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Abstract

We consider an environment with stochastic trading opportunities and incomplete markets and analyze how trading in secondary markets for government debt and access to unsecured credit affect inflation. When secondary markets are not active, there exists a unique monetary steady state where public debt does not affect inflation dynamics. In contrast, we find that when agents trade in secondary markets, agents are buying government bonds above their fundamental value. As a result, Ricardian equivalence does not hold and multiple steady states can not be ruled out as government bonds generate a liquidity premium. In particular, we find that the gross interest payment on public debt is non-linear in bond holdings. Because of this liquidity premium, real government bonds matter for inflation. To rule out real indeterminacies, we show that active monetary policy is more likely to deliver a unique monetary steady state regardless the stance of fiscal policy. Moreover, trading in secondary markets further amplify the effectiveness of active monetary policies in reducing steady state inflation. Finally, we show that a spread-adjusted Taylor rule delivers a unique steady state, thus ruling out real indeterminacies.

JEL Codes: C70, E40, E61, E62, H21.

Keywords: taxes; inflation; secondary markets, liquidity premium.

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1 Introduction

Over the last four decades, households in the United States have experienced various financial innovations that have changed the composition of their portfolios and how trades are settled. Before the 1960s, credit card use was very limited, however, by 2011, 77% of adults in the United States owned at least one credit card.[1] Financial developments have also help increased the volume of transactions in the secondary markets for government debt. For instance, from 1986 to 1993, the volume of secondary market sovereign debt sales increased from $7 to $273 Billion.[2] The impact of these financial developments on inflation and bond dynamics have not been fully studied. Here we contribute to this literature.

In this paper we analyze how innovations in secondary markets and access to unsecured credit have changed the interactions between monetary and fiscal policies.[3] We do so within the context of the Great Moderation. To explore how inflation is affected by these financial developments, we consider an environment similar to Berentsen and Waller (2011). Each period is subdivided into three sub-periods where agents can trade sequentially in three different markets. In the first sub-period, after a preference shock is realized, agents enter a costly secondary market (SM) where they can trade bonds for fiat money. In the second sub-period, agents have access to a decentralized frictional goods market (DM), where anonymous buyers and sellers are randomly and bilaterally matched. In the last sub-period, agents trade in a frictionless centralized goods market (CM). Here agents can rebalance their portfolio, produce and consume the general CM good. Finally, the government needs to finance an exogenous stream of government expenditures.

Within this environment, we study how a Taylor rule and a fiscal rule, that links revenues to real public debt, affect monetary and fiscal policy interactions. We find that inflation and bonds dynamics crucially hinge on whether agents participate in secondary markets for government debt. Depending on the cost to participate in this market, we observe various monetary equilibria. When there is no trade in secondary markets and households have very limited access to unsecured credit, there exist a unique monetary steady state where public debt does not affect inflation dynamics. Moreover, we obtain the same active/passive stabilization policy prescriptions as in Leeper (1991).[4] In contrast, when there is trade in secondary markets and there is access to unsecured credit, which can be thought as the Great Moderation period, the resulting monetary

[1] On average in 2011 households spent 10,500 US $ annually. See myFICO (2012) for more information.

[2] We refer to Power (1996) for more on the evolution of secondary markets.

[3] To determine how monetary and fiscal policies interact, requires a full characterization of price dynamics which critically depends on the beliefs about future inflation. These beliefs are not only influenced by fiscal and monetary policies, as noted by Sargent and Wallace (1981) and Leeper (1991), but also by financial frictions, as highlighted by Fernández-Villaverde (2010), Leeper and Nason (2015), and Gomes and Seoane (2015), just to name a few.

[4] An active authority pursues its objectives unconstrained by the state of government debt and is free to set its policies as it sees fit. But then the other authority must behave passively to stabilize debt, constrained by the active authority's actions and private sector behavior.

equilibria are drastically different. In particular, multiple monetary steady states are typically observed. This is the case as bonds exhibit a liquidity premium, delivering an inflation adjusted nominal interest rate that depends on bonds outstanding. This endogenous liquidity premium generates a *liquidity Laffer* curve as the total interest payment on governments bonds is non-linear. This is the case as buyers are willing to pay prices for government bonds that are above their fundamental value. As a result the fiscal authority can reduce the tax burden of issuing government debt, relative to an environment without a liquidity premium, thus breaking Ricardian equivalence. This property changes then the fiscal backing of bonds which ultimately affects inflation expectations.

Regardless of how many steady states exist, the liquidity premium increases the price on government debt, thus changing the traditional substitution and wealth effects observed in economies without liquidity premiums. This is the case as in traditional frameworks the relative price between fiat money and bonds do not take into account the liquidity services bonds provide.[5] In this economy since agents are willing to purchase bonds above their fundamental value, there is then a difference between the financing of government expenditures through bonds or lump sum taxes. This is the case as bonds can help enlarge the consumption possibilities in some markets. Thus the impact of revaluing government debt through changes in prices, when there is a premium for public debt, drastically changes inflation expectations and the nature of stabilization policies.

To rule out real indeterminacy, we show that active monetary policy is more likely to deliver a unique monetary steady state regardless of the fiscal policy stance. Moreover, secondary markets further amplify the effectiveness of active monetary policies in reducing steady state inflation. In our environment with an endogenous liquidity premium for government debt, traditional policy prescriptions are generically not operative. For instance, independently of whether fiscal policy is active or passive, we find that a passive monetary policy delivers indeterminate equilibria, whenever the steady state is unique. However, we also find that a passive monetary policy can lead to multiple steady states. One is generally stable, even when monetary policy follows an interest peg. In contrast to Canzoneri and Diba (2005), the provision of bond liquidity services here is endogenous. Moreover, our numerical results show that those equilibria exist in regions where the steady state is not unique and therefore those policies, although nominally stable, can lead to real indeterminacy. Finally, we analyze an interest spread-adjusted Taylor rule, as in the spirit of Cúrdia and Woodford (2010). Under this new operating procedure for monetary policy, inflation dynamics are independent of government debt and we can ensure steady state

[5] In traditional settings, news of lower surpluses raises the price level and reduces the value of outstanding debt. Higher nominal debt raises the price level next period, reflecting the impact of higher nominal household wealth. Lower future surpluses (lower taxes or higher transfers) or higher initial nominal assets, raise households' demand for goods when there is no prospect that future taxes will rise to offset the higher wealth. We refer to Woodford (2001) for more on this channel.

uniqueness, ruling out real indeterminacy. Moreover, we show how a spread-adjusted Taylor rule modifies the set of fiscal policies that can deliver locally determinate equilibria.

Improved monetary policy or declining volatility of economic disturbances are unlikely to be the sole contributors of delivering the inflation experiences of the Great Moderation in the US.[6] This paper shows the role of financial innovations in amplifying the effects of active monetary policy. Our findings suggest that, with a more developed secondary market for public debt, ceteris paribus, monetary policy does not need to be as aggressive to achieve a lower inflation. To anchor inflation expectations monetary policy must respond less aggressively to changes in inflation, over and above adjustments prescribed by the Taylor principle in economies without a liquidity premium for government debt.

The paper is organized as follows. Section 2 offers a literature review. Section 3 describes the environment and characterizes the monetary equilibria. In Section 4 we perform a numerical analysis. A conclusion then follows.

2 Literature Review

This paper connects with two different literatures. One where stabilization policy is analyzed in environments where financial markets are frictionless and monetary policy follows a Taylor rule, while the fiscal authority has a rule that link taxes to real public debt. The other literature we relate to, is the one where monetary policy is analyzed in an environment where financial markets are incomplete, there are stochastic trading opportunities and government bonds can exhibit a liquidity premium.

Conventional stabilization policy suggests that monetary policy controls inflation while fiscal policy stabilizes debt through an appropriate adjustment in current or future taxation, as initially suggested by Friedman (1968). In contrast, proponents of the fiscal theory of the price level emphasize that fiscal policy can also determine the path of the price level.[7] When real resources fully back debt, Sargent and Wallace (1981) obtain equilibria where fiscal policy is inflationary only if the central bank monetizes deficits.[8] But when nominal debt is not backed by real resources, fiscal policy creates a direct link between current and expected deficits and inflation. Then the government can trade current for future inflation through debt operations and then

[6]Clarida, Galí, and Gertler (1999) and Lubik and Schorfheide (2004), among others, have emphasized the importance of these two features. Eusepi and Preston (2013), on the other hand, emphasize the role of learning and the maturity of structure in delivering the inflation experiences during the Great Moderation. More in line with this paper, De Blas (2009) emphasizes the role of financial frictions.

[7]The Fiscal Theory of the Price Level (FTPL) was developed primarily by Leeper (1991), Sims (1994), Woodford (1994) and Cochrane (2001). This literature highlights that bonds are denominated in nominal terms so that they may be fully backed by real resources or backed only by nominal cash flows. We refer to Canzoneri et al. (2011) and Leeper et al (2016) for excellent surveys of the FTPL.

[8]In their environment, fiscal rules are independent of inflation and government debt, while the central bank follows a constant money growth rate rule.

fiscal policies can help stabilize the price level. This fiscal result is robust to different monetary and cashless environments.[9] However, these different stabilization policies (the ones proposed by Friedman and proponents of the fiscal theory of the price level) critically depend on having rational expectations, lump sum taxation, government bonds not providing liquidity services and having agents access to frictionless financial markets. Once agents are boundedly rational, as in Evans and Honkapohja (2007) or Eusepi and Preston (2011, 2013), taxes are distortionary as in Canzoneri et al. (2016), government bonds provide liquidity services, as in Canzoneri et al. (2005, 2016) and Andolfatto and Williamson (2015), or when an economy randomly switches between active and passive policies, as in Davig and Leeper (2011), or financial markets are not complete, as in Gomis-Porqueras (2016), public debt matters for inflation dynamics. Here we add to these papers by considering an endogenous liquidity premium while specifying government policies through Taylor and fiscal rules.

This paper complements the growing search theoretic literature that analyzes policy design in environments with incomplete markets, where agents have access to money and bonds. Because of the underlying frictions of the environment, government bonds exhibit a liquidity premium. Within this class of models, Berensten and Waller (2011) show that, in contrast to Wallace's (1981) result for open market operations, the money/bond composition of a government's debt portfolio does affect the equilibrium allocation. This is the case as all transactions are voluntary, implying no taxation or forced redemption of private debt.[10] In a similar environment, Berentsen et al (2014) show that the optimal policy restricts access to secondary markets because portfolio choices exhibit a pecuniary externality. When the government needs to finance government expenditures and taxation is possible, Williamson (2012) finds that non-passive fiscal policy and costs of operating a currency system imply that an optimal policy deviates from the Friedman rule. A liquidity trap can exist in equilibrium away from the Friedman rule, and there exists a permanent non-neutrality of money, driven by an illiquidity effect. Along the same lines, Shi (2014) studies open market operations in a model where bonds are partially acceptable and where there is temporary separation between the bonds market and the goods market. The author shows that shocks in the open market that are independent over time can have persistent effects on interest rates and real output.

Our paper is closest to Canzoneri and Diba (2005) and Andolfatto and Williamson (2015). Canzoneri and Diba (2005) consider a modified cash in advance constraint framework where

[9] Within the FTPL, there are two strands of the literature regarding the role of fiat money. In the first one, real balances are valued by agents as they provide direct utility, as in Leeper (1991), or because of the transactional frictions that require agents to have sufficient cash available before buying, cash in advance constraint, as in Sims (1994). In contrast, the other strand considers an environment with no monetary frictions, cashless framework, where fiat money is just a unit of account, as in Woodford (1998).

[10] In this economy private agents must be willing to pay a nominal "fee" to receive government services. This implies that the government is constrained in how much revenue it can generate to redeem outstanding government debt.

bonds can be used to pay for goods by specifying an exogenous liquidity function. Within this environment, they analyze the stabilization properties of Taylor and fiscal rules. Once bonds provide liquidity, fiscal policy becomes a key determinant for inflation dynamics. As a result a peg interest rate and a passive fiscal rule can yield locally determinate equilibria. Within the same spirit, Andolfatto and Williamson (2015) construct a model where government debt plays a key role in exchange, and can bear a liquidity premium. If asset market constraints bind, then there need not be deflation under an indefinite zero interest rate policy. A liquidity premium on government debt creates additional Taylor rule perils, because of a persistently low real interest rate.

In contrast to these papers, our framework considers trading in secondary market for government debt which can deliver a liquidity premium. We show how the liquidity premium can lead to multiple steady states and, therefore, real determinacy when the government follows a Taylor rule and the fiscal authority has a rule that links taxes to public debt. We also analyze alternative monetary rules and demonstrate how various combinations of monetary and fiscal policies and a spread-adjusted Taylor rule can rule out real indeterminacy.

3 The environment

The basic framework builds on Berentsen and Waller (2011). Time is discrete and there is a continuum of infinitively-lived agents of measure one that discount the future. These agents have access to fiat money and nominal government bonds. These are the only durable assets in the economy. As in Lagos and Wright (2005), agents face preference shocks, have stochastic trading opportunities and sequentially trade in various markets that are characterized by different frictions. In particular, each period has three sub-periods. In the first one, after the preference shocks are realized, agents enter a secondary market for government debt (SM). In the second sub-period, agents can trade in a decentralized frictional goods market (DM) where sellers and buyers are randomly and bilaterally matched. Finally, in the last sub-period, agents trade in a frictionless centralized market (CM) where they can produce and consume a general good as well as re-adjust their portfolio.

3.1 Preferences and Technologies

Agents have preferences over consumption of the general CM good (x_t), effort to produce the CM good (h_t), consumption of the specialized DM good (q_t) and effort to produce the DM good

(e_t). Their expected utility is then given by

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\ln(x_t) - h_t + \chi \frac{q_t^{1-\xi}}{1-\xi} - e_t \right], \tag{1}$$

where $\beta \in (0,1)$ represents the discount factor, $\chi > 0$ captures the relative weight on DM consumption and $\xi \in (0,1)$ is the inverse of the inter-temporal elasticity of substitution of DM consumption.

All perishable goods in the economy are produced according to a technology where labor is the only input. The production function is such that one unit of labor yields one unit of output.

3.2 Government

The government must finance a constant stream of exogenous expenditures, $G > 0$, through lump sum CM taxes and by issuing nominal bonds and fiat money. The corresponding per period government budget constraint is given by

$$\tau_t^{CM} + \phi_t M_t + \phi_t B_t = G + \phi_t M_{t-1} + \phi_t R_{t-1} B_{t-1}; \tag{2}$$

where M_t denotes money supply at time t, B_t represents nominal bonds, R_{t-1} is the gross nominal interest rate on bonds issued at $t-1$, τ_t^{CM} denotes lump sum taxes in CM and ϕ_t is the real price of money in terms of the CM good. The real value of all bond issues at every period is assumed to be bounded above by a sufficiently large constant in order to avoid Ponzi schemes.

To implement monetary and fiscal policy, the central bank follows a Taylor rule so that nominal interest rates are linked to inflation. The fiscal authority considers a rule whereby taxes are related to the previous level of real debt. These rules are given by

$$R_t = \alpha_0 + \alpha\, \Pi_t, \tag{3}$$

$$\tau_t^{CM} = \gamma_0 + \gamma\, \phi_{t-1} B_{t-1}; \tag{4}$$

where $\Pi_t = \frac{\phi_{t-1}}{\phi_t}$ denotes the gross inflation rate at time t.

3.3 Agent's Problem

Given the sequential nature of the problem, we solve the representative agent's problem backwards. Thus we first solve the CM problem, then the DM and finally solve the SM problem, respectively.

3.3.1 CM Problem

All agents in CM can produce and consume the general consumption good, x_t. Since there are no frictions, agents can produce and consume the CM good. A medium of exchange is not essential in this market. Agents can settle their trades with any assets or CM goods.

An agent in period t enters CM with a portfolio of fiat money ($\tilde{M}_{t-1}$), nominal government bonds ($\tilde{B}_{t-1}$) and unsecured real loans ($\tilde{l}_{t-1}$). This portfolio is different across agents depending what kind of preference shock they received in SM and the type of trade they had in the previous DM. In particular, we have that

$$\phi_t\tilde{M}_{t-1} = \begin{cases} \phi_t\left(M_{t-1} - a_t\, y_{b,t}\right), & \text{if the agent is a DM buyer with credit or no trade in } t, \\ \phi_t\left(M_{t-1} - a_t\, y_{b,t} - D_t^M\right), & \text{if the agent is a DM buyer in a trade with money in } t, \\ \phi_t\left(M_{t-1} - a_t\, y_{s,t}\right), & \text{if the agent is a DM seller with credit or no trade in } t, \\ \phi_t\left(M_{t-1} - a_t\, y_{s,t} + D_t^M\right), & \text{if the agent is a DM seller in a trade with money in } t, \end{cases}$$

$$\phi_t\tilde{B}_{t-1} = \begin{cases} \phi_t\left(B_{t-1} + y_{b,t}\right), & \text{if the agent is a DM buyer in } t, \\ \phi_t\left(B_{t-1} + y_{s,t}\right), & \text{if the agent is a DM seller in } t, \end{cases}$$

$$\tilde{l}_{t-1} = \begin{cases} -l_{t-1}, & \text{if the agent is a DM buyer in a trade with credit in } t, \\ l_{t-1}, & \text{if the agent is a DM seller in a trade with credit in } t, \\ 0, & \text{otherwise,} \end{cases}$$

where bonds purchased by the seller (buyer) are denoted by $y_{s,t}$ ($y_{b,t}$) and $a_t > 0$ represents the money price of bonds in the secondary market at time t.

Given this portfolio, the problem of the representative agent in CM can be written as follows

$$W(\tilde{M}_{t-1}, \tilde{B}_{t-1}, \tilde{l}_{t-1}) = \max_{x_t, h_t, M_t, B_t} \left\{ \ln(x_t) - h_t + \beta\left[\frac{1}{2}\, V_s^{SM}(M_t, B_t) + \frac{1}{2}\, V_b^{SM}(M_t, B_t)\right]\right\}$$
$$\text{s.t. } x_t + \phi_t M_t + \phi_t B_t = h_t - \tau_t^{CM} + \phi_t\tilde{M}_{t-1} + \phi_t R_{t-1}\tilde{B}_{t-1} + \tilde{l}_{t-1}, \tag{5}$$

where V_s^{SM} (V_b^{SM}) is the value function of a seller (buyer) in SM and $\frac{1}{2}$ reflects the fact that an agent has equal probability to be either a buyer or a seller in the ensuing DM.

The corresponding first order conditions are given by

$$\frac{1}{x_t} - 1 = 0, \tag{6}$$

$$-\phi_t + \beta\left[\frac{1}{2}\frac{\partial V_s^{SM}(M_t, B_t)}{\partial M_t} + \frac{1}{2}\frac{\partial V_b^{SM}(M_t, B_t)}{\partial M_t}\right] = 0, \tag{7}$$

$$-\phi_t + \beta \left[\frac{1}{2} \frac{\partial V_s^{SM}(M_t, B_t)}{\partial B_t} + \frac{1}{2} \frac{\partial V_b^{SM}(M_t, B_t)}{\partial B_t} \right] = 0, \tag{8}$$

and the associated envelope conditions are $\frac{\partial W_t}{\partial M_{t-1}} = \phi_t$, $\frac{\partial W_t}{\partial B_{t-1}} = \phi_t R_{t-1}$ and $\frac{\partial W_t}{\partial l_{t-1}} = 1$.

3.3.2 DM Problem

Before CM and right after SM, buyers/sellers enter DM. This market is characterized by random and bilateral trading opportunities as well as imperfect record-keeping. Matches in DM are such that with probability $\sigma \in (0, 1)$, a buyer (seller) is matched with a seller (buyer). Conditional on being matched, agents have access to record-keeping services for DM goods with probability $\kappa \in (0, 1)$, so that a buyer has access to credit. With probability $(1-\kappa)$ buyers do not have access to record-keeping services. As in Aruoba and Chugh (2010), Berentsen and Waller (2011) and Martín (2011), among others, government bonds are viewed as book-entries in the government's record.[11] Thus when financial record-keeping services in DM are not available, bonds cannot be used as a medium of exchange nor unsecured credit is available to buyers. As in Berentsen, Camera and Waller (2007), this environment has two types of record-keeping services: one for goods and one for financial transactions. These two services do not have to be simultaneously available nor linked to each other. This is what we assume in our paper. Here only goods record services can be available. Given this structure of records, the only feasible trade in these states of the world is the exchange of goods for fiat money.

An agent in period t enters DM with a portfolio of fiat money ($\hat{M}_{t-1}$) and nominal government bonds ($\hat{B}_{t-1}$). These will differ across agents depending on the preference shock they have received at the beginning of the period. In particular, we have that

$$\phi_t \hat{M}_{t-1} = \begin{cases} \phi_t \left(M_{t-1} - a_t y_{b,t} \right), & \text{if the agent is a DM buyer in } t, \\ \phi_t \left(M_{t-1} - a_t y_{s,t} \right), & \text{if the agent is a DM seller in } t, \end{cases}$$

$$\phi_t \hat{B}_{t-1} = \begin{cases} \phi_t \left(B_{t-1} + y_{b,t} \right), & \text{if the agent is a DM buyer in } t, \\ \phi_t \left(B_{t-1} + y_{s,t} \right), & \text{if the agent is a DM seller in } t. \end{cases}$$

The expected utility of a buyer entering DM with a portfolio $(\hat{M}_{t-1}, \hat{B}_{t-1})$ is then given by

$$V_b^{DM}(\hat{M}_{t-1}, \hat{B}_{t-1}) = \sigma\kappa \left[\chi \frac{q_t^{C\,1-\xi}}{1-\xi} + W(\hat{M}_{t-1}, \hat{B}_{t-1}, -l_{t-1}) \right] +$$

[11] Alternatively, this could be interpreted as a fraction of sellers where government bonds are not recognized as in Shi (2014) or Rocheteau, Wright and Xiao (2016). This could be endogenized as in Lester et al. (2012) or as Li et al. (2012). This treatment is beyond the scope of this paper.

$$+\sigma(1-\kappa)\left[\chi\frac{{q_t^M}^{1-\xi}}{1-\xi}+W(\hat{M}_{t-1}-D_t^M,\hat{B}_{t-1},0)\right]+(1-\sigma)W(\hat{M}_{t-1},\hat{B}_{t-1},0),$$

where q_t^C (q_t^M) denotes the DM quantity of goods traded with unsecured credit (fiat money) and D_t^M represents the DM cash payments. By feasibility, buyers can not pay more than the fiat money they brought into the match so that $D_t^M \leq \hat{M}_{t-1}$.

Similarly, the expected utility of a seller is given by

$$V_s^{DM}(\hat{M}_{t-1},\hat{B}_{t-1})=\sigma\kappa\left[-q_t^C+W(\hat{M}_{t-1},\hat{B}_{t-1},l_{t-1})\right]+\sigma(1-\kappa)\left[-q_t^M+W(\hat{M}_{t-1}+D_t^M,\hat{B}_{t-1},0)\right]+$$

$$+(1-\sigma)W(\hat{M}_{t-1},\hat{B}_{t-1},0).$$

When unsecured credit is feasible, the terms of trade are determined by a buyer take it or leave it offer. Thus we have that

$$\max_{q_t^C,l_{t-1}}\left\{\chi\frac{{q_t^C}^{1-\xi}}{1-\xi}+W(M_{b,t-1},B_{b,t-1},-l_{t-1})\right\}\text{ s.t. }\; -q_t^C+W(M_{s,t-1},B_{s,t-1},l_{t-1})\geq W(M_{s,t-1},B_{s,t-1},0),$$

which results in the following quantities and payments: $q_t^C=q_t^*=\chi^{\frac{1}{\xi}}$ and $l_{t-1}=q_t^C$.

Similarly, the terms of trade in meetings where record-keeping services are not available are given by a buyer's take it or leave it offer. This implies the following problem

$$\max_{q_t^M,D_t^M}\left\{\chi\frac{{q_t^M}^{1-\xi}}{1-\xi}+W(M_{b,t-1}-D_t^M,B_{b,t-1},0)\right\}\text{ s.t.}$$
$$M_{b,t-1}-D_t^M\geq 0,$$
$$-q_t^M+W(M_{s,t-1}+D_t^M,B_{s,t-1},0)\geq W(M_{s,t-1},B_{s,t-1},0),$$

which yield the following first order conditions

$$\frac{\chi}{{q_t^M}^{\xi}}=1+\lambda_t,$$
$$\lambda_t(M_{b,t-1}-D_t^M)=0,$$
$$q_t^M=\phi_t D_t^M,$$

where λ_t represents the Lagrange multiplier associated with the payment feasibility constraint, whereby a buyer can not pay the seller more fiat money than the one that he brought into the match. These terms of trade imply the following envelope conditions for fiat money

$$\frac{\partial V_{b,C}^{DM}}{\partial M_{b,t-1}}=\phi_t,\quad \frac{\partial V_{b,M}^{DM}}{\partial M_{b,t-1}}=\frac{\chi}{{q_t^M}^{\xi}}\frac{\partial q_t^M}{\partial M_{b,t-1}}-\phi_t\frac{\partial D_t^M}{\partial M_{b,t-1}}+\phi_t\;\text{ and }\;\frac{\partial V_{b,0}^{DM}}{\partial M_{b,t-1}}=\phi_t;$$

while for bones are

$$\frac{\partial V_{b,C}^{DM}}{\partial B_{b,t-1}} = \frac{\partial V_{b,M}^{DM}}{\partial B_{b,t-1}} = \frac{\partial V_{b,0}^{DM}}{\partial B_{b,t-1}} = \phi_t R_{t-1}.$$

For the seller we obtain similar expressions except for the fiat money envelope condition which is given by

$$\frac{\partial V_{s,M}^{DM}}{\partial M_{s,t-1}} = -\frac{\partial q_t^M}{\partial M_{s,t-1}} + \phi_t \frac{\partial D_t^M}{\partial M_{s,t-1}} + \phi_t.$$

Throughout the rest of the paper we focus on monetary equilibria with positive nominal interest rates so that $R_t > 1$. This type of equilibria then implies that $\lambda_t > 0$ so that buyers spend all their money when purchasing DM goods. Thus we have that $\frac{\partial D_t^M}{\partial M_{t-1}} = 1$.

3.3.3 SM Problem

At the beginning of each period, agents have a preference shock that determines whether they are a buyer or a seller in the next DM. Agents face the same probability of being a buyer or a seller. After the shock is realized, agents enter a secondary market for government debt where they can re-adjust their portfolio. In order to trade bonds, buyers and sellers incur a utility cost $\rho \geq 0$ per unit of (real) bonds traded. This parameter ρ measures the degree of financial innovation in the secondary market and affects the ability of this market to provide liquidity for the ensuing DM. Ceteris paribus, a higher ρ makes it more costly to participate in secondary markets.[12]

An agent that has M_{t-1} and B_{t-1} units of government liabilities at the beginning of SM solves the following problem

$$\begin{aligned}
&\max_{y_{b,t}} \frac{1}{2} \left\{ \rho \phi_t y_{b,t} + V_b^{DM}(M_{t-1} - a_t y_{b,t}, B_{t-1} + y_{b,t}) \right\} \\
+&\max_{y_{s,t}} \frac{1}{2} \left\{ -\rho \phi_t y_{s,t} + V_s^{DM}(M_{t-1} - a_t y_{s,t}, B_{t-1} + y_{s,t}) \right\} \\
&\qquad + \phi_t \mu_{b,t} \left[M_{t-1} - a_t y_{b,t} \right] \\
&\qquad + \phi_t \theta_{b,t} \left[B_{t-1} + y_{b,t} \right] \\
&\qquad + \phi_t \mu_{s,t} \left[M_{t-1} - a_t y_{s,t} \right] \\
&\qquad + \phi_t \theta_{s,t} \left[B_{t-1} + y_{s,t} \right] - \phi_t \varsigma_{b,t} y_{b,t} + \phi_t \varsigma_{s,t} y_{s,t} \ ,
\end{aligned}$$

where $\mu_{b,t}, \theta_{b,t}, \mu_{s,t}$ and $\theta_{s,t}$ are the corresponding Lagrange multipliers. These reflect the fact that buyers and sellers cannot trade more bonds and fiat money than the amounts that they brought into SM.

[12]Berentsen et al (2014) consider a similar environment but rather than agents paying a cost to trade in the secondary market, agents face an exogenous probability that dictates whether they can participate or not in this financial market.

It is worth highlighting that for the buyer, $M_{t-1} - a_t y_{b,t} \geq 0$ cannot bind. This implies that $\mu_{b,t} = 0$. Similarly, for the seller, $B_{t-1} + y_{s,t} \geq 0$ cannot bind so that $\theta_{s,t} = 0$. The corresponding first order conditions for $y_{b,t}$ and $y_{s,t}$ are then

$$\frac{1}{2}\rho\phi_t - \frac{1}{2}a_t\frac{\partial V_b^{DM}}{\partial M_{b,t-1}} + \frac{1}{2}\frac{\partial V_b^{DM}}{\partial B_{b,t-1}} + \phi_t\theta_{b,t} - \phi_t\varsigma_{b,t} = 0,$$

$$-\frac{1}{2}\rho\phi_t - \frac{1}{2}a_t\frac{\partial V_s^{DM}}{\partial M_{s,t-1}} + \frac{1}{2}\frac{\partial V_s^{DM}}{\partial B_{s,t}} - a_t\phi_t\mu_{s,t} + \phi_t\varsigma_{s,t} = 0.$$

Various monetary equilibria can be observed depending which of the different constraints bind. We next consider the various possibilities.

Region 0: Agents do not trade in SM. Thus we have that $y_{b,t} = y_{s,t} = 0$.

Case $\mathcal{I}$: Agents participate in SM and their optimal trading is such that $y_{b,t}$ and $y_{s,t}$ are both interior solutions. This then implies that

$$\frac{1}{2}\rho\phi_t - \frac{1}{2}a_t\frac{\partial V_b^{DM}}{\partial M_{b,t-1}} + \frac{1}{2}\frac{\partial V_b^{DM}}{\partial B_{b,t-1}} = 0, \text{ and } -\frac{1}{2}\rho\phi_t - \frac{1}{2}a_t\frac{\partial V_s^{DM}}{\partial M_{s,t-1}} + \frac{1}{2}\frac{\partial V_s^{DM}}{\partial B_{s,t-1}} = 0.$$

Case $\mathcal{I}_m$: Agents participate in SM and their optimal trading is such that there is an interior solution for $y_{s,t}$ and the short-selling constraint on bonds satisfies $B_{t-1} + y_{b,t} = 0$. These optimal decisions imply the following

$$\frac{1}{2}\rho\phi_t - \frac{1}{2}a_t\frac{\partial V_b^{DM}}{\partial M_{b,t-1}} + \frac{1}{2}\frac{\partial V_b^{DM}}{\partial B_{b,t}} + \phi_t\theta_{b,t} = 0, \text{ and } -\frac{1}{2}\rho\phi_t - \frac{1}{2}a_t\frac{\partial V_s^{DM}}{\partial M_{s,t-1}} + \frac{1}{2}\frac{\partial V_s^{DM}}{\partial B_{s,t-1}} = 0.$$

Case $\mathcal{I}_b$: Agents participate in SM and their optimal trading is such that there is an interior solution for $y_{b,t}$ but the short-selling constraint is $M_{t-1} - a_t y_{s,t} = 0$. We then have that

$$\frac{1}{2}\rho\phi_t - \frac{1}{2}a_t\frac{\partial V_b^{DM}}{\partial M_{b,t-1}} + \frac{1}{2}\frac{\partial V_b^{DM}}{\partial B_{b,t-1}} = 0, \text{ and } -\frac{1}{2}\rho\phi_t - \frac{1}{2}a_t\frac{\partial V_s^{DM}}{\partial M_{s,t-1}} + \frac{1}{2}\frac{\partial V_s^{DM}}{\partial B_{s,t-1}} - a_t\phi_t\mu_{s,t} = 0.$$

Region 1: Agents participate in SM and agents are constrained on both money and bonds holdings so that $M_{t-1} - a_t y_{s,t} = 0$ and $B_{t-1} + y_{b,t} = 0$. These conditions imply that

$$\frac{1}{2}\rho\phi_t - \frac{1}{2}a_t\frac{\partial V_b^{DM}}{\partial M_{b,t-1}} + \frac{1}{2}\frac{\partial V_b^{DM}}{\partial B_{b,t-1}} + \phi_t\theta_{b,t} = 0, \text{ and } -\frac{1}{2}\rho\phi_t - \frac{1}{2}a_t\frac{\partial V_s^{DM}}{\partial M_{s,t-1}} + \frac{1}{2}\frac{\partial V_s^{DM}}{\partial B_{s,t-1}} - a_t\phi_t\mu_{s,t} = 0.$$

It is easy to show that the bond multiplier for the buyer is given by

$$2\theta_{b,t} = -\rho + a_t \left[1 + \sigma(1-\kappa)\left(\frac{\chi}{q_t^{M\xi}} - 1\right)\right] - R_{t-1}, \tag{9}$$

where the first term of the right hand side of equation (9) reflects the cost of trading in SM, the second term captures the DM consumption benefit of acquiring an additional nominal bond and the last term reflects the opportunity cost of selling the nominal bond.

The money multiplier for the seller is given by

$$2a_t\mu_{s,t} = -\rho + R_{t-1} - a_t, \tag{10}$$

where the first term reflects the cost of trading in SM, the second term captures the benefit of acquiring an additional nominal bond and the last term reflects the opportunity cost of selling the fiat money for bonds in the secondary market.

Depending on whether the various multipliers are strictly positive or not, we are going to observe different prices and interest rates, which will result in vastly different inflation and bond dynamics. Throughout the rest of the paper we focus on monetary equilibria in Region 0 and in Region 1, which can be roughly thought as before and during the Great Moderation, respectively.

3.4 Monetary Equilibrium in Region 0

This monetary equilibrium is one where there is no trade in secondary markets. Given $\left\{\tau_t^{CM}, R_t, G\right\}_{t=0}^{\infty}$ and (M_{-1}, B_{-1}), a dynamic monetary equilibrium is a sequence $\left\{x_t, q_t^C, q_t^M, l_{t-1}, M_t, B_t, \phi_{t+1}\right\}_{t=0}^{\infty}$ satisfying market clearing and the household's problem. A monetary equilibrium satisfies the following conditions

$$x_t = 1, \quad \& \quad l_{t-1} = q_t^C = \chi^{\frac{1}{\xi}}, \tag{ME1-3,R0}$$

$$q_t^M = \phi_t M_{t-1}, \tag{ME4,R0}$$

$$\phi_t = \beta\phi_{t+1}R_t, \tag{ME5,R0}$$

$$\phi_t = \beta\phi_{t+1}\left[1 + \frac{\sigma(1-\kappa)}{2}\left(\frac{\chi}{q_t^{M\xi}} - 1\right)\right], \tag{ME6,R0}$$

$$\tau_t^{CM} + \phi_t M_t + \phi_t B_t = G + \phi_t M_{t-1} + \phi_t R_{t-1} B_{t-1}. \tag{ME7,R0}$$

where $R_t = \alpha_0 + \alpha\Pi_t$ and $\tau_t^{CM} = \gamma_0 + \gamma\phi_{t-1}B_{t-1}$, as prescribed by the corresponding monetary and fiscal policy authorities.

After repeated substitution, it is easy to show that the evolution of inflation and real bonds

$(b_t = \phi_t B_t)$ is described by

$$\Pi_{t+1} = \beta \left[\alpha_0 + \alpha\, \Pi_t\right], \tag{DS-p-R0}$$

$$b_t = G - \gamma_0 + \left(\frac{1}{\beta} - \gamma\right) b_{t-1} + \frac{m_{t-1}}{\Pi_t} - m_t, \tag{DS-b-R0}$$

where $m_t = \phi_t M_t$ represents real balances that satisfy the following equation

$$\frac{\sigma(1-\kappa)}{2}\left(\chi \frac{\Pi_t}{{m_{t-1}}^{\xi}} - 1\right) = \alpha_0 + \alpha\, \Pi_t - 1.$$

As we can see from (DS-p-R0) and (DS-b-R0), the evolution of future inflation is independent of real government bonds as in Leeper (1991). Moreover, if credit was available in all states of the world, $\kappa = 1$, then we would recover the same decoupled system as in the frictionless and cashless environments of Woodford (1998).

3.4.1 Steady States

After imposing steady state conditions on (DS-p-R0) and (DS-b-R0), we have that the monetary steady state is given by

$$\Pi = \frac{\beta\alpha_0}{1-\beta\alpha}; \quad m = \left(\frac{\chi\sigma(1-\kappa)}{2\left(\frac{\Pi}{\beta} - 1\right) + \sigma(1-\kappa)}\right)^{\frac{1}{\xi}} \Pi,$$

$$b = \frac{1}{1 - \frac{1}{\beta} + \gamma}\left[(G - \gamma_0) + \left(1 - \frac{\beta\alpha_0}{1-\beta\alpha}\right)\left(\frac{\chi\sigma(1-\kappa)}{2\left(\frac{\alpha_0 - 1 + \beta\alpha}{(1-\beta\alpha)}\right) + \sigma(1-\kappa)}\right)^{\frac{1}{\xi}}\right].$$

Clearly, steady state inflation is unique in Region 0. Access to unsecured credit affects the steady state value of real balances and real government bonds. In economies where credit is less available, the demand for real balances increases and the demand for real bonds decreases. This is not surprising as fiat money and unsecured credit are substitute means of payment for DM transactions.

3.4.2 Local Dynamics

The corresponding Jacobian for this monetary equilibrium is given by

$$\mathcal{J} = \begin{bmatrix} \beta\alpha & 0 \\ \omega_0 & \frac{1}{\beta} - \gamma \end{bmatrix},$$

where $\omega_0 = \frac{\partial b_t}{\partial \Pi_t} \neq 0$. The corresponding eigenvalues are $\lambda_M = \beta\alpha$ & $\lambda_F = \frac{1}{\beta} - \gamma$.

As we can see, the monetary equilibrium with no active secondary markets delivers the same stabilization policy prescription of active/passive or passive/active monetary/fiscal policies as in Leeper (1991). The availability of unsecured credit affects the steady state level of real money balances and, through seigniorage, the steady state level of real bond holdings. However, having access to unsecured credit does not affect the steady state inflation nor the stability of the economy. Thus we can conclude that the traditional policy prescriptions are also consistent with a fairly unsophisticated financial system where there is no trade in secondary markets. Thus inflation expectations generated in this monetary equilibrium are the same as those observed in models with frictionless and perfect financial markets.

3.5 Monetary Equilibrium in Region 1

The monetary equilibrium in Region 1 is one where there is trade in secondary markets and access to unsecured credit is more readily available. These two features can be thought as reflecting the Great Moderation period, where secondary markets became more relevant and unsecured credit was more prevalent among households.

Given $\left\{\tau_t^{CM}, R_t, G\right\}_{t=0}^{\infty}$ and (M_{-1}, B_{-1}), a dynamic monetary equilibrium is a sequence of consumptions $\left\{x_t, q_t^C, q_t^M\right\}_{t=0}^{\infty}$ as well as assets and prices $\{l_{t-1}, M_t, B_t, \phi_{t+1}, \theta_{b,t+1}, \mu_{s,t+1}\}_{t=0}^{\infty}$ satisfying market clearing and the agents' problem which imply the following

$$x_t = 1, \quad \& \quad l_{t-1} = q_t^C = \chi^{\frac{1}{\xi}}, \tag{ME1-3-R1}$$

$$q_t^M = \phi_t(M_{t-1} - a_t y_{b,t}), \tag{ME4-R1}$$

$$M_{t-1} - a_t y_{s,t} = 0, \tag{ME5-R1}$$

$$B_{t-1} + y_{b,t} = 0, \tag{ME6-R1}$$

$$y_{s,t} + y_{b,t} = 0, \tag{ME7-R1}$$

$$2\theta_{b,t} = -\rho + a_t\left[1 + \sigma(1-\kappa)\left(\frac{\chi}{q_t^{M\,\xi}} - 1\right)\right] - R_{t-1}, \tag{ME8-R1}$$

$$2a_t\, \mu_{s,t} = R_{t-1} - \rho - a_t, \tag{ME9-R1}$$

$$\phi_t = \beta\phi_{t+1}\left[R_t + \theta_{b,t+1}\right], \tag{ME10-R1}$$

$$\phi_t = \beta\phi_{t+1}\left[1 + \frac{\sigma(1-\kappa)}{2}\left(\frac{\chi}{q_t^{M\,\xi}} - 1\right) + \mu_{s,t+1}\right], \tag{ME11,R1}$$

$$\tau_t^{CM} + \phi_t M_t + \phi_t B_t = G + \phi_t M_{t-1} + \phi_t R_{t-1} B_{t-1}, \tag{ME12,R1}$$

where $R_t = \alpha_0 + \alpha\Pi_t$ and $\tau_t^{CM} = \gamma_0 + \gamma\phi_{t-1}B_{t-1}$.

After repeated substitution, the evolution of inflation and real bond holdings in Region 1 is given by

$$\Pi_{t+1} = \beta \left(\alpha_0 + \alpha \Pi_t + \theta_{b,t}\right), \tag{DS-p-R1}$$

$$2b_t = G - \gamma_0 + \left(\frac{1}{\beta} - \gamma - \frac{\theta_{b,t-1}}{\Pi_t} + \frac{1}{\Pi_t}\right) b_{t-1}, \tag{DS-b-R1}$$

where $a_t = 1$ and $\theta_{b,t-1}$ captures the bond liquidity premium that is given by

$$\theta_{b,t-1} = -\rho - \frac{\Pi_t}{\beta} + 1 + \sigma(1-\kappa)\left[\chi\left(\frac{\Pi_t}{2b_{t-1}}\right)^{\xi} - 1\right],$$

which depends on both real bonds and inflation. As a result of this premium on public debt, the inflation-adjusted nominal interest rate is not constant. It now depends on the level of real public debt. This is not surprising as DM buyers are willing to sell bonds for cash as to reduce their liquidity constraint in the ensuing DM. Thus, in this equilibrium bonds carry a liquidity premium. This is a critical property that drastically changes the characteristics and nature of the monetary equilibria. This is the case as the government can reduce the tax burden of issuing public debt as agents are willing to pay a price for them above their fundamental value, thus braking the Ricardian equivalence.

As we can see from (DS-p-R1) and (DS-b-R1), the evolution of future inflation depends on current inflation and real government bonds. Moreover, the evolution of current bonds not only depends on the dynamics of current and past inflation but also on the amount of bonds previously issued. This is a direct consequence of having a liquidity premium for public debt. Since bonds can help expand the consumption possibilities in DM, its price is higher. Thus the underlying wealth and substitution effects when revaluing public debt, through changes in price levels, are drastically different to environments without a liquidity premium. Thus we can conclude that having a liquidity premium for government debt fundamentally changes the way monetary and fiscal policies interact.

3.5.1 Steady States

From (DS-p-R1) and (DS-b-R1), it is easy to show that steady state inflation and real bond holdings solve the following non-linear equations

$$\Pi = \frac{1}{\frac{2}{\beta} - \alpha}\left[\alpha_0 + 1 - \rho + \sigma(1-\kappa)\left[\chi\left(\frac{\Pi}{2b}\right)^{\xi} - 1\right]\right],$$

$$b = \frac{(G - \gamma_0)\,\Pi}{(2 - \alpha + \gamma)\,\Pi - (1 + \alpha_0)}.$$

Lemma 1 *Steady states in Region 1 are generically not unique.*

All proofs can be found in the Appendix.

The monetary equilibrium in Region 1 may exhibit multiple monetary steady states. This is a direct consequence of the liquidity properties of government bonds. Notice the nominal interest rate depends on real bonds. As a result, the total interest payment on bonds is non-linear, yielding bond seigniorage that is entirely driven by the liquidity needs of buyers. This is the case as buyers are willing to pay prices for government bonds that are above their fundamental value.[13] As a result, the fiscal authority can reduce the tax burden when issuing public debt. This is the case even when the economy reaches the steady state. This relative increase in revenue changes the fiscal backing of bonds when compared to economies without a liquidity premium, changing the fiscal backing of bonds. This new fiscal environment critically alters the expectations about future inflation, which in turn has important implications for the evolution of inflation and public debt, relative to environment without premiums. In this section we examine these consequences.

Regardless of the number of steady states in Region 1, in order for an allocation to be a monetary equilibrium, the multipliers need to be non-negative. These are given by

$$\theta_b = \left(\frac{1}{\beta} - \alpha\right)\Pi - \alpha_0, \;\; \& \;\; \mu_s = \frac{1}{2}\left(\alpha_0 + \alpha\Pi - \rho - 1\right).$$

We can now establish some necessary conditions for the existence of a monetary equilibrium.

Lemma 2 *The equilibrium steady state inflation* Π *in Region 1 must satisfy the next conditions:*
(i) $\Pi \geq \frac{1+\rho-\alpha_0}{\alpha}$ *and (ii) if* $\alpha_0 \geq 0$ *and* $\alpha\beta < 1$*, then* $\Pi \geq \frac{\alpha_0\beta}{1-\beta\alpha}$*, or*
(i) $\Pi \geq \frac{1+\rho-\alpha_0}{\alpha}$ *and (iii) if* $\alpha_0 \leq 0$ *and* $\alpha\beta > 1$*, then* $\Pi \leq \frac{\alpha_0\beta}{1-\beta\alpha}$*.*

When there is no trade in secondary markets, the steady state inflation in Region 0 equals $\frac{\alpha_0\beta}{1-\beta\alpha}$, which is the bound in conditions *(ii)* and *(iii)*.[14] Therefore, whenever monetary policy is traditionally passive, $\beta\alpha < 1$, Region 1 delivers a steady state inflation that is higher than the one implied by Region 0. Alternatively, when monetary policy is traditionally active, $\alpha\beta > 1$, Region 1 implies a steady state inflation lower than the one in Region 0. We can conclude then that trading in secondary markets, consistent with the period during the Great Moderation, can further amplify the effectiveness of active monetary policy in reducing steady state inflation. This has been an aspect that has not been highlighted by the literature and is solely driven by the endogenous liquidity premium of public debt.

When multiple steady states are possible, we are faced with real indeterminacy. Moreover, increased volatility can be observed as one can always construct sunspot equilibria between those

[13] This bond liquidity Laffer curve effect is also found in Gomis-Porqueras (2016).
[14] Note that as gross inflation Π needs to be positive, we consider $\alpha_0 \leq 0$ ($\alpha_0 \geq 0$) when $\alpha\beta > 1$ ($\alpha\beta < 1$).

steady states.[15] Are there any policies that can help rule-out this real indeterminacy and reduce the potential volatility?

Proposition 1 *With a monetary policy such that $\alpha = \frac{2}{\beta}$ or a combination of monetary and fiscal policies such that $\alpha = 2 + \gamma$, a monetary steady state in Region 1, if one exists, is unique.*

As we can see, a *traditional* aggressive monetary policy ($\alpha > \frac{2}{\beta}$) and adequate monetary and fiscal policies ($\alpha = 2 + \gamma$) are able to rule-out real indeterminacies. When agents trade in secondary markets, cetirus paribus, aggressive monetary policies seem more likely to generate unique monetary steady state. This findings suggests that having an aggressive monetary policy becomes more important during the Great Moderation, which was characterized by increased trading in secondary markets and having more access to unsecured credit.

3.5.2 Local Dynamics

The corresponding Jacobian for the monetary equilibrium in Region 1 is given by

$$\mathcal{J} = \begin{bmatrix} \omega_1 \beta \alpha + \omega_3 \omega_2 & \frac{\omega_3}{2}\left(\frac{1}{\beta} - \gamma - \omega_4\right) \\ \omega_2 & \frac{1}{2}\left(\frac{1}{\beta} - \gamma - \omega_4\right) \end{bmatrix},$$

with $\omega_1 = \frac{1}{\left(1 - \beta \frac{\partial \theta_b}{\partial \Pi}\right)}$; $\omega_2 = -\frac{(1-\theta_b)b + \Pi \frac{\partial \theta_b}{\partial \Pi} b}{2\Pi^2}$; $\omega_3 = \beta \frac{\partial \theta_b}{\partial b}\omega_1$; and $\omega_4 = -\frac{\theta_b}{\Pi} + \frac{1}{\Pi} + \frac{\frac{\partial \theta_b}{\partial b} b}{\Pi}$. Note that the values outside of the main diagonal are in general not zero. This occurs as the liquidity premium on public debt can reduce the tax burden of issuing public debt. As a result, real government bonds matter for inflation, creating a link between the path of government debt, taxes and inflation. Thus the traditional prescriptions of active/passive monetary and fiscal policies of Leeper (1991) are not going to be operative in a monetary equilibrium where agents trade in secondary markets.

Given that we can not analytically characterize the eigenvalues, in latter sections of the paper we conduct a numerical exercise where we compare the equilibrium properties of monetary equilibria in Regions 0 and 1.

3.5.3 Spread-Adjusted Taylor Rules

In this section we explore the usefulness of alternative Taylor rules in eliminating real indeterminacies. The monetary equilibrium in Region 1 is such that buyers are willing to buy public debt above their fundamental value. This is the case as trading them for fiat money in secondary markets can help expand their consumption possibilities when trading in DM. This additional value is captured by the interest spread between the natural rate in the economy and the total

[15] We refer to Azariadis (1981) and Cass and Shell (1983), among others, for more discussions on sunspot equilibria.

return (takes into account the store of value and liquidity services) on government debt. Note that this spread has nothing to do with having different risk profiles.

Within the spirit of Cúrdia and Woodford (2010), here we consider a spread-adjusted Taylor Rule. In our setting we consider the following modified Taylor rule

$$R_t = \alpha_0 + \alpha \Pi_t - \left(\tilde{R}_t - R_t \right)$$

where $\tilde{R}_t - R_t = \theta_{b,t+1}$. It is easy to show that under this new monetary rule, the dynamic monetary equilibrium for Region 1 is given by

$$\Pi_{t+1} = \beta \left(\alpha_0 + \alpha \Pi_t \right), \tag{DSL-p,R1}$$

$$2b_t = G - \gamma_0 + \left(\frac{1}{\beta} - \gamma - \frac{\theta_{b,t-1} - 1}{\Pi_t} \right) b_{t-1}. \tag{DSL-b,R1}$$

As we can see, with this spread-adjusted Taylor rule, public debt does not affect inflation. Let us now consider the corresponding monetary steady states of this economy.

Lemma 3 *Under a spread-adjusted Taylor rule, the monetary steady state is unique and the steady state inflation is identical to the steady state inflation in Region 0.*

Lemma 3 highlights that once the monetary authority takes into account the additional value that public debt gives to buyers, it can then internalize the liquidity Laffer curve generated by agents willing to purchase bonds above their fundamental value. This helps rule out real indeterminacies.

Let us now explore the local stability properties. The corresponding Jacobian for this monetary equilibrium is given by

$$\mathcal{J} = \begin{bmatrix} \alpha\beta & 0 \\ \omega_2 & \frac{1}{2}\left(\frac{1}{\beta} - \gamma - \omega_4 \right) \end{bmatrix},$$

where $\omega_2 = -\frac{(1-\theta_b)b + \Pi \frac{\partial \theta_b}{\partial \Pi} b}{2\Pi^2}$; and $\omega_4 = -\frac{\theta_b}{\Pi} + \frac{1}{\Pi} + \frac{\frac{\partial \theta_b}{\partial b} b}{\Pi}$.

With the spread-adjusted Taylor rule, public debt does not affect inflation, thus the system is now de-coupled so that fiscal considerations do not affect the stability properties associated with the monetary eigenvalue. The fiscal and monetary eigenvalues of the system are given by

$$\lambda_M = \beta\alpha \;\; \& \;\; \lambda_F = \frac{1}{2}\left(\frac{1}{\beta} - \gamma - \omega_4 \right).$$

Even though public debt does not affect inflation, traditional prescriptions for stabilization policies based on frictionless financial markets are still not operative. While the monetary eigenvalue is the standard one, the fiscal eigenvalue depends on the spread-adjusted Taylor rule (α_0

and α) on financial market conditions (ρ, κ and σ) as well as on the fiscal stance (γ_0 and γ). Since closed-form solutions can not be obtained for the fiscal eigenvalue, a numerical analysis is required to determine when the monetary equilibria is locally determinate.

4 A Numerical Exploration

Given that a numerical analysis is required to find further properties of the various monetary equilibria, we need to parametrize the model. As a benchmark, we first consider an economy with no trade in secondary markets and no access to unsecured credit, which corresponds to Region 0 of our model. This scenario roughly captures the era before the Great Moderation, which we take to be from 1960 to 1984.

To provide some discipline when deciding the parameter values, we proceed as follows. To determine the underlying discount factor, we compute the average annual real interest rate from 1960 to 1984, which is 2.5%. This results in $\beta = 0.9758$. To pin down the preferences parameters for the DM utility, we calibrate ξ and χ to yield the ratio of M1 to GDP at two different interest rates. Specifically, we consider the ratios equal to 22% and 40%, which correspond to interest rates equal to 5% and 2.5%, respectively.[16] To determine G, γ_0 and α_0, we match the long-run average from 1960-1984 of government spending to GDP, government debt to GDP and the annual CPI inflation rate to be 20%, 34% and 5.27%, respectively.[17] For the rest of the parameters, we assume a probability of trading in DM to be $\sigma = 0.5$, set the cost of participating in secondary markets equal to $\rho = 0.01$ and consider no access to credit so that $\kappa = 0$.

To analyze the consequences for inflation dynamics when changing the aggressiveness of monetary and fiscal rules, we consider a range of values for α and γ. To further discipline the model and to provide a meaningful comparison, for each of the values for α and γ, the policy intercepts α_0 and γ_0 are re-calibrated so that Region 0 delivers the same steady state values for inflation and real bond holdings. Table 1 summarizes our calibration targets.

Table 1: Calibration Targets

Parameter	Target
$\beta = 0.9758$	Annual real interest rate of 2.5 %
χ and ξ	Real money holdings of 23 (41.8) % of CM GDP when $R - 1$ is 5 (2.5) %
$G = 0.21$	Government spending of 21 % of CM GDP
γ_0	Government debt of 35.7 % of CM GDP
α_0	Inflation rate of 5.27 %

[16] In terms of CM output, these ratios are equivalent to 23% and 42% respectively. The money demand data is taken from Berentsen et al. (2014) for the period 1950-1989.

[17] In terms of CM output, the first two correspond to 21% and 36%.

With this benchmark calibration, we first explore the effects of active and passive monetary policies on the long-run characteristics of the monetary equilibrium. We then study the robustness of active monetary policies in delivering a unique steady state and locally stable equilibria for a wide range of fiscal policies and changes in the economic environment. Finally, we analyze spread-adjusted Taylor rules.

4.1 Active Monetary Policies

In this section we analyze the resulting monetary equilibria that one obtains in the benchmark calibration with an active monetary policy (MP) and a passive fiscal policy (FP). In addition, we explore how changes in matching frictions, costs of participating in secondary markets and access to credit (σ, ρ and κ, respectively) affect the properties of the monetary equilibria.

Table 2 reports the real money balances, real bond holdings, the interest spread ($\tilde{R}-R$), and the eigenvalues in Regions 0 and 1. The first two columns describe the monetary steady states for the benchmark calibration with an active monetary policy, $\alpha = 1.50$, and a passive fiscal policy, $\gamma = 0.025$. The rest of the columns on Table 2 describe the resulting equilibria in Region 1 when various features of the economic environment change.

Table 2: Active MP, Passive FP: Changes in σ, ρ and κ

	Region 0	Region 1			
	All	Benchmark	$\sigma = 1.00$	$\rho = 0.00$	$\kappa = 0.15$
Π	1.0527	1.0325	1.0274	1.0147	1.0341
b	0.3569	0.1521	0.1571	0.1917	0.1504
$\tilde{R}-R$	0	0.0193	0.0240	0.0362	0.0177
λ_M	1.4638	0.7613	0.7612	0.7603	0.7614
λ_F	0.9998	1.0206	1.0219	1.0248	1.0201

Benchmark parameters: $\alpha = 1.50$, $\gamma = 0.025$, $\sigma = 0.50$, $\rho = 0.01$, and $\kappa = 0.00$.

As we can see from Table 2, one finds a unique steady state in both Regions. Relative to Region 0, and consistent with Lemma 2, an active monetary policy induces a lower steady state inflation in Region 1 and delivers unique steady states. The long run inflation in Region 1 is 3.25%, which is close to the annual average inflation observed between 1985 and 2006 (3.06%). The resulting equilibrium interest rate spread is equal to 1.93% which is approximately equal to the one experienced during the Great Moderation (2.48%).[18]

While the steady states in each Region are stable, the corresponding eigenvalues are very different. In particular, we find that when agents trade in secondary markets this tends to

[18]The interest rate spread data has been calculated as the difference between the AAA corporate bond yield and the 1-year treasury constant maturity rate.

dampen the monetary eigenvalue, λ_M, while strengthen the fiscal one, λ_F.[19] The reasons for being determined are also very different. In Region 0, the driver for the dynamic determinacy is the aggressiveness of monetary policy. While for Region 1 is the liquidity services of bonds coupled with an adequate fiscal policy. This difference across monetary equilibria is not surprising as the underlying dynamics equations characterizing Region 1 are not de-coupled, while those describing Region 0 are. As a result for Region 1, monetary and fiscal eigenvalues are jointly determined by both monetary and fiscal policies. This is a direct consequence of having a liquidity premium on government bonds.

These initial results suggest that when agents trade in secondary markets for government debt, active monetary policy amplifies the effectiveness in reducing long run inflation. Ignoring the trading in secondary markets and interest rate spreads increases inflation by 2%. Moreover, it is more effective at stabilizing debt. This is the case as the speed of convergence to the steady state is faster as it delivers eigenvalues inside the unit circle that are smaller.

Table 2 also shows how changes in search frictions (σ), cost of trading in the secondary market (ρ) and access to unsecured credit (κ) affect the monetary equilibrium of Region 1. The third column of Table 2 shows the consequences of lowering search frictions. When these are reduced, the expected benefit of carrying an additional unit of money increases. This is the case as it is more likely that buyers match with a seller. Thus it is not surprising that we find a further decrease in the inflation rate and an increase in the interest spread.

When the participation costs in secondary markets are lower, fourth column in Table 2, the attractiveness of acquiring additional bonds increases.[20] This is the case as the insurance value of holding cash to consume in DM is reduced. Thus we observe a further reduction in inflation, an increase in the spread and in the fiscal eigenvalue which increases the speed of convergence to the steady state. These findings suggest that with improvements in the development of secondary markets active monetary policy becomes more effective in reducing long run inflation as well as stabilizing debt.

Finally in the fifth column of Table 2, we report the consequences of having access to unsecured credit by setting κ to 0.15.[21] Now agents have an alternative payment instrument to finance their DM purchases that does not require inter-temporal costs; i.e, carrying fiat money or bonds. As a result, fiat money is less useful as a means of payment in frictional goods market. Thus better access to unsecured credit increases steady state inflation, decreases the spread and reduces the fiscal eigenvalue. These effects are quantitatively small. Finally, we note that as κ tends to one,

[19] We name the monetary eigenvalue as the one that would be traditionally the monetary one. Similarly, we denote the other eigenvalue as the fiscal one.

[20] Higher costs (larger ρ) tend to lead to the non-existence of Region 1.

[21] This value corresponds to the size of unsecured credit during the Great Moderation when analyzed through the prism of a search model of money. We refer to Aruoba et al. (2011) for more details on the size of unsecured credit.

Region 1 disappears as money and secondary markets are less valued by buyers.

What would happen to the monetary equilibria where agents trade in secondary markets if the fiscal authority follows an active policy? Table 3 answers this question by changing the benchmark calibration for the stance of fiscal policy from $\gamma = 0.025$ to $\gamma = 0.024$.

Table 3: Active MP, Active FP: Changes in σ, ρ and κ

	Region 0	Region 1			
	All	Benchmark 2	$\sigma = 1.00$	$\rho = 0.00$	$\kappa = 0.15$
Π	1.0527	1.0270	1.0223	1.0118	1.0285
b	0.3569	0.1569	0.1615	0.1950	0.1555
$\tilde{R} - R$	0	0.0244	0.0286	0.0389	0.0230
λ_M	1.4638	0.7611	0.7611	0.7603	0.7611
λ_F	1.0008	1.0226	1.0240	1.0261	1.0222

Benchmark parameters: $\alpha = 1.50$, $\gamma = 0.024$, $\sigma = 0.50$, $\rho = 0.01$, and $\kappa = 0.00$.

As before, we can see from Table 3 that Region 1 yields lower steady state inflation relative to the pre Great Moderation era. Against conventional wisdom, an active monetary policy paired with an active fiscal policy does not lead to locally indeterminate equilibria. In Region 1, the liquidity premium reduces the monetary eigenvalue just enough to deliver determinacy. This is not the case for Region 0 which delivers the traditional indeterminate equilibria. Once a liquidity premium exists there is a reduction in the tax burden from issuing bonds as buyers pay a price for these nominal assets above their fundamental value. This reduction in the need for additional revenue changes the fiscal backing for bonds relative to a model without a liquidity premium. As a result, monetary policy does not have to be as aggressive relative to environments without a liquidity premium. The effect of changes in σ, ρ, and κ on the long-run properties of the monetary equilibria are similar to those reported with a passive fiscal policy.

Does an active monetary policy always lead to a steady state that is unique and locally stable? To answer this question we consider two different active monetary polices. In doing so we keep the same parameters for κ and σ as in the benchmark calibration. This allows us to assess the robustness of active monetary policies in ruling out real indeterminacy. In particular, in Figure 1a (1b), we consider $\alpha = 1.50$ ($\alpha = 2.25$) and different degrees of aggressiveness in fiscal policy, γ, and different levels of SM participation costs, ρ.

Figure 1a (1b) depicts whether uniqueness of steady sates are possible as well as the stability of steady states in Region 1. The green horizontal line denotes the boundary of fiscal policies. Values above (below) this line are passive (active).

Figure 1a: Active MP with $\alpha = 1.50$

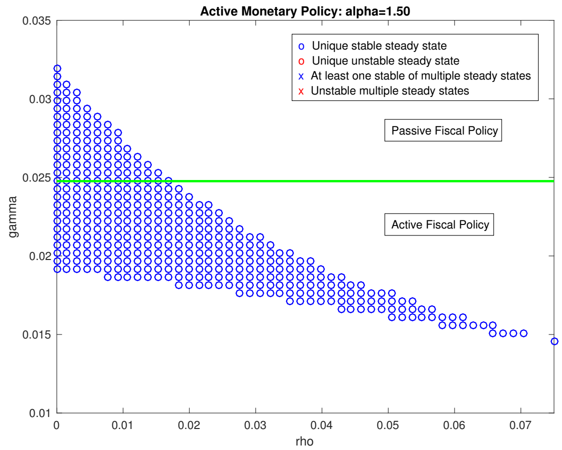
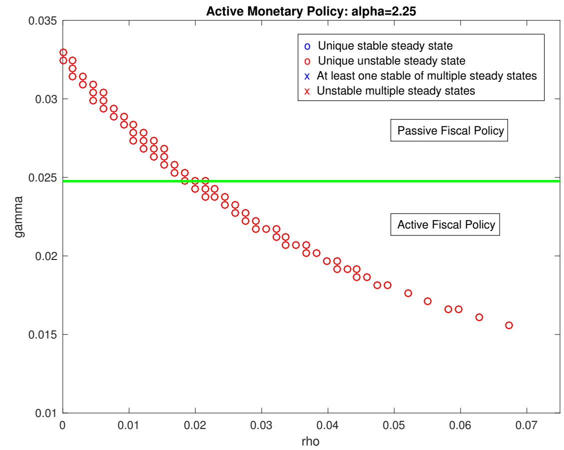


Figure 1b: Active MP with $\alpha = 2.25$



Benchmark parameters: $\sigma = 0.50$ and $\kappa = 0.00$.

As we can see from Figure 1a, for moderately active monetary policies, we generally find that Region 1 exists for a sufficiently low participation cost in secondary markets. This is quite intuitive as for high ρ it is too costly for agents to exchange bonds for money. However, as shown in Figure 1b, when monetary policy is very aggressive (a very high α), Region 1 exists only for intermediate levels of participation costs in secondary markets. In this region, the higher ρ induces an increase in inflation that may compensate and make trades in SM attractive for agents. Finally, in Figures 1a and 1b, we find that an active monetary policy leads to a unique steady state. These unique steady states are stable for moderately active monetary policies, $\alpha = 1.50$. However they are unstable for highly aggressive monetary policies such as $\alpha = 2.25$.

These findings emphasize that active monetary policies are quite effective at ruling out real and dynamic indeterminacies for a large class of fiscal policies. However, when monetary policy is very aggressive, it induces locally indeterminate equilibria.

4.2 Passive Monetary Policies

Here we analyze the resulting equilibria when the monetary authority follows a passive policy. This policy has been widely suggested as being a culprit for the inflation episodes before the Great Moderation.[22] Here we analyze its consequences and how they might have changed if agents traded in secondary markets. Table 4 and 5 report the resulting equilibria when the fiscal authority follows an active and passive policy, respectively, under the same benchmark calibration used in the previous section. They also report the resulting monetary equilibria for different changes in the economic environment. For the passive fiscal policy we consider $\gamma = 0.025$ and for the active fiscal stance we set $\gamma = 0.024$.

[22]We refer to by Clarida, Galí, and Gertler (1999) and Lubik and Schorfheide (2004), among others, for more on this issue.

Table 4: Passive MP, Active FP: Changes in σ, ρ and κ

	Region 0	Region 1			
	All	Benchmark	$\sigma = 1.00$	$\rho = 0.00$	$\kappa = 0.15$
Π	1.0527	1.1580	1.1513	1.1783	1.1604
b	0.3569	0.0413	0.0417	0.0371	0.0411
$\tilde{R} - R$	0	0.0157	0.0147	0.0188	0.0161
λ_M	0.9270	0.4865	0.4844	0.4869	0.4872
λ_F	1.0008	0.9662	0.9656	0.9570	0.9663

Benchmark parameters: $\alpha = 0.95$, $\gamma = 0.024$, $\sigma = 0.50$, $\rho = 0.01$, and $\kappa = 0.00$.

Table 5: Passive MP, Passive FP: Changes in σ, ρ and κ

	Region 0	Region 1			
	All	Benchmark	$\sigma = 1.00$	$\rho = 0.00$	$\kappa = 0.15$
Π	1.0527	1.1465	1.1413	1.1681	1.1484
b	0.3569	0.0464	0.0468	0.0411	0.0463
$\tilde{R} - R$	0	0.0140	0.0132	0.0172	0.0143
λ_M	0.9270	0.4861	0.4842	0.4865	0.4867
λ_F	0.9998	0.9706	0.9696	0.9607	0.9709

Benchmark parameters: $\alpha = 0.95$, $\gamma = 0.025$, $\sigma = 0.50$, $\rho = 0.01$, and $\kappa = 0.00$.

Independently of whether fiscal policy is active or passive, and consistent with Lemma 2, a passive monetary policy leads to a steady state inflation that is higher in Region 1 than in Region 0. This is in line with the findings of the previous section. Independent of the fiscal policy, a passive monetary policy dampens both the fiscal and the monetary eigenvalues. With a passive monetary policy and a passive fiscal policy, the equilibrium in Region 1 is indeterminate as in Region 0. However, even when the fiscal policy is active, a passive monetary policy leads to indeterminate equilibria. This is markedly in contrast to Canzeroni and Diba (2005) that find that the liquidity premium makes the equilibrium determinate when monetary policy is passive, and even when monetary policy follows an interest rate peg. Under our calibration, this finding highlights the importance of explicitly modeling the liquidity services that bonds provide as they imply different tax burdens when issuing public debt, which ultimately alter the fiscal backing of bonds. This relative reduction in the tax burden to issue public debt drastically changes inflation expectations.

With a passive monetary policy, the effects of changes in σ and κ on inflation are similar to those with an active monetary policy. Lower frictions (lower σ) decrease steady state inflation, while higher access to unsecured credit (higher κ) increase steady state inflation. However, and different to the effect with an active monetary policy, lower frictions decrease the interest spreads and lower the fiscal policy eigenvalue, while higher access to credit has the opposite effect. With a passive monetary policy, reductions in the participation costs in secondary markets (ρ) increase interest spreads and the fiscal policy eigenvalue as with an active fiscal policy. However, they have the opposite effect on inflation. Now decreases in the secondary markets costs ρ increase steady state inflation.

Does a passive monetary policy always lead to a unique and unstable steady state? To answer this question we consider two different passive monetary polices. In doing so we keep the same parameters for κ and σ as in the benchmark configuration. This allows us to determine if real indeterminacy, multiple steady states, is a robust phenomena when passive monetary policy is in place. In particular, we consider $\alpha = 0.95$ and $\alpha = 0.00$, which are depicted by Figures 2a and 2b, respectively. In these figures we report whether uniqueness is observed and the corresponding stability of steady states in Region 1 for different stances of fiscal policy, γ, and various participation costs in secondary markets, ρ.

Figure 2a: Passive MP with $\alpha = 0.95$

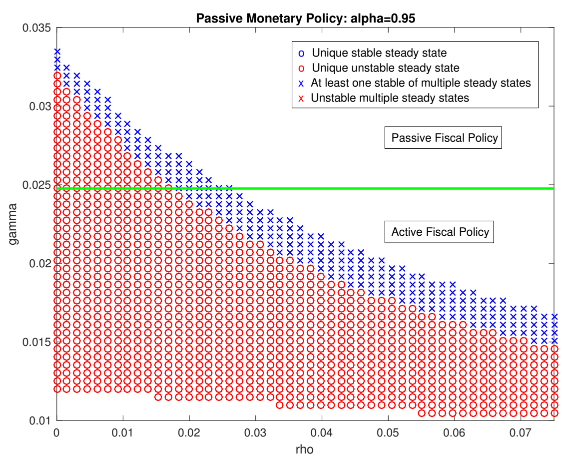
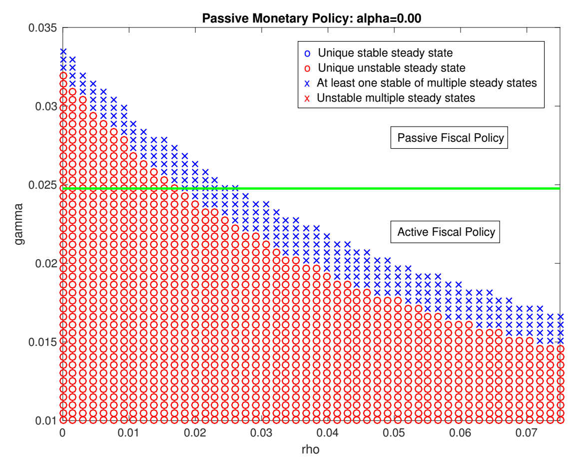


Figure 2b: Passive MP with $\alpha = 0.00$



Benchmark parameters: $\sigma = 0.50$ and $\kappa = 0.00$.

As in the previous subsection, Figures 2a and 2b show that Region 1 exists for sufficiently low participation costs in secondary markets. In contrast, we do not find a range of parameters for which increases in ρ lead to existence of Region 1. This is the case as now increases in ρ decrease inflation, making secondary markets exchanges less attractive. Interestingly, and independently of the stance of monetary and fiscal policies, Figures 2a and 2b show that a passive monetary policy leads to multiple steady states in Region 1. Typically, one is stable and the other one is unstable. For a given fiscal policy stance, γ, this region with multiple steady states appears for relatively higher participation costs in secondary markets. Real indeterminacy under passive monetary policies is a robust phenomena, which can then generate excess volatility as sunspot equilibria can be easily constructed. These results are in sharp contrast to Canzeroni and Diba (2005) who find that passive monetary policy paired with passive fiscal policy can lead to stable steady states. This is the case even when the monetary policy follows an interest peg, $\alpha = 0$. Figures 2a and 2b show that this only happens in combination with the existence of multiple steady states, and therefore, the potential for real indeterminacy. Our robustness checks show that a passive monetary policy leads to a unique unstable equilibrium. Moreover, this finding is independent of the fiscal policy stance. As we can see whether agents have a choice to trade in secondary markets or not can drastically change the nature of the resulting monetary equilibria. Thus we can conclude that how bond liquidity is modeled critically matters for the nature of the monetary equilibria we obtain.

In Tables 6 and 7, we further explore the properties of the steady states with passive monetary policy in a region of parameter space where multiple steady states can exist. We do so when there is an active and passive fiscal policy, respectively.

Table 6: Passive MP, Active FP: Changes in σ, ρ and κ

	Region 0	Region 1							
	All	Benchmark		$\sigma = 0.25$		$\rho = 0.025$		$\kappa = 0.15$	
	One SS	SS1	SS2	SS1	SS2	SS1	SS2	SS1	SS2
Π	1.0527	1.0530	1.1282	1.0596	1.1379	1.0701	1.1025	1.0543	1.1298
b	0.3569	0.1210	0.0508	0.1127	0.0504	0.0919	0.0636	0.1199	0.0515
$\tilde{R} - R$	0	0.0001	0.0113	0.0010	0.0127	0.0026	0.0074	0.0002	0.0115
λ_M	0.9270	0.4829	0.4857	0.4839	0.4890	0.4837	0.4849	0.4831	0.4862
λ_F	1.0003	1.0153	0.9794	1.0139	0.9810	1.00731	0.9917	1.0150	0.9798

Benchmark parameters: $\alpha = 0.95$, $\gamma = 0.0247$, $\sigma = 0.50$, $\rho = 0.0184$, and $\kappa = 0.00$.

Table 7: Passive MP, Passive FP: Changes in σ, ρ and κ

	Region 0	Region 1							
	All	Benchmark		$\sigma = 0.25$		$\rho = 0.025$		$\kappa = 0.15$	
	One SS	SS1	SS2	SS1	SS2	SS1	SS2	SS1	SS2
Π	1.0527	1.0547	1.1239	1.0618	1.1322	1.0778	1.0923	1.0561	1.1252
b	0.3569	0.1192	0.0541	0.1098	0.0531	0.0841	0.0713	0.1174	0.0540
$\tilde{R} - R$	0	0.0003	0.0106	0.0013	0.0119	0.0037	0.0059	0.0005	0.0108
λ_M	0.9270	0.4829	0.4855	0.4841	0.4886	0.4840	0.4845	0.4831	0.4861
λ_F	0.9998	1.0143	0.9812	1.0127	0.9831	1.0034	0.9964	1.0140	0.9816

Benchmark parameters: $\alpha = 0.95$, $\gamma = 0.025$, $\sigma = 0.50$, $\rho = 0.0184$, and $\kappa = 0.00$.

As can be seen from Tables 6 and 7, Region 1 displays two steady states. One has higher inflation and lower real bond holdings and the other one has lower inflation and higher real bond holdings. These findings are consistent with the multiplicity of steady states generated by a liquidity Laffer curve. As mentioned earlier, one steady state is stable and the other one is unstable. In the stable steady state, the fiscal eigenvalue is above unity and provides determinacy to the steady state.

Consistent with Lemma 2, with a passive monetary policy, all steady states in Region 1 display an inflation rate larger than in Region 0. The effect of changes in σ, ρ and κ on the properties of the unstable steady state are similar to the ones reported in Tables 4 and 5. Changes in σ and κ have also similar effects on the steady state inflation of the stable steady state. However, increases in the cost of participation in the secondary market increase steady state inflation in the stable steady state and decrease it in the unstable steady state. The changes in parameters also affect the eigenvalues, although minimally. Note also that for the equilibria considered in Tables 6 and 7, changes in parameter values can affect the existence of multiple steady states. Increases in σ and decreases in ρ lead to a unique unstable steady state in Region 1. Large enough increases in ρ lead to non-existence of Region 1.

While we have considered the period of pre Great Moderation as one with no secondary markets. Our findings also suggest that the existence of secondary markets during that period might have been an important factor in delivering higher inflation rates. The liquidity premium on bonds amplified the effects of fiscal policy. Furthermore, increases in the access to unsecured credit κ may have also contributed to the higher inflation in the pre Great Moderation era.

4.3 Existence, Stability and Uniqueness

Proposition 1 states that with an appropriate active monetary policy, a steady state in Region 1 is unique. Table 8 illustrates Proposition 1 and the multiplicity of equilibria observed under passive monetary policy.

Table 8: Changes in MP Stance and Multiplicity of Equilibria

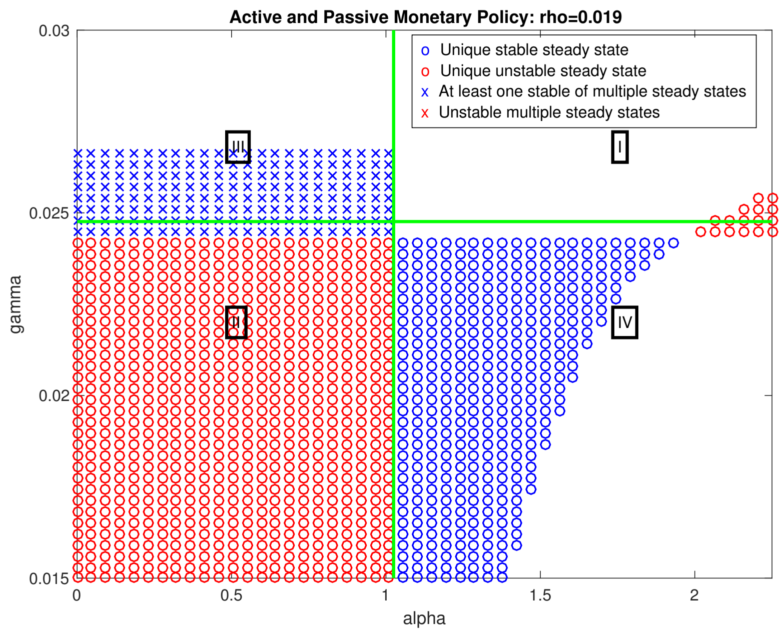
	Region 0			Region 1				
	$\alpha = 0.00$	$\alpha = 0.95$	$\alpha = \frac{2}{\beta}$	$\alpha = 0.00$		$\alpha = 0.95$		$\alpha = \frac{2}{\beta}$
	One SS	One SS	One SS	SS1	SS2	SS1	SS2	One SS
Π	1.0527	1.0527	1.0527	1.0538	1.0919	1.0547	1.1239	1.0234
b	0.3569	0.3569	0.3569	0.1192	0.0514	0.1192	0.0541	0.1188
$\tilde{R} - R$	0	0	0	0.0021	0.0803	0.0003	0.0106	0.0601
λ_M	0	0.9270	2.0000	0	0	0.4830	0.4855	1.0475
λ_F	0.9998	0.9998	0.9998	1.01429	0.9806	1.01422	0.9812	1.0112

Benchmark parameters: $\gamma = 0.025$, $\sigma = 0.50$, $\kappa = 0.00$, and $\rho = 0.0184$.

As we can see from Table 8, a passive monetary policy, either moderately passive $\alpha = 0.95$ or an interest rate peg $\alpha = 0$, induces multiplicity of steady states. However, an adequate active monetary policy, as those suggested in Proposition 1, with $\alpha = (2/\beta)$, delivers a unique steady state in Region 1. Although unique, that equilibrium is however unstable. To determine the robustness of this finding, in Figure 3 we report the regions where uniqueness of equilibria is possible as well as the stability of steady states in Region 1 for different stances for fiscal and monetary policies. Following the traditional policy prescriptions and the nomenclature used in Leeper (1991), Area I on Figure 3 represents active monetary policy and passive fiscal policy.

Area II corresponds to passive monetary policy paired with active fiscal policy. Area III is one with passive monetary policy and passive fiscal policy. Finally, Area IV represents active monetary policy paired with active fiscal policy.

Figure 3: Uniqueness and Stability of Steady States with $\rho = 0.019$



Benchmark parameters: $\alpha = 1.50$, $\gamma = 0.025$, $\sigma = 0.50$, and $\kappa = 0.00$.

Figure 3 shows that for passive monetary policy, there may be one or two steady states. While for active monetary policy, there is at most one steady state in Region 1. With passive monetary policy, the unique steady state is unstable in Region 1. When there are multiple steady states, one is unstable and the other one is stable. With active monetary policy, a unique steady state may be stable or unstable. Unstable unique steady states with active monetary policy appear in the same parameter space as multiple steady states with passive monetary policy. In fact, as illustrated in Table 8 and Figure 3, for the same parameter values and fiscal policy stance, a passive monetary policy leads to multiple steady states. Moreover, a non-aggressive active monetary policy leads to the non-existence of Region 1 and an aggressive active monetary policy leads to a unique equilibria. It is worth emphasizing that there seems to be a threshold level of fiscal policy, γ, above which passive monetary policy leads to multiple steady states and active monetary policy leads to either non-existence of Region 1 or uniqueness.

The above findings are very robust to changes in the parameter values, as can be seen in Figure 4 which can be found in the Appendix. Changes in the parameters modify the level of aggressiveness of fiscal policy for which multiple steady states can exist. I also alters the relative size of each region.

The findings in this section highlight the importance of explicitly considering the role of bonds in providing a liquidity premium when thinking about stabilization polices and debt management. This is the case as ignoring them is not as innocuous as it may seem a priori as the nature of monetary equilibrium drastically changes.

4.4 Spread-Adjusted Taylor Rules

Here we analyze the resulting equilibria that one obtains when the monetary authority follows a spread-adjusted Taylor rule, as specified in Section 3.5.3. We do so within the context of an active monetary policy using the benchmark calibration from Section 4.1. Table 9 reports our numerical findings for both passive and active fiscal policies.

Table 9: A Spread-Adjusted Taylor Rule: FP Passive/Active

	Region 0		Region 1	
	$\gamma = 0.025$	$\gamma = 0.020$	$\gamma = 0.025$	$\gamma = 0.020$
Π	1.0527	1.0527	1.0527	1.0527
b	0.3569	0.3569	0.0039	0.0029
λ_M	1.4638	1.4638	1.4638	1.4638
λ_F	0.9998	1.0048	0.1400	0.1599

Benchmark parameters: $\alpha = 1.50$, $\sigma = 0.50$, $\rho = 0.01$, and $\kappa = 0.00$.

As Table 9 shows, with a spread-adjusted Taylor rule, there is a unique steady state inflation in Region 1, which is the same one as in Region 0. In terms of stability, the monetary eigenvalue is identical to the one in Region 0. The fiscal eigenvalue however, is much lower, and below unity. This is independent of whether fiscal policy is traditionally active or not. Therefore, active monetary policies with a spread-adjusted Taylor rule deliver the expected target inflation as well as real and nominal determinacy. These results are robust to different parameterizations.

Table 10: A Spread-Adjusted Taylor Rule: Changes in σ, ρ and κ

	Region 0	Region 1			
	All	Benchmark	$\sigma = 1$	$\rho = 0.00$	$\kappa = 0.15$
Π	1.0527	1.0527	1.0527	1.0527	1.0527
b	0.3569	0.0039	0.0037	0.0039	0.0040
λ_M	1.4638	1.4638	1.4638	1.4638	1.4638
λ_F	0.9998	0.1400	0.1339	0.1445	0.1419

Benchmark parameters: $\alpha = 1.50$, $\gamma = 0.025$, $\sigma = 0.50$, $\rho = 0.01$, and $\kappa = 0.00$.

Changes in σ, ρ and κ, reported in Table 10, have a small quantitative impact relative to the benchmark calibration. Therefore, traditional active monetary policy paired with either passive or active fiscal policy tend to induce nominal determinacy. Thus a spread-adjusted Taylor rule is able to rule out both real and dynamic indeterminacies.

Our findings suggest the potential benefits for real and dynamic determinacy of considering spread-adjusted Taylor rule when thinking about stabilization policies. Once the monetary authority explicitly incorporates interest rate spreads in their decision making, it can help internalize the added value that agents obtain when purchasing bonds, helping anchor inflation expectations.

5 Conclusions

Using an environment where public debt is used not only as a store of value but also as an asset that can help enlarge consumption possibilities in frictional markets, this paper provides new insights on how active monetary policies can be useful in ruling out real and dynamic indeterminacies.

The properties and nature of the monetary equilibria of a frictional environment with incomplete markets critically depends on whether agents trade in secondary markets for government debt. When agents trade in secondary markets, we observe a liquidity premium and government bonds matter for inflation dynamics. When buyers are willing to pay prices for government bonds that are above their fundamental value, Ricardian equivalence does not hold anymore as the fiscal authority can reduce the tax burden of issuing public debt. This in turn makes interest payment on public debt non-linear, allowing for the possibility of multiple monetary steady states and drastically changing inflation expectations.

To rule out real indeterminacies, we show that active monetary policy is more likely to deliver unique monetary steady state regardless what is the stance of fiscal policy. Moreover, a spread-adjusted Taylor rule ensures a unique steady state. Our analytical and numerical results also show that trading in secondary markets and having more access to unsecured credit amplify steady state inflation when monetary policy is passive. In contrast, it dampens steady state inflation when monetary policy is active. Moreover, trading in secondary markets change the stability properties of the economy. Traditional policy prescriptions to deal with nominal indeterminacy are no longer useful. Finally, we show that a spread-adjusted Taylor rule can rule out real indeterminacies by delivering a unique monetary steady state.

Improved monetary policy or declining volatility of economic disturbances are unlikely to have been the main factors in delivering the US inflation experience of the Great Moderation. This paper shows the role of trading in secondary markets for public debt in amplifying the effects of monetary policy. Our findings suggest that more developed secondary markets, ceteris paribus, require a less aggressive stance on monetary policy.

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Appendix

Proof of Lemma 1 Once we substitute the steady state bond equation into the equation that defines the steady state inflation rate, we obtain the following

$$\left(\frac{2}{\beta}-\alpha\right)\Pi-(\alpha_0+1-\rho)=\sigma(1-\kappa)\left[\chi\left(\frac{\Pi}{\frac{2(G-\gamma_0)\Pi}{(2-\alpha+\gamma)\Pi-(1+\alpha_0)}}\right)^{\xi}-1\right].$$

As can be seen, the resulting equation characterizing the steady state inflation is highly non-linear. Thus multiple steady states can not be ruled out.

Proof of Lemma 2

It is easy to see that condition (i) guarantees that μ_s is positive and conditions (ii) and (iii) for different parameter values, that θ_b is positive.

Proof of Proposition 1

Let us consider an economy where $G>\gamma_0$, $\alpha_0<0$ and $2+\gamma>\alpha$. When $\alpha=\frac{2}{\beta}$, it is easy to show that the steady state inflation is unique and given by

$$\pi=\frac{2\left(G-\gamma_0\right)}{\left(2-\frac{2}{\beta}+\gamma\right)}\left(\frac{\rho+\sigma(1-\kappa)-\alpha_0-1}{\sigma(1-\kappa)\chi}\right)^{\frac{1}{\xi}}+\frac{(1+\alpha_0)}{\left(2-\frac{2}{\beta}+\gamma\right)}.$$

Note that for this inflation rate to be an equilibrium, it is required that

$$0<\frac{1+\rho-\alpha_0}{2\beta}\leq\frac{2\left(G-\gamma_0\right)}{\left(2-\frac{2}{\beta}+\gamma\right)}\left(\frac{\rho+\sigma(1-\kappa)-\alpha_0-1}{\sigma(1-\kappa)\chi}\right)^{\frac{1}{\xi}}+\frac{(1+\alpha_0)}{\left(2-\frac{2}{\beta}+\gamma\right)}\leq-\beta\alpha_0$$

which can satisfied as long as $\beta>\frac{1}{\sqrt{2}}$.

Let us consider an economy where $G>\gamma_0$, $\alpha_0<0$ and $\alpha\beta>1$. When $\alpha=2+\gamma$, it is easy to show that the steady state inflation is unique and given by

$$\pi=\frac{1}{\frac{2}{\beta}-\alpha}\left[\sigma(1-\kappa)\left(\frac{-\alpha_0-1}{2\left(G-\gamma_0\right)}\right)^{\frac{1}{\xi}}+1+\alpha_0-\rho-\sigma(1-\kappa)\right].$$

Note that for this inflation rate to be an equilibrium we have to satisfy

$$0<\frac{1+\rho-\alpha_0}{\alpha}\leq\frac{1}{\frac{2}{\beta}-\alpha}\left[\sigma(1-\kappa)\left(\frac{-\alpha_0-1}{2\left(G-\gamma_0\right)}\right)^{\frac{1}{\xi}}+1+\alpha_0-\rho-\sigma(1-\kappa)\right]\leq\frac{\beta\alpha_0}{1-\beta\alpha}.$$

Proof of Lemma 3

Imposing that the variables are in steady state when the monetary authority follows a spread-adjusted Taylor rule, it is easy to show that there is a unique steady state inflation rate equal to

$$\Pi = \frac{\beta\alpha_0}{1 - \beta\alpha,}$$

and a unique real public debt that is

$$b = \frac{G - \gamma_0}{2 + \gamma - \frac{1}{\beta} + \frac{\theta_b - 1}{\Pi}},$$

where $\theta_b = \left(\frac{1}{\beta} - \alpha\right)\Pi - \alpha_0$.

Additional Robustness Analysis

Figure 4: Steady State Uniqueness and Stability in Region 1: Robustness Analysis

Figure 4a: Benchmark 1

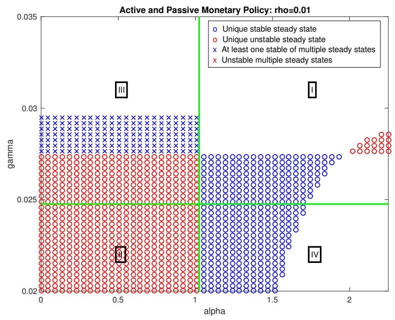


Figure 4b: Benchmark 1 with $\sigma = 1.0$

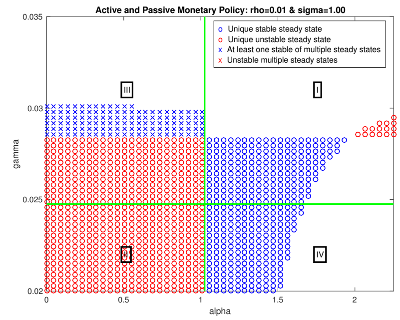


Figure 4c: Benchmark 1 with $\kappa = 0.15$

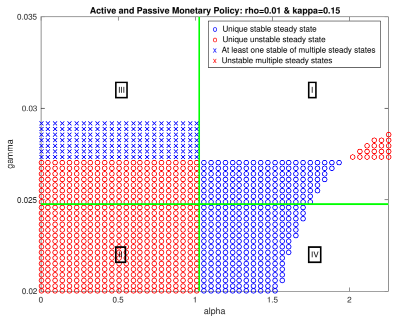


Figure 4d: Benchmark 1 with $G = 0.40$

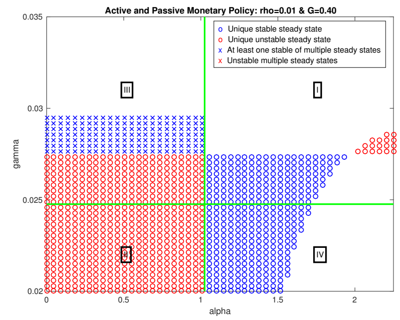


Figure 4e: Benchmark 1 with $B = 0.60$

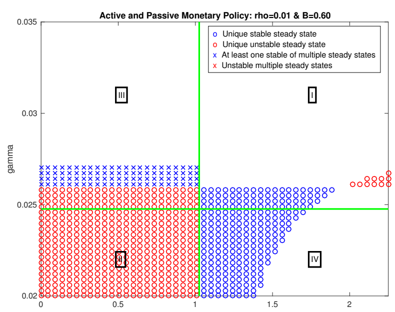


Figure 4f: Benchmark 1 with $\beta = 0.97$

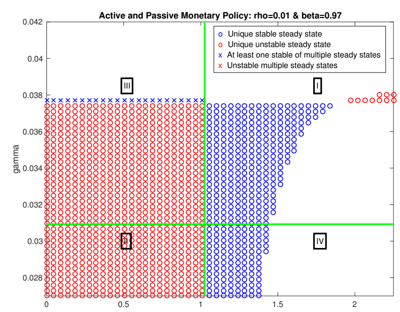


Figure 4g: Benchmark 1 with $M = 0.35$ at 2.5%

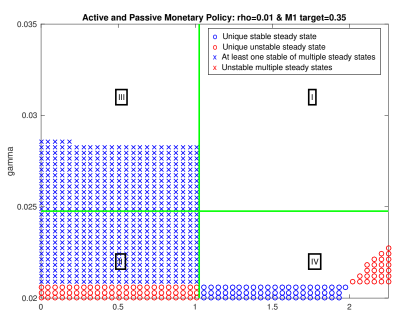
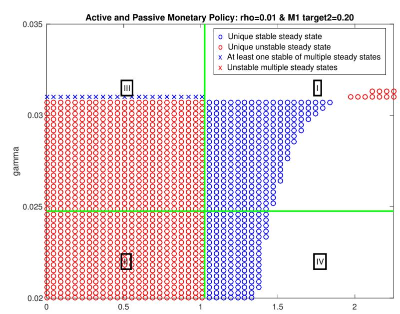


Figure 4h: Benchmark 1 with $M = 0.20$ at 5%



Benchmark 1: $\alpha = 1.50$, $\gamma = 0.025$, $\sigma = 0.50$, $\rho = 0.01$, and $\kappa = 0.00$.