Comments on "Optimal Monetary and Fiscal Policy: A Linear-Quadratic Approach" by Pierpaolo Benigno and Michael Woodford.*

Stefania Albanesi

Duke University

August 2003 (First version: June 2003)

1 Introduction

Benigno and Woodford seek to offer an integrated analysis of optimal fiscal and monetary policy building on two literatures. The first is the one on dynamic optimal taxation, stemming from the seminal contribution of Lucas and Stokey (1983)[1]. The second literature is on optimal monetary stabilization policy, as in Goodfriend and King (1997), Rotemberg and Woodford (1997) and Woodford (2000)[2]. Both literatures consider the problem of a benevolent government

*Prepared for the NBER Macroeconomics Annual Conference, April 4-5 2003. I wish to thank Larry Christiano and Henry Siu for stimulating discussions.

[1]An excellent survey of this literature can be found in Chari and Kehoe (1999).

[2]Additional important contributions in this literature are King and Wolman (1998), Kahn, King and Wolman (2000), and Giannoni and Woodford (2001)

seeking to stabilize the response of economic outcomes to exogenous shocks with a combination of fiscal and monetary policies chosen once and for all at some previous date. The optimal taxation literature considers *fiscal* shocks, such as fluctuations in government expenditures, and rules out lump sum taxes in the tradition of Ramsey (1927). Distortionary taxes generate *wedges* between marginal rates of transformation and marginal rates of substitution and government policy becomes a source of frictions. The monetary stabilization literature, instead, considers environments where frictions are present even without government policy. These frictions are due to nominal rigidities and imperfect competition on product or labor markets. The corresponding wedges reduce the level of economic activity and may be subject to stochastic fluctuations, known as *cost-push* shocks. The government's only fiscal policy instrument is a lump sum tax.

Both literatures are characterized by an underlying tension. The fiscal shocks considered by the optimal taxation literature do not affect any wedges and should ideally be offset through lump sum taxes. Yet, the government only has access to distortionary fiscal instruments. The optimal stabilization literature considers fluctuations in wedges which could be offset with appropriate fiscal instruments acting on the same margins, but the government only has access to lump sum taxes. Given this tension, monetary policy acquires an auxiliary role in responding to shocks. Lucas and Stokey show that it is optimal to respond to fiscal shocks by appropriately setting the state contingent returns on government debt. Taxes and real returns on government debt inherit the serial correlation structure of underlying shocks, and taxes are smooth, in the sense of having a small variance relative to fiscal shocks. Chari, Christiano and Kehoe (1991, 1995) extend the analysis to monetary economies with risk-free debt and show that it is optimal to use state-contingent inflation as a fiscal shock absorber. They find that the standard deviation of optimal taxes is close to zero while real returns on government debt are highly volatile for calibrated examples. In the monetary stabilization literature, rigidities in nominal prices and wages imply that innovations in inflation reduce the average mark-ups and increase equilibrium output. At the same time, nominal rigidities imply that inflation generates relative price distortions. The resulting trade-off between inflation and output stabilization implies that the volatility and persistence of optimal inflation will depend on the stochastic properties of the cost-push disturbances and on the degree on nominal rigidity. Hence, the interdependence between fiscal and monetary policy is generated in both literatures by a lack of "appropriate" fiscal instruments. Given appropriate instruments, the government would be indifferent to the stochastic path of inflation.

Recent contributions to the optimal taxation literature, such as Correia, Nicolini and Teles (2001), Schmitt-Grohe and Uribe (2001) and Siu (2001), have incorporated monopolistic competition and nominal price rigidity. Correia, Nicolini and Teles (2001) assume that state-contingent bonds are available. Their theoretical analysis allows for fiscal shocks as well as cost-push shocks, and shows that the same equilibrium outcomes can be achieved as in a flexible price economy. In addition, they describe the assumptions on fiscal instruments required for the path of inflation to be neutral to equilibrium outcomes, thus remarking the auxiliary role of inflation in this class of policy problems. Schmitt-Grohe and Uribe (2001) and Siu (2001) focus on government consumption shocks and do not allow for state-contingent debt, thus reinstating the role of inflation as a fiscal shock-absorber. However, with sticky prices, the benefits of volatile inflation must be balanced against the resource misallocation resulting from the associated relative price distortions. They find that for government consumption processes with similar volatility to the post-war US, the departures from optimal policy with flexible prices are striking. Optimal inflation volatility is very close to zero even for very small degrees of price rigidity. Tax rates and the real value of government debt exhibit a random walk behavior, as in Barro (1979), irrespective of the degree of autocorrelation of the underlying shocks. Siu (2001) also considers *large* fiscal shocks, such as fluctuations in government expenditure that would arise in an economy alternating between war and peace. He finds that optimal inflation volatility is high irrespective of the degree of price stickiness for large fiscal shocks. The intuition for this is that the benefits of using inflation as a shock-absorber outweigh the costs of the resulting misallocation in this case. Hence, the stochastic properties of taxes and inflation in a Ramsey equilibrium with monopolistic competition and nominal rigidities can be understood as the outcome of a struggle between the costs of volatile inflation and the benefits of smoothing government outlays in the face of fiscal shocks.

Benigno and Woodford's main contribution is to allow for both fiscal and cost-push shocks. Their analytical results demonstrate that the different time series behavior of optimal policies in flexible and sticky price environments do not depend on the nature of the underlying shocks. With flexible prices, state-contingent inflation is used to offset fiscal shocks, implying volatile real debt returns. However, since taxes are set to offset cost-put shocks and stabilize output, their variance is not necessarily small. With sticky prices, volatile inflation is costly and taxes are used to respond to both fiscal and cost-push shocks. Taxes and real debt returns have a unit root behavior, irrespective of the stochastic properties of underlying shocks, and output cannot be stabilized. Unfortunately, Benigno and Woodford's quantitative exercise is limited to fiscal shocks. They find that the optimal response of inflation to a one time increase in government expenditure is inversely related to the degree of price rigidity. This is not surprising, given the findings in the previous studies.

The rest of this note expands on the previous discussion. In Section 2, I relate the analytical results in Benigno and Woodford to those in the literature on optimal taxation. It discusses the benefits and costs of state-contingent inflation as function of the volatility of exogenous shocks and raises several concerns on the solution method. Section 3 illustrates the notion of optimal policy from a *timeless perspective* with a simple example and relates it to limited commitment. I conclude with some questions open for further research.

2 Optimal Policy With Nominal Rigidities

Benigno and Woodford (BW, henceforth) adopt a standard new-Keynesian framework, with monopolistic competition in product markets and Calvo pricing. They allow for labor market frictions by assuming that a wage mark-up, as well as a price mark-up, is present, and they abstract from monetary frictions. There are four types of shocks: government consumption and government transfer shocks, preference shocks and wage mark-up shocks. The first three are common to the optimal taxation literature, while wage-mark up shocks are typically considered by the optimal monetary stabilization literature. The government's objective is to maximize the representative agent's lifetime utility. In the linear-quadratic problem, the government has two policy instruments, the tax rate on sales, $\hat{\tau}_t$, and the inflation rate, π_t[3]. These instruments are set to respond to a *cost-push* shock, u_t, and a *fiscal* shock, f_t. The variables u_t and f_t are not primitive shocks, but a complex convolution of those primitive disturbances. In particular, the primitive shocks contributing to the cost-push or fiscal shock depend on the available policy instruments and on the degree of price stickiness. However, the shock u_t can only arise if wage mark-up shocks are present.

The evolution of equilibrium outcomes in response to the shocks and government policy is summarized by the expectational Phillips curve:

$$\pi_t = \kappa \left[y_t + \psi \hat{\tau}_t + u_t \right] + \beta E_t \pi_{t+1}. \tag{1}$$

[3] All variables denote percent deviations from steady state values.

The expression in (1) makes clear that by setting the tax rate according to $\hat{\tau}_t^* = -u_t/\psi$, the government can completely stabilize output in the face of cost-push shocks. This is because cost-push shocks and the tax rate on sales act on the same margin. Hence, fluctuations in equilibrium output away from the steady state behave according to:

$$y_t \,\tilde{}\, \left(\hat{\tau}_t - \hat{\tau}_t^*\right).$$

The evolution of equilibrium outcomes and policy must also satisfy the government's intertemporal budget constraint:

$$\hat{b}_{t-1} + f_t - \pi_t - \sigma^{-1} y_t - (1-\beta) E_t \sum_{T=t}^{\infty} \beta^{T-t} \left(b_y y_t + b_\tau \left(\hat{\tau}_t - \hat{\tau}_t^*\right)\right) = 0.$$

This equation clarifies that setting taxes equal to $\hat{\tau}_t^*$ requires inflation to fully respond to the fiscal stress shock.

The government strives to achieve three goals (see equation 2.4 in BW). The first two, output and inflation stabilization, appear directly in the objective function. The third goal is to minimize the intertemporal cost of raising government revenues measured by $\phi_{2,t}$, the multiplier on the government's intertemporal budget constraint. These goals are traded-off based on the available policy instruments. In the monetary stabilization literature, taxes are lump sum and $\phi_{2,t} = 0$. Hence, f_t does not influence y_t or π_t. However, u_t cannot be offset and $y_t \neq 0$.

In the optimal taxation literature, the stochastic properties of optimal policy depend on whether the returns on government debt are state contingent. In a monetary economy with nominal risk free debt, bond returns can be made state contingent by appropriately setting the process for inflation. If no distortions are associated with inflation, as in the case with fully flexible prices, it is optimal to use inflation as a fiscal shock absorber:

$$\begin{aligned} \pi_t - E_{t-1}\pi_t &= f_t - E_{t-1}f_t, \\ \hat{b}_t &= -E_t f_{t+1}, \end{aligned}$$

as in Chari, Christiano, and Kehoe (1991, 1995). Taxes can then be set to meet the output stabilization objective, so that $\hat{\tau}_t = \hat{\tau}_t^*$ and $y_t = 0$. This implies that the cost of raising government revenues is equalized across states in each period:

$$\phi_{2,t} = \phi_{2,t-1}.$$

Consequently, $\hat{\tau}_t$, π_t and $\hat{b}_t$ inherit the stochastic properties of the underlying shocks. If the primitive shocks are stationary, tax rates, inflation and the real value of government debt will also be stationary. The difference with a Ramsey model with only shocks to government spending, is that smoothing the cost of raising fiscal revenues across states does not correspond to a smooth path of taxes. The volatility of the optimal taxes will depend on the volatility of the cost-push shocks.

With nominal risk-free debt and some degree of price rigidity, the properties of optimal fiscal and monetary policy resemble the ones in a real economy and risk-free debt, as in Barro (1979) and Aiyagari, Marcet, Sargent and Seppala (2002). The optimal policy will smooth the cost of raising taxes over time, given the costs of fully smoothing it across states. This imparts a martingale behavior to the shadow cost of raising government revenues:

$$\phi_{2,t} = E_t \phi_{2,t+1}. \tag{2}$$

Inflation does not fully respond to fiscal stress:

$$\begin{aligned} \pi_t &= -\omega_\phi \left(\phi_{2,t} - \phi_{2,t-1} \right), \\ \hat{b}_t &= -E_t f_{t+1} - \eta_b \phi_{2,t}, \end{aligned}$$

and taxes cannot be set to fully stabilize output:

$$y_t = m_\phi \phi_{2,t} + \eta_\phi \phi_{2,t-1} \neq 0.$$

The unit-root behavior of the shadow cost of raising government revenues makes the equilibrium response of taxes, output, prices and the real value of government debt to cost-push and fiscal shocks non-stationary, irrespective of the autocorrelation properties of the primitive shocks.

2.1 Discussion

While in a real economy with risk-free debt, the government has no alternative but to smooth the cost of raising distortionary revenues according to (2), in a monetary economy with nominal bonds, it is possible to make bond returns state contingent in real terms by setting ex post inflation. However, if nominal rigidities are present, the government faces a trade off between the costs of market incompleteness and the costs of volatile inflation. The properties of optimal policy will depend on the relative size of these costs. BW and previous studies focus on models in which the resource misallocation associated with volatile inflation increases with the degree of price stickiness. The costs of market incompleteness, on the other hand, should depend on the size and persistence of the primitive shocks. To understand this issue, it is useful to review the findings in Siu (2001) for a very similar environment, since BW's linear quadratic approach cannot be used to explore this aspect[4].

Siu studies Ramsey policy in a cash-credit good economy with monopolistic competition in which in each period a fraction of firms set their prices before current exogenous shocks are realized. The remaining firms set prices after the realization of the current exogenous shocks[5]. Government purchases, g, follow a two state first order Markov process with support: $\left[\underline{g}, \bar{g}\right]$ and $\underline{g} < \bar{g}$. Siu characterizes optimal policies as a function of the unconditional standard deviation of government purchases with a non-linear numerical procedure. He finds that the optimal inflation volatility decreases with the degree of price stickiness for business cycle fluctuations in g, while for g-processes designed

[4] The approximation is only valid for stochastic processes with an absorbing state and a small range. See section 2.2 for further discussion.

[5] The impact effect of a shock on the nominal price index in Siu's model is the same as the one in a model with Calvo pricing if the fraction of prices that remain unchanged in any period is set equal across the two models. In Siu's model, all remaining price adjustment takes place in the subsequent period, while the adjustment is smoothed across several periods with Calvo pricing.

to model an economy fluctuating between war and peace -*large* fiscal shocks- optimal inflation volatility is high irrespective of the degree of price stickiness, as illustrated in Figure 1 and 2, reproduced from Siu[6].

The percentage loss in output which occurs in the economy with sticky prices under the Ramsey policy corresponding to the flexible price economy is a measure of the misallocation caused by volatile inflation. Figure 3[7] illustrates the behavior of this measure. The horizontal axis measures L_s/L_f, the labor demand from sticky price firms relative to flexible price firms, and the vertical axis measures the corresponding misallocation. In each graph, the star on the left corresponds to a sequence $\left[\underline{g}, \underline{g}\right]$, the one on the right corresponds to a sequence $[\bar{g}, \bar{g}]$ [8]. When the current value of g is low, sticky price firms have higher prices than flexible price firms and $L_s/L_f < 1$. Concavity in production implies that the cost in terms of foregone output is very large for a large misallocation and decreases at a decreasing rate. The graphs suggest that the misallocation cost is large and increasing in the size of government spending shocks when the fluctuations in the spending shock are small, but it is small for large fiscal shocks. This pattern stems from the incentive for firms setting prices to *frontload* and set high prices to insure against the possibility of having negative profits. Since government consumption shocks are persistent, if the shock was high in the pre-

[6] The calibration is based on US data for the 20th century. The small shock case matches fluctuations in government purchases that occur in the post war US. The transition probability between the $\bar{g}$ and $\underline{g}$ states is $\rho = 0.95$ and the standard deviation of g is 6.7%. For the large shock case, the standard deviation is 21% and all other parameters are kept constant.

[7] I thank Henry Siu for providing Figure 3 and Figure 4.

[8] Given the assumed persistence of the government consumption process, these are the most likely sequences.

vious period, sticky price firms will set high prices. If the shock in this period is high, inflation will be high under the Ramsey policy for the flexible price economy, and the misallocation will be small. If the shock was low in the previous period, firms setting prices will still set them high. If the realized value of g is low, inflation will be low and this will give rise to a large misallocation. The tendency to frontload is a general feature of sticky price models and is exacerbated when firms fix prices for longer periods of time.

Figure 4 plots the misallocation cost in consumption equivalents against the volatility of government consumption when 10% of firms have sticky prices. It raises steeply initially but then flattens out. The cost in terms of foregone consumption of not being able to smooth government revenues across states as a function of the variability of government consumption shocks[9] is also shown. Not surprisingly it is increasing in the variance of the shocks. This explains the finding that for large government expenditure shocks optimal inflation volatility is high even when a large fraction of prices are fixed, while for business cycle type fluctuations in government consumption optimal inflation volatility is very close to 0. For very small expenditure shocks, the costs of not using inflation to make real bond returns respond to government consumption is low, as is inflation volatility in the Ramsey equilibrium for the flexible price economy. Since the distortion caused by taxation is first order[10], it will be optimal to

[9] This is the welfare loss in average consumption equivalents of using the Ramsey policy for the sticky price economy in the flexible price economy.

[10] This is true in BW's model. Recall that the steady state wedge between the marginal rate of substitution between consumption and leisure and the marginal product of labor, Φ, is positive if the initial level of public debt is positive.

have a smooth path of taxes and volatile inflation.

The role of the size of fiscal shocks for the stochastic behavior of taxes and policy with nominal price rigidities raises a number of questions for future research. Do these results depend on the nature of the shock? Would they differ if government transfers rather than government purchases were considered? Would the findings change for wage mark-up shocks? This is of interest since the consideration of wedge type shocks is the novelty in BW's analysis. And lastly, what is the welfare cost of lack of state-contingency relative to non-fiscal shocks? These questions cannot be addressed within BW's linear-quadratic approach as I explain below.

2.2 The linear-quadratic approach

BW solve the optimal policy problem by analyzing the exact solution to a linear-quadratic problem which should coincide with the solution to a linear approximation of the policy problem for the original economy. This amounts to a local approximation around a non-stochastic steady state. Chari, Christiano and Kehoe (1995) provide a number of examples of inaccurate linear approximations in a similar context. They show that the inaccuracy is particularly severe for the computation of policies. In one example, for which the analytical solution is available, they show that the linear approximation misses on such basic statistics as the mean and the standard deviation of tax rates. The degree of inaccuracy appears to increase with the curvature of preference and technology parameters and with the volatility of driving processes.

An additional and more severe concern arises in the model with sticky prices. Since equilibrium responses are non-stationary and the economy permanently drifts away from the initial steady state in response to shocks, the analysis must be limited to stochastic processes with small range and with an absorbing state. This is a very restrictive assumption for the purpose of studying stabilization policy from a quantitative standpoint. It rules out, for example, analyzing responses to business cycle type fluctuations which are naturally of interest in macroeconomics. More importantly, it raises the question of which steady state should be considered as a benchmark for the approximation. Aiyagari, Marcet, Sargent and Seppala (2002) numerically characterize the Ramsey equilibrium for a real economy with risk free debt, where the lack of state-contingency of government debt returns also imparts a unit root behavior to taxes and real variables[11]. They show that if the exogenous shock has an absorbing state, the analogue of $\phi_{2,t}$ converges to a value that depends on the realization of the path for the exogenous shocks when the economy enters the absorbing state. The incomplete markets allocation coincides with the complete markets allocation that would have occurred under the same shocks but for a different initial debt. They also consider the case in which the government expenditure process does not have an absorbing state. In this case, the analogue of $\phi_{2,t}$ converges to 0. Hence, the incomplete markets allocation converges to the first best allocation and no distortionary taxes need to be raised absent upper bounds on government

[11] Siu (2001) derives the constraint imposed on the set of attainable equilibria with sticky prices and shows that it is of the same nature as the one arising in the real economy with risk-free debt analyzed by Aiyagari, Marcet, Sargent and Seppala (2002).

asset accumulation.

3 Timeless Perspective and Limited Commitment

BW characterize the solution to the policy problem from a *timeless perspective*. This approach amounts to a particular recursive formulation of the optimal policy problem under commitment. As is well known, the Ramsey problem is not recursive in the natural state variables. This complicates the analysis substantially in the presence of stochastic shocks. However, it is possible to formulate the Ramsey problem recursively by augmenting the set of natural state variables with a vector of *costate* variables, which depend on the specific problem. Solving this recursive problem gives rise to policy rules that are Markovian in the augmented set of states and the shocks for $t \geq 1$. This method was first suggested by Kydland and Prescott (1980) and generalized by Marcet and Marimon (1999). Aiyagari, Marcet, Sargent and Seppala and Siu also adopt a variant of this approach. The Ramsey equilibrium outcome depends on the values of exogenous state variables at time 0. There are different ways to deal with this dependence. The timeless perspective proceeds by imposing that the Markovian policy rule which is optimal from the standpoint of $t \geq 1$ is also optimal at time 0. This amounts to endogenizing the initial values of the exogenous states.

To see how this works in practice, it is useful to work through a simple example. Government policy is given by $\Pi_t = \{\tau_t, R_t\}$, where τ_t is a linear tax on labor and R_t is the state contingent bond return. Government consumption, g_t, is exogenous. Consumers solve the problem:

$$
\begin{aligned}
&\max_{\{c_t, n_t, b_{t+1}\}} \sum_{t=0}^{\infty} \beta^t u\left(c_t, n_t\right) \text{ s.t.} \\
b_{t+1} &\leq b_t R_t + \left(1 - \tau_t\right) n_t - c_t,
\end{aligned}
$$

where b_t denoted holdings of government issued bonds at time t. Their first order conditions are:

$$
\begin{aligned}
u_{c,t} &= \lambda_t, \\
-u_{n,t} &= \lambda_t \left(1 - \tau_t\right), \\
\lambda_t &= \beta \lambda_{t+1} R_{t+1},
\end{aligned}
$$

where λ_t is the multiplier on their budget constraint. A competitive equilibrium is a policy $\{\tau_t, R_t, g_t\}$ and an allocation $\{c_t, n_t, b_{t+1}\}_{t \geq 0}$ such that the allocation solves the consumer's problem given the policy and the government budget constraint:

$$
b_{t+1} + \tau_t n_t = b_t R_t + g_t,
$$

is satisfied. A Ramsey equilibrium is a competitive equilibrium which maximizes the representative consumer's lifetime utility.

The solution to the household problem clearly displays the potential for time inconsistency in the Ramsey problem: the fact that household have to choice b_{t+1} based on expectations of R_{t+1}, hence, the government might have an incentive to change R_{t+1} at $t+1$. This time inconsistency makes the Ramsey problem non-recursive in b_t. Despite this, it is possible to formulate the Ramsey problem recursively. For $t > 0$, the consumer's first order conditions can be used to define a mapping from policy at time t to the competitive equilibrium allocation at time t and the shadow value of outstanding wealth, λ_t :

$$\begin{aligned} x_t &\equiv (c_t, n_t, b_{t+1}) = d(b_t, \Pi_t, \lambda_t), \\ \lambda_t &= h(\Pi_t, b_t, \lambda_{t-1}). \end{aligned}$$

The policy problem can then be rewritten as follows:

$$\begin{aligned} v(b, \lambda_{-1}) &= \max_{\phi, x, \lambda} \{u(c,n) + \beta v(b', \lambda)\} \\ \text{s.t.} \qquad x &= d(b, \Pi, \lambda), \\ \lambda &= h(\Pi, b, \lambda_{-1}), \\ g &\leq \tau n + b' - Rb \end{aligned}$$

The solution to this problem is the function, $\hat{\Pi}(b, \lambda_{-1})$, which represents a Markovian policy rule, in the state (b, λ_{-1}). The constraint $\lambda = h(\phi, b, \lambda_{-1})$ embeds the assumption of commitment since it ties today's choices to decisions made in the past, by linking them through the costate variable λ. It is unusual because it goes back in time. The government solution to this problem selects the value of λ that the government *wants* to commit to, because it induces future governments to chose the policy that is optimal from the standpoint of the current period.

Clearly, this procedure does not pin down the value of λ_0. This implies that the policy problem at time 0 is different from other periods. The policy problem at time 0 is:

$$\begin{aligned} \Pi_0(b_0) &= \arg\max_{\phi_0, x_0, \lambda_0} u(c_0, n_0) + \beta v(b_1, \lambda_0) \\ \text{s.t.} \qquad x_0 &= d(b_0, \Pi_0, \lambda_0), \\ g &\leq \tau_0 n_0 + b_1 - R_0 b_0 \end{aligned}$$

The policies chosen at at time 0 depend on initial conditions and influence the solution for all future periods. Adopting a timeless perspective involves removing this dependence on initial conditions by imposing that the choice of λ_0 and of policy at time 0 is governed by the same Markovian rule which is optimal from time 1 onwards. The system:

$$\begin{aligned} \Pi_0(b_0) &= \hat{\Pi}\left(b_0, \lambda_{(-1)}\right), \\ \lambda_0 &= h\left(\Pi_0, b_0, \lambda_{(-1)}\right), \end{aligned}$$

defines an implicit equation for $\lambda_{(-1)}$ and λ_0. The second constraint pins down $\lambda_{(-1)}$ as a function of b_0 and λ_0 and the first constraint, which imposes consistency between the solution to the time 0 problem and the Markovian decision rule, pins down b_0. This procedure only affects the average level of taxes and does not alter the stochastic properties of the optimal policy. It is important to note that the recursive formulation of Ramsey problems discussed here does not imply that the resulting optimal choices are time consistent, even if it gives rise to Markovian policy rules. A government choosing policy sequentially under discretion would not make these choices. The discretionary solution would generate Markovian policy rules in the natural state, in this case, b_t.

This approach is appealing not only because it provides a tractable algorithm for solving Ramsey equilibria, but also because it is related to a notion of *limited commitment*. Time inconsistency may arise in Ramsey models because private agents take certain actions before the government chooses policy and, therefore, must base their decisions on expectations of government policy. To ensure that the Ramsey equilibrium is implemented, it is not required that the government commits at time 0 to the entire path of future policy. A limited one period ahead commitment to those policies that influence expectations is in general enough. A recursive formulation of the Ramsey problem naturally identifies the minimum set of variables that the government must commit to. A draw back is that these variables are not primitive. They are rather complex functions related to the shadow value of government surpluses at the start of the following period. Hence, implementation of this solution with a simple strategy is incredibly valuable.

BW suggest that the optimal policy can be implemented with the flexible inflation target:

$$\pi_t + a\pi_{t-1} + b\left(y_t - y_{t-1}\right) \;=\; 0 \tag{R1}$$

$$E_t\pi_{t+1} \;=\; 0. \tag{R2}$$

They also propose a particular institutional arrangement associated with this rule. The monetary authority should have a mandate over both inflation and output stabilization. It should sets interest rates so that R1 is met. The fiscal authority should have a mandate defined over inflation stabilization only, and set the path of debt so that R2 is met.

This institutional set up does relate to ones that have been proposed and implemented[12] to tackle the potential time inconsistency problem in monetary policy. It embeds a notion of independence, since the monetary authority takes path of government debt as given, and the fiscal authority takes path of output as given. However, endowing the fiscal authority with a mandate over inflation stabilization seems rather unusual. One also wonders whether it would be viable, given the strong prevalence of political considerations in the dabate over fiscal policy.

[12] The central bank of New Zealand and most, recently, of Brazil's central bank follow a flexible inflation targeting scheme.

4 Concluding remarks

The Ramsey literature and the optimal monetary stabilization literature have two important elements in common: the assumption of commitment and the auxiliary role of monetary policy.

Woodford (2002) and Clarida Gali and Gertler (1999) have underlined how the optimal monetary stabilization policy under commitment differs in terms of stochastic responses from the policy under discretion. Woodford shows that inflation tends to overreact to cost-push shocks under discretion relative to commitment. This *stabilization bias* can arise even when no inflation bias is present, where by inflation bias I mean a tendency for average inflation to be higher when the government cannot commit. The stabilization bias arises due to the lack of alternative policy instruments, since lump sum taxes cannot remove the distortions generated by cost-push shocks. Albanesi, Chari and Christiano (2002) show in a general equilibrium model with monetary frictions that the resource misallocation due to price dispersion may be large enough, with plausible parameters, to eliminate the inflation bias under discretion. They also show that multiple Markov equilibria are possible, giving rise to a potential for alternating high and low inflation regimes under discretion. It would be interesting to explore the joint role of monetary policies and distortionary taxation without commitment. Would the possibility of responding to cost-push shocks via fiscal policy remove the over reaction in inflation that occurs with lump sum taxes? What is optimal inflation volatility in response to fiscal shocks under discretion? Is the misallocation resulting from the price dispersion associated with inflation sufficient to reduce the inflation bias in general?

The auxiliary role for monetary policy in these literatures stems from the fact that in these models money is not *essential*. The optimal monetary stabilization literature often abstracts from money demand all together. The Ramsey literature usually considers money in the utility function or cash-in-advance models. These assumptions are meant to stand in for some role for money that is not made explicit but ought to be. Instead, money is essential when spatial, temporal and informational frictions make the use of money an efficient arrangement, as in the search-theoretic approach pioneered by Kiyotaki and Wright (1989, 1993)[13]. The essential nature of money has implications for optimal monetary policy. For example, optimality of the Friedman rule generally obtains in Ramsey models. This result stems from the fact that money does not overcome any primitive frictions and agents use it for transactions because they are forced to. Hence, it is optimal to equate the return on money to that of other assets to minimize the distortions associated with this arrangement[14]. In environments where money is essential, the optimal monetary policy responds to changes in the distribution of liquidity needs. Levine (1991) and Kocherlakota (2003) show that in this case higher interest rates increase welfare[15]. Research on the properties of optimal monetary policy when money is essential is still in its infancy,

[13] Additional contributions include Shi (1995), Trejos and Wright (1995), Kocherlakota (1998) and Wallace (2001).

[14] Albanesi (2002) considers a costly non-monetary transactions model with heterogeneous agents in which departures from the Friedman rule redistribute towards high income households and the Friedman rule may not optimal.

[15] See also Woodford (1990) for some related examples. Lagos and Wright (2002) show that optimality of the Friedman rule obtains in an environment where money is essential. However, in their model the distribution of currency is degenerate.

however, this class of environments constitute the most natural laboratory for understanding the effect of monetary policy on the economy.

References

[1] Aiyagari, S. Rao, Albert Marcet, Thomas J. Sargent, and Juha Seppälä, "Optimal Taxation without State-Contingent Debt", Journal of Political Economy, Volume 110, Number 6, December 2002.

[2] Albanesi, Stefania, 2002, "Optimal and Time Consistent Monetary and Fiscal Policy with Heterogeneous Agents", CEPR DP 3713.

[3] Albanesi, Stefania, V.V. Chari, and Lawrence J. Christiano, 2002, "Expectation Traps and Monetary Policy", *The Review of Economic Studies*, forthcoming.

[4] Chari, V.V., Lawrence J. Christiano, Patrick Kehoe, 1991, "Optimal Fiscal and Monetary Policy: Some recent Results", Journal of Money, Credit and Banking 23: 519-539.

[5] Chari, V.V., Lawrence J. Christiano, Patrick Kehoe, 1995, "Policy analysis in business cycle models", in Thomas J. Cooley, ed., Frontiers of Business Cycle Research, Princeton University Press.

[6] Chari, V.V., and Patrick J. Kehoe. 1999. Optimal Fiscal and Monetary Policy. *Handbook of Macroeconomics*, Volume 1, Elsevier.

[7] Clarida, Richard, Jordi Gali, Mark Gertler, 1999, "The Science of Monetary Policy: A New-Keynesian Perspective", NBER WP 7147.

[8] Correia, Isabel, Juan-Pablo Nicolini, Pedro Teles, 2001, "Optimal Fiscal and Monetary Policy: Equivalence Results", CEPR DP 3730.

[9] Goodfriend, Marvin, and Robert G. King, 1997, "The New Neoclassical Synthesis and the Role for Monetary Policy", NBER Macroeconomics Annual: 402-417.

[10] Kahn, Abhuk, Robert G. King, Alexander Wolman, 2000, "Optimal Monetary Policy", manuscript, Boston University.

[11] King, Robert G., Alexander Wolman, 1999, What should monetary policy do if prices are sticky?", John B. Taylor ed., Monetary Policy Rules, University of Chicago Press for NBER, Cambridge, MA, 349-404.

[12] Kiyotaki, Nobuhiro, and Randall Wright, 1989, "A contribution ot the pure theory of money", Journal of Economic Theory 53: 215-235.

[13] Kiyotaki, Nobuhiro, and Randall Wright, 1993, "A search-theoretic approach to monetary economics", American Economic Review 83: 63-77.

[14] Kocherlakota, Narayana, 1998, "Money is Memory", Journal of Economic Theory 81: 232-251

[15] Kocherlakota, Narayana, 2003, "Societal Benefits of Illiquid Bonds", Journal of Economic Theory 102: 179-193.

[16] Kydland, Finn, and Edward Prescott, 1980, "Dynamic Optimal Taxation, Rational Expectations and Optimal Control", Journal of Economic Dynamics and Control 2: 79-91.

[17] Lagos, Ricardo and Randall Wright, 2002, "A Unified Framework for Monetary Theory and Policy Analysis," manuscript, New York University.

[18] Levine, David, 1991, "Asset Trading Mechanisms and Expansionary Policy", Journal of Economic Theory 54: 148-164.

[19] Lucas, Robert E. and Nancy Stokey, 1983, "Optimal Fiscal and Monetary Policy in an Economy without Capital", Journal of Monetary Economics 12: 55-93.

[20] Ramsey, F.P., 1927, "A Contribution to the Theory of Taxation", Economic Journal 37: 47-61.

[21] Rotember, Julio, and Michael Woodford, 1997, "An Optimization based Framework for the Evaluation of Monetary Policy", NBER Macroeconomics Annual 12: 297-346.

[22] Schmitt-Grohe, Stephanie, and Martin Uribe, 2001 A, "Optimal Fiscal and Monetary Policy Under Sticky Prices", manuscript, Rutgers University and University of Pennsylvania.

[23] Shi, Shouyong, 1995, "Money and prices: a model of search and bargaining", Journal of Economic Theory 67: 467-496.

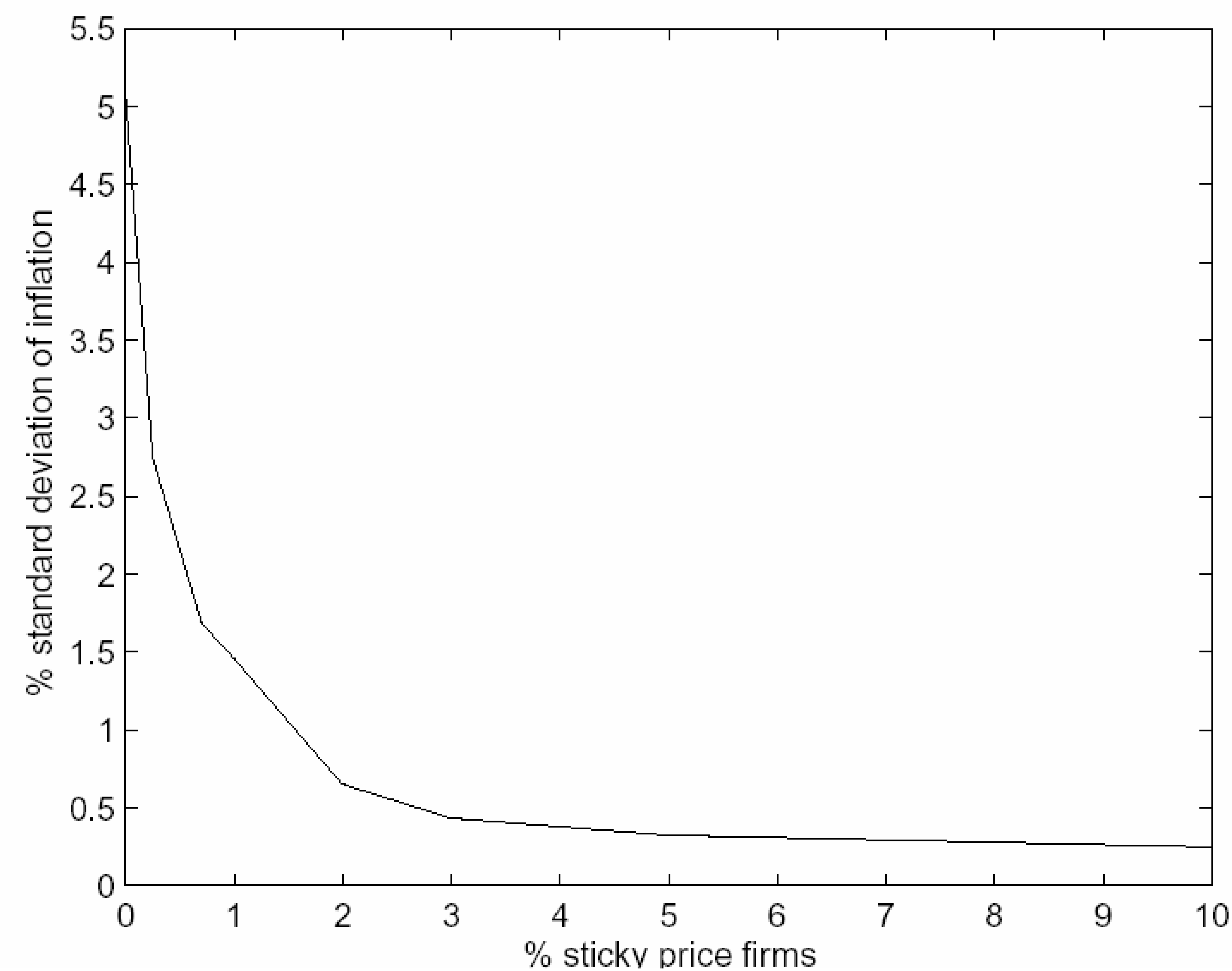
[24] Siu, Henry, 2001, "Optimal Fiscal and Monetary Policy with Sticky Prices", University of British Columbia, Department of Economics DP 02-13.

[25] Trejos, Alberto, and Randall Wright, 1995, "Search, Bargaining, Money and Prices", Journal of Political Economy 103: 118-141.

[26] Woodford, Michael, 1990, "The Optimum Quantity of Money", *Handbook of Monetary Economics- Volume II*, Benjamin M. Friedman and Frank H. Hahn Editors, North Holland.

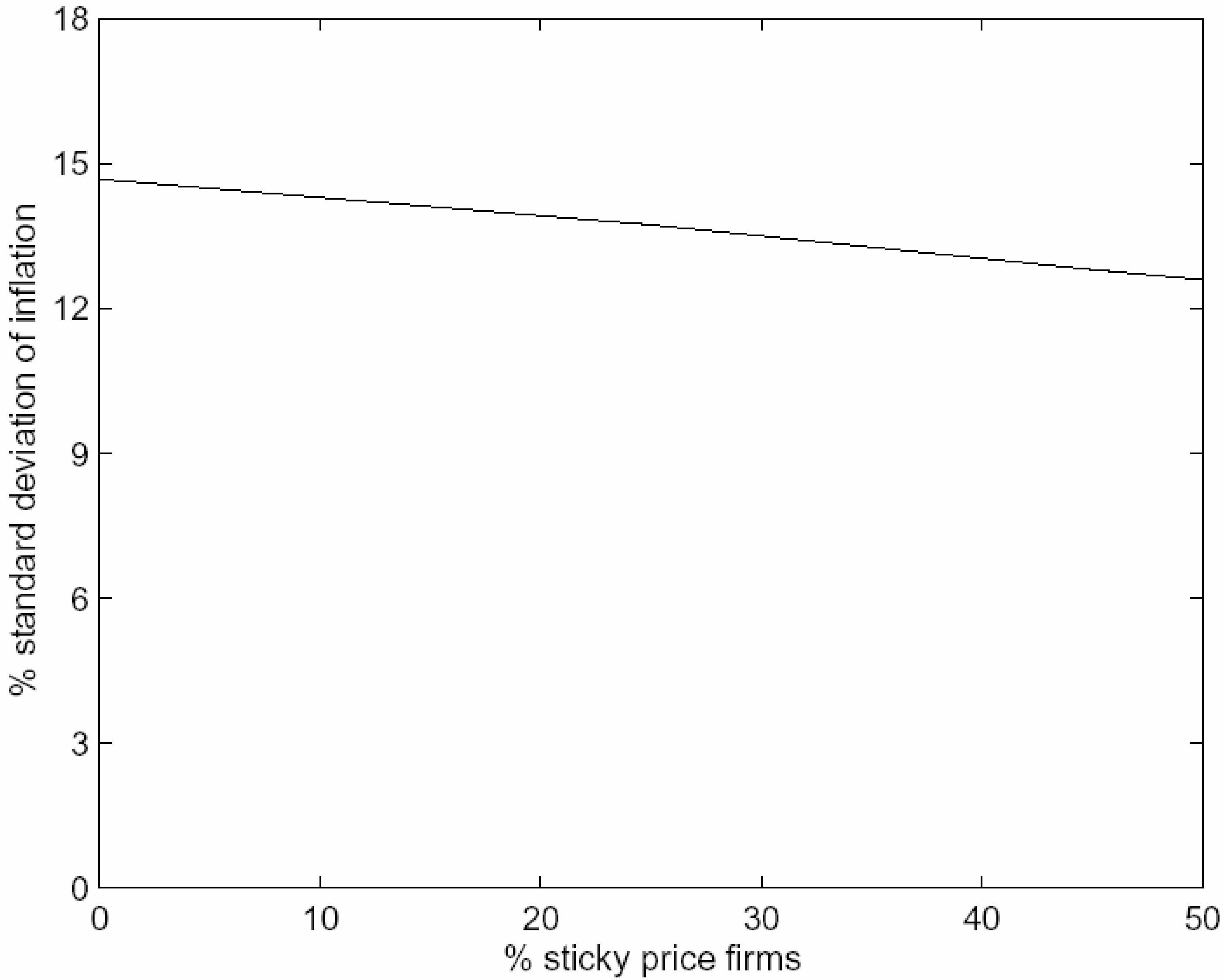
[27] Woodford, Michael, 2000, "Interest and Prices", manuscript, Princeton University.

Figure 1: Optimal Inflation Volatility for *Small* Shocks



Reproduced from Siu (2001)

Figure 2: Optimal Inflation Volatility for *Large* Shocks



Reproduced from Siu (2001)

Figure 3: The Output Cost of Relative Price Distortions

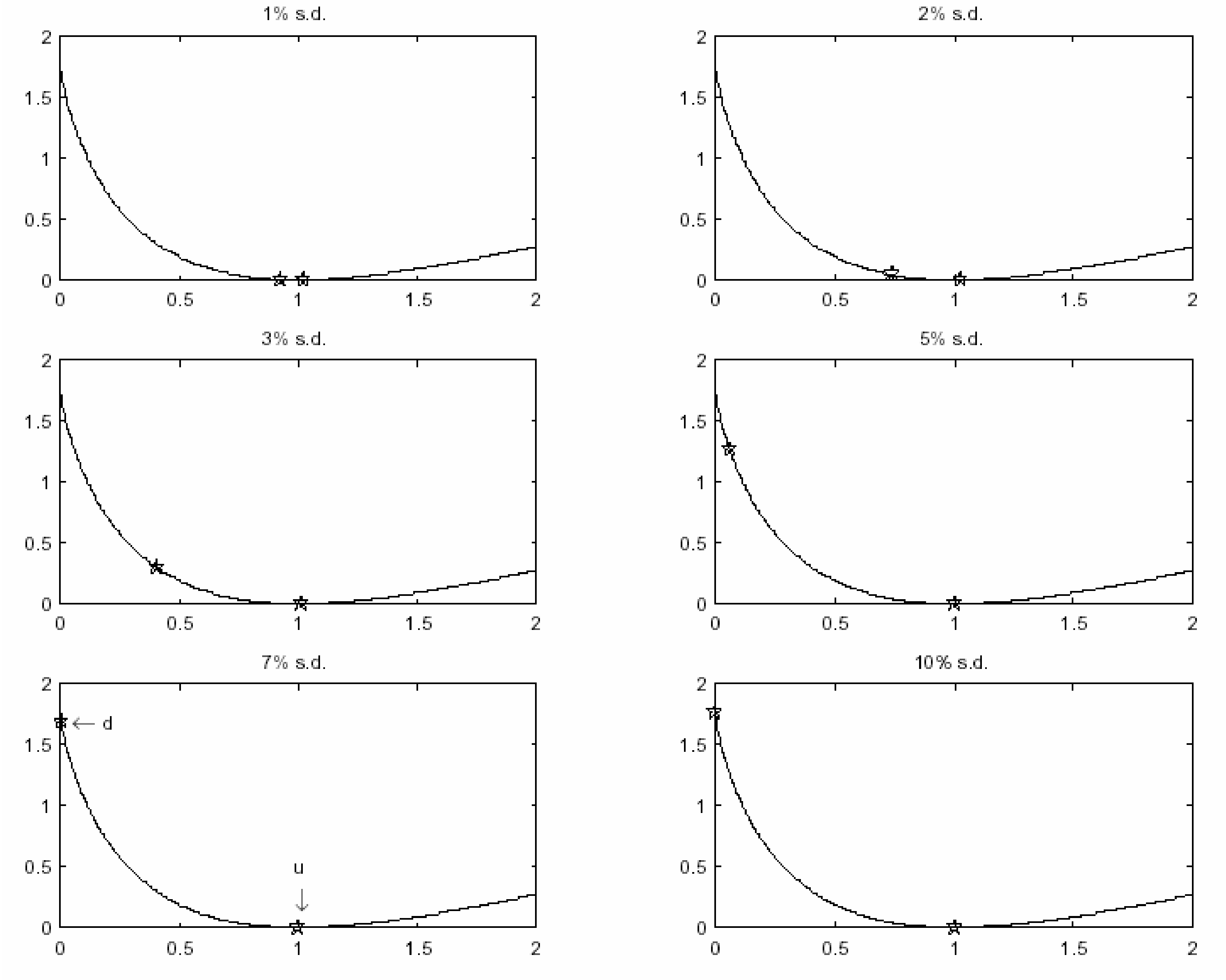


Figure 4: The Trade-Off Between Inflation and Tax Volatility