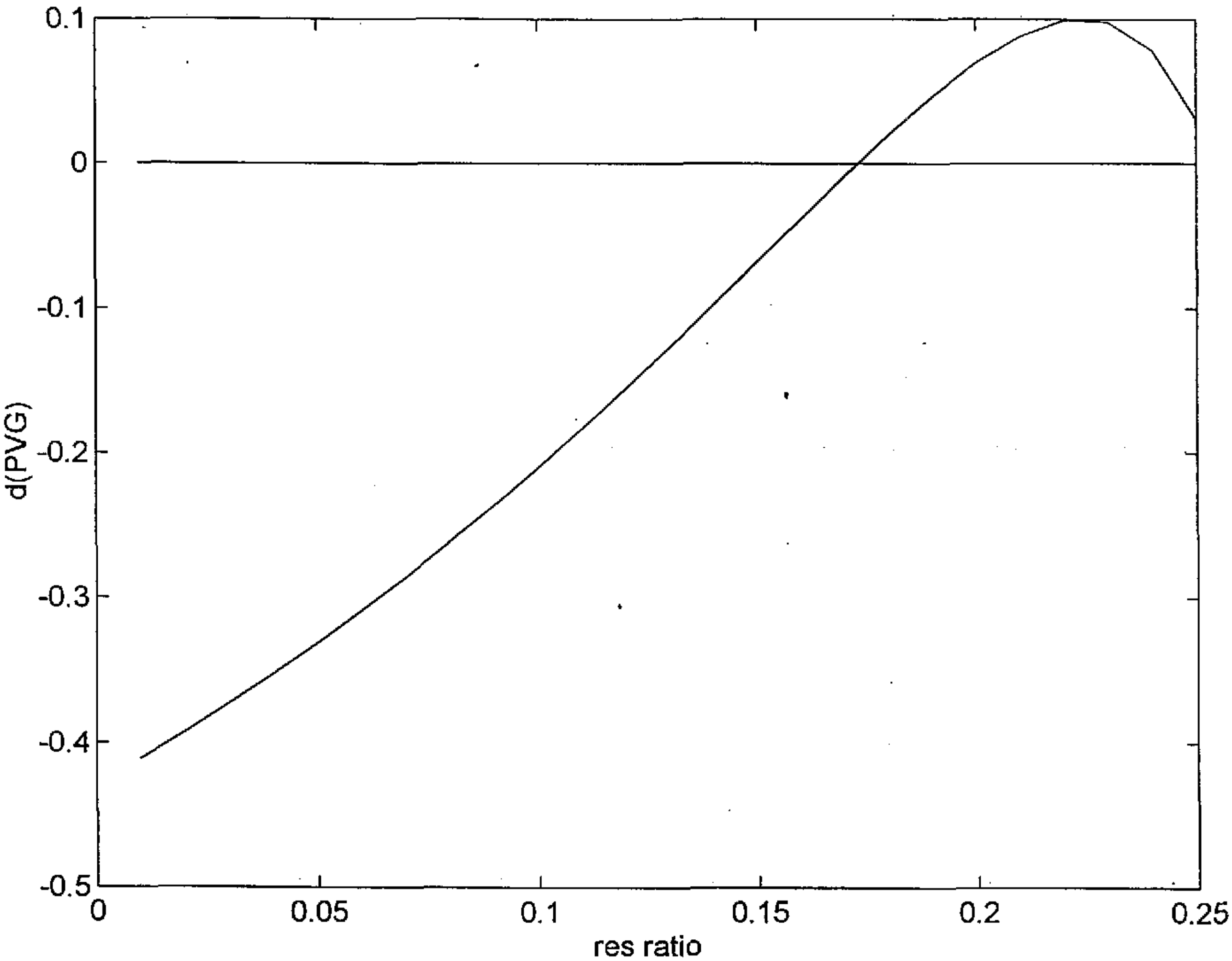
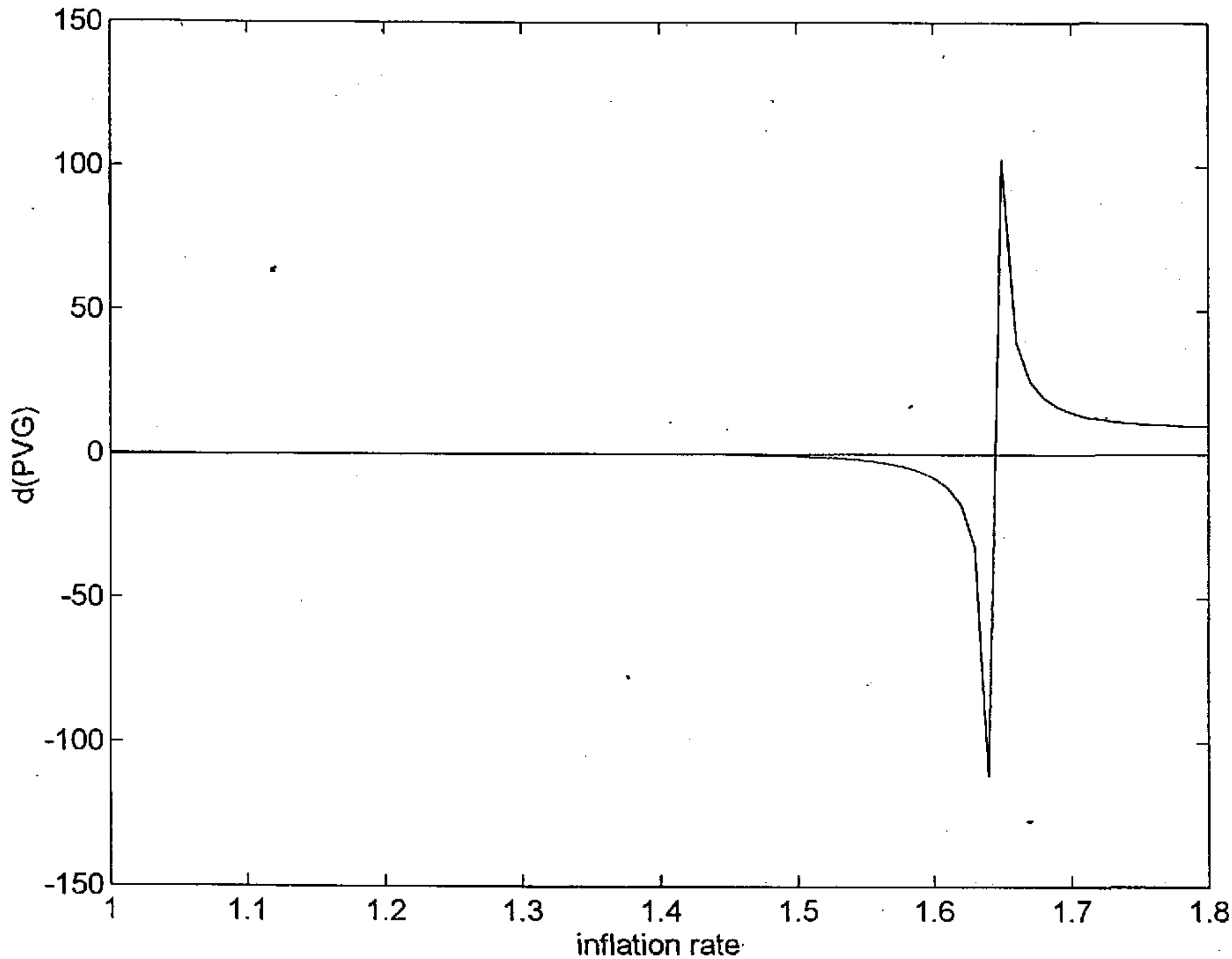


Figure 2a



150
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-50
-100
-150
d(PVG)
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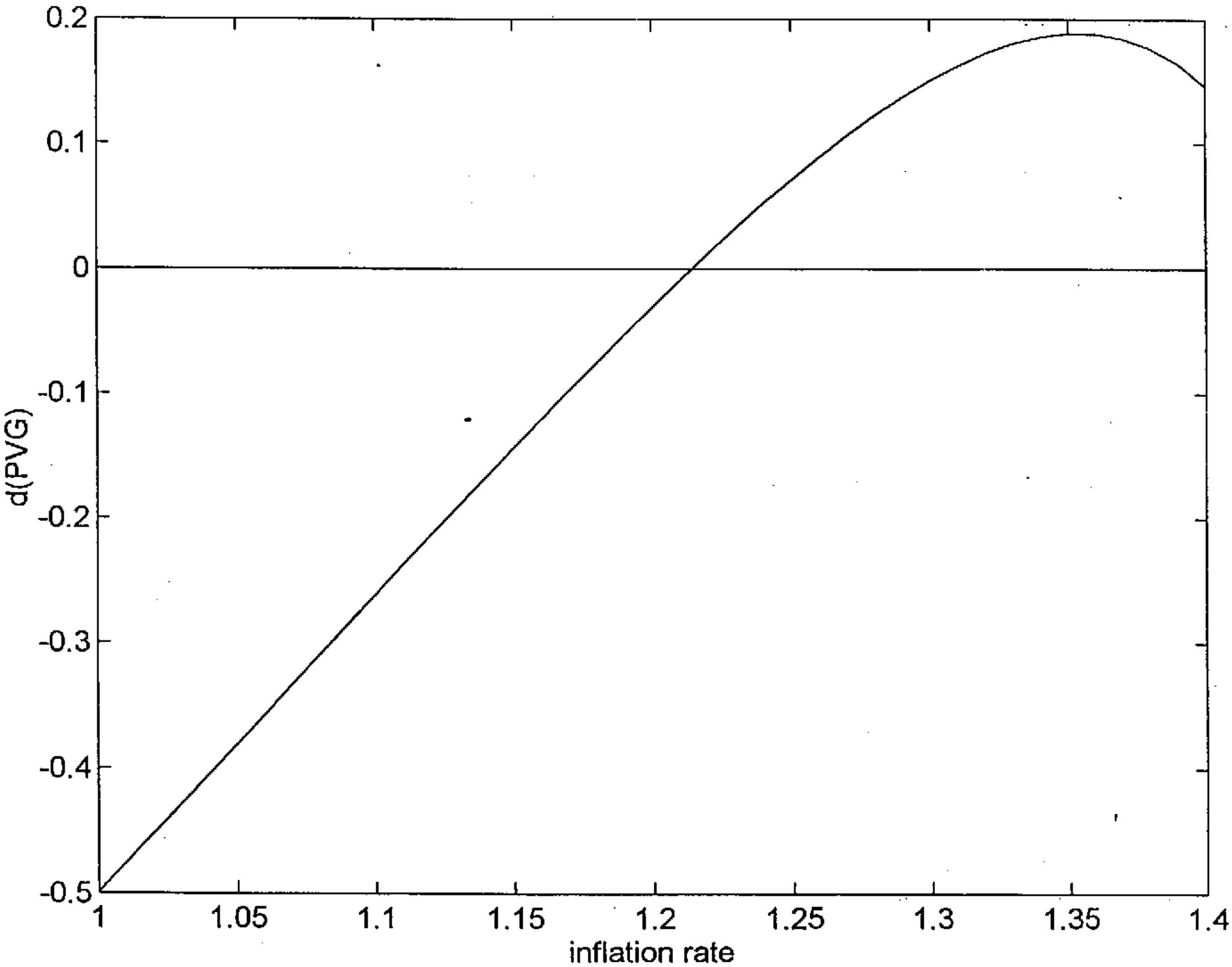
1.3
1.4
1.5
1.6
1.7
1.8
inflation rate

Figure 2b


0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
d(PVG)
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1.15
1.2
1.25
1.3
1.35
1.4
inflation rate

Figure 3

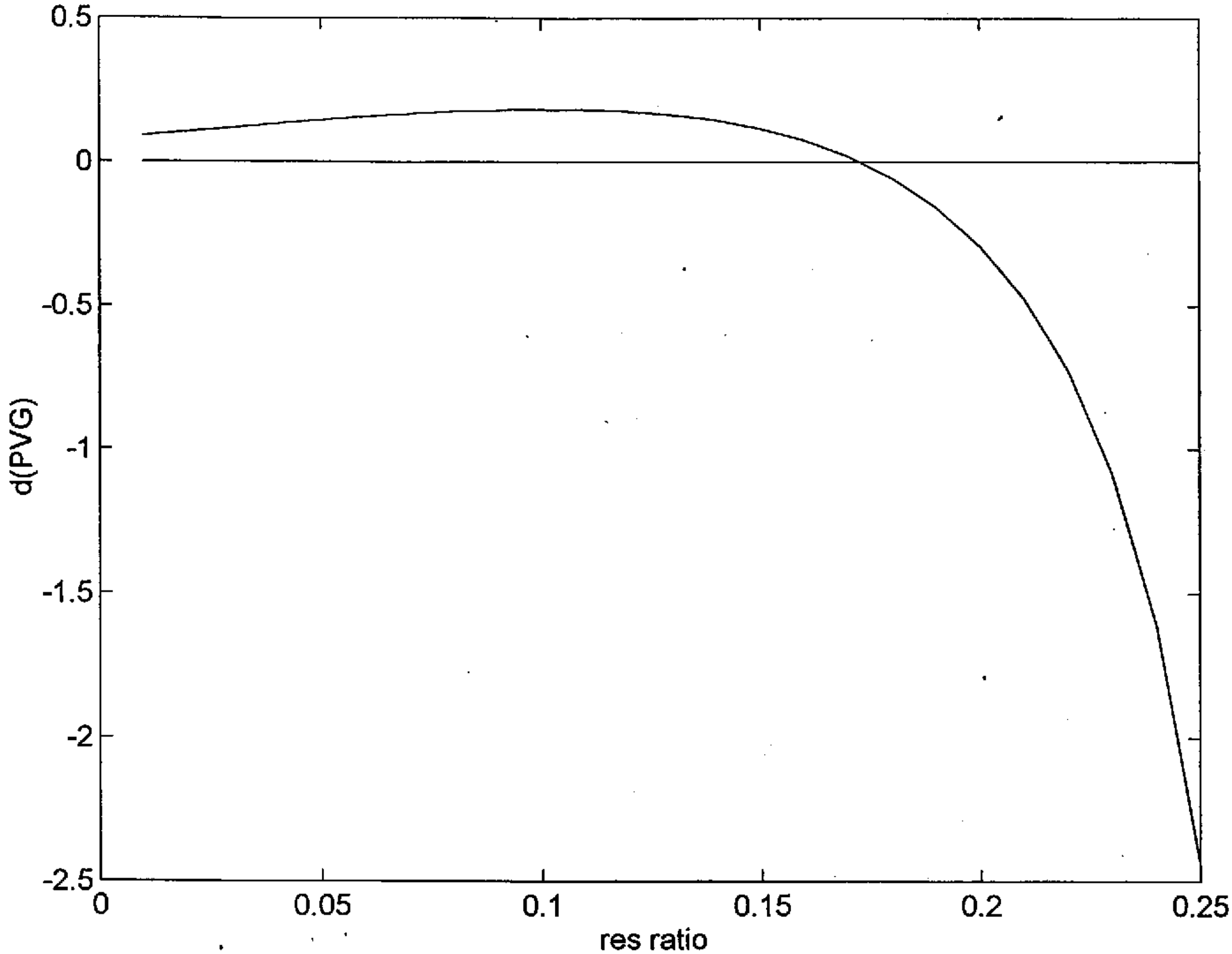

Figure 4

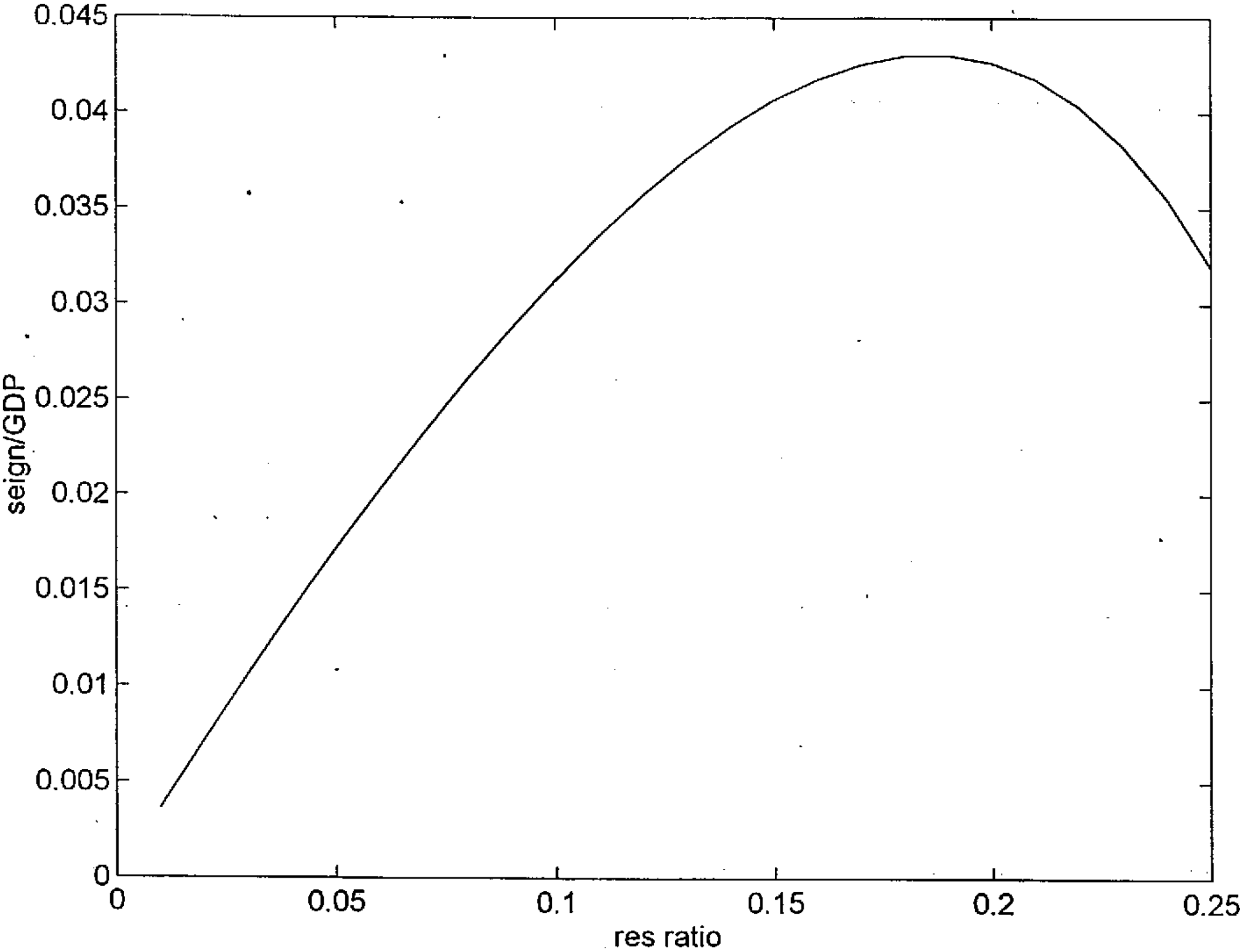

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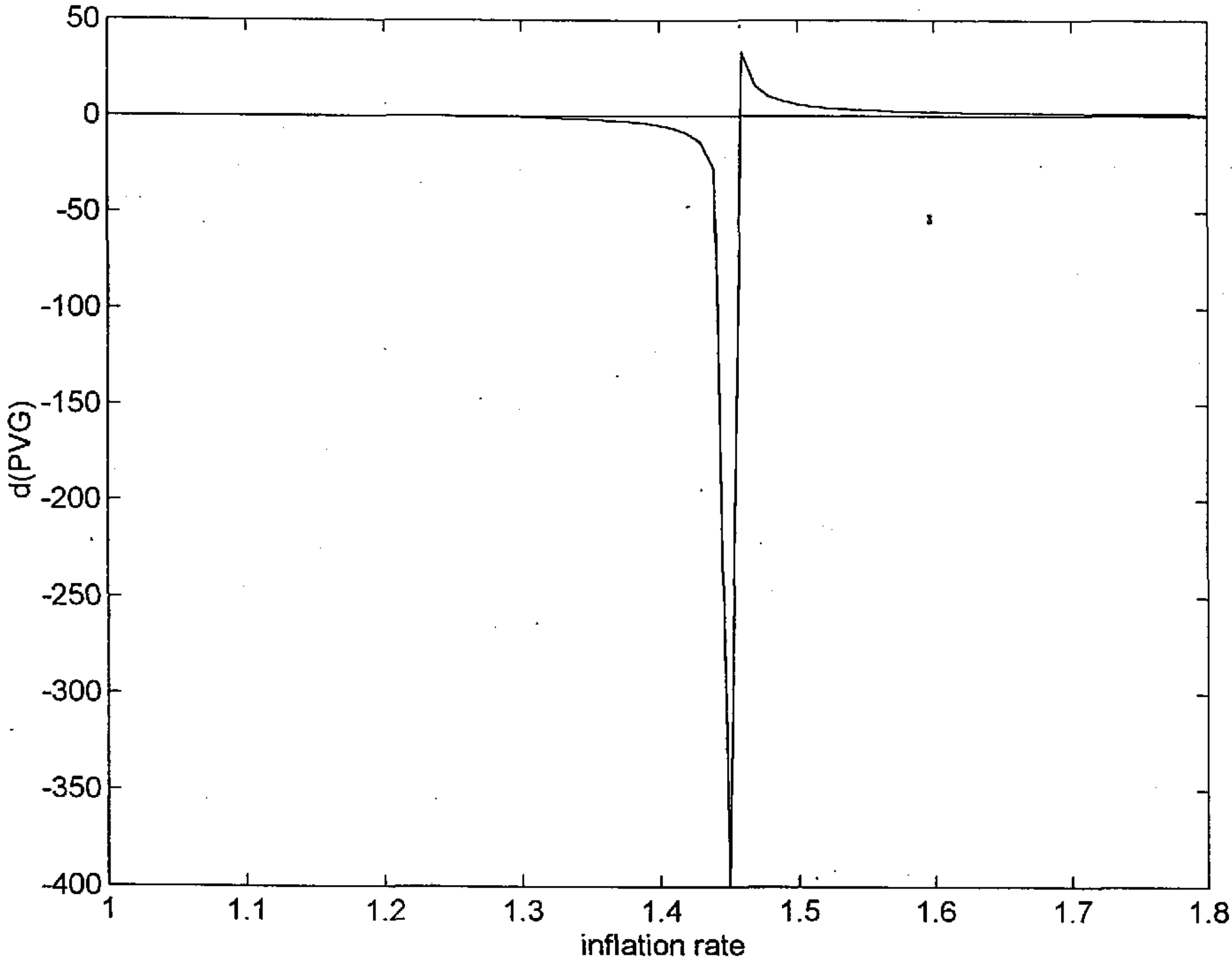
Figure 5a



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-300
-350
-400
d(PVG)
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1.7
1.8
inflation rate

Figure 5b

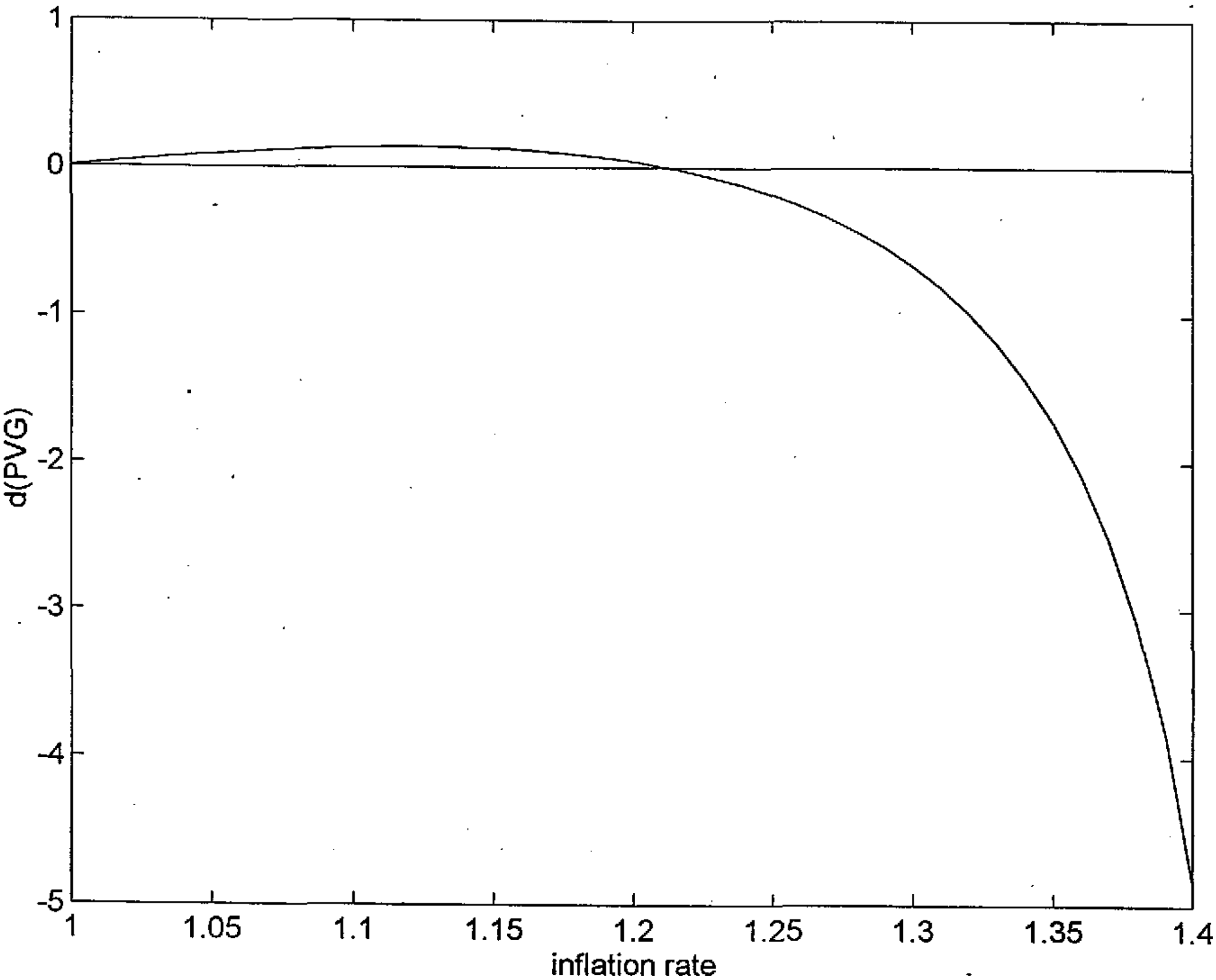
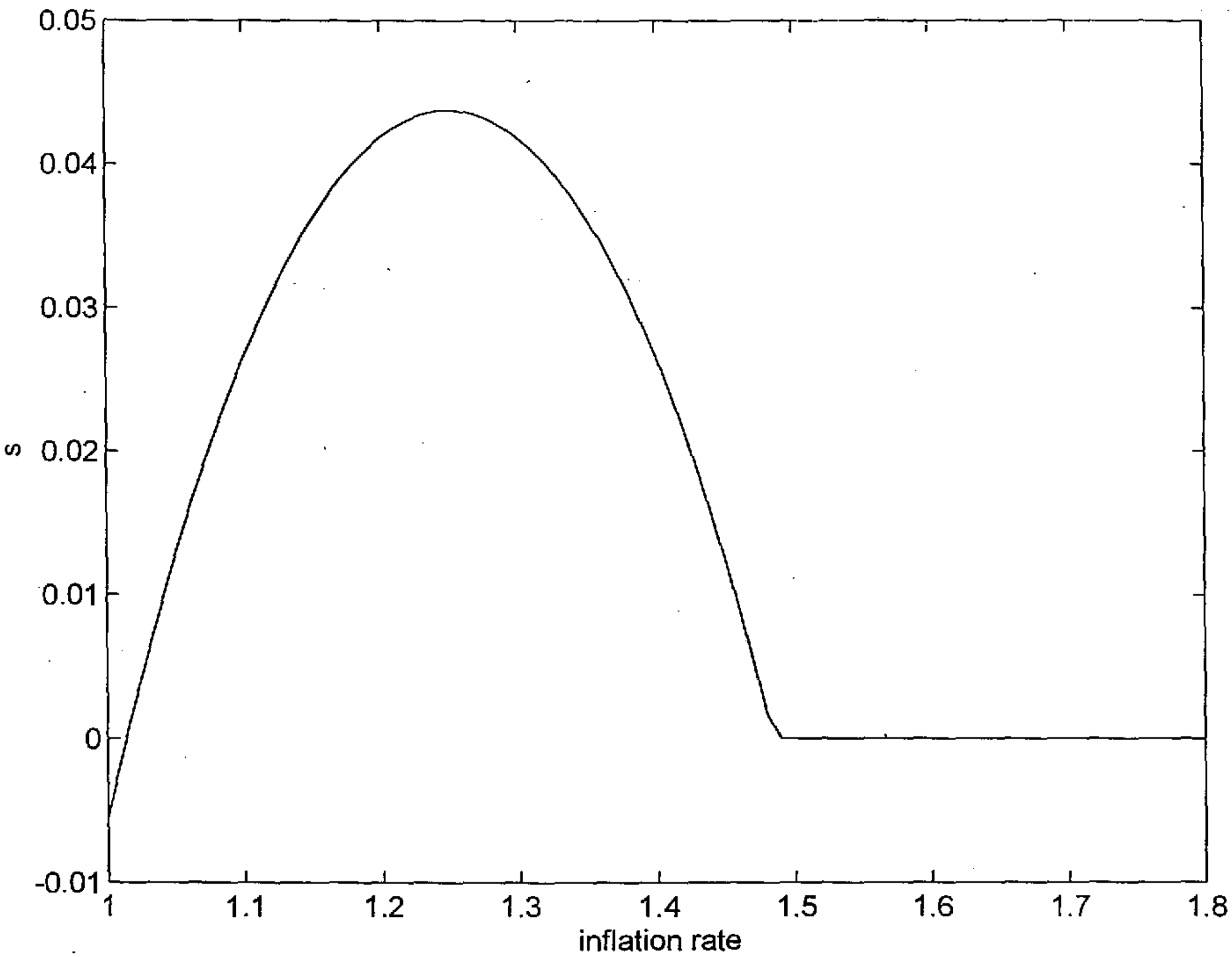


Figure 6



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1.6
1.7
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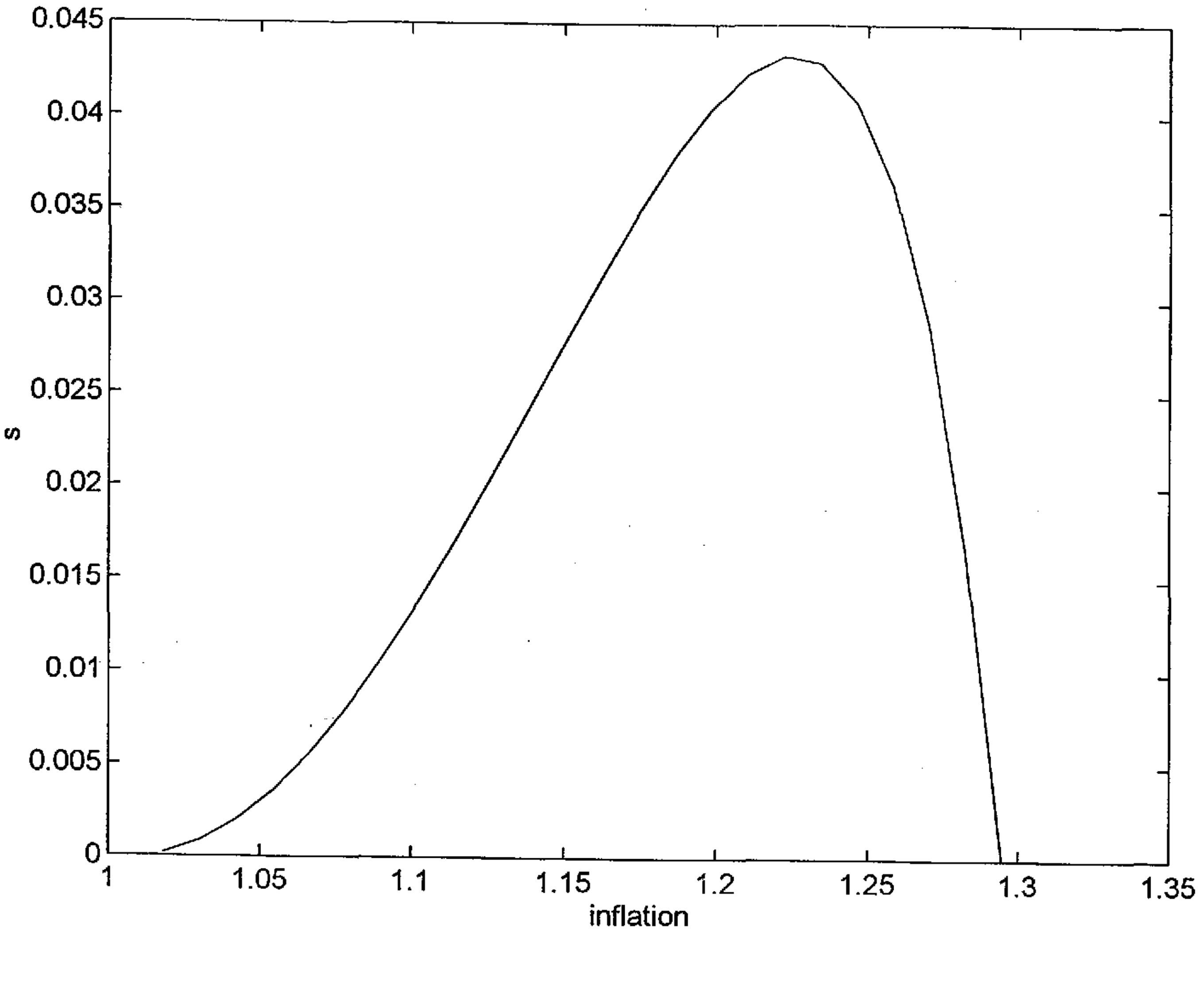
inflation rate

Figure 7



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1.35
inflation

Data Appendix

Country Name	Avg. Growth Per Capita Output	Avg. Inflation	Avg. Res Ratio	Avg. Change in Base Money / Nominal GDP
Algeria	8.736	11.547	26.097	0.873
Australia	1.662	8.156	6.145	0.245
Austria	2.557	4.734	6.155	0.428
Bahrain	4.239	6.116	23.710	1.653
Bangladesh	1.324	13.048	71.193	1.437
Barbados	5.806	8.316	13.753	1.083
Belgium	2.364	5.507	2.1683	0.211
Burundi	1.563	9.207	11.789	0.421
Cameroon	1.808	8.740	5.027	0.300
Canada	1.944	6.361	4.318	0.184
Chile	1.873	84.800	32.544	2.406
Congo	0.841	6.914	4.920	0.337
Costa Rica	1.959	18.672	30.691	1.421
Cote d'Ivoire	-0.201	7.876	7.421	0.298
Cyprus	4.549	70.029	67.465	0.684
Denmark	1.796	7.097	3.406	0.290
Domin. Rep.	2.043	17.996	37.092	0.731
Ecuador	2.587	27.301	31.677	0.763
El Salvador	0.339	9.046	11.702	0.578
Ethiopia	-1.375	8.545	26.045	1.234
Finland	2.179	8.008	4.923	0.333
France	2.051	7.237	3.403	0.165
Gabon	8.364	7.285	5.330	0.125
Gambia	1.603	12.823	21.064	0.568
Germany	1.666	3.840	9.486	0.520
Ghana	-0.422	40.056	42.606	0.442
Greece	2.378	16.171	19.717	0.877
Grenada	-0.446	12.780	28.276	3.677
Guatemala	0.557	12.728	24.383	0.540
Guyana	0.078	20.879	21.118	1.913
Honduras	1.353	37.997	30.855	0.216
Iceland	3.635	29.897	23.488	0.148
India	4.637	12.434	20.928	0.420
Indonesia	6.992	11.050	12.626	0.655
Ireland	3.465	9.667	10.992	0.473
Israel	0.905	8.811	23.953	3.204
Italy	2.659	10.859	15.638	0.748
Jamaica	2.953	8.664	9.566	1.283
Japan	2.682	5.232	2.318	0.538
Jordan	2.387	15.287	32.141	2.241
Kenya	0.832	14.055	10.823	0.858

Korea	4.339	4.451	8.312	1.217
Lesotho	1.657	14.095	20.307	0.831
Madagascar	-2.155	12.897	11.168	0.441
Malaysia	8.264	6.589	56.480	4.913
Maldives	0.883	9.791	14.331	0.980
Malta	6.516	4.278	27.128	4.267
Mexico	2.304	17.139	45.287	0.789
Morocco	1.806	7.478	5.378	0.997
Myanmar	2.254	10.581	17.190	0.586
Nepal	5.902	9.583	11.550	1.296
Netherlands	1.773	4.611	0.648	0.417
New Zealand	1.132	10.177	4.656	0.087
Niger	0.440	5.204	21.205	0.585
Nigeria	0.986	21.231	14.796	0.628
Norway	2.918	7.471	1.834	0.256
Pakistan	0.968	14.425	13.101	0.672
Papau New Guinea	0.768	7.202	13.214	0.217
Paraguay	1.601	62.727	31.639	1.880
Phillipines	6.758	4.372	8.363	1.341
Portugal	3.517	16.177	13.800	1.325
Rwanda	-2.834	9.053	15.314	0.278
Senegal	-0.571	6.868	11.855	0.556
Seychelles	5.984	8.791	7.800	0.861
Sierra Leone	-0.224	43.375	38.757	0.671
Singapore	5.240	6.561	5.261	0.652
South Africa	-0.300	12.330	5.254	0.221
Spain	2.322	11.230	11.211	0.722
Sri Lanka	2.117	8.648	11.410	1.064
St.Lucia	5.115	6.738	15.138	1.230
St.Vincent	0.559	11.080	17.064	0.295
Sudan	-1.228	38.474	33.912	0.830
Sweden	1.326	7.993	2.629	0.489
Switzerland	1.164	4.213	8.889	0.323
Syria	2.403	13.674	12.160	0.597
Thailand	4.260	11.145	2.777	1.970
Trinidad & Tobago	-0.210	6.341	7.634	0.703
United Kingdom	1.826	9.220	4.696	0.175
United States	1.441	5.921	4.858	0.271
Uruguay	0.066	18.360	19.182	0.562
Venezuala	1.429	9.337	8.661	0.417
Zambia	-2.096	45.542	22.043	0.485

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