Revenue-Maximizing Monetary Policy

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January 1998

Research Department

Working Paper

98-01

Federal Reserve Bank of Dallas

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Abstract

In this paper, we examine the impact that changes in the rate of money creation and reserve requirements have on real seigniorage revenue. We consider two additional features that differ from previous analyses. First, the model economies grow endogenously, and that growth depends on the accumulation of intermediated capital. Second, agents have two means of financing; one is bank deposits against which reserves must be held and the other is a nonbank intermediary. Thus, growth-rate effects and financing-substitution effects are both present, and one can assess the quantitiative importance of each factor.

1. Introduction[1]

What effect do monetary policy actions have on real seigniorage revenue? Researchers have long been interested in the answer to this question. To note just a few, Bailey (1956) applied partial-equilibrium analysis, establishing the result that maximum seigniorage revenue was obtained when elasticity of money demand with respect to the inflation rate equalled one. Friedman (1971) showed that Bailey's result held if output was constant. In Friedman's more general setting, both the growth rate and elasticity of money demand with respect to output affected the revenue-maximizing inflation rate. Brock (1989) extended Friedman's result, changing the setting from a partial equilibrium to a general equilibrium setup. Easterly, Mauro, and Schmidt-Hebbel (1995) derive the seigniorage-maximizing

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inflation rate in a continuous-time Ak-model which allows money and bonds to be used for transactions, noting that the revenue-maximizing inflation rate falls as the elasticity of substitution between money and bonds rises.

The purpose of this paper is to examine the effects that two monetary policy actions–changes in reserve requirements and money creation–have on the present value of real seigniorage revenue. Our aim to use the different model economies to quantitatively assess the importance of several mechanisms through which monetary policy might operate. In particular, we are interested in assessing the importance of the relationship between monetary policy actions and growth within the context of real seigniorage revenue. In addition, we are interested in the relationship between monetary policy actions and the development of the financial system, focusing on how such development might affect the revenues earned from money creation.

The statistical relationship between inflation and growth has been documented by numerous authors, including Fischer (1991), DeGregario (1992), and Gomme (1993). Our question is, supposing monetary policy actions do influence the rate of growth, how important are the growth-rate effects on the present value of real seigniorage revenue? We view the experiments as natural extensions of the literature on tax policy and growth. Ireland (1994), for example, examined the supply-side considerations of income-tax policy, computing the rate that maximizes the present value of income tax revenue.

Another way in which monetary policy can affect the quantity of real seigniorage revenue is through its effects on the equilibrium quantity of real base money. We consider two ways in which this could happen: substitution among different methods of financing capital and substitution among different means of payment. For the first channel, we examine an economy in which two means of financing are available. More specifically, households can use either bank deposits or nonbank contracts to finance capital accumulation. The banks face a reserve requirement, which is the mechanism through which monetary policy actions affect the rate of growth. Faster money creation or higher reserve requirements reduce the rate of return offered in the competitive banking industry. Nonbank contracts do not face a reserve requirement but do incur a resource cost for each unit of capital financed. Households will switch from bank deposits to nonbank contracts when money growth or the reserve requirement increases, an effect we refer to as disintermediation. We can then assess how important this channel is for real seigniorage revenue.

Another way in which monetary policy might affect the quantity of real base money is through the means of payment. We look at an economy in which the household has a choice between paying for goods with credit or with cash. Clearly, the household's decision regarding the holding of currency or paying with credit affects the size of the tax base upon which real seigniorage revenue is generated.

By focusing on revenue maximization, we ignore welfare considerations. The baseline model has two equivalent optimal policy settings: set the reserve requirement ratio equal to zero or apply the Friedman rule so that the gross inflation rate is equal to the household's time rate of preference.[2] Our sense of history is that sovereign nations generally do not follow either of these two welfare-maximizing policy prescriptions. Rather than search for models in which observed policy settings are close to optimal, we look at standard models and consider the seigniorage-revenue implications of different monetary policies.

Our results can be summarized as follows. In each model economy, we focus on the quantitative magnitudes of the tensions present. Our results show that if monetary policy affects the growth rate, revenue-maximizing values for both the inflation rate and reserve ratio are less than 10%. With currency in the model, the revenue maximizing inflation rate and reserve ratio are both around 20%. Coincidentally, the revenue-maximizing reserve ratio and inflation rate is quite close to the mean values we compute from our multi-country dataset.

The paper is organized as follows. In Section 2, we describe the baseline model economy. Computational experiments are presented in Section 3. To assess the importance of the different effects, we modify the basic economy to eliminate the growth-rate effect and the capital-substitution effect in Section 4. In Section 5, we extend the model economy to include currency and the role of substituting alternative means of payments. We review the findings and suggest several extensions in Section 6.

2. The Baseline Model

In this paper, growth-rate and disintermediation effects are opposite to the "direct" effects associated with the monetary policy variables. The seigniorage tax

[2]See Chari, Christiano, and Kehoe (1996) for recent findings on the optimal monetary policy. In Mulligan and Sala-i-Martin (1996), the authors consider an alternative motive for holding fiat money–shopping-time– and derive different settings for optimal monetary policy. In this paper, we used a rationale for holding fiat money that is more like the Chari, Christiano, and Kehoe setup. Dotsey and Ireland (1996) consider welfare in an environment where using credit as a means of payment requires labor effort.

rate is positively associated with the inflation rate. The bank holds fiat money to satisfy a reserve requirement. Consequently, the seigniorage tax base, holding everything else constant, is positively related to the reserve requirement. In contrast, output growth is inversely related to both the inflation rate and the reserve requirement. Thus, the growth-rate effect translates into a tax base that increases at a slower rate. Moreover, a higher inflation rate or reserve ratio, for instance, has a one-time allocative effect, causing households to shift from acquiring capital through the bank to acquiring capital through the nonbank intermediary. Throughout this paper, we refer to changes in the means of financing as disintermediation, though strictly speaking all capital is intermediated in this model economy. The computational experiments show the change in the present value of real seigniorage revenue for different values of the inflation rate and the reserve ratio.

The economy is populated by five types of decision-makers: firms, households, banks, nonbank intermediaries, and the government. Firms rent capital from banks, producing units of the consumption good. Banks offer deposit contracts, maturing in one period, to households. The deposits are used to acquire capital or fiat money. Households receive the principal and interest from the deposit contracts and the (gross) rental payments from the capital plus any undepreciated capital to acquire consumption, capital, or deposits.

The nonbank intermediary (hereafter, nonbank) also offers one-period contracts to households. Each nonbank contract stipulates that the nonbank accepts one good from the household, promising to repay the household next period with R^n goods. The nonbank then uses these contracts to acquire capital, which is then rented to firms in a competitive market to produce the capital-consumption good. The gross return on nonbank contracts, unlike deposits, is determined by the quantity of good received by the nonbank. To this end, we assume that the nonbank faces a resource cost $f(k^n)$, where k^n stands for the number of contracts executed with the nonbank.

The government taxes capital income and makes lump-sum transfer payments to households. The government can finance a deficit in any period by issuing one-period bonds. The bond sells for b_t^g units of the consumption good and pays off $R_{t+1}b_t^g$ units one period later. For simplicity, we assume that government bonds and capital are perfect substitutes. Throughout the analysis, we assume that the quantity of government debt is small enough that bonds, deposits, and nonbank contracts will be held by households.

2.1. Model Specification

We assume that there are a large number of identical households who solve the following problem:

$$\max \sum_{t=0}^{\infty} \beta^t \left(\frac{c_t^{1-\sigma} - 1}{1-\sigma} \right) \tag{P1}$$

$$s.t.: c_t + b_{t+1}^g + d_{t+1} + k_{t+1}^n \leq R_t d_t + R_t^n (b_t^g + k_t^n) + G_t \tag{2.1}$$

where d_{t+1} denotes the quantity of goods deposited with the bank at time t, k_t^n denotes the stock of nonbank contracts available at time t, R_t denotes the gross real return on deposits, R_t^n denotes the gross real return offered on nonbank contracts and government bonds, τ_t denotes the tax rate on both bank-financed and nonbank-financed capital, and G_t denotes the value of the government transfer.[3] We assume the time rate of preference, β, lies in the open unit interval. Similarly, capital depreciates at a constant rate, with $0 \leq \delta \leq 1$. The constant elasticity of substitution parameter, $1/\sigma$, is strictly positive. Finally, population is constant so that there is no aggregation bias associated with treating per-capita quantities as aggregate quantities.

Equation 2.1 is a fairly standard budget constraint. The household uses proceeds from bank deposits, government bonds, and nonbank contracts plus the real value of government transfer payments to acquire units of the consumption good and storage. Goods can be stored for future consumption by acquiring deposits, government bonds, or nonbank contracts. Here, we are assuming that government bonds and nonbank contracts are perfect substitutes.

Letting λ_t denote the Lagrangian multiplier, the consumer's first-order conditions are:

$$\beta^t c_t^{-\sigma} - \lambda_t = 0 \tag{2.2}$$

$$\beta^{t+1} c_{t+1}^{-\sigma} - \lambda_{t+1} = 0 \tag{2.3}$$

$$\lambda_{t+1} R_{t+1} - \lambda_t = 0 \tag{2.4}$$

[3]Income taxes will not play a crucial role in the experiments. In equilibrium, the rate of return on deposits will depend on the income tax rate. We also conducted the quantatitive analysis with $\tau = 0$. The results for the no-income-tax case are not materially different from those reported here and are available from the authors upon request.

$$\lambda_{t+1}R^n_{t+1} - \lambda_t = 0 \tag{2.5}$$

$$R_t d_t + R^n_t(b^g_t + k^n_t) + G_t - c_t - d_{t+1} - k^n_{t+1} - b^g_{t+1} = 0 \tag{2.6}$$

where the first-order conditions, equations (2.2)-(2.6), are taken with respect to c_t, c_{t+1}, d_{t+1}, b^g_{t+1} (and k^n_{t+1}), and λ_t, respectively. Equations (2.4) and (2.5) imply that deposits, government bonds, and nonbank contracts will offer the same rate of return in equilibrium. In addition, a transversality condition is necessary to ensure the existence of the household's present-value budget constraint. The household's terminal constraint is interpreted as a no-Ponzi-condition in which the household cannot borrow against the sum of future deposits, nonbank contracts, and government bonds, at a rate greater than can be repaid. Formally, the transversality condition is represented as

$$\lim_{T\to\infty}\left[\frac{b^g_T + k^n_T + d_T}{\prod_{s=0}^{T-1} R_s}\right] = 0 \tag{2.7}$$

As such, the date-t budget constraint (2.1) can be combined into an infinite horizon, present value budget constraint. We now describe the environment from the perspective of the other types of decisionmakers in the model economy. Throughout our analysis, we assume that units of the consumption good can be transformed into units of capital at a one-for-one rate.

The firm rents capital from either banks or nonbanks, using it to produce the capital-consumption good. Capital is perfectly substitutable in the production process and the firm is a price-taker in the input market. The production technology is of the form

$$Y_t = A(k_t + k^n_t) \tag{2.8}$$

where k_t is the stock of intermediated capital rented from banks and $k^n_t$is the stock of capital rented from the nonbank. The laws of motion for bank-financed and nonbank-financed capital are:

$$k_{t+1} = (1-\delta)k_t + x_t, \tag{2.9}$$

$$k^n_{t+1} = (1-\delta)k^n_t + x^n_t, \tag{2.10}$$

where x_t and x_t^n denote the amount of investment added in time t. The rental price of bank-financed and nonbank-financed capital, denoted q_t and q_t^n, are determined competitively.

Because the firm rents capital from two sources at a competitively determined price, profit maximization simplifies to a series of static problems. Formally, the firm's problem is written as

$$\max_{k_t, k_t^n} A(k_t + k_t^n) - q_t k_t - q_t^n k_t^n \tag{P2}$$

The first-order conditions for the firm are $A = q = q^n$. (We drop the time subscripts since A is not dependent on time.)

Banks accept one-period deposits from the households, using the proceeds to acquire capital and fiat money. Capital is then rented to firms and fiat money is held to satisfy a reserve requirement imposed by the government. The bank maximizes profits in a perfectly competitive environment. For simplicity, we assume that the bank costlessly provides intermediary services. Because the deposits are one-period contracts, the bank's infinite-horizon program reduces to a sequence of static problems. When deposits are liquidated, the bank transforms its assets into the consumption good. Hence, each unit of capital rented to firms returns $A + (1 - \delta)$ units of the consumption good.

Because fiat money is rate of return dominated by capital, the reserve requirement γ_t dictates how much fiat money the bank will hold. In short, rate-of-return dominance implies that the asset allocation constraint, $\gamma_t p_{t-1} d_t \leq m_t$, is binding at each date t, where m denotes the per-household quantity of fiat money balances. The bank's profit-maximization problem is

$$\max_{k_t, m_t, d_t} (A + 1 - \delta)k_t + \frac{p_{t-1} m_t}{p_t} - R_t d_t \tag{P3}$$

subject to the reserve-requirement constraint and a balance-sheet identity, which is represented as $k_t + \frac{m_t}{p_t} = d_t$. Thus, the bank's first-order conditions can be represented as

$$R_t = (1 - \gamma_t)(A + 1 - \delta) + \frac{\gamma_t}{\pi_t} \tag{2.11}$$

where $\pi_t \equiv \frac{p_t}{p_{t-1}}$ denotes the rate of inflation. Equation (2.11) indicates that the rate of return on deposits is inversely related to the inflation rate and the reserve ratio.

Capital can also be acquired from the nonbank intermediary. We move on to the problem solved by the nonbank. The nonbank intermediary accepts goods with the promise to pay off the contract one period later. With one-period contracts, the nonbank maximizes a series of static problems. Formally, the nonbank's date-t profit maximization problem is given by

$$\max_{k_t^n} (A+1-\delta)k_t^n - f(k_t^n) - R_t^n k_t^n \tag{P4}$$

The nonbank's first-order condition is

$$R_t^n = (A+1-\delta) - f'(k_t^n). \tag{2.12}$$

As we have already noted in the household's problem, the return to nonbank contract and bank deposits will be equal in equilibrium.

In the data, both banks and nonbanks are used to finance capital accumulation. For our model economy to match this observation, there must be some wedge between the return offered on nonbank contracts and the marginal product of capital. We introduce the resource cost, denoted $f(k_t^n)$, as a way to generate an equilibrium in which both bank deposits and nonbank contracts would coexist. Without the resource-cost function, nonbank contracts would rate-of-return dominate bank deposits. We assume the resource-cost function has a positive marginal cost function; that is, $f'(\cdot) \geq 0$. Moreover, we assume that the resource-cost function is convex; that is, $f''(\cdot) \geq 0$. It is fairly straightforward to show that the arbitrage condition requires that $f''(\cdot) \geq 0$ for the model economy to exhibit disintermediation. Formally, $\frac{dk^n}{d\gamma}$ and $\frac{dk^n}{d\pi}$ are nonnegative as long as the resource-cost function is convex.[4]

The nonbank's resource-cost function is structured so that some properties of the model economy match some observations in the actual data. For example, Goldsmith (1969) finds that the ratio of bank assets-to-GNP had an upward trend during the period 1869-1963. With $A < 1$, our model economy can account for Goldsmith's observation. There is a price for this setup. In our model economy, the ratio of investment financed through bank deposits to output is constant along the balanced-growth path. However, the ratio of investment financed through nonbank contracts to output approaches zero. Thus, all growth is financed with capital financed through the bank. This aspect of the model economy is not

[4]The resource cost can be interpreted as a monitoring cost incurred because the nonbank does not have access to specialized banking resources. Bernanke (1983) has cited the loss of these specialized resources as a major propagation mechanism for the Great Depression. This specification is isomorphic to one in which households pay a monitoring cost to observe the nonbank's behavior.

observed in the data. One way to get around this problem is to make all growth exogenous. Another way would be to introduce technological innovation into the nonbank sector captured as changes in $f(\cdot)$ over time. In addition, we consider stationary economies later in this paper, thereby eliminating growth as a channel through which monetary policy can affect seignorage.

Finally, the government commits to a sequence $\{G_t\}_{t=0}^{\infty}$ of transfers which are financed by a combination of taxes and seigniorage. The government's budget constraint is

$$R_t b_t^g + G_t = \frac{m_t - m_{t-1}}{P_t} + \tau_t A[k_t + k_t^n] + b_{t+1}^g.$$

The government has at its disposal two tools of monetary policy: the reserve requirement and the rate of money growth. We assume that money evolves according to the policy rule: $m_t = \theta_t m_{t-1}$, where θ is the money growth rate. Moreover, the government's ability to issue debt is constrained such that

$$\lim_{T\to\infty} \left[\frac{b_T^g}{\prod_{s=0}^{T-1} R_s}\right] = 0$$

which ensures the government's infinite-horizon, present-value budget constraint exists.

2.2. Equilibrium and balanced-growth equations

An equilibrium in this model economy is a sequence of prices $\{p_t,\ q_t,\ q_t^n,\ R_t,\ R_t^n\}_{t=0}^{\infty}$, real allocations $\{c_t,\ x_t,\ x_t^n,\ k_t,\ k_t^n\}_{t=0}^{\infty}$, stocks of financial assets $\{m_t,\ d_t,\ b_t^g\}_{t=0}^{\infty}$, and policy variables $\{\gamma_t,\ \theta_t,\ \tau_t, G_t\}_{t=0}^{\infty}$ such that

(i) the real allocations and stocks of financial assets solve the household's maximization problem, (P1), given prices and policy variables;

(ii) the real allocations solve the firm's date-t profit maximization problem, (P2), given prices and policy variables;

(iii) the stock of financial assets solve the bank's date-t profit maximization problem, (P3), given prices and policy variables;

(iv) the stock of financial assets solve the nonbank's date-t profit maximization problem, (P4), given prices and policy variables;

(v) the money market equilibrium condition $m_{t-1} = \gamma_t d_t p_{t-1}$ is satisfied $\forall t \geq 0$;

(vi) the goods market equilibrium condition $c_t + k_{t+1} - (1-\delta)k_t + k^n_{t+1} - (1-\delta)k^n_t = A(k_t + k^n_t)$ is satisfied $\forall t \geq 0$.

In this economy, eventually all capital will be financed through the bank. The household's first-order conditions imply that the gross real return on deposits and nonbank contracts will be identical. Hence, $R_t = R^n_t$. (Note that the household pays taxes on capital income. Consequently, the gross after-tax real return is $(1-\gamma_t)[(1-\tau_t)A + 1 - \delta] + \frac{\gamma_t}{\pi_t}$.)[5] This arbitrage condition is represented as

$$(1-\gamma_t)[(1-\tau_t)A + 1 - \delta] + \frac{\gamma_t}{\pi_t} = [(1-\tau_t)A + 1 - \delta] - f'(k^n_t). \tag{2.13}$$

Now all one needs to solve for the two types of capital is an initial condition stipulating the quantity of total capital. Throughout the analysis here, we assume that the date-0 total capital stock–$k^n + k$–equals one. From (2.13), the stock of nonbank-financed capital will be constant as long as the policy variables and the total factor productivity terms are constant. With $x^n_t = \delta k^n_t$ for all t, the ratio of nonbank-financed capital to total capital approaches zero as $t \to \infty$. With $0 < A < 1$, the bank's asset-to-output ratio will rise over time. Thus, the model economy's prediction for intermediated capital matches with a stylized fact regarding banks' behavior.

The consumer's first-order conditions also imply that

$$\frac{c_{t+1}}{c_t} = (\beta R_t)^{\frac{1}{\sigma}}. \tag{2.14}$$

Balanced growth implies that bank-financed investment, output, deposits, government spending will grow at the same rate as consumption. With deposits growing at the same rate as consumption, the money market clearing condition implies the following relationship between money growth and inflation:

$$\theta_t = (\beta R_t)^{\frac{1}{\sigma}} \pi_t. \tag{2.15}$$

Therefore, we can consider the government as directly controlling the inflation rate, rather than simply the rate of money creation.

As noted in King and Rebelo (1990), the agent's utility is finite if and only if $\beta(\beta R_t)^{\frac{1-\sigma}{\sigma}} < 1$. The King-Rebelo condition holds for all experiments conducted

[5] As noted in Footnote 3, income taxes do not play a crucial role. We included them mainly to keep the amount of seigniorage within a reasonable range. See Haslag (1994) for details.

in this paper. For the remainder of the paper, we consider only cases where the policy variables are constant over time. We also choose to disregard certain portions of the parameter space. As Jones and Manuelli (1992) show, part of the parameter space results in no growth. In our model, this implies that all capital will be financed through the nonbank. We therefore limit ourselves to the part of the parameter space for which the quantity of intermediated capital is strictly positive and endogenous growth occurs.

3. Monetary Policy Experiments

In this section, we compute the present value of government revenues for various settings of the reserve ratio and the inflation rate. Following Ireland (1994), we begin our investigation by setting the baseline values of G^0, γ^0, and π^0. We then ask whether it is possible to fund the same sequence of expenditures for different values of γ or π. In essence, we ask whether the growth effects and capital-substitution effects induced by changes in monetary policy will result in revenue sufficient to cover the revenue losses due to a lower tax base (reserve requirements) or tax rate (inflation rate).

3.1. Calibration

To quantitatively assess this model economy, we must first select parameter values. Table 1 presents the parameter settings used in the baseline computational experiments. Most are standard in the literature; accordingly, we reserve more detailed discussion for selecting values of the model-specific parameters. The values for the inflation rate and reserve requirement were obtained from cross-country data. We obtained price, bank reserve, and bank deposit data for a sample of 82 countries, spanning the period 1975-94. The (gross) inflation rate and reserve ratio presented in Table 1 are the sample averages for those 82 countries.

There is little guidance in calibrating the parameters for the nonbank contracts. One useful observation is the fraction of the capital stock that could be financed using bank deposits. Data on the stock of private capital is measured in current dollars, using end-of-year figures. Capital is defined as the net value of fixed private capital plus consumer durable goods . (These data are taken from *Fixed Reproducible Tangible Wealth in the United States, 1925-89).* We use Federal Reserve's definition of M2, subtracting currency held by the nonbank public to get an aggregate measure of deposits in the two classifications.[6] In the model economy, the bank's balance sheet identity is $d = m + k$. We next subtract the value of bank reserves. The result is a measure of what fraction of capital accumulation would be financed by bank deposits, provided the bank acquired capital with deposits proceeds that were not used to satisfy the reserve requirement. Flow of funds data give us observations on banks holdings of government bonds, which need to be subtracted from $d - k$ to obtain a measure of private capital. For the period 1959-89, the fraction of bank-financed capital fluctuates around 22%.

To pin down the fraction of bank-financed capital in the model economy, we need to specify a functional form for $f(k^n)$ and use eqn. (2.13). Above, we argued that the resource-cost function must be convex for disintermediation to occur in the event of either higher reserve ratios or higher inflation rates. Consequently, the functional form is chosen from the family of functions $f(k^n) = B(k^n)^\omega$, where $\omega > 1$. We use the parameter B to help pin down the fraction of capital financed by nonbank contracts. Clearly, both B and ω affect the equilibrium outcome. With so little to guide our selection of these two parameters, it seems essential that we consider several different combinations to determine whether a robust set of results emerges. We use four combinations B and ω such that the model economy's fraction of bank-financed capital is roughly 22% at $\pi = 1.04$ and $\gamma = 0.07$: (i) $B = 0.0042$ and $\omega = 1.5$; (ii) $B = 0.0031$ and $\omega = 5$;(iii) $B = 0.0053$ and $\omega = 10$;.(iv) $B = 21.5$ and $\omega = 50$.

3.2. Computational Experiments

In this paper, the computational experiments involve the present-value of the government budget constraint. Balanced growth simplifies the computations in the sense that real transfer payments grow at the same rate as output. Hence, the ratio of real government spending to output is constant.

We begin by characterizing the government's budget constraint. Consider a case in which the government is balancing its budget at each date t. Thus, with $b_t^g = 0, \forall\, t$, the constraint becomes

$$G_t = \frac{m_t - m_{t-1}}{p_t} + \tau A[k_t + k_t^n]. \tag{3.1}$$

[6]After 1992, reserve requirements apply against checkable deposits but not time and savings accounts. We use M2 deposits, checkable deposits and time and savings accounts, because reserve requirements applied against both deposits types for most the sample period and across most of the sample countries.

With $\alpha = G_t/K_t$ a constant,[7] one can represent the value of government's date-t expenditures as

$$G_t = \alpha A \left\{ \beta \left[(1-\gamma)((1-\tau_t)A + 1 - \delta) + \frac{\gamma}{\pi} \right] \right\}^{\frac{t}{\sigma}}. \qquad (3.2)$$

Next, we set equations (3.1) equal to (3.2) and substitute the money supply rule, yielding

$$(\theta - 1)\frac{\gamma d_t}{\pi} + \tau A[k_t + k_t^n] = \alpha A \left\{ \beta \left[(1-\gamma)((1-\tau_t)A + 1 - \delta) + \frac{\gamma}{\pi} \right] \right\}^{\frac{t}{\sigma}}. \qquad (3.3)$$

Further substitution of the bank's asset allocation constraint yields the date-t budget constraint as a function of the reserve requirement, the inflation rate, the income tax rate, and the stocks of capital financed through banks and nonbanks. Formally,

$$\frac{(\theta-1)\gamma}{(1-\gamma)\pi} k_t + \tau A[k_t + k_t^n] = \alpha A \left\{ \beta \left[(1-\gamma)((1-\tau_t)A + 1 - \delta) + \frac{\gamma}{\pi} \right] \right\}^{\frac{t}{\sigma}}. \qquad (3.4)$$

The first term on the left-hand side of (3.4) is date-t real seigniorage revenue. Summing over all dates yields the present value government budget constraint

$$PVG = \sum_{t=0}^{\infty} (R)^{-t} \left[\frac{(\theta-1)\gamma}{(1-\gamma)\pi} k_t + \tau A\left(k_t + k_t^n\right) - G^0 \right]. \qquad (3.5)$$

where G^0 is the "baseline" present value of government spending. In other words, G^0 represents the present value associated with monetary policy parameters set at γ^0 and π^0 and constant τ. Note that PVG is measured in units of the consumption good.

Now we characterize the change in the present value government budget constraint, $d(PVG)$, for a given change in monetary policy. Suppose, for example, monetary policy parameters change to new values, denoted π^1 and γ^1. The experiment asks whether the same sequence of expenditures, with the possibility of short-term debt-financing, can be financed while the present-value of government expenditures is still in balance. The present value of the government's budget

[7] A constant value for G/K is equivalent to limiting condition that G/Y is constant. We use G/K and equation (3.2) because it closely parallels the derivation in Ireland (1994).

constraint under the new parameters is computed and compared with the initial setting. The government can fund the same sequence of transfers if and only if

$$d(PVG) = \frac{x^1 k_t^1 + \tau A k_t^{n1}}{R^1 - (\beta R^1)^{\frac{1}{\sigma}}} - \frac{x^0 k_t^0 + \tau A k_t^{n0}}{R^1 - (\beta R^0)^{\frac{1}{\sigma}}} \geq 0 \tag{3.6}$$

where $x^0 \equiv \frac{(\theta^0-1)\gamma^0}{(1-\gamma^0)\pi^0} + \tau A$ and $x^1 \equiv \frac{(\theta^1-1)\gamma^1}{(1-\gamma^1)\pi^1} + \tau A$. Equation (3.6) will be the basis for our computational experiments. Specifically, the experiments quantify differences in the present value of government expenditures for different settings of the monetary policy parameters. As such, the results compare two different economies with different anticipated, permanent values for the inflation rate and reserve requirement ratio.

From equation (3.6), it is straightforward to account for the multiple channels through which movements in the monetary policy variables operate on the change in the present-value of government spending. Consider, for instance, an increase in the reserve requirement. First, the term x merges movements in the seigniorage tax base and tax rate. For an increase in the reserve requirement, x increases; the higher the reserve requirement, the more fiat money the bank is forced to hold. Second, as noted from equation (2.11), an increase in the reserve requirement lowers the return on deposits. This effect manifests itself through a decrease in intermediated capital. Ultimately, the substitution from bank deposits to nonbank contracts, referred to as disintermediation reduces the seigniorage tax base. In addition, the lower return on deposits means that the economy's growth rate falls, implying a permanent decrease in the path of government expenditures. Lastly, the discount factor in the denominator of (3.6) is inversely related to the return on deposits. Hence, an increase in the reserve requirement means that the lower path of government purchases is discounted less heavily over time.

Overall, the effect of the increase in reserve requirements on the present-value of government expenditures is ambiguous. Similar ambiguities arise when one considers an increase in the inflation rate. Thus, the computational experiments quantify the effects that different monetary policy settings have on government spending. Whether the present-value of spending rises or falls in response to economies with lower (higher) inflation rates can also identify whether a dynamic Laffer curve is present for inflationary finance.

Figure 1 plots $d(PVG)$ associated with a change in the reserve requirement ratio, starting with the initial value $\gamma^0 = 0.173$.[8] Each cell in Figure 1 corresponds

[8]We compute $d(PVG)$ for $\gamma \in [0.01, 0.25]$. Note that as $\gamma \to 0.35$, the graph is dominated by

to a different setting for the nonbank's resource-cost function. The experiments take the stream of expenditures and the policy settings as given. The question is whether the present value of real seigniorage revenue increases, decreases, or stays the same when there is a permanent, anticipated change in a policy variable. What the four cases show is that the model economies are qualitatively very similar. In each case, $d(PVG) > (<)\ 0$ for $\gamma < (>)\ \gamma^0$. The most striking feature is the consistency of the plots; that is, the profile is fairly flat, dropping off for reserve ratios above 17%. Closer inspection indicates that a revenue-maximizing reserve ratio is present for each resource-cost function.

The quantitative findings mirror the economics embodied in equation (3.6). Specifically, the model's data indicate that with a lower reserve ratio, faster growth and the substitution from nonbank contracts to bank deposits combine to raise the tax base upon which seigniorage revenue is computed. Compared with the baseline policy settings, the increase in the tax base more than offsets the reduction in the tax base stemming from the lower reserve ratio in present value terms.

Generally speaking, ω determines the speed of disintermediation; More specifically, a one-percentage-point increase in reserve ratios produces a larger decline in the fraction of date-1 capital financed via bank deposits when $\omega = 1.5$ than when $\omega = 50$. For seigniorage revenue, the different values of ω, therefore, imply that a given increase in the reserve ratio has a larger effect on the tax base when ω is smaller. In effect, smaller values of ω intensify disintermediation.[9] Despite the large difference in the resource-cost function, there is only a smaller quantitative difference in the revenue-maximizing values of the reserve ratio. Panel A of Table 2 reports the reserve ratio that maximizes the present-value of real seigniorage revenue for each of the four resource-cost functions. In our experiments, the revenue-maximizing reserve ratio is 2% for $\omega = 1.5$ and 8% for $\omega = 50$.[10]

the huge spike which arises because R^1 approaches $(\beta R^0)^{\frac{1}{\sigma}}$ from above, causing the denominator of $d(PVG)$ to change from a positive number to a negative number. A similar effect arises in the inflation rate experiments. Graphs for these cases are available from the authors upon request.

[9] To get a sense of the speed of disintermediation across the different cases. With $\omega = 50$, the fraction of date-1 capital financed via banks falls from 23.3% at $\gamma = 0.01$ to 17.7% at $\gamma = 0.25$. With $\omega = 1.5$, the fraction of date-1 capital financed via banks falls from 88.1% at $\gamma = 0.01$ to 1.6% at $\gamma = 0.04$.

[10] Another implication of the equation (3.6) is that one can see that the effects of monetary policy settings are not independent of one another. Instead of using the sample mean from the cross-country dataset, we use the sample mean for the U.S. sample computed using data for the period 1959-95; that is, $\pi = 1.042$. We then redid the reserve-ratio experiments. The chief difference is that given a one-percentage-point increase in the reserve ratio, the decrease in the equilibrium rate of output growth is smaller when the inflation rate is lower. There is also

Figure 2 plots $d(PVG)$ in the inflation-rate experiments. We compute the change in the present value of real seigniorage revenue for $\pi \in [1.0, 1.40]$. As with the reserve ratio experiments, we consider four sets of parameter settings for the nonbanks' resource-cost function. The cells in Figure 2 look similar to one another and similar to those in Figure 1. There is small quantitative difference in the revenue-maximizing inflation rates across the different resource-cost functions. Panel B of Table 2 reports the inflation rates that maximize the present value of real seigniorage revenue. Our findings indicate that a 1% inflation rate maximizes the present value of real seigniorage revenue when disintermediation is relatively fast and that 9% inflation rate maximizes the revenue measure when disintermediation is slower.

Overall, our results show that a dynamic Laffer curve is present for reasonably calibrated economies. These findings reflect the fact that higher reserve ratios and inflation rates result in slower growth rate and reduce the fraction of capital financed via bank deposits. The presence of the Laffer curve indicates that the growth-rate effects and disintermediation cause reductions in the quantity of real fiat money balances, more than offsetting the effects that higher reserve ratios and higher inflation rates have directly on real seigniorage revenue. Interestingly, the results of computational experiments suggest that the revenue-maximizing policy settings are well below the sample means taken from the cross-country data.

4. Assessing quantitative importance

In this section, we quantitatively assess the contribution of the growth-rate and capital-substitution effects. In other words, how much does the revenue-maximizing policy setting change for a case in which either endogenous growth or disintermediation is eliminated?

4.1. The growth-rate effect

In this model economy, the agent's budget constraint is given by:

$$c_t + d_{t+1} + b^g_{t+1} \leq R_t(d_t + b^g_t) + G_t \tag{4.1}$$

less saving since the gross rate of return on deposits (and nonbank contracts) also falls. With $\omega = 50$, the revenue-maximizing reserve requirement is 8% when $\pi = 1.214$, but falls to 1% for the case in which $\pi = 1.042$.

Note that the budget constraint eliminates nonbank contracts as a means to finance future consumption. (We also assume that government bonds and bank deposits are perfect substitutes as a means to store for future consumption.) In the absence of the nonbank contracts, there is no capital-substitution effect. With this modification, the present-value expression becomes

$$d(PVG) = \frac{x^1 k_t^1}{R^1 - (\beta R^1)^{\frac{1}{\sigma}}} - \frac{x^0 k_t^0}{R^1 - (\beta R^0)^{\frac{1}{\sigma}}} \geq 0 \tag{4.2}$$

The question is, How does $d(PVG)$ respond to changes in the reserve requirement or the inflation rate? Figures 3 and 4 provide quantitative answers to these questions, plotting the value of $d(PVG)$ for different values of the reserve requirement and the inflation rate, respectively. As in previous figures, both show a $d(PVG)$ curve that is hump-shaped. The chief difference is where the revenue-maximizing values of the reserve ratio and inflation rate occur.

In the absence of nonbank contracts, a higher reserve requirements lowers the return to bank deposits, which has two effects: the rate of growth declines and saving is less attractive. For real seigniorage revenue, deposits grow more slowly, resulting in a slower growth in the tax base. For this model economy, the present value of real seigniorage revenue is maximized when $\gamma = 0.23$.

Figure 4 plots $d(PVG)$ for alternative values of the inflation rate. As with the experiments in which the reserve requirement changes, the $d(PVG)$-curve is hump-shaped. The qualitative reasons are the same as those given for the reserve-ratio experiments. For the inflation-rate experiments, the present value of real seigniorage revenue reaches a maximum at $\pi = 1.34$.

The experiments in this section offer some insight into how important disintermediation is for real seigniorage revenue. With disintermediation eliminated, the revenue-maximizing reserve ratio increases from 8% to 23% while the revenue-maximizing inflation rate increases from 9% to 34%.

The experiments in this section focus on an extremely unsophisticated economy from the standpoint of financial development. With no other means to store for future consumption than bank deposits, the results from our counterfactual experiments suggest that the revenue-maximizing policy settings would be higher than the sample means taken from across countries.

4.2. Disintermediation

Here, we assume that nonbank contracts are present, but changes in monetary policy settings do not affect the rate of growth. We assume that there is a stationary level of bank deposits and nonbank contracts. Consequently, disintermediation is present, but the growth-rate effect is eliminated. In steady-state, real seigniorage revenue is constant. For this no-growth case, comparisons are made between the steady-state values of real seigniorage revenue instead of the present-value of government receipts.

Figures 5 and 6 plot the difference in steady-state seigniorage revenue for different values of the reserve requirement and inflation rate, respectively. The steady-state value of real seigniorage revenue is computed, using the following expression:

$$\frac{\gamma}{1-\gamma}k(1-\frac{1}{\theta}). \tag{4.3}$$

The quantity of bank deposits, and hence k, is inversely related to both the reserve ratio and inflation rate. However, k does not increase over time.

For these experiments, we use the baseline parameter settings for the reserve ratio and inflation rate. Figure 5 plots the change in real seigniorage revenues, comparing the steady-state level of real seigniorage at different reserve ratios with seigniorage raised with $\gamma = 0.173$. We use the four versions of the nonbank's resource-cost functions as we did in the experiments in the baseline economy. In three of the four experiments, real seigniorage revenue exhibits a hump-shaped pattern. These three experiments correspond to cases in which the nonbank's resource-cost function results in the fastest disintermediation. With $\omega = 50$, disintermediation is at its slowest, and higher reserve ratios result in greater real seigniorage revenue. These results are not too surprising; faster disintermediation translates roughly into measuring the speed of adjustment in bank reserves. Clearly, as bank reserves fall quickly in response to higher reserve requirements, disintermediation will tend to quantitatively dominate the higher reserve ratio. If, however, disintermediation is "too slow," bank reserves will rise despite the decline in bank deposits and real seigniorage revenue rises.

Figure 6 plots the change in real seigniorage revenue for different inflation rates. As in the experiments above, the baseline value is $\pi = 1.214$. In two of the four inflation-rate experiments, real seigniorage revenue exhibits the hump-shaped pattern. Interestingly, in the case in which disintermediation is occurring at the fast pace, $\omega = 1.5$, real seigniorage revenue is strictly increasing in the inflation rate. In this case, the steady-state level of bank deposits is quite low at $\pi = 1.0$. Even though disintermediation occurs rapidly, recall that we assume deposits are nonnegative. Consequently, there is not enough of a change in bank deposits to offset the increase in the tax rate that corresponds to a higher inflation rate when $\omega = 1.5$. With $\omega = 5$ or $\omega = 10$, bank deposits are large enough so that at low inflation rates, disintermediation is rapid enough that the hump-shaped pattern emerges.

The purpose of this exercise is to assess the importance of the growth-rate effect on real seigniorage revenue. The computational experiments eliminate growth from the economy, not just the ability of monetary policy to influence growth. Our results suggest that eliminating growth, the revenue-maximizing policy settings are very high, except for the economies in which disintermediation is extremely (and probably implausibly) rapid.

5. Does currency matter?

Thus far, the experiments ignore the role the taxing currency could have on the revenue-maximizing inflation rate. The obvious question is whether including currency affects the quantitative results. Because currency accounts for such a large fraction of base money in many countries, there is a sense in which currency matters more than bank reserves. This section explores how currency (the tax base) responds to movements in monetary policy variables.

In general, the date-t equilibrium value of real revenue earned from money creation can be expressed as follows

$$(s_t + r_t)(1 - \frac{1}{\theta}) \tag{5.1}$$

where s denotes real currency balances while r denotes real reserves. Obviously, the crucial feature for revenue maximization is the way in which currency is introduced into the model.

For the seigniorage rate, what is important is the condition that the marginal rate of substitution between the cash good and the credit good equals the nominal interest rate. Following Lucas and Stokey (1983), we introduce a cash-in-advance constraint into the our basic reserve-requirement economy. Suppose, for example, the momentary utility function is

$$(1 - \sigma)^{-1}[(c1^{-\psi} + \eta * c2^{-\psi})^{-1/\psi}]^{1-\sigma}, \tag{5.2}$$

where $c1$ is the consumption good acquired through accumulated cash (the cash good) and $c2$ is acquired with current period receipts (the credit good).[11] For this specification, $\psi \geq -1$ determines the rate at which households are willing to substitute the credit good for the cash good. With this utility function, the first-order condition is written as

$$\frac{c2}{c1} = \eta I^{\frac{1}{1+\psi}}, \tag{5.3}$$

where $I = \pi R$. Equation (5.3) establishes the inverse relationship between the cash good and the inflation rate. Further, with a binding cash-in-advance constraint; that is, $s = c1$. It follows immediately that real currency holdings are negatively related to the inflation rate.

Consider two special cases for setting the parameter ψ. For $\psi \to -1$, the two consumption goods are (approaching) perfect substitutability. With an increase in the inflation rate, consumption of the cash good will approach zero. Equation (5.1) tells us that seigniorage from currency approaches zero. In contrast, with $\psi \to \infty$, the two consumption goods are approaching perfect complementarity. Because the cash good and consumption are consumed in fixed proportions, a higher inflation rate has an imperceptible effect on the s. Thus, seigniorage revenue increases in response to higher inflation.

For our purposes, the question is whether including currency significantly affects either the reserve ratio or the inflation rate that maximizes the present value of seigniorage revenue. We run the inflation-rate experiments with $\psi = -0.7$ and $\psi = 5.0$.[12] Figures 7 and 8 plots $d(PVG)$ for the case in which $\psi = -0.7$ and $\omega = 50$. The parameter setting may appear a bit awkward; for $\omega = 50$ disintermediation is at slowest setting while $\psi = -0.7$ sets substitution between cash and credit goods at a fairly quick pace. As such, the parameters settings seem to

[11] The Federal Reserve Board commissioned two surveys on consumer expenditures. In both the 1984 and 1986 surveys, roughly 30% of consumer expenditures were conducted using currency. To calibrate the model with a cash-in-advance constraint, we use the survey data as a measure of $c2/c1$. In addition, we use the average inflation rate and reserve ratio for the U.S. over the period 1975-93. Equation (5.3) is used as the guide to back out the value of η that is consistent with the ratio of $c2/c1$, taking the value of ψ as given. For $\psi = -0.7(5.0), \eta = 1.1489(142.6282)$.

[12] In an indirect way, the substitution between the cash and credit goods captures open-economy features. The credit good can be broadly defined as goods purchased with any means other than the domestic currency. The closer the substitution is between currencies, the closer the ψ parameter will be to -1. Conversely, movements in ψ away from -1 capture the presence of foreign currency controls. The essential feature of our model economy is what happens to the quantity of real domestic currency.

have disparate consequences. The first line of defense is to say that the parameter settings considered in these paper do not materially affect the outcome in terms of changing the plots of $d(PVG)$. In an effort to save space, therefore, we make the plots with other parameter settings available upon request. Note that in the model economies, currency accounts for between 80% and 87% of the total quantity of fiat money.

In Figure 7, one sees the hump-shaped pattern in the $d(PVG)$ curve. The present value of real seigniorage revenue is maximized at a reserve ratio equal to 17%. The revenue-maximizing inflation rate is 17% for these parameter settings.[13] It is somewhat surprising to us that for these model economies, the revenue-maximizing policy settings are very close to the sample mean values computed from the cross-country data. Thus, on average, the world sets monetary policy quite close to levels that maximize the present value of real seigniorage revenue. The model is calibrated to come close to the quantity of the tax base for real seigniorage revenue that prevails. Still, it is somewhat of a surprise that with the model's preferences and technology, we find that the revenue-maximizing setting is so close to the world's average policy setting.

6. Summary and conclusions

In this paper, we quantify the effect of two alternative monetary policies, the inflation rate and the reserve requirement, on the present-value of government expenditures. Revenue in our model comes from a combination of income and inflation taxes, where the inflation tax has a tax base that is directly dependent on the reserve requirement. We then look at several different model economies to assess the quantitative importance of different channels through which these monetary policies operate. Specifically, we consider three channels. One is an economy that grows endogenous and the growth rate is inversely related to the monetary policy variables. The other two are means of avoiding the inflation tax: disintermediation and credit. Disintermediation occurs because there are two means of financing. One can avoid the inflation tax by shifting funds to an account that is not subject to reserve requirements. With faster money growth, households shift into credit and out of currency, thus avoiding the inflation tax.

A dynamic Laffer curve is present in those model economies in which growth

[13] For this experiment, total reserves account for approximately between 13% and 20% of base money, depending on the inflation rate. Note that total reserves are approximately 20% of the quantity of high-powered money in the U.S.

is endogenous. Hence, our monetary policy experiments are similar to the results found in Ireland (1994) for fiscal policy. In an economy with a fairly sophisticated financial system and competing methods of payment, we find that the revenue-maximizing values for the monetary policy variables are surprisingly close to cross-country sample means observed in the data. The relationship between monetary policy and the rate of growth is the determining factor in finding a Laffer curve. Indeed, we run the experiments in a stationary economy, finding that Laffer curve is evident for the part of the parameter space we consider. Though smaller quantitatively, the level of financial development bears on the revenue-maximizing monetary policy settings. If one eliminates currency from the model, the Laffer curve shifts to the left; that is, the revenue-maximizing reserve ratio and inflation rate both decline.

The specific quantitative results are as follows:

-when both the growth and financing-substitution effects are present, the revenue-maximizing reserve requirement is 8% and the revenue-maximizing inflation rate is 9%;

-for the same set of experiments, the revenue-maximizing reserve ratio and inflation rate fall to 2% and 1%, respectively in economies with extremely fast disintermediation;

-when only the growth effect is present, the settings are 23% and 34%, respectively;

-when only the financing-substitution effect is present, the revenue-maximizing settings are above the portion of the parameter space considered in this paper;

-when currency is added, the revenue-maximizing settings are around 17%.

Our main goal is to quantify the present value of real seignorage revenue across several different model economies. The economies are linked by systematically eliminating specific channels that affect the seignorage tax base. Other authors have computed revenue-maximizing inflation rates. Fry (1981), for example, finds that real seignorage revenue is maximized at with inflation rates in excess of 50% for a stationary economy in which governments have monopoly power over both currency and deposits. Our chief contribution, therefore, is that we can assess the impact of a supply-side channel and two different avoidance channels on the present value of real seignorage revenue.

We have considered only revenue as a motivating factor for monetary policy. One potential extension would be to consider revenue issues at business cycle frequencies. In such models, it may be possible to build on Auernheimer (1974). Another extension would be to focus on strategic issues between policymakers:

when the monetary and fiscal authorities do not coordinate actions, what are the revenue implications? Such questions hark back to issues of decentralized policy-making common in the 1970s–would the fiscal authority try to use the inflation tax to covertly collect revenue in a model in which both fiscal and monetary authorities operate independently? It is likely that such considerations would lead to very different conclusions than the ones reached in this paper.

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Table 1

Calibrating the model's parameters

Variable	Baseline value
β	0.95
σ	2
A	0.165
δ	0.10
τ	0.2
π^0	1.214
γ^0	0.173

Table 2
Revenue-maximizing policy settings

Panel A:

Parameter settings	$\gamma^{\max}$
$B = 0.0042, \omega = 1.5$	0.02
$B = 0.0031, \omega = 5$	0.03
$B = 0.0053, \omega = 10$	0.06
$B = 21.5, \omega = 50$	0.08

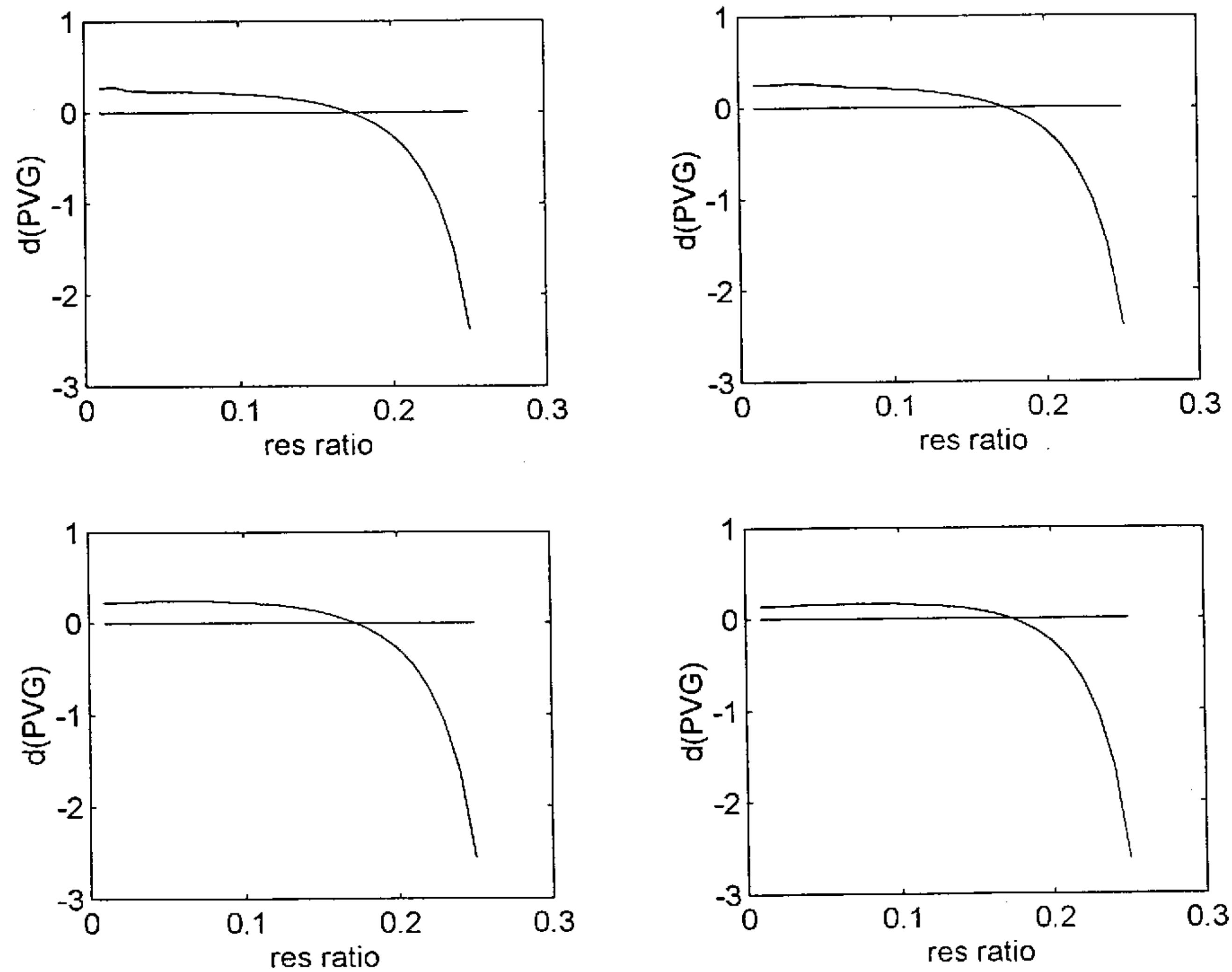
Panel B:

Parameter settings	$\pi^{\max}$
$B = 0.0042, \omega = 1.5$	1.03
$B = 0.0031, \omega = 5$	1.01
$B = 0.0053, \omega = 10$	1.06
$B = 21.5, \omega = 50$	1.09

Figure 1

Reserve Requirements Experiments -- Baseline Model

$\omega = 1.5$ $\omega = 5$



$\omega = 10$ $\omega = 50$

Figure 2

Inflation Rate Experiments -- Baseline Model

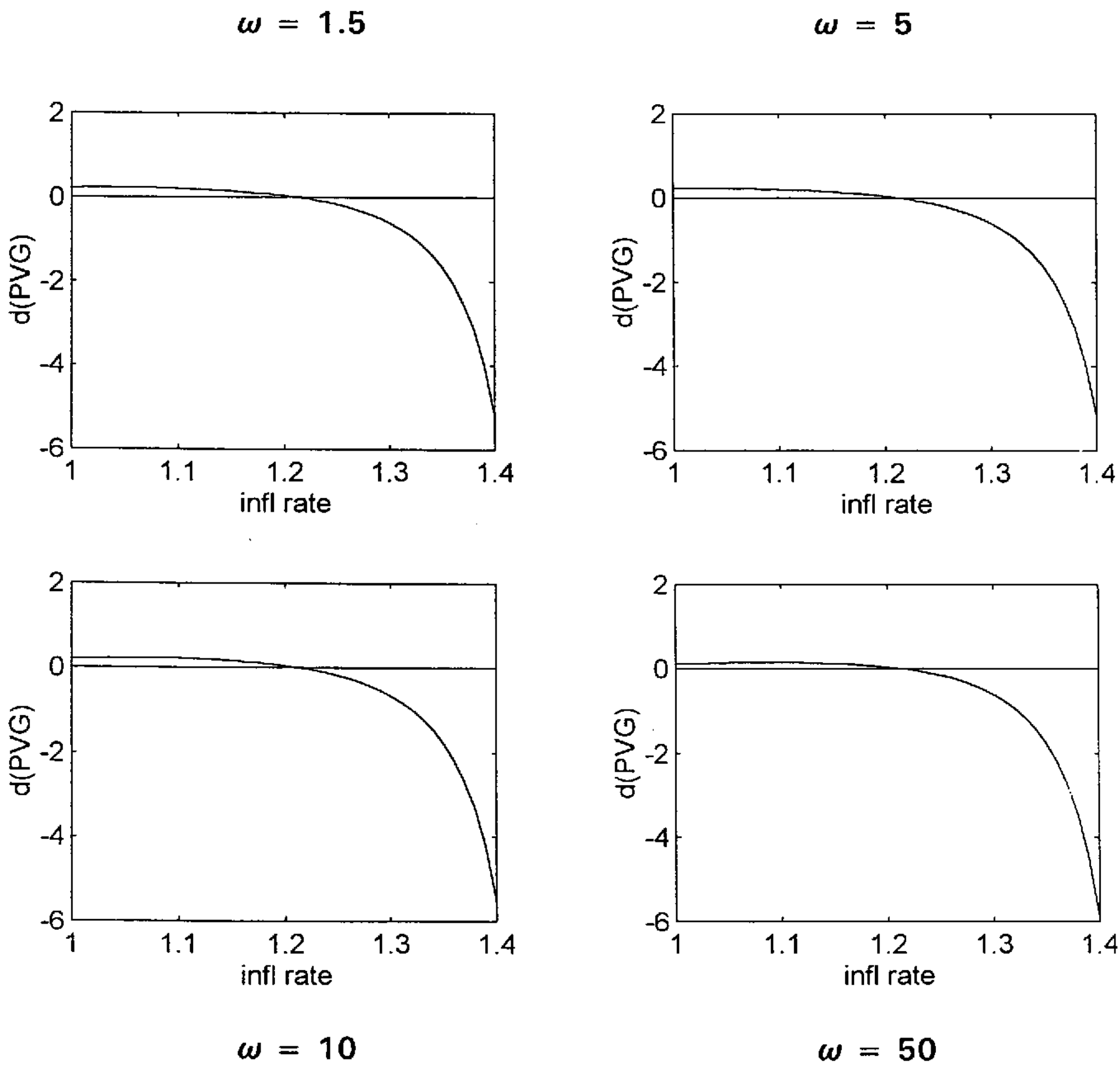


Figure 3

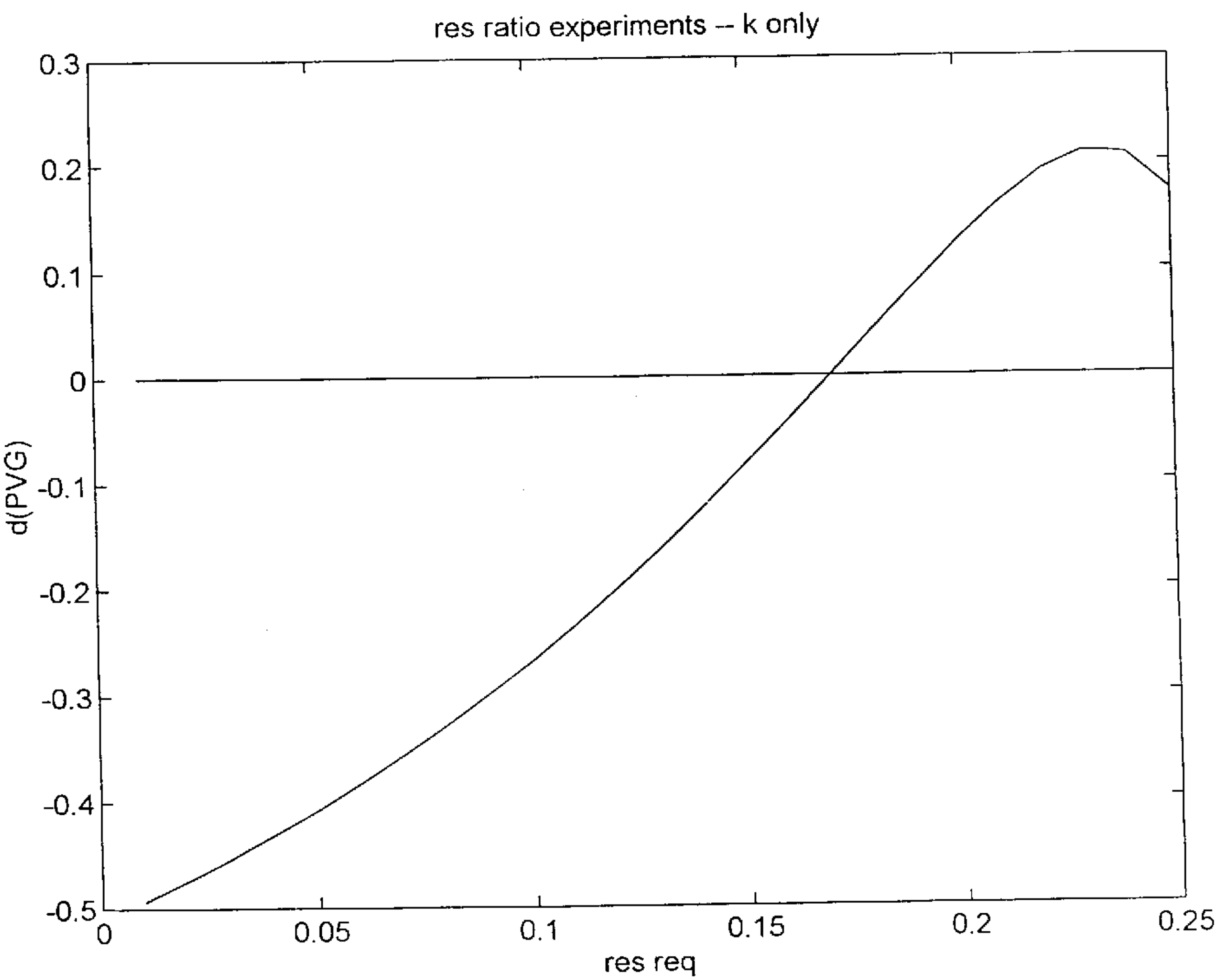
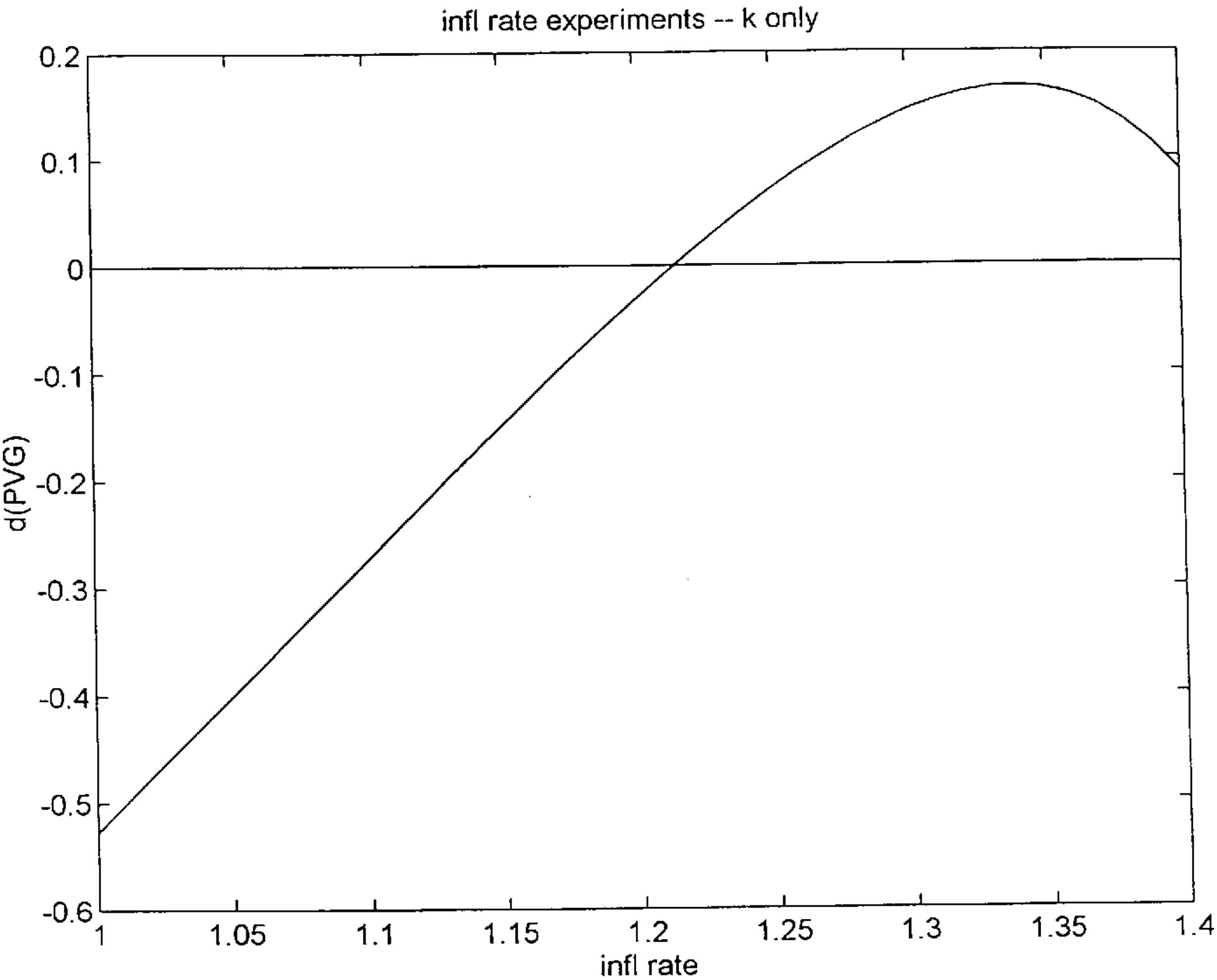

res ratio experiments -- k only
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
d(PVG)
0
0.05
0.1
0.15
0.2
0.25
res req

Figure 4



infl rate experiments -- k only
d(PVG)
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
1
1.05
1.1
1.15
1.2
1.25
1.3
1.35
1.4
infl rate

Figure 5

Res Req Experiments -- No Growth Effects

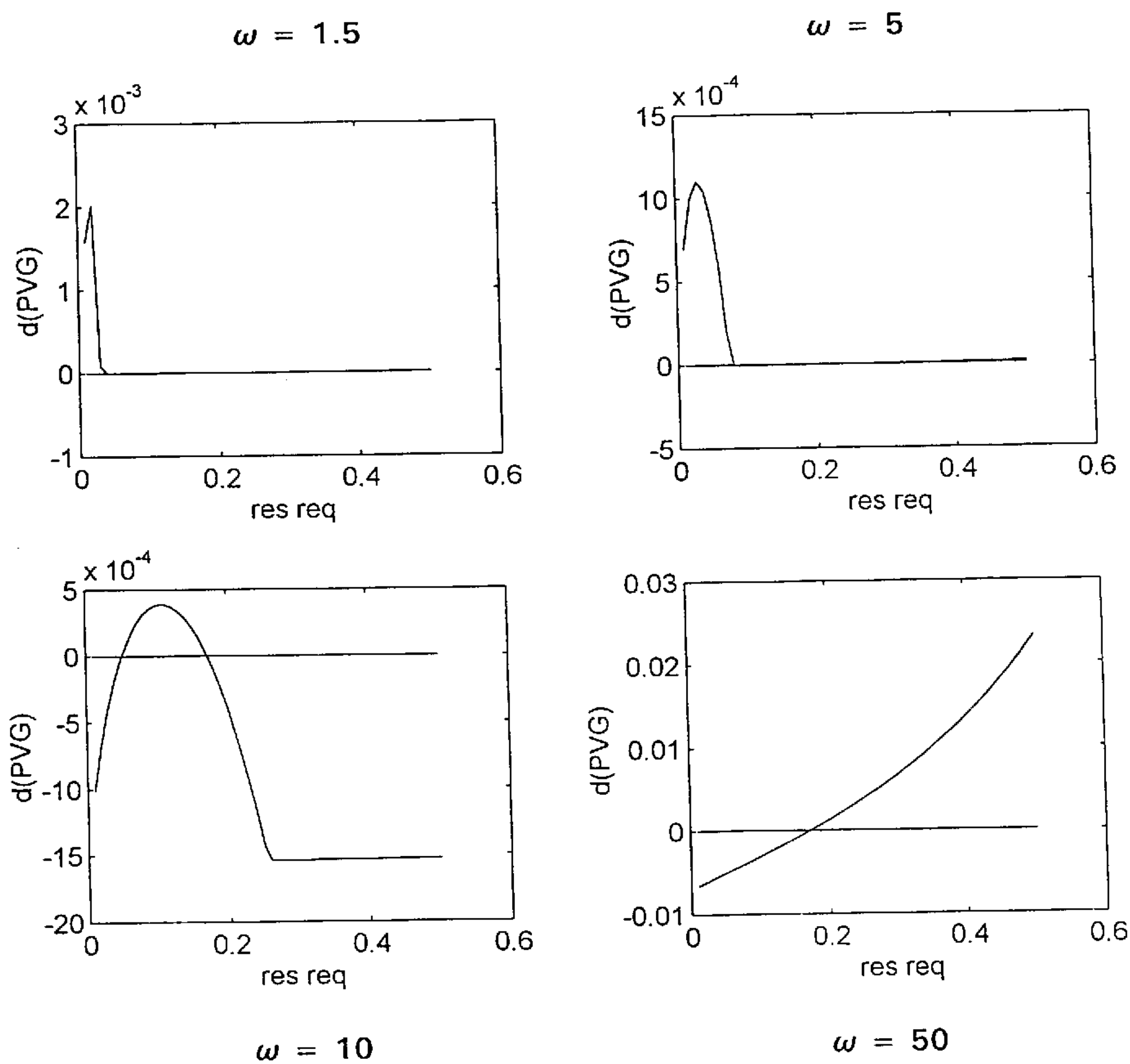


Figure 6

Infl Rate Experiments -- No Growth Effects

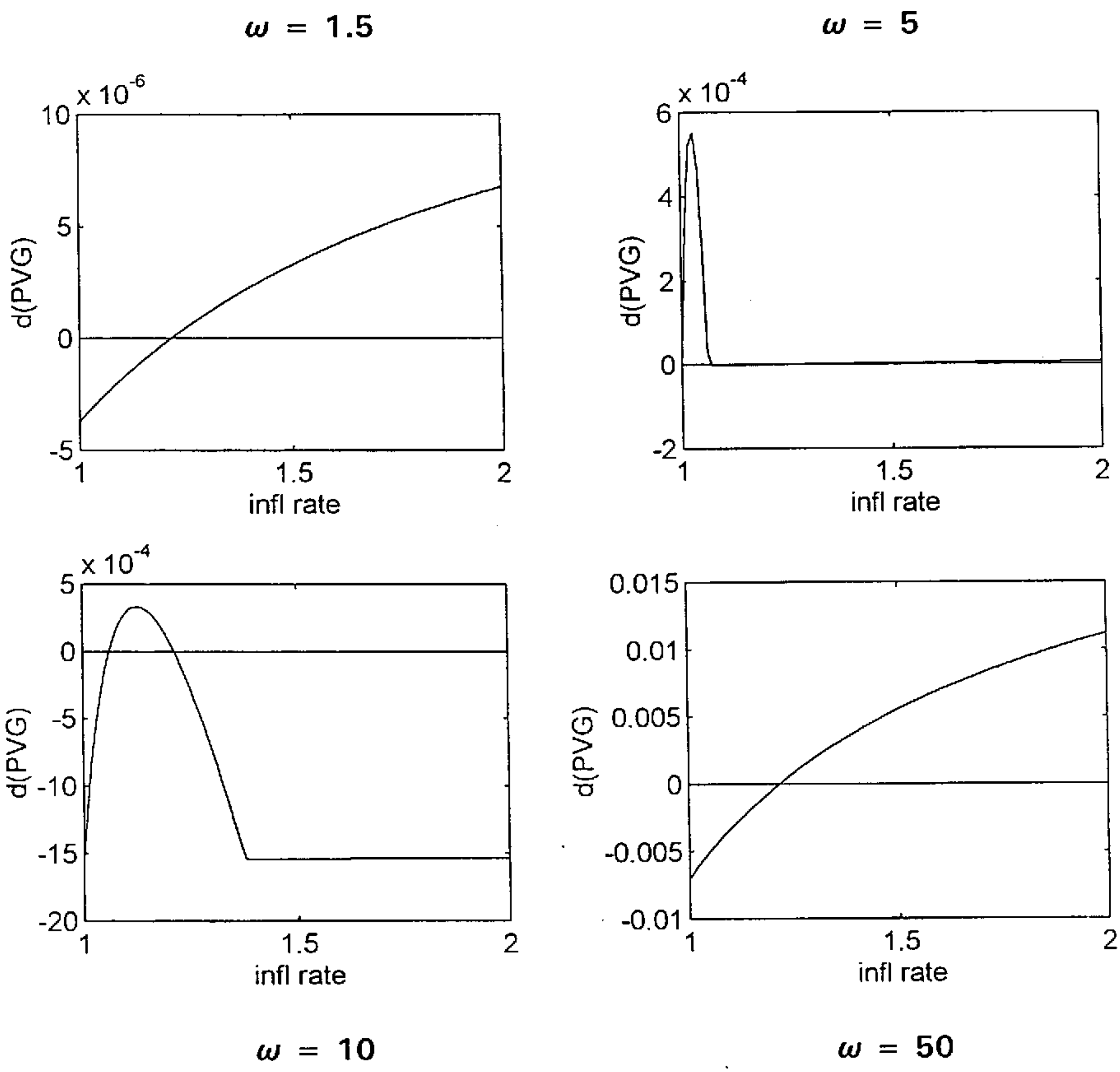


Figure 7

Res Req Experiments -- currency included

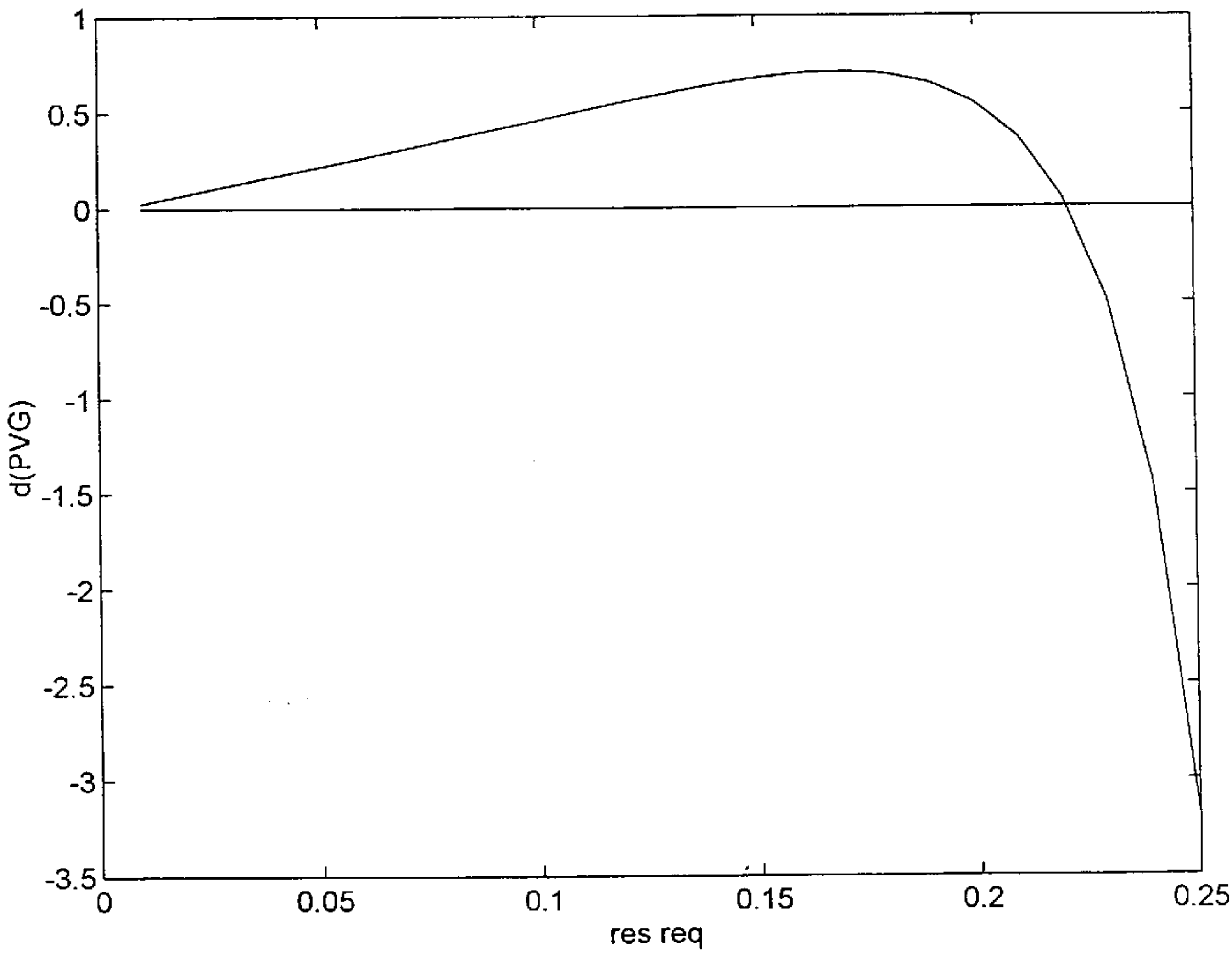
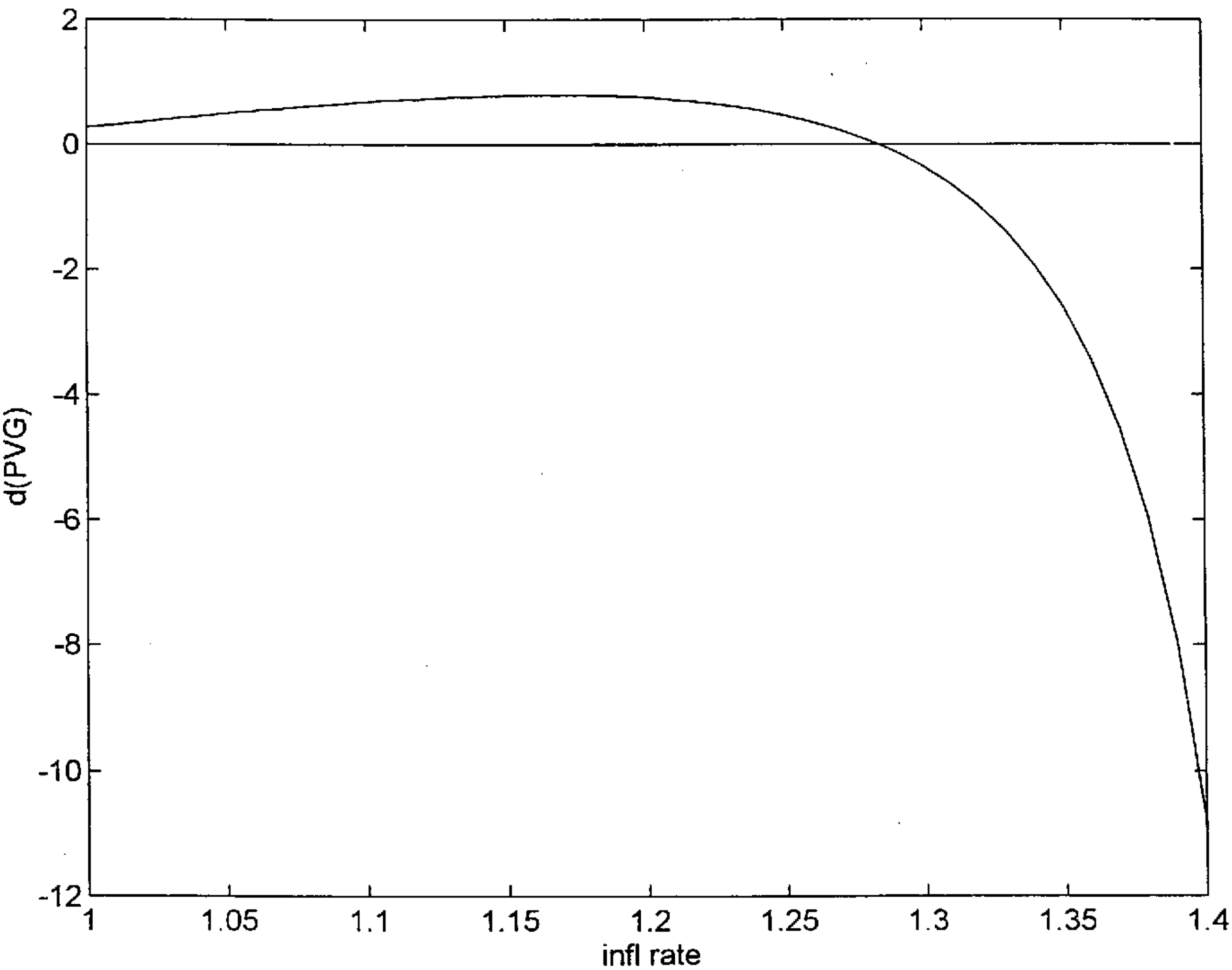


Figure 8

Infl Rate Experiments -- currency included



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