THE EFFECTS OF MONETARY POLICY IN A MODEL WITH RESERVE REQUIREMENTS

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The Effects of Monetary Policy in a Model with Reserve Requirements

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In this paper, the effects of monetary policy are examined in a simple convex model with endogenous growth. In an economy with a reserve requirement, monetary policy has growth-rate effects. I compare quantitatively the effect that changes in money growth cum inflation have on growth, on the welfare costs of inflation, and on seignorage revenue, contrasting the results with a reserve requirement with other types of distortions considered in the literature. I show that the inflation rate affects the growth rate in a model with reserve requirements. More specifically, the growth-rate effects are larger in a model with reserve requirements than previous estimates in which other distortions are present. Not surprisingly, larger growth-rate effects translate into larger estimates of the welfare costs of inflation. Indeed, the welfare costs of moderate inflations are moderately higher than previous estimates. Finally, I show that if seignorage revenue is a small contributor to total tax revenues then the growth-rate effects more than offset a decline in the inflation rate or reserve requirements.

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1. Introduction

The convex model of endogenous growth provides an interesting laboratory for studying the effects of macroeconomic policy and growth. Larry Jones and Rodolfo Manuelli (1990) argue that differences in policy can explain differences in growth across countries. Robert King and Sergio Rebelo (1990) calibrated a simple model with endogenous growth to quantify the effects that tax policies have on economic growth, thereby characterizing persistent differences in growth rates across countries. Peter Ireland (1994) asks about the government budget consequences of a change in income tax rates. Which dominates the present value of tax revenues, the lower tax rate or the faster growing tax base? Ireland estimates that the present value of tax revenues rises when the government lowers the income tax rate from 20% to 15% using the King-Rebelo model.

Tax and trade policies have received a great deal of attention. A reasonable question is whether monetary policy has a significant role in explaining movements in growth rates. Because of the statistical regularity professed to exist between money growth and output growth, one would presume that much has been written on the subject. However, only a few studies have examined the effects of monetary policy on growth.

What effect do changes in money growth cum inflation have on output growth? The answer has evolved quite a bit over the years. For many years, the dominant empirical relationship guiding empirical work was the Phillips curve. James Tobin (1965) explains the positive correlation between money growth and output growth in a general equilibrium model in which money and capital are substitutes. The "Tobin effect" notes that a higher inflation rate lowers the return on money balances, causing agents to trade for the higher yielding capital. In contrast, Milton Friedman (1977) questions the existence of positive correlation, interpreting evidence from several countries as indicating a weak negative relationship between inflation and output growth.[1] Subsequently, theory sought to explain

[1] See also, evidence supplied by Roger Kormendi and Philip Meguire (1985).

why such a negative relationship would exist. Alan Stockman (1981) and Jeremy Greenwood and Greg Huffman (1987) construct models in which agents hold money to satisfy a cash-in-advance constraint. In these model economies, consumption and leisure are gross substitutes. Hence, as the inflation rate increases, the return on money falls, inducing agents to consume more leisure and thus, lowering the amount of output.

Theory matches the key qualitative aspects in the data. However, estimates of the effects of monetary policy on growth and welfare suggest that changes in money growth cum inflation are small.[2] Recently, Larry Jones and Rodolfo Manuelli (1993) have examined the role of monetary policy in an endogenous growth model. In a model with no distortions, Jones and Manuelli show that the growth rate is independent of changes in money growth. The authors recognize that either introducing distortions into the model or letting the production technology have increasing returns to scale would generate a negative correlation between money growth and output growth. Jones and Manuelli quantify the effect of monetary policy in a setting with nominal depreciation allowances. They estimate that inflation (such as 10%) has a negligible effect on the rate of growth (less than 0.1 percentage point). Correspondingly, the welfare costs of moderate inflations are about 0.5% of GNP. In a model with increasing returns to scale, Jones and Manuelli find that the rate of growth increases by 0.1 percentage point and the welfare cost rises to 1.5% of GNP. Thus, the estimates of the welfare costs of inflation are slightly higher for models with a potential growth-rate effect than those generated by Thomas Cooley and Gary Hansen (1989). In a stationary model economy, Cooley and Hansen find that the welfare costs of a 10% inflation rate is 0.15% of consumption.

In another approach, Paul Gomme (1993) examines the effects of money growth in a model in

[2] The relationship between changes in the rate of growth and welfare are made clear in Robert Lucas' (1987) experiments. Lucas estimates that in an economy with a 3% growth rate, consumption would have to increase by 17% to make the agent as well off as if the economy's growth rate was 4%.

which agents buy both physical and human capital. In the Gomme paper, agents face a cash-in-advance constraint. An increase money growth taxes the consumption good and lowers the return to labor. Similar to Greenwood and Huffman, agents intratemporally substitute for the credit good, leisure, which reduces the accumulation of human capital, thereby permanently lowering the rate of growth. Interestingly, Gomme estimates the welfare costs of moderate inflation to be an order of magnitude *smaller* than estimates in Cooley and Hansen, despite the growth-rate effect. Thus, despite models that find inverse relationships between money growth and output growth, the exercises suggest that quantitatively, moderate rates of inflation do not substantially affect the rate of growth or have significant welfare costs.

In this paper, I ask whether other distortions can generate results in which monetary policy has quantitatively larger effects on the growth rate and welfare. Specifically, I ask whether introducing a reserve requirement into an endogenous growth model is sufficient for *anticipated monetary policy actions* to have larger effects on the rate of growth, and, correspondingly on the welfare costs of inflation. Jones and Manuelli note reserve requirements are another distortion that would result in inflation having growth effects qualitatively similar to the introduction of nominal depreciation allowances. The contribution of this paper is to quantify the effects of monetary policy in a model economy with reserve requirements. The investigation seems appropriate since reserve requirements are policy in many countries. Furthermore, the growth-rate effect is in line with the correlations reported in Gomme. In particular, Gomme reports the correlation between the inflation rate and output growth for 82 countries in a histogram. The central tendency is in the -0.2 to -0.4 range.

In this setup, banks are forced to hold a fraction of their deposits in the form of fiat money. This reserve requirement implies that money is a "forced" complement to intermediated capital, in the sense that banks can only acquire more intermediated capital (for a given increase in deposits) by also getting more fiat money. This distinction means that monetary policy affects the accumulation of intermediated capital. Insofar as some fraction of capital is intermediated, a reserve requirement ratio crowds out capital formation. Money growth cum inflation makes intermediated capital less attractive because the reserve balances are taxed at a higher rate, thus lowering the return on competitively provided deposits. The tax incidence on intermediated capital provides a direct channel through which monetary policy actions can affect the return on capital. As a minor point, the model economy permits one to consider changes in both monetary policy instruments--the reserve requirement ratio and the rate of money growth--as it affects the return on deposits.

Clearly, the financial intermediary introduced into this environment plays a crucial role. The reserve requirement is applied against deposits at a bank. Economies with a reserve requirement have been studied by Fama (1980), Romer (1985), and Freeman (1987). Because there is no uncertainty in this environment, the emphasis is on reserve requirements as a tax on intermediation. Some investment projects are large enough that agents must pool their savings. This illiquidity motivates intermediation. Hence, the tax on intermediation is more accurately represented as a tax on intermediated capital. The inflation tax operates in a similar way. By taxing money holdings, raising the inflation tax makes deposits less attractive and inhibits capital accumulation. Thus, raising either reserve requirements or the inflation rate results in slower growth by discouraging agents from buying intermediated capital. The model is the laboratory tool for quantifying the effects of these policy interventions. By varying the inflation rate and reserve requirements, it is possible to study the effects on growth, welfare, and seignorage revenue. As such, the analysis builds on work by Cooley and Hansen, Jones and Manuelli, and Gomme.

The results of these experiments are easily summarized. In the model economy with reserve requirements, the computational experiments indicate that the growth-rate effects of changes in monetary policy are relatively large. The parameter settings are the same as in the literature, implying that the changes in the inflation rate have a larger effect on the "after-tax" return on capital than when the other distortions are used. For example, the case in which the inflation rate falls from 10% to 0% results in the rate of output growth increasing by about 0.4 percentage points and the welfare costs of a 10% inflation rate is 3.4% of consumption. The point is that the reserve requirement seems to be a larger distortion, so that monetary policy would appear to have nontrivial effects on output growth and welfare. This estimate may seem quite large, especially since the correlation between the inflation rate and output growth is about -0.2 for the United States. A decrease in the elasticity of intertemporal substitution reduces the growth-rate effect. Indeed, with the elasticity of substitution parameter set equal to 0.20, the inflation rate experiment adds only 0.17 percentage points to the rate of output growth. With smaller estimates of the growth-rate effects, the welfare gains associated with lowering the inflation rate from 10% to 0% are 0.7% of consumption, comparable to the findings presented in Jones and Manuelli.

I also consider the effects that monetary policy actions have on revenue. The findings indicate that the present value of seignorage revenue falls in response to lowering either the inflation rate or the reserve requirement. For the benchmark parameter setting, total revenue--the sum of income tax revenue and seignorage revenue--rises for small changes in either the inflation rate or reserve requirement. However, for the high elasticity of substitution setting, total revenues decline with any decrease in the monetary policy instruments. Monetary policy simply does not induce enough growth to offset the lower tax rate. In a setting in which intermediated capital is a small fraction of total capital, changes in the monetary policy instruments have a very small effect on the overall tax rate. Computational experiments with this version of the model economy indicate that even with small growth-rate effects, the present value of government revenues rises. This finding suggests that in economies with little intermediated capital relative to the total stock, then total government revenues are inversely related to movements in the monetary policy instruments rather than directly related.

The outline for the paper is as follows: Section 2 describes the model and derives the main theoretical results. The calibration of the model and results from the computational experiments with regard to the growth-rate responses are reported in Section 3. Sections 4 and 5 examine the welfare effects and seignorage revenue impacts, respectively. Section 6 offers a brief summary.

2. The Model

The economic environment consists of three types of decisionmakers: firms, households, and banks. In each period, firms maximize profits in a perfectly competitive markets for both inputs and outputs. Firms produce a single consumption good, Y_t, where $t = 0, 1, 2, \ldots$ indexes periods. Production is accomplished using a common-knowledge technology, represented by

$$(1) \qquad Y_t = AK_t, \qquad A > 0,$$

where K denotes capital. Equation (1) specifies a constant-returns technology in which the quantity K is interpreted as a composite of both physical and human capital.[3] The firm pays the rental price, q, for the composite input and sells the output at the price, p. Both p and q are measured in units of fiat money. King and Rebelo (1990) and Rebelo (1991) explore the properties of this linear production technology. The authors show that the linear production function captures mostly all the long-run policy implications of more general convex models of endogenous growth in which the accumulation of multiple capital goods is considered explicitly.

Over time, capital depreciates at the rate δ and is expanded by investment X. I assume that the consumption good is costlessly transformed into the capital good at a one-for-one rate. Thus, the law of motion for capital is expressed as

[3] The linear specification assumes that these two forms of disaggregated capital are perfect substitutes in production. Barro (1990) shows that each type of capital can have decreasing returns alone, but constant returns in both applied together.

(2) $K_{t+1} = (1-\delta)K_t + X_t.$

All capital must be intermediated. I assume that there is a minimum investment size, κ_t.[4] I further assume that the minimum investment size is a linear function of output.[5] This assumption guarantees that the small saver does not outgrow the need for intermediation services.

Households in this model economy are atomistic, infinitely lived with preferences described by the time separable CES utility function

(3)
$$U = \sum_{t=0}^{\infty} \beta^t \frac{c_t^{1-\sigma}-1}{1-\sigma},$$

where c is the quantity of the consumption good, $0 < \beta < 1$ is the time rate of preference, and $\sigma > 0$ where $1/\sigma$ is the elasticity of intertemporal substitution. Population is assumed constant such that there is no aggregation bias in treating movements in per-capita quantities as equal to movements in aggregate quantities.

In each period t, the government makes a lump-sum transfer equal to G_t units worth of the consumption good. Initially, I assume that seignorage revenue is the only means of financing the transfer. The government budget constraint, therefore, is

(4) $G_t = (M_t - M_{t-1})/p_t.$

This transfer, combined with income and the gross return on goods deposited at banks, is used by households to purchase the consumption good and deposits that will be carried over into the next period. Formally, the household's date t budget constraint is

(5) $R_tD_t + G_t = c_t + D_{t+1},$

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[4] This illiquidity assumption is adapted from John Bryant and Neil Wallace (1980) and Scott Freeman (1987), who employs this technology in stationary economies to generate the need for financial intermediation. Essentially, the primitive intermediary serves a pooling function for small savers.

[5] This assumption may be motivated by appeal to some information frictions that keep banks from making loans larger than some fraction of output.

where D_t denotes the deposits (measured in units of the consumption good) carried over from date t-1 to date t, and R_t is the gross rate of return on these deposits.

In addition, the representative household faces a terminal constraint. Consistent with this terminal constraint is the notion that the household can sell claims against future deposits, but never at a value greater than can be repaid. The terminal constraint is

(6)
$$\lim_{T\to\infty}\left[\frac{D_T}{R_T}\right] = 0 \ ,$$

which guarantees that the period budget constraints (5) can be combined into an infinite horizon, present value budget constraint. Since the marginal utility of consumption goes to infinity as consumption goes to zero, an interior solution for c_t and D_{t+1} is guaranteed. Consumers take the initial positive quantity deposits, D_0, and the sequences $\{\gamma_t\}^{\infty}_{t=0}$, $\{M_t\}^{\infty}_{t=0}$, $\{G_t\}^{\infty}_{t=0}$, and $\{R_t\}^{\infty}_{t=0}$, as given when maximizing (3) subject to (5) and (6).

The bank accepts deposits, using the proceeds to purchase real money balances and capital. Capital is then rented to firms. Banks maximize profits, assuming banking services are provided costlessly. The bank is operating in a competitive environment. Every unit of capital returns A + (1-δ) units of the consumption good in the next period. Money is held by banks to meet a reserve requirement, denoted γ_t. The bank takes the sequences $\{R_t\}^{\infty}_{t=0}$ and $\{\gamma_t\}^{\infty}_{t=0}$ as given when maximizing profits.

The government is assumed to have committed itself to a sequence of $\{\gamma_t\}^{\infty}_{t=0}$, $\{M_t\}^{\infty}_{t=0}$, taking the sequence of interest rates as given. The government takes the initial stock of deposits, D_0, and the sequence of deposits and price level, $\{D_t\}^{\infty}_{t=0}$ and $\{p_t\}^{\infty}_{t=0}$, as given. The date t price level is determined by the money market equilibrium condition:

(7)
$$M_{t-1} = \gamma_t \, D_t \, p_{t-1}.$$

The implication is that the sequence of transfer payments is determined by the sequence of fiat money, the sequence of reserve requirement ratios, and, implicitly, the sequence of prices. Money carried over from date t-1 purchases $1/p_t$ units of the date t consumption good. Hence, the gross rate of return on fiat money is p_{t-1}/p_t. Throughout this paper, assume $A + (1-\delta) > p_{t-1}/p_t$.

The demand for money represented in equation (7) characterizes one part of the bank's asset allocation decision. Because money is rate-of-return dominated, the bank will invest all deposits above the required amount in capital; that is, $K_t = (1-\gamma_t)D_t$. The return to the bank's portfolio (and hence, to depositors) is represented as:

(8)
$$R_t = (1-\gamma_t)\,[A+(1-\delta)] + \gamma_t \frac{p_{t-1}}{p_t} ,$$

where $A+(1-\delta)$ is the gross return on capital after replacement, and p_{t-1}/p_t is the gross return on fiat money balances. The return on deposits is simply a weighted average of the returns to the two assets held by banks, with the weight being a function of the reserve requirement ratio. With $p_{t-1}/p_t <$ $A+(1-\delta)$ (rate of return dominance), equation (8) implies that the return offered by banks is inversely related to changes in the reserve requirement ratio.

The representative person's first-order condition implies that output, deposits, and consumption grow at the rate ρ_t between dates t-1 and t. This growth rate is expressed as

(9)
$$\rho_t = (\beta R_t)^{1/\sigma} = (\beta[(1-\gamma_t)A+(1-\delta)+\gamma_t \frac{p_{t-1}}{p_t}])^{1/\sigma}.$$

Equation (9) implies that the economy's growth rate is inversely related to the reserve requirement ratio. David Romer (1985) and Scott Freeman (1987) show how reserve requirements could crowd out capital. Their results, however, apply to the effect changes in reserve requirements have on the *level* of output. In the limit, with $\gamma = 0$, monetary policy becomes divorced from output growth. As in Jones and Manuelli, the absence of reserve requirements means that the rate of return on capital is independent of changes in money growth. Throughout this paper, I assume that $\theta > 1$ and $\gamma > 0$ so that the reserve requirement is a binding constraint. Here, the reserve requirement ratio affects capital accumulation through the gross return offered by the agent's portfolio. The intuition behind this effect is straightforward. According to 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.[6]

Equation (9) implies that the economy's growth rate is inversely related to the rate of money growth and, hence, to inflation. Suppose the supply of money follows the rule: $M_t = \theta M_{t-1}$. Using equation (7), and recognizing that $D_{t+1}/D_t = \rho$, then for a given rate of growth, $\theta = \rho\pi$. In equation (8), constant money growth implies that $p_{t-1}/p_t = 1/\pi$. As money growth rises, the inflation rate rises and the rate of output growth falls. The intuition is the same for an increase in the reserve requirement ratio; higher inflation drives down the return offered on deposits, making date t consumption more attractive. This result is qualitatively similar to that in earlier papers, but the mechanism is very different. With a positive reserve requirement ratio, higher inflation makes money balances less attractive. Instead of influencing the intratemporal tradeoff as occurs in the models with a cash-in-advance constraint, higher inflation results in a lower return on intermediated capital, translating into slower output growth. Thus, the mechanism highlights the role that monetary policy actions have on intertemporal substitution.

For a constant reserve requirement ratio and constant money growth, output, consumption, and deposits all grow at the same rate across time; that is, $\rho = \beta\{(1-\gamma)[A+(1-\delta)] + \gamma\theta\}$, where θ is the constant growth rate of money. As King and Rebelo note, the representative person in this model economy has finite utility if and only if $\beta\rho^{1-\sigma} < 1$. This condition holds in all the experiments

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[6] Jones and Manuelli (1990) briefly discuss the negative effect a decrease in the (after-tax) return has on output growth across two countries.

conducted in this paper.

3. Monetary Policy and Growth

First, I consider the quantitative impact changes in monetary policy have on the growth rate of the model economy. In doing so, the results provide some measure of the effect a change in monetary policy will have on economic growth.

3.1 Calibration

Obviously, to proceed one must select a set of parameter values. For this analysis, the model'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 set $\sigma = 2$ and $\delta = 0.1$.[7] For the inflation rate, I use the average increase in the fixed-weight GNP deflator over the 1959:1-1991:3 period, which is 4.1%. As noted above, the rate of money growth is fixed such that $\theta = \pi\rho$. Selecting a reserve requirement ratio for these experiments is difficult because the reserve requirement structure is nonlinear for checkable deposits and varies by the type of deposit. To calculate the average marginal reserve requirement across time, one would need data on the type of deposit and on the size of the bank in which the deposit was made. Such data are not available. Instead, I use the reserve requirement ratio on personal demand deposits at the largest banks as a rough guide. Before the enactment of the Depository Institution Deregulation and Monetary Control Act of 1980 (DIDMCA), the reserve requirement ratio against demand deposits at the largest banks was 16 1/4%. After December 1991, the reserve requirement ratio was 10%. With $\gamma^0 = 0.1625$, the gross after-reserve-requirement return is 1.048, so that $\beta = 0.9733 = (1.02/1.048)$.[8]

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[7] As is conventional, with $\sigma = 1$, the momentary utility is logarithmic.

[8] The parameters are consistent with rate of return equal to 6.5% when the reserve requirement ratio equals zero. In general, $\beta = 1.02/R$, where R is given by equation (8).

3.2 Monetary Policy Actions

The difference in the rate of economic growth for two different monetary policies is simply

(10)
$$100*(\beta*R^1)^{1/\sigma} - 100*(\beta*R^0)^{1/\sigma} ,$$

where R^i, $i = 0,1$ denoting the return on deposits under the baseline monetary policy action (0) and the new monetary policy action (1).

Figure 1 plots the rate of economic growth for different values of the reserve requirement ratio with a constant inflation rate. For this experiment, the constant rate of money growth is set so that the inflation rate equals 4.1%. The plot depicts combinations of the new reserve requirement (γ^1) ratio and the change in the rate of output growth for the case in which the initial reserve requirement (γ^0) ratio is 16 1/4% and inflation is held constant. For example, lowering the reserve requirement from 16 1/4% to 0% adds slightly more than 0.9 percentage points to the growth rate compared with what it would have been if no change to reserve requirements were implemented. Presently, the reserve requirement ratio is 10%. Letting $\gamma^1 = 0.10$, Figure 1 shows that output growth is nearly 0.5 percentage points higher. According to the benchmark setting, the reductions in reserve requirements dictated by DIDMCA added roughly 1/2 percentage point to the rate of growth.

Figure 2 plots the change in the growth for a money growth cum inflation rate experiment. Specifically, consider a case in which the initial inflation rate (π^0) is 10%. The plot is a combination of the change in the growth rate of output and the new inflation rate (π^1). For this experiment, the reserve requirement ratio is 10%. Eliminating inflation in this economy adds around 0.40 percentage points to the rate of growth. Reducing the inflation rate from 10% to 4%, such as in the Volcker disinflation, adds 0.2-percentage points to the growth rate. Note that if the reserve requirement were higher, output growth would increase even more for a given reduction in the inflation rate.

Because both money growth and reserve requirements jointly affect the return to deposits, the question arises as to how much of the growth-rate effect depends on the setting for the other monetary policy instrument. The return to deposits is inversely related to changes in both reserve requirements and the inflation rate. The cross-partial of the return is positive, indicating that, for a given reduction in reserve requirements, the size of the growth-rate effect is larger as the inflation rate increases. Figure 3 plots combination of the change in the growth rate and the value of the constant inflation rate for the case in which the reserve requirement ratio is reduced from 16 1/4% to 10%. As Figure 3 indicates, the growth rate effect is smaller as the inflation rate is lower. For example, reducing the reserve requirement with a constant 10% inflation adds slightly less than 1 percentage point to growth. For the case in which the constant inflation rate is set equal to zero, the rate of output growth rises by only a 0.2 percentage point for the given reduction in reserve requirements. The intuition behind this result is straightforward. A reduction in reserve requirements affects the growth rate of output based on the spread between returns to capital and returns to money. For a given reduction in the reserve requirement ratio, the larger the spread between intermediated capital and fiat money, the larger the gain to the return on deposits. Though not presented here, a similar argument holds for a given change in the inflation rate on growth and the size of the reserve requirement ratio. For a given decrease in money growth, the effect on output growth increases as the reserve requirement ratio is larger. Basically, the increase in the return to money is passed through more completely when the reserve requirement ratio is high. The implication is that for low reserve requirement economies, changing the inflation rate has muted growth-rate effects.

Overall, monetary policy actions have relatively large effects on output growth, especially in light of the growth-rate effects estimated for economies in which other distortions or increasing returns are present. Indeed, the growth rate effects are perhaps too large to be believable.[9] Since

[9] Gomme presents a simple histogram with the contemporaneous correlation between inflation and output growth for 82 countries. The highest frequency is at -0.3 and -0.4.

monetary policy operates through the intertemporal substitution, I consider alternative values of the elasticity of substitution to determine how sensitive the results are to changes in this parameter.

Table 1 reports the increase in the rate of output growth for three specific monetary policy actions and three different values of the elasticity of substitution parameter. The particular monetary policy experiments are listed as row headings. In addition to the setting with $\sigma = 2$ (the setting chosen by Jones and Manuelli), I examine the case with logarithmic utility and with $\sigma = 5$. In each monetary policy experiment, the growth-rate effect declines as the elasticity of substitution, i.e., $1/\sigma$, is decreased. For example, in the case in which $\sigma = 5$, if the monetary authority lowers the reserve requirement from 16 1/4% to 10%, the rate of growth increases by 0.19 percentage points. Similarly, if the inflation rate falls from 10% to 0%, output growth increases by 0.17 percentage points. We also estimate the effects with logarithmic utility. But the estimates with $\sigma = 2$ are at the upper bound of estimated growth-rate effects then the estimates with logarithmic utility are too large to be empirically relevant. Even with the elasticity of substitution equal to two, the growth-rate effects are quite large. In the rest of this paper, I will use $\sigma = 2$ and $\sigma = 5$ to calculate welfare costs and the effects on seignorage revenue.

4. Welfare Effects

Another issue is, What effect do changes in the monetary policy instruments have on the welfare of the representative agent? This question is raised by Cooley and Hansen in a stationary model economy. In Cooley and Hansen, the loss of seignorage revenue meant that other distortionary taxes might have to be raised to maintain the same path of government transfers. Cooley and Hansen report that a 10% inflation rate costs about 0.15 percent of consumption. In an endogenous growth model, Jones and Manuelli find welfare costs somewhat larger than those reported in Cooley and Hansen, but Gomme reports a welfare gain roughly 1/10th the size of these estimates.

Here, two separate policy experiments are considered; one asks how welfare responds to a reduction in the reserve requirement ratio, and the other examines the effect of a reduction in the inflation rate. More specifically, what happens to welfare when (a) the reserve requirement ratio falls from 16 1/4% to 10% and (b) the inflation rate falls from 10% to 0%.

The measure of welfare requires comparison of the sequences of consumption under the alternative policies. Let $\{c_t^0\}_{t=1}^{\infty}$ denote the sequence of consumption when the policy instrument is set equal to baseline value and let $\{c_t^1\}_{t=1}^{\infty}$ be the sequence of consumption under the new policy setting. when the reserve requirement is 10%. Then the calculation is

(11) $$U(\{c_t^0\}(1+\phi)_{t=1}^{\infty}) = U(\{c_t^1\}_{t=1}^{\infty}).$$

Then ϕ measures the percentage-change in consumption that would be necessary to make the agent just as well off in the baseline policy setting as in the new policy setting. To simulate the consumption path, a special case of the model is established in which the initial capital stock, K_0, is set equal to 1. As with Cooley and Hansen, welfare is measure as ϕ.

For the first experiment, the baseline reserve requirement ratio (γ^0) is set equal to 16 1/4% and is compared with the outcomes in which the reserve requirement is set equal to 10% (γ^1). Money growth in this case is set so that the inflation rate equals 4.1%. Table 2 reports the effects that a lower reserve requirement has on initial consumption, the rate of growth, and welfare for the three different values of the elasticity of substitution. In each case, initial consumption falls in response to a lower reserve requirement. To accumulate more capital, the agent forgoes consumption initially in response to the higher return on deposits offered by competitive banks in the low reserve requirement setting. For these parameter settings, initial consumption falls about 9%. Meanwhile, the growth rate of output (and consumption) is slightly more than 0.4 percentage points higher with $\gamma^1 = 0.10$ than it would have been with $\gamma^0 = 0.1625$ when period utility functions are logarithmic. With higher values for σ, the welfare effects are muted, as are the growth rate effects and loss of initial consumption. The estimates indicate that consumption would have to be 7.6 percentage points higher for the agent to be as well off with $\gamma^0 = 0.1625$ as with $\gamma^1 = 0.10$ and logarithmic utility, but only 0.6 percent greater for the case with $\sigma = 5$.

Table 3 reports the welfare gains achieved for a case in which the money growth is lowered so that the inflation rate falls from 10% to 0%. The reserve requirement ratio is 10% in this experiment. With $\sigma = 2$, the welfare costs of 10% inflation are 3.4% of consumption. As an additional experiment, I computed the welfare costs with the same parameter values, except the reserve requirement ratio is set at 16 1/4%. In this setting, the welfare costs jump to 6.5% of consumption.[10] With $\sigma = 5$, the welfare costs of the moderate inflation is 0.7% of consumption. Using the same parameter values, the welfare costs of inflation are about seven times the estimates obtained with a nominal depreciation allowance distortion and more than twenty times the estimates in a stationary economy. With lower values for the elasticity of substitution, the growth-rate effects are closer to correlations found in the data and the welfare costs of a 10% inflation are quite similar to estimates presented using a nominal depreciation allowance. The implication is that the existence of reserve requirements produces a moderately larger distortion for monetary policy than if monetary policy actions operate through money illusion distortions in the tax code.

5. Seignorage Revenue

In this set of experiments, I ask whether changes lowering either reserve requirements or the inflation rate will generate enough growth so that the same sequence of government expenditures can be financed. The answer to this question says something about seignorage revenue but also ensures

[10] Asye İmrohoroğlu and Edward Prescott (1991) estimate the size of the welfare costs of inflation in a stationary economy with reserve requirements. Their estimates are between 0.5% and 1.0% of consumption with reserve requirement ranging from 49% to 100%. This yields a rough measure of the importance that the growth-rate effects have in calculating the welfare costs of inflation.

that the welfare comparisons made above are indeed comparable. This is essentially the same question asked by Ireland (1994) regarding the effects of a change in the income tax rate. The issues are essentially the same; lowering either the inflation rate or reserve requirements lowers the tax rate. As shown above, the tax base is expanding at a faster rate. The question, therefore, is in the spirit of a present-value Laffer curve.

The model needs to be specified more fully for these exercises. As equation (4) specifies, the only source of funds is seignorage revenue. Later, I also consider the effects on present-value revenue when an income tax is present. Lastly, I introduce unintermediated capital into the model.

I assume that the growth rate of government expenditures is determined by the growth rate of the economy. Here, the question is whether the government can fund the same sequence of expenditures under lower reserve requirement or slower money growth. In other words, can the government lower reserve requirement ratios or the rate of money growth and still balance the present-value budget constraint without raising reserve requirement or money growth in the future?

The first step is to characterize the present value of the government budget constraint. With government expenditures growing at the same rate as the economy, the ratio of government spending to output will remain constant. Let $\alpha = G_t/Y_t$. Then the date t value of government expenditures can be written as

(12)
$$G_t = \alpha A\left[\beta\left[(1-\gamma)(A+1-\delta)+\frac{\gamma}{\pi}\right]\right]^{t/\sigma}.$$

Substituting the money supply rule into equation (4) yields the following expression for date t government budget constraint:

(13)
$$(\theta-1)\gamma\frac{D_t}{\pi} = \alpha A\left[\beta\left[(1-\gamma)(A+1-\delta)+\frac{\gamma}{\pi}\right]\right]^{t/\sigma}.$$

Further substitution using the bank's asset allocation condition gives the date t budget constraint as a function of reserve requirements and the inflation rate; that is,

(13')

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

From equation (13'), it is straightforward to show that real seignorage revenue (the right-hand side) is positively related to the reserve requirement ratio and money growth. Next, summing over all the dates, the present value of the government budget constraint is represented as:[11]

(14)

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

The next step is to characterize the change in the present-value budget constraint for a given change in a monetary policy instrument. For example, let the "high" reserve requirement ratio be γ^0, while the "low" reserve requirement ratio is γ^1. Over an infinite horizon, the government's present-value budget constraint is zero. In equation (12), substitute for G_t, letting $\gamma = \gamma^0$ be the reserve requirement ratio. Set $\gamma = \gamma^1$ as the revenue path under the lower reserve requirement ratio. Finally, substitute $\gamma = \gamma^1$ and $\pi = p_t/p_{t-1}$ into equation (8) to obtain the discount factor. With $K_0 = 1$, the government can fund the same sequence of transfers if and only if

(15)

$$\sum_{t=0}^{\infty}\left[\frac{\frac{(\theta-1)}{\pi}\left(\frac{\gamma^1}{1-\gamma^1}K_t - \frac{\gamma^0}{(1-\gamma^0)}K_t\right)}{[(1-\gamma^1)(A+1-\delta)+\gamma^1]^t}\right] \geq 0 .$$

With $K_t = \beta[(1-\gamma)(A+1-\delta) + \gamma/\pi]^{t/\sigma}$, one can see that changes in the monetary authority's instruments can affect the present-value budget constraint through three channels. First, the seignorage revenue rate is positively related to changes in reserve requirements and money growth.

[11] Government borrowing is not considered in this setup. One include government borrowing into the model with the appropriate terminal condition. A no-Ponzi condition assumption guarantees that the infinite horizon government budget constraint can be written and does not quantitatively alter the results.

Second, the path of capital accumulation is inversely related to changes in reserve requirement ratios and money growth. The Laffer curve-type tension present in this numerical exercise is whether the tax-rate effect or the tax-base effect dominates. Third, the reduction in the reserve requirement ratio raises the return on deposits and thus decreases the present value of the government's future receipts and expenditures.

With $R > 1$, equation (15) can be further simplified, written as

(16)
$$PVBC = \frac{n^1}{R^1 - (\beta R^1)^{1/\sigma}} - \frac{n^0}{R^1 - (\beta R^0)^{1/\sigma}}$$

where $n^1 = (\theta-1)\gamma^1/(1-\gamma^1)\pi$, $n^0 = (\theta-1)\gamma^0/(1-\gamma^0)\pi$, $R^1 = (1-\gamma^1)(A+1-\delta) + \gamma^1/\pi$, and $R^0 = (1-\gamma^0)(A+1-\delta) + \gamma^0/\pi$. Because this monetary policy instrument has an ambiguous effect on PVBC, the next step is to apply numerical techniques to calculate the present-value budget constraint; that is, can the same sequence of transfer payments be financed with a lower reserve requirement ratio, using reasonable parameter values?

5.1 Economies with only Seignorage Revenue

The first experiment is to examine the effect a change in the reserve requirement ratio has on the present-value budget constraint [equation (15)]. Figure 4 plots the combination of PVBC and the new reserve requirement ratio, γ^1. The initial reserve requirement ratio is $\gamma^0 = 0.1625$. Money growth is set so that the inflation rate in these experiments is set equal to 4.1%. In addtion, $\sigma = 5$ so that the growth-rate effects used are the more conservative ones. With $\gamma = 0.1625$, the ratio of seignorage revenue to output is about 7% at date $t=1$, nearly three times the steady-state values for the seignorage-output ratio estimated in İmrohoroğlu and Prescott (1991).[12] Of course, seignorage revenue is the only source of revenue in this version of the model. As Figure 4 shows, PVBC is

[12] With the inflation rate equal to 10% and the reserve requirement ratio equal 16 1/4%, the tax rate on capital is 2.2%. With the reserve requirement set at 10% and inflation at 4%, the tax rate falls to 0.65%.

negative for all values of the reserve requirement ratio considered. Hence, lowering the reserve requirement from 16 1/4% to 10%, as the Federal Reserve has done since the 1980s, results in a sequence of seignorage revenue that is smaller than what would have been funded if the reserve requirement ratio were left unchanged.

Next, consider the effect of a change in money growth. For this, equation (16) is altered, with $n^1 = (\theta-1)\gamma/(1-\gamma)\pi^1$, $n^0 = (\theta-1)\gamma/(1-\gamma)\pi^0$, $R^1 = (1-\gamma)(A+1-\delta) + \gamma/\pi^1$, and $R^0 = (1-\gamma)(A+1-\delta) + \gamma/\pi^0$, where π^0 is the initial inflation rate, and π^1 is the new inflation rate. The value of reserve requirements used in these experiments is 16 1/4% and $\sigma = 5$. Figure 5 plots combinations of PVBC and the new inflation rate, π^1. The initial value of the inflation rate is 10%, or $\pi^0 = 1.10$. As the plot shows, PVBC is negative at all values of π^1. In this model economy, lowering the inflation rate results in a decline in the present value of seignorage revenue. This result is consistent with Cooley and Hansen. So even with the faster rate of output growth, the reduction in the tax rate dominates the present-value calculation of the change in seignorage revenue.

Overall, the evidence suggests that, with only seignorage revenue as the source, lowering reserve requirements or money growth would result in a revenue shortfall such that balancing the budget would require a smaller sequence of government expenditures. These estimates are consistent with the Cooley and Hansen result in that a lower inflation rate would require increases in other distortionary taxes to maintain the same path for government expenditures.

5.2 Economies with seignorage and income taxes

Consider one modification to the model to include an income tax rate, denoted τ. The date t budget constraint is

(17)
$$G_t = \tau A K_t + \frac{(\theta-1)\gamma}{(1-\gamma)\pi} K_t,$$

and with constant money growth and reserve requirement ratios, the return to deposits is

(18) $R_t = [(1-\tau)A + (1-\delta)](1-\gamma) + \gamma/\pi.$

After substituting for the return on deposits and the date t budget constraint into the present-value budget constraint, the expression looks like PVBC in equation (16), with the values of $n^1 = \tau A + (\theta-1)/\pi * \gamma^1/(1-\gamma^1)$, $n^0 = \tau A + (\theta-1)/\pi * \gamma^0/(1-\gamma^0)$. Further, γ^1 and γ^0 are substituted into R^1 and R^0, respectively.

Figure 6 plots the combination of the change in PVBC and the new reserve requirement ratio. The initial reserve requirement ratio is 16 1/4% for these experiments. In this case, the change in PVBC is negative for every value of the reserve requirement ratio considered. Figure 7 plots the combination of the change in PVBC and the rate of inflation. The initial policy sets the inflation rate at 10%. As with the reserve requirement experiments, a decline in the inflation rate is not enough to offset the reduction in the tax rate.

In both cases, monetary policy has virtually no impact on output growth for the parameter settings chosen. Because the growth rate effects are small, the decline in the tax rate more than offsets the increase in the tax base. To demonstrate how sensitive PVBC is to the size of the growth rate effect, consider the reserve requirement and money growth experiments with an income tax present and $\sigma = 2$.

Panels (a) and (b) in Figure 8 redo the reserve requirement and inflation rate experiments, respectively, setting $\sigma = 2$. In both monetary policy experiments, the change in PVBC is positive for small to moderate movements in the monetary policy parameters. The implication is that small changes in the tax rate result in sufficient growth in the tax base to increase the present value of total revenue. However, the figures are also telling in that relatively large changes in the monetary policy variables fail to generate enough growth in the tax base to raise the present value of total revenues. For example, the effect on PVBC is different for the two policies; lowering reserve requirements from 16 1/4% to 10% would result in PVBC < 0, but lowering the inflation rate from 10% to 4%

would result in PVBC > 0.

The effect that monetary policy actions have on the government's present-value budget constraint depend on the potency (in terms of impact on the growth rate) of the policy action. If the growth-rate effects are negligible, seignorage revenue falls in response to a lower inflation rate and lower reserve requirements. Moreover, total revenue also falls. However, if the elasticity of substitution is smaller, monetary policy actions have larger growth-rate effects, and small changes in the inflation rate or reserve requirements result in a higher present value for total revenues in this model economy.

5.3 Economies with unintermediated capital

In this section, I relax the assumption that all capital is intermediated. This modification does not affect the growth-rate effects but appropriately limits the tax base to that portion of the capital stock that is financed by banks. This approach addresses the size of seignorage revenue relative to income. The question, therefore, is, What happens to total tax revenues if the taxing powers of the monetary authority are limited to intermediated capital? The basic issue is still the same--the tradeoff between the tax rate and tax base. Both the tax rate and tax base shrink in this modified version, but the rate of the tax base is not affected.

To obtain the distribution of savings between intermediated and unintermediated capital, the arbitrage condition requires that the returns be equal. Unintermediated capital is not subject to a reserve requirement ratio but has a diminishing marginal product. Let the technology transforming unintermediated capital into consumption goods be

$$B(K^u)^\omega,$$

where K^u denotes the stock of unintermediated capital. With population constant, this is a Cobb-Douglas production technology. For this computational experiment, it is necessary to quantify the initial stock of unintermediated and intermediated capital. In period 0, let the sum of the two types of capital be equal to 1. Then arbitrage condition can be used to solve for the initial stock of unintermediated capital. Formally,

(19)
$$(1-\gamma)\left[(1-\tau)A+(1-\delta)\right]+\frac{\gamma}{\pi} = \omega(1-\tau)A(K^{u})^{\omega-1}+(1-\delta) .$$

Using equation (19) to solve for K^u, the stock of intermediated capital is simply $1-K^u$.

For the computational experiment, B = 0.35 and ω = 0.35. All other values are equal to their baseline values and $\sigma = 5$. For this case, the ratio of seignorage revenue to output is 0.009% and the ratio of the initial stock of intermediated capital to total capital is 27% of the total capital stock. Figure 9 then calculates the change in PVBC for the two alternative policy actions. The growth rate of consumption, deposits, and output is unaffected by introducing unintermediated capital.[13] Panel (a) plots the outcomes of the reserve requirement experiments; that is, the combination of the change in PVBC and the new reserve requirement ratio when original policy value is $\gamma^0 = 0.1625$. Panel (a) shows that the PVBC is positive at every value so that lowering reserve requirements results in larger present value for revenues. Panel (b) plots the PVBC for the inflation rate experiments in which the original policy is setting money growth such that the inflation rate is 10%. Again, PVBC is positive for every decrease in the inflation rate considered.

Thus, the present value of government revenues rises in response to lower inflation rates and lower reserve requirements. Despite the lower tax rates, the model economy with unintermediated

[13] The return to capital with a linear production function does not depend on the quantity of capital. Consequently, a growing capital stock does not affect return to intermediated capital as it does unintermediated capital. The upshot is that as $t \rightarrow \infty$, then $K/(K+K^u) \rightarrow 1$. One could make a policy action neutral with respect to the ratio of intermediated capital to total capital by letting the technological constant grow at the same rate as intermediated capital. The growth rate of intermediated capital would not be affected by technology-driven growth in the unintermediated sector. Thus, the path for seignorage revenue in these experiments would be unaffected by maintaining a constant ratio for $K/(K+K^u)$.

and intermediated capital grows enough to offset the lower rates. In this case, seignorage revenue is just such a small fraction of total taxes that altering the rates has virtually no effects on the overall tax rate. Consequently, the policy actions considered result in faster, albeit small, growth so that tax revenues rise.

The main result of this section is that economies in which seignorage revenue is a small fraction of total revenues can generate more revenue by choosing a lower inflation rate or lower reserve requirement. In addition, the results indicate that the same sequence of government expenditures can be financed by lowering either monetary policy instrument. This finding validates the welfare estimates presented earlier. Moreover, the evidence suggests that it is not necessary to raise income taxes to offset lower seignorage taxes in a growing economy.

6. Summary

In this paper, a simple general equilibrium model with endogenous growth is used to examine the effects of monetary policy on the growth rate. In this setup, savers are forced to use banks because capital is illiquid in the sense that there is a minimum size restriction on an investment project. In general, reduced money growth (lower inflation) and/or lower reserve requirements result in increased output growth because the return on deposits is increased. The model is similar to other endogenous growth models used to examine the role of monetary policy except in one important respect. In this model economy, a reserve requirement distortion is introduced so that monetary policy actions affect the return on intermediated capital directly. This direct effect also translates into larger growth-rate effects and more substantial welfare gains. In short, the marginal effect that monetary policy actions have on the return to capital means that monetary policy is moderately more powerful as a tool to influence growth and welfare.

In computational experiments, the estimates of growth-rate and welfare effects generated under conventional parameter settings are large. With a relatively small elasticity of substitution parameter, the growth-rate and welfare effects are smaller, but the welfare cost of inflation is still quite large compared with earlier estimates.

What these findings demonstrate is how monetary policy actions affect the economy when they affect the choices between consumption today and consumption tomorrow. The reserve requirement is a distortion that affects these choices. Because reserve requirements are so prevalent across the world, this distortion makes this mechanism empirically relevant and thus worthy of examination. The results from the computational experiments indicate that reserve requirements are a bigger distortion than other distortions considered in this literature, in the sense that changes in monetary policy have relatively large effects under "normal" parameter settings. Several questions are raised by this research. Of course, one question involves the transition dyanmics, which are excluded in this setup. Another issue is the primitive money demand specificatio. If people held money as a savings vehicle, a "Tobin effect" would be present. A higher inflation rate would result in some substitution between money in its saving role to capital, thus muting the monetary policy effects. In addition, the absence of uncertainty means that information problems are not taken seriously into consideration. Lastly, this setup does not permit a characterization of dinintermediation. It would interesting to study the effect that change in the inflation rate would have bank financing versus direct financing.

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Table 1

Changes in Growth Rates
for Various Values of σ
(measured in percentage points)

	$\sigma = 1$	$\sigma = 2$	$\sigma = 5$
π falls from 10% to 0% (holding res req constant at 10%)	0.87	0.43	0.17
γ falls from 16 1/4% to 10% (holding infl rate constant at 4.1%)	0.94	0.47	0.19

Table 2

Welfare Effects of a Change in the
Reserve Requirement Ratio from 16 1/4% to 10%

Panel A: $\sigma = 2$

	$\gamma^0 = 16\ 1/4\%$	$\gamma^1 = 10$	% Change
Initial consumption	0.0550	0.0519	- 5.6
Growth rate	1.0	1.31	0.31
Welfare (ϕ)	---	---	2.1

Panel B: $\sigma = 5$

	$\gamma^0 = 16\ 1/4\%$	$\gamma^1 = 10$	% Change
Initial consumption	0.0610	0.0598	- 2.0
Growth rate	0.40	0.52	0.12
Welfare (ϕ)			0.6

Table 3

Welfare Effects of a
Change in the Inflation Rate

Panel A: $\sigma = 2$

	$\pi^0 = 10\%$	$\pi^1 = 0\%$	% Change
Initial consumption	0.0466	0.0422	- 8.6
Growth rate	1.84	2.28%	0.44
Welfare (ϕ)			3.4

Panel B: $\sigma = 5$

	$\pi^0 = 10\%$	$\pi^1 = 0\%$	% Change
Initial consumption	0.0577	0.0559	- 3.1
Growth rate	0.73	0.91	0.18
Welfare (ϕ)			0.7

Figure 1

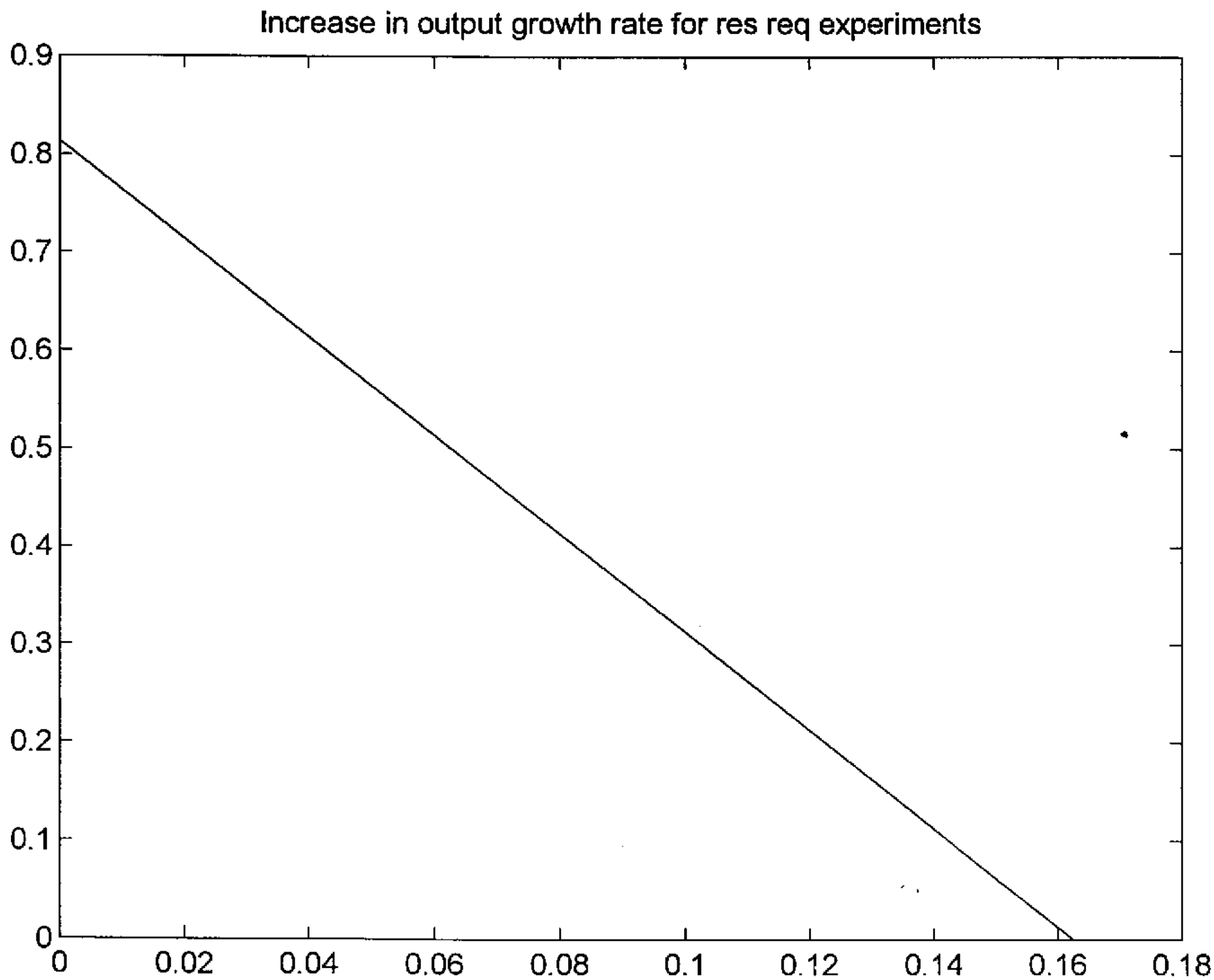

Increase in output growth rate for res req experiments
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18

Figure 2

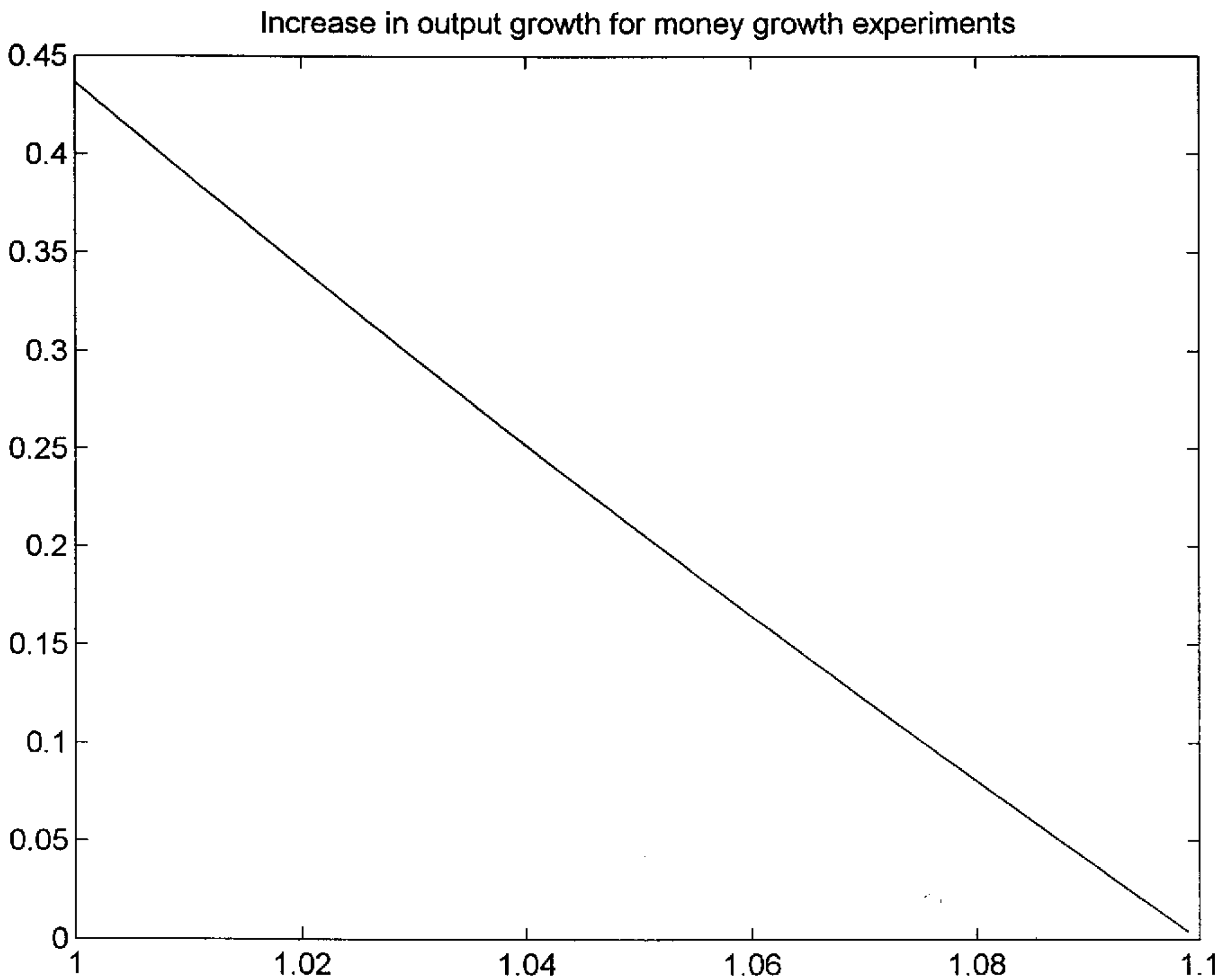

Increase in output growth for money growth experiments
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1
1.02
1.04
1.06
1.08
1.1

Figure 3

Growth-rate effects for a given change in res req
under alternative values of the constant inflation rate

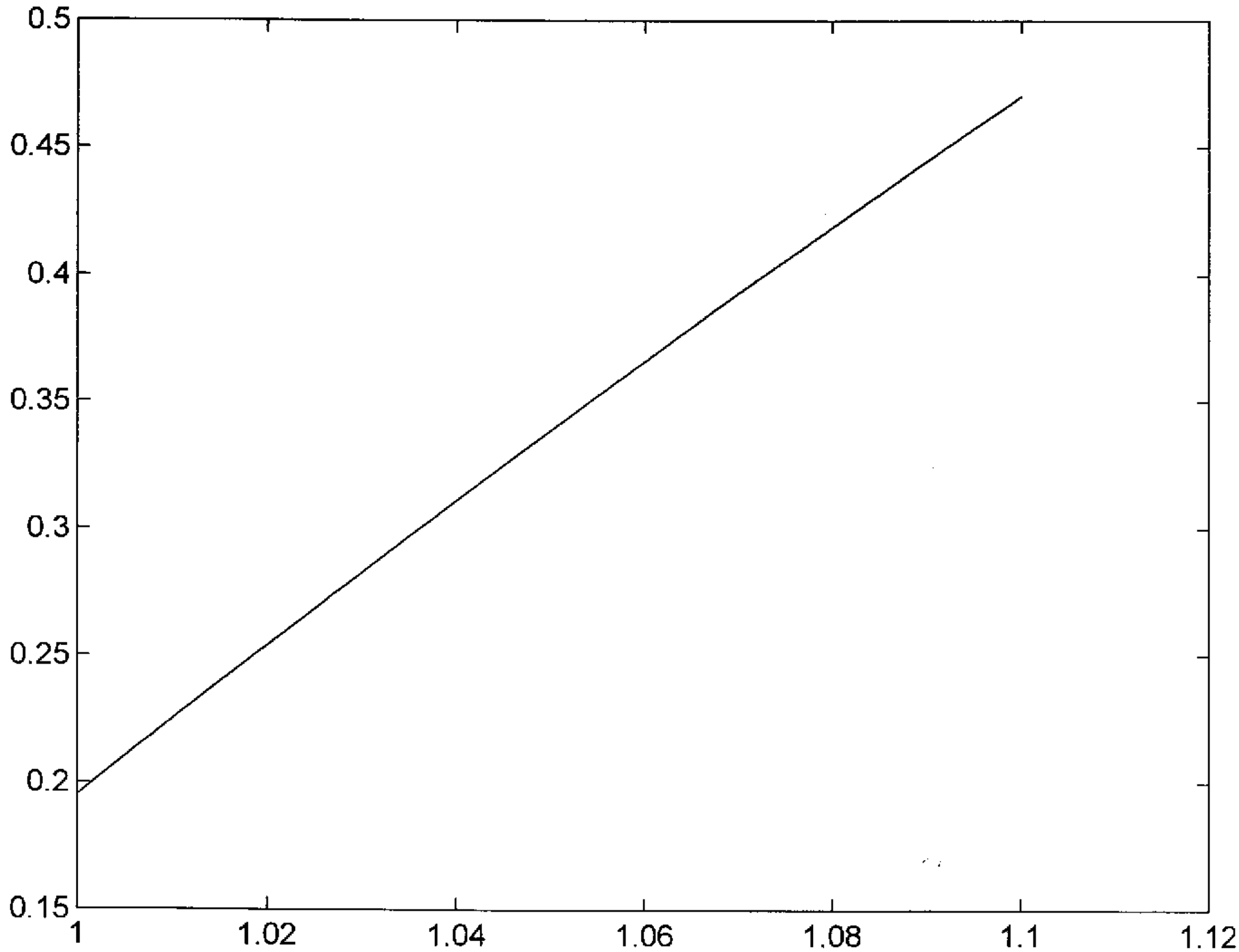
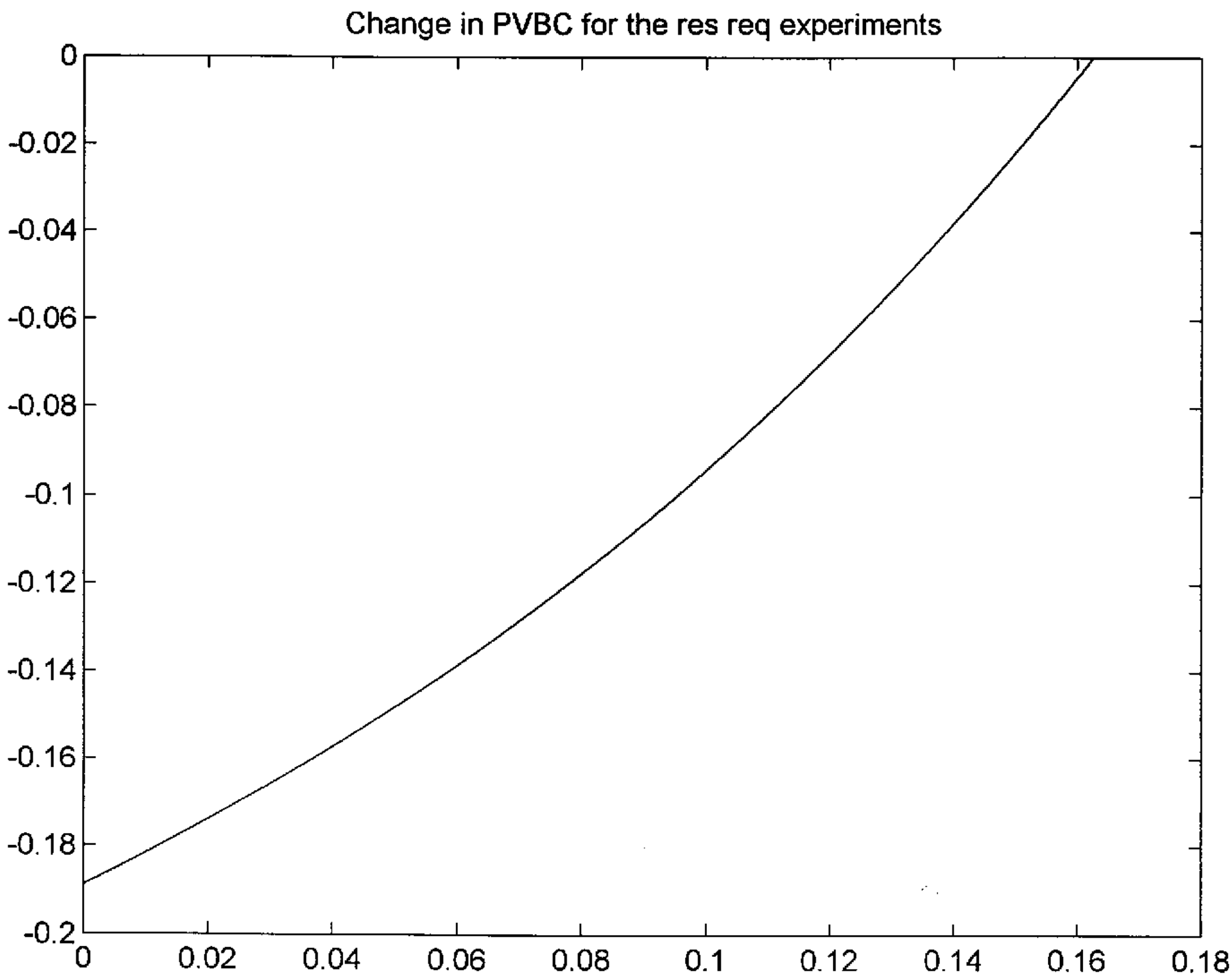
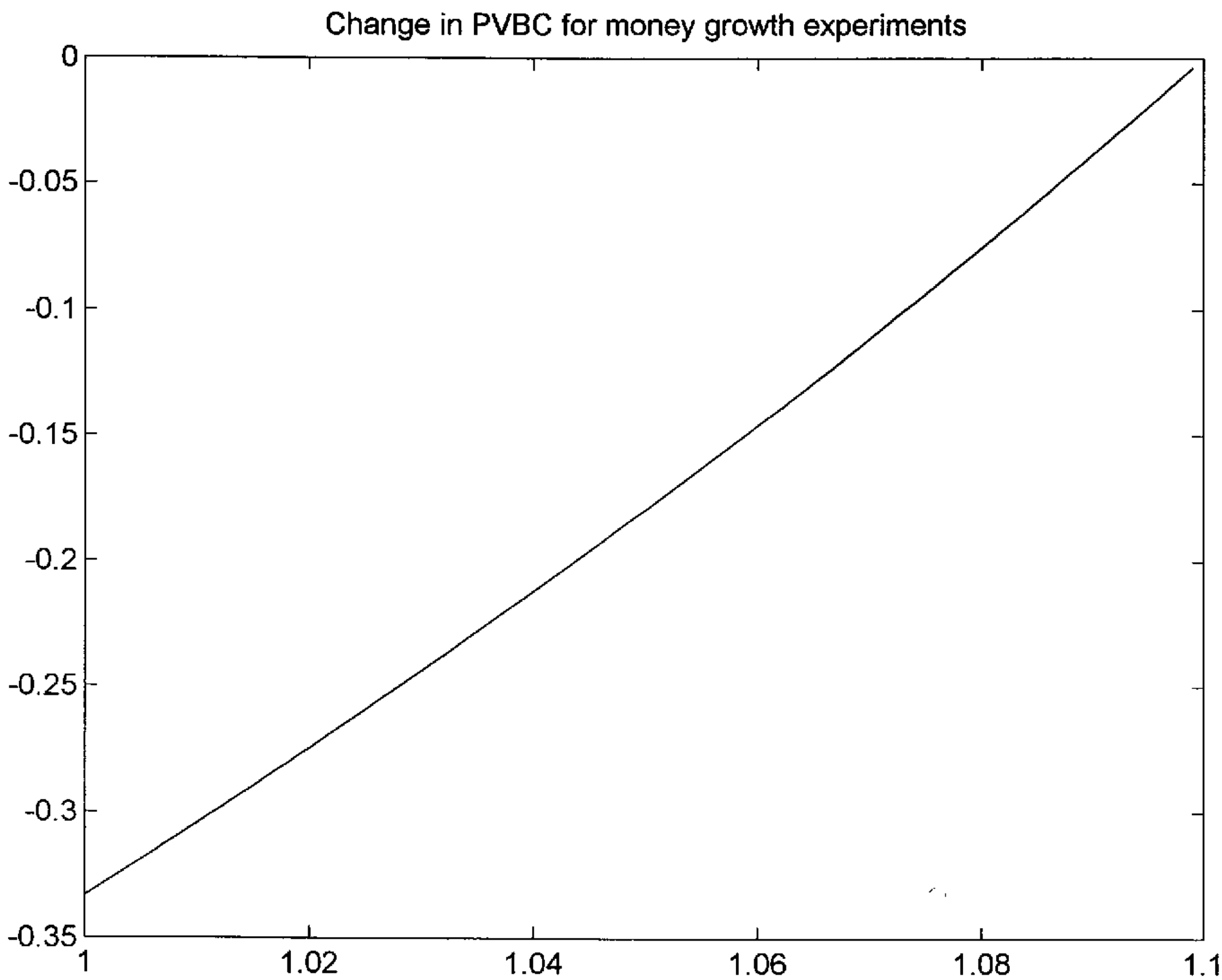


Figure 4



Change in PVBC for the res req experiments
0
-0.02
-0.04
-0.06
-0.08
-0.1
-0.12
-0.14
-0.16
-0.18
-0.2
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18

Figure 5



Change in PVBC for money growth experiments
0
-0.05
-0.1
-0.15
-0.2
-0.25
-0.3
-0.35
1
1.02
1.04
1.06
1.08
1.1

Figure 6

Change in PVBC for reserve requirement
experiments with $\tau = 20\%$ and $\sigma = 5$

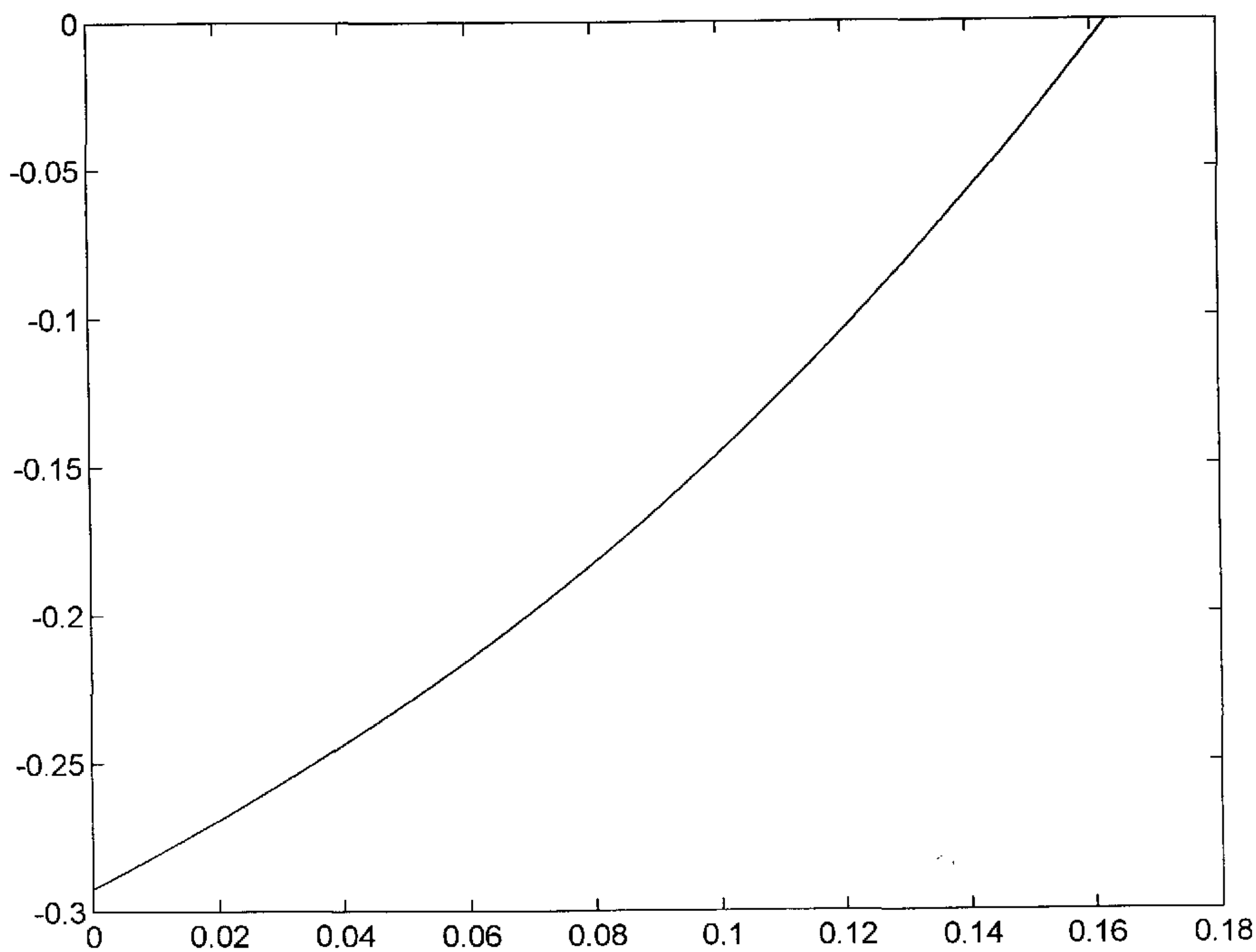


Figure 7

Change in PVBC for inflation rate
experiments with τ = 20% and σ = 5

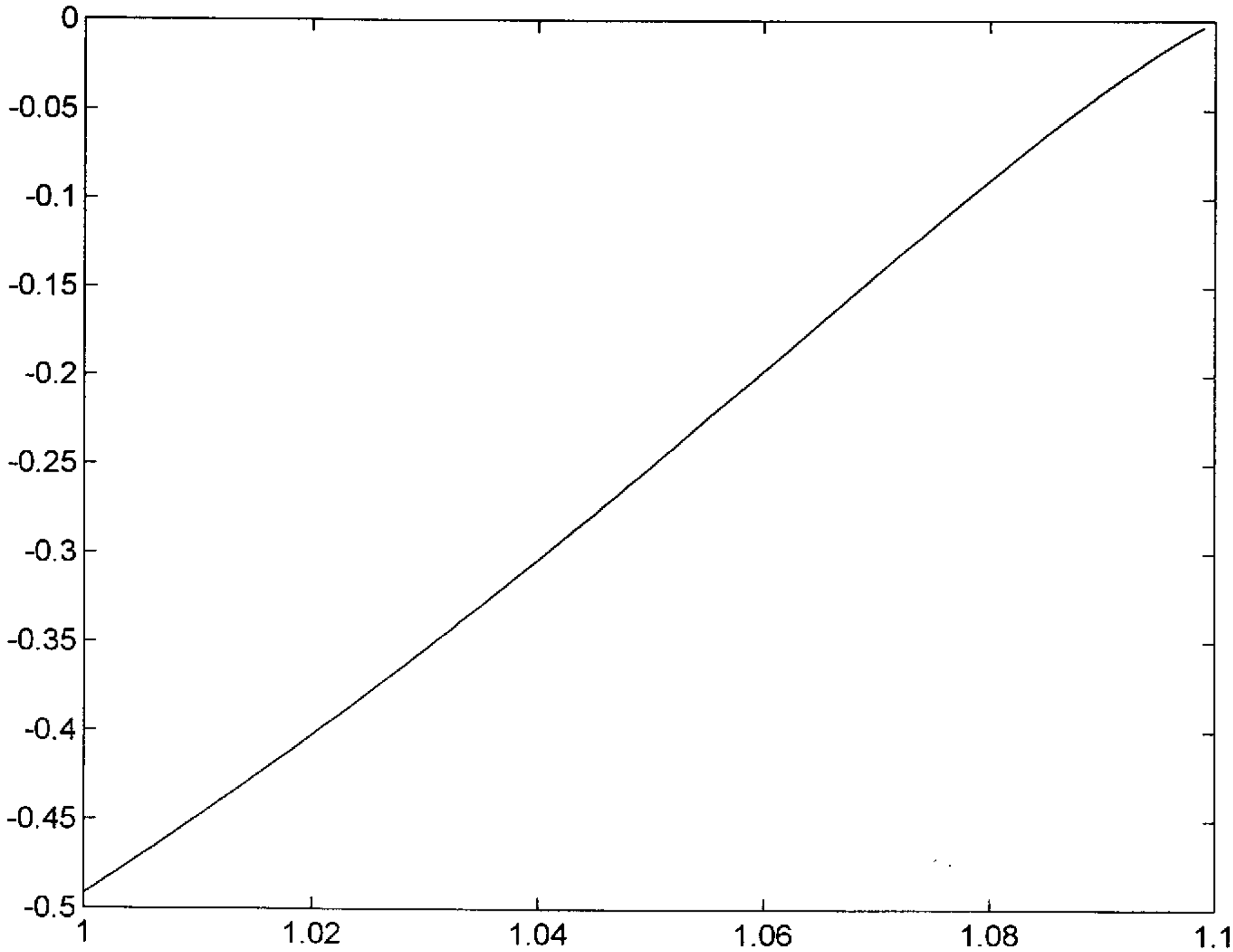


Figure 8(a)

Change in PVBC for reserve requirement experiments with τ = 20% and σ = 2

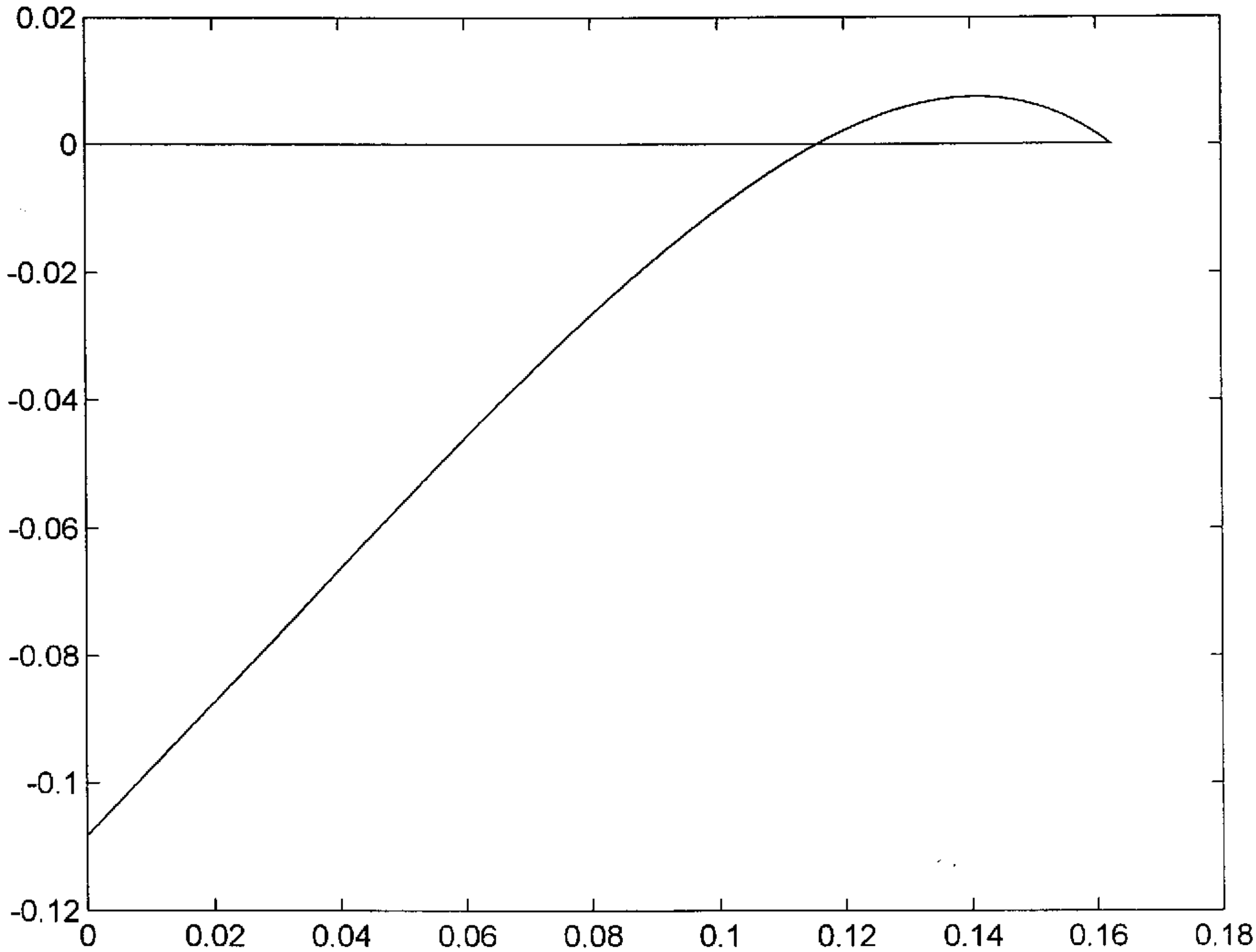


Figure 8(b)

Change in PVBC for inflation rate
experiments with τ = 20% and σ = 2

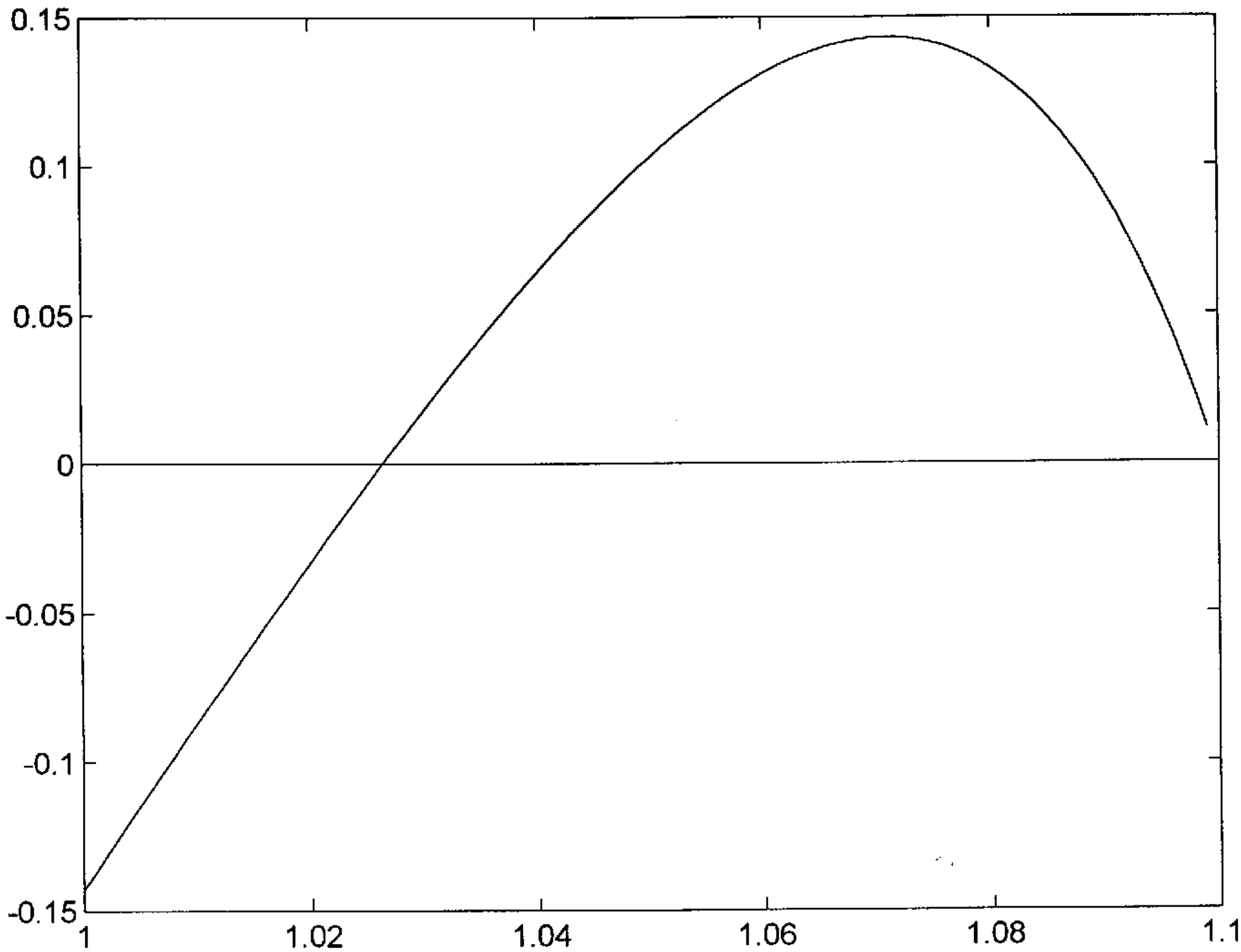


Figure 9(a)

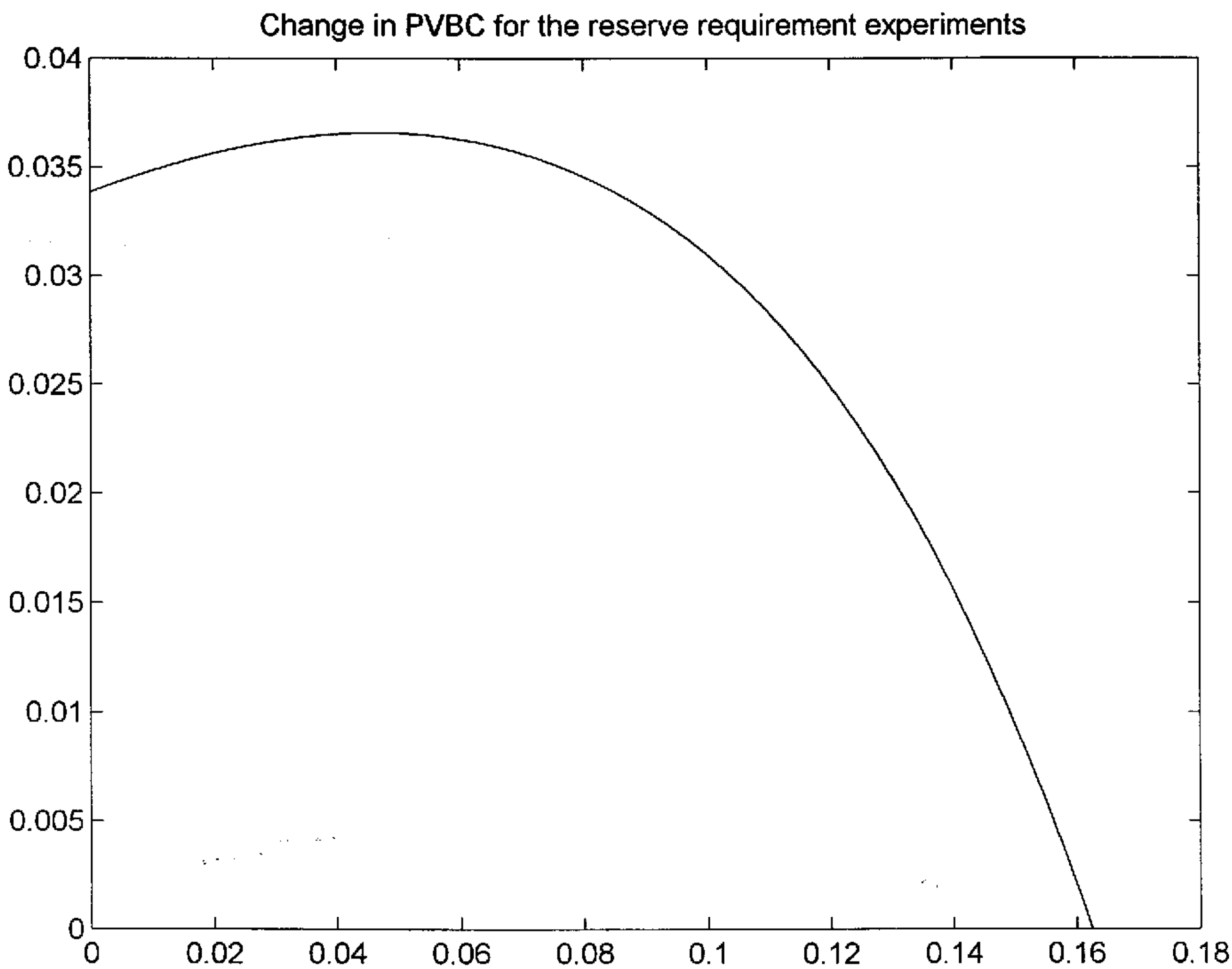
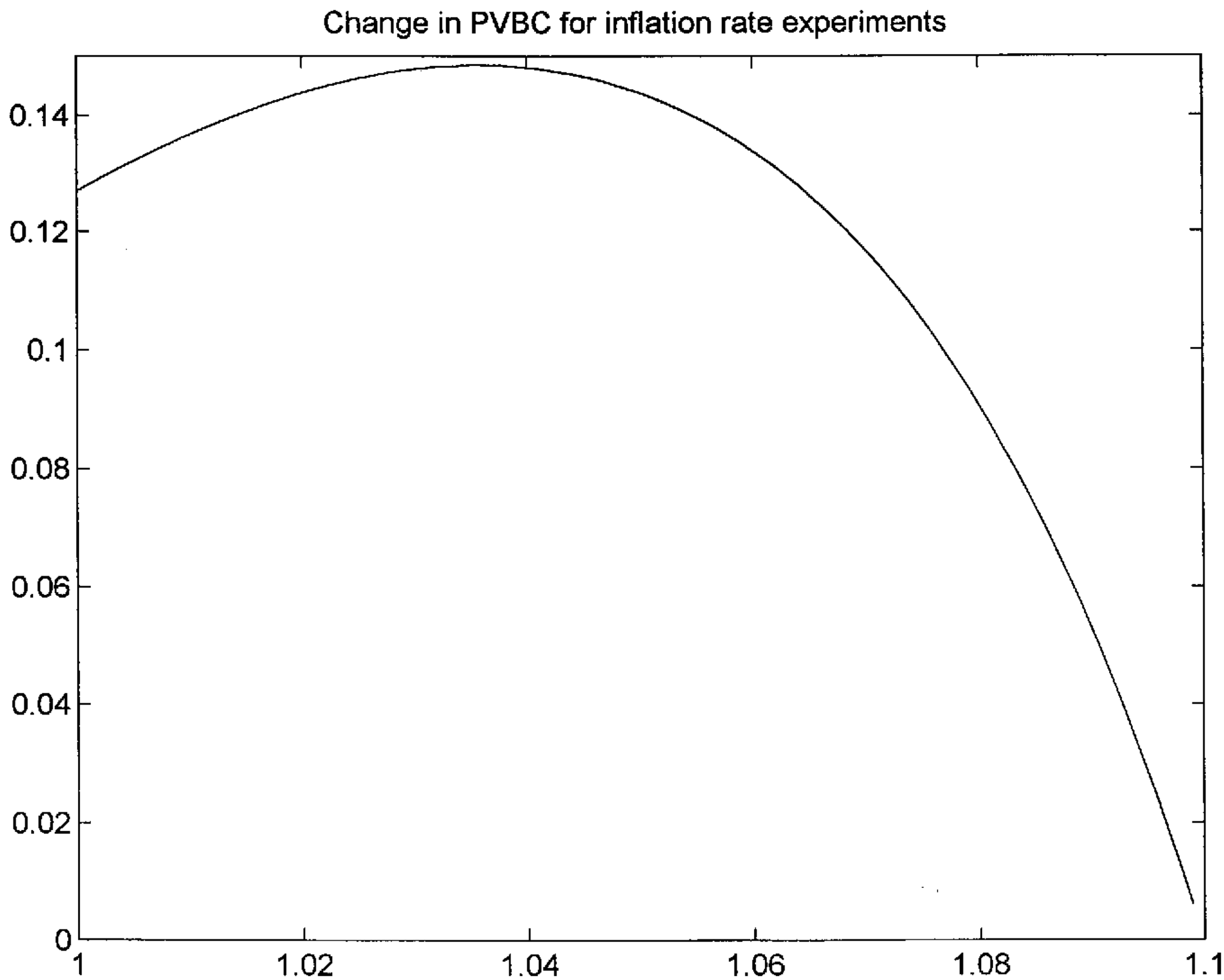

Change in PVBC for the reserve requirement experiments
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18

Figure 9(b)


Change in PVBC for inflation rate experiments
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1
1.02
1.04
1.06
1.08
1.1

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