“*Whatever it takes*” Is All You Need: Monetary Policy and Debt Fragility*

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Abstract

The valuation of government debt is subject to strategic uncertainty. Pessimistic lenders, fearing default, bid down the price of debt, leaving a government with a higher debt burden. This increases the likelihood of default and thus confirming the pessimism of lenders. Can monetary interventions mitigate debt fragility? With one-period commitment to a state contingent policy, the monetary authority can indeed overcome strategic uncertainty. Under discretion, debt fragility remains unless reputation effects are sufficiently strong. Simpler forms of interventions, such as an inflation target, cannot eliminate debt fragility.

Keywords: *monetary policy, seignorage, inflation, sovereign debt, self-fulfilling debt crisis, sunspot equilibria.*

JEL classification: E42, E58, E63, F33.

1 Introduction

But there is another message I want to tell you. Within our mandates, the ECB is ready to do whatever it takes to preserve the euro. And believe me, it will be enough. [Mario Draghi, July 2012]¹

This paper studies the interaction of fiscal and monetary policy in the presence of strategic uncertainty over the value of government debt. In real economies, beliefs of investors about the likelihood of government default, and hence the value of its debt, can be self-fulfilling. Pessimistic investors, fearing government default, will only purchase government debt if there is a sufficient risk premium. The resulting increase in the cost of funds makes

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¹This statement is an excerpt from the address of Mario Draghi, President of the European Central Bank, at a financial conference, in July 2012.

default more likely.² Pessimism can be self-fulfilling even if fundamentals are sound enough that an equilibrium without default exists as well.

These results hold for real economies, in which the intervention of a monetary authority is not considered. Does debt fragility exist in a nominal economy? The presence of a monetary authority can provide an alternative source of revenue through an inflation tax and perhaps use its influence to stabilize real interest rates. Can the monetary authority act to eliminate strategic uncertainty over the value of sovereign debt? If so, will it have an incentive to do so? The answers to these questions are relevant for assessing appropriate monetary interventions to strategic uncertainty in debt markets and for guidance on the conduct of monetary policy.

This emphasis on strategic uncertainty and monetary policy was also recognized by Mario Draghi. Later, in September 2012, he said:³

...the assessment of the Governing Council is that we are in a situation now where you have large parts of the euro area in what we call a “bad equilibrium”, namely an equilibrium where you may have self-fulfilling expectations that feed upon themselves and generate very adverse scenarios...

The overlapping generations model with active fiscal and monetary interventions provides a framework for analysis. The model is structured to highlight strategic uncertainty in the pricing of government debt stemming from the default choice of a government. By construction, there is an equilibrium without default, and in general there are other equilibria with state contingent default.

The monetary authority intervenes through transfers to the fiscal entity, financed by an inflation tax. The monetary intervention has a number of influences. First, the inflation tax delivers real resources to the government, thus reducing the debt burden from taxation. Second, the realized value of inflation alters the real value of debt and consequently the debt burden left to the fiscal authority. Third, it may impact expectations of future inflation and thus the tax base for seignorage.

Given these transfers and its outstanding obligations, the fiscal authority chooses to default or not. Our analysis emphasizes the dependence of this default decision, and thus the extent of strategic uncertainty, on the conduct of monetary policy. The capacity of the monetary authority to stabilize sovereign debt markets relies on the interplay of the inflation and expectation channels, not on the collection of revenue from the inflation tax.

The paper is constructed around two polar cases, distinguished by the ability of the monetary authority to commit and the complexity of its intervention. In the first case, studied in Section 3, monetary policy decisions are made by an independent central bank with the ability to commit.

One leading example of monetary policy under commitment is strict inflation targeting, a relatively common form of monetary rule. As the central bank is bound to deliver an unconditional inflation rate, it has no flexibility to respond to variations in sentiment. Despite the ability to commitment, strategic uncertainty in the valuation of debt remains in this monetary economy.

However, there is a more nuanced monetary intervention that can eliminate debt fragility. Under the policy we design, the central bank uses its commitment power to have a stabilizing influence on sovereign's debt valuations. Interestingly, this desired intervention does not “bail-out” the fiscal authority. Rather, the countercyclical nature

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²This interaction between beliefs and default is central to Calvo (1988); and other contributions that followed, including Cole and Kehoe (2000), Roch and Uhlig (2012) and Cooper (2012).

³This quote is taken from <http://www.ecb.europa.eu/press/pressconf/2012/html/is120906.en.html>.

of the policy induces an accommodative fiscal stance only in times of low productivity. In effect, the intervention relies on the unique capacity of the central bank to turn a non state-contingent nominal asset into a real state contingent asset, by distributing the effects of inflation across states.⁴ Overall, this policy rule leans against negative sentiments of investors and preserves the fundamental price of debt. Further, it does not endanger the primary objective of the central bank, to anchor inflation expectations around an inflation target, as in its mandate.

This particular intervention is effective as an off-equilibrium threat, where its mere announcement is enough to stabilize debt valuations. It is reminiscent of the European Central Bank policy, reflected in the above quote of Mario Draghi. We denote this policy “*wit*”, to follow his statement to do “*whatever it takes*” to counter pessimistic self-fulfilling expectations in Eurozone sovereign debt markets.

But absent a mechanism for commitment, is this policy credible? This brings us to a second case in which the monetary authority operates under discretion. Though there is no direct *ex post* cost of inflation, the reputation of the monetary authority can depend upon its past actions.⁵ Given the state of the economy, money creation and labor taxes are set to minimize tax distortions, keeping in mind the impact of these choices on its reputation. Default is also chosen optimally. In equilibrium, these fiscal and monetary choices determine inflation expectations.

If reputation effects are strong enough, the “*wit*” policy is credible, so that commitment to its implementation is not needed. The implementation is built upon a punishment: a deviating monetary authority returns to a strict inflation target regime. Not surprisingly, all else the same, a patient monetary authority is less likely to deviate. But there is another element in the analysis: the higher the risk of self-fulfilling debt crisis in the inflation target regime, the **more** credible is the promise of the central bank to intervene *ex post* to counter pessimistic beliefs on debt valuation.

Evidently, the combination of a patient central banks and large enough strategic uncertainty in the absence of intervention supports a desired outcome. At the other extreme, a very impatient monetary authority, operating under discretion, will yield to the temptation of using a non-distortionary inflation tax to finance fiscal needs. We show that this policy does not eliminate debt fragility. Indeed, our nominal environment captures the expectation reaction to monetary discretion: anticipating monetary financing, private agents adjust their demand for money and investors charge a higher nominal interest rate to make up for expected inflation. This lead to the incapacity of the central bank to provide some relief when operating under discretion, and self-fulfilling debt crisis go hand in hand with self-fulfilling inflation.

Other analyses examine possible strategies for central banks to address self-fulfilling debt crises. Calvo (1988) extends his real economy to include a discussion of inflation as a form of partial default. He argues that there may exist multiple equilibria in the determination of inflation and the nominal interest rate on government debt. For this analysis, there is no interaction between fiscal and monetary debt repudiation.

Corsetti and Dedola (2013) augments Calvo’s framework to study the interaction of fiscal and monetary policy. Their analysis retains some of the central features of Calvo’s model, including exogenous demand for money and costly *ex post* inflation. They argue that monetary interventions through the printing press will not generally resolve

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⁴The benefit of flexible monetary policy rules have been outlined for instance by Calvo and Guidotti (1993) in the context of an optimal taxation program: the inflation tax should absorb all source of randomness, i.e. be countercyclical. Our analysis stresses an additional benefit of such rules, namely the possibility to stabilize sovereign debt markets.

⁵As explained further below, the analysis is asymmetric, allowing reputations to matter for monetary but not fiscal entities. This reflects our interest in understanding how the monetary authority can cope with debt fragility rather than the sources of that fragility.

debt fragility. But, the central bank, through its holding of government debt, can have a stabilizing influence.

Aguiar, Amador, Farhi, and Gopinath (2013) build a nominal economy with debt roll-over crisis, as in Cole and Kehoe (2000). They investigate the optimal degree of conservativeness of the central bank (as in Rogoff (1985)) as a tool to address inefficient debt crises. Moderate inflation aversion contains the occurrence of self-fulfilling debt crisis and restrains the inflation bias in normal times.⁶

Our analysis differs from these papers in a couple of fundamental ways. First, money demand is endogenous in our model, derived from household intertemporal optimization. This creates a complementarity between expected and realized inflation. In equilibrium, both real economic activity and money demand reflect expected inflation. This link from anticipations about monetary policy to real decisions is a novel feature of our model relative to these other papers and has a direct influence on the characterization of equilibria under discretion.

Second, the absence of an explicit *ex post* cost of inflation in our model provides a strong incentive for *ex post* inflation. Without commitment, the inflation tax is a non-distortionary form of revenue.⁷ Our model derives an endogenous reputation cost of surprise inflation and relates it to the presence of debt fragility. In some cases, reputation effects create an effective endogenous *ex post* cost of inflation and can be strong enough to support an equilibrium where the monetary authority is induced to stabilize debt valuations. In other cases, reputation costs are not strong enough, and any intervention of the monetary authority is doomed to generate high inflation on top of self-fulfilling debt crisis. Thus our paper provides conditions such that reputation effects substitute for an ad hoc cost of *ex post* inflation, and contribute to eliminating debt fragility. Further, it makes clear how a high cost of generating surprise inflation, through a reputation loss, anchors inflation expectations, disciplines the monetary authority, and makes interventions that stabilizes debt markets credible.

Finally, in contrast to Aguiar, Amador, Farhi, and Gopinath (2013) and Corsetti and Dedola (2013), our paper finds conditions for state contingent monetary interventions to deter debt fragility. The stabilizing policy anchors inflation expectations and is anticipated to respond to strategic uncertainty in a manner that deters state contingent default. In equilibrium, these interventions are never observed and debt markets are stable. When policymakers are sufficiently patient and/or strategic uncertainty is severe enough, this outcome can be supported without commitment. In equilibrium, the value of maintaining a reputation allows the central bank to both stabilize debt markets and anchor inflation expectations.

The approach we take is close in spirit to Chari, Christiano, and Eichenbaum (1998). They study reputation building as a mechanism to anchor inflation expectations under monetary discretion.⁸ As in their analysis, the choices of private agents and policy-makers are based upon well articulated objectives and constraints. As they emphasize, the adherence to micro-foundations makes the results immune to the Lucas critique and paves the way for an understanding of the effects of alternative policy regimes on the choices of private agents.

The paper is structured as follows. Section 2 describes the economic environment and the fiscal problem of

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⁶Relatedly, Bacchetta, Perazzi, and van Wincoop (2015) evaluate quantitatively the credibility of monetary interventions to deter interest rate accumulation and self-fulfilling default, in a New Keynesian environment with ‘slow-moving’ debt crisis, as in Lorenzoni and Werning (2013).

⁷Aguiar, Amador, Farhi, and Gopinath (2013) argue that the *ex post* cost of inflation in their model can serve as a “reduced form proxy” for a reputation effect. Still, in their environment, the policy maker acting under discretion pays this *ex post* cost, which is at odd with the mechanisms underlying reputation building.

⁸Still, the economies we study are quite different. In particular, their analysis of monetary policy does not include fiscal interventions. Further, they use reputation effects to sustain a variety of monetary equilibria, including ones in which fundamentals respond to sunspots. In contrast, we consider monetary policy’s role in stabilizing the effects of sunspots on debt valuation.

the government. The equilibrium concept is defined here as well. Section 3 investigates the presence of debt fragility under commitment and considers two policies: (i) an inflation target and (ii) “*whatever it takes*”. Section 4 characterizes the equilibria in a regime without monetary commitment. It presents conditions such that the “*whatever it takes*” policy is credible. Section 5 concludes.

2 Economic Environment

Consider an overlapping generation economy with domestic and foreign agents. Agents live two periods. Time is discrete and infinite.

There are a couple of key components of the model. First, agents differ in productivity in young age and form a demand for savings. Relatively poor agents hold money as a store of value rather than incurring a cost to save through an intermediary. Importantly, money demand is endogenous, thus making the tax base for seignorage dependent on inflation expectations of young agents.

Second the government issues debt each period and faces a choice on how to finance the repayment of its obligations. In particular, the government can tax labor income, print money or default on its debt.

In this section, we describe the choices of private agents and the fiscal environment. The conduct of monetary policy is specified in subsequent sections.

2.1 Private Agents

Every period, a continuum of mass 1 of domestic agents (households) is born and lives two periods. These agents consume only when old, so that they have an explicit motive for saving between young and old age.

Domestic agents produce a perishable good in both young and old age. Production is linear. In youth, productivity is heterogenous. A mass ν^m of agents have low productivity $z^m = 1$. A mass $\nu^I = 1 - \nu^m$ of agents have high productivity $z^I = z > 1$. In old age, productivity A is stochastic, i.i.d., and common to all old agents.⁹

Agents have access to two technologies to store value: money or financially intermediated claims. Access to the latter is costly: agents pay a participation cost Γ for access to intermediaries. Limited financial market participation sorts agents in two groups. For convenience, we will refer to *poor* agents, who will hold only *money* in equilibrium, and *rich* agents, who hold *intermediated claims*. Intermediated claims are invested either in nominal government bonds or in a risk-free asset, e.g. storage, that delivers a real return $R > 1$.

2.1.1 Poor Households

Poor households have low labor productivity $z^m = 1$ in youth. Their savings between young and old age are composed only of money holdings, whose real return is given by $\tilde{\pi}'$, the inverse of the gross inflation rate.¹⁰ Their labor supply decisions in young and old age solve:

$$\max_{n, n'} E[u(c') - g(n')] - g(n), \quad (1)$$

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⁹Formally, the distribution of A has full support on the closed and compact set $[A_l, A_h]$. $F(\cdot)$ is the associated cumulative distribution function, and $f(\cdot) = F'(\cdot)$.

¹⁰We verify later that these agents prefer to save via money rather than costly intermediaries in equilibrium.

subject to young and old age real budget constraints:

$$m = n \tag{2}$$

$$c' = A'n'(1 - \tau') + m\tilde{\pi}' + t'. \tag{3}$$

In youth, poor agents supply labor n and have real money holdings, m , carried on from young to old age. Return on money is given by the gross inverse inflation rate $\tilde{\pi}'$. In old age, poor agents supply labor n' , which is augmented by aggregate productivity A' . τ' is the tax rate on labor income of old agents and $t' \geq 0$ a possible lump-sum transfer. Denote by n_y^m and n_o^m the optimal labor supply decision of young and old poor agents.

The analysis imposes a particular form of the utility function: $u(c) = c$ and $g(n) = \frac{n^2}{2}$. The linear quadratic structure is introduced to neatly capture the reaction of agents to government policy choices.¹¹ With these preferences, labor supply decisions are:

$$n_y^m = E(\tilde{\pi}') \quad \text{and} \quad n_o^m = A'(1 - \tau'). \tag{4}$$

Labor supply in both young and old age are driven by real returns to working. In youth, agents form expectations $\tilde{\pi}^e = E(\tilde{\pi}')$, and supply labor accordingly: if agents expect high inflation, i.e. a low $\tilde{\pi}^e$, they will reduce labor supply and the associated demand for real money holding. Similarly, taxes on old age labor income is distortionary: a high tax rate reduces return to working and hence the labor supply of old agents.

In contrast to, for example, Calvo (1988), money demand is endogenous in our model, reflecting a labor supply and asset market participation decisions. Consequently, expected monetary interventions can influence the magnitude of the *ex post* tax base created by money holdings. This interaction between the tax base and the inflation tax rate is a key element to the equilibria arising under commitment and discretion.

2.1.2 Rich Households and Financial Intermediation

Rich households differ from poor agents by their productivity in youth, $z^I = z > 1$. This higher productivity induces them to pay the fixed cost Γ to access intermediated saving. A parametric restriction ensures that young rich agents save via the financial sector for any positive expected inflation rate.¹² Formally,

Assumption 1.

$$z^2 > \frac{R\Gamma}{R^2 - 1} > 1. \tag{A.1}$$

The rich solve:

$$\max_{n, n'} E[u(c') - g(n')] - g(n), \tag{5}$$

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¹¹The risk neutrality of agents eliminates risk sharing from the model, thus allowing us to focus on the key issue of the efficiency of labor and inflation taxes.

¹²We verify this in characterizing equilibria.

subject to young and old age real budget constraints:

$$m + s = zn - \Gamma \quad (6)$$

$$s = b^I + k \quad (7)$$

$$c' = A'n'(1 - \tau') + \tilde{\pi}'m + \mathbb{1}_D(1 + i')\tilde{\pi}'b^I + Rk + t'. \quad (8)$$

In youth, rich agents supply labor n and produce zn . After incurring the fixed cost Γ , they invest a per capita amount s in intermediated claims. These claims are invested in government bonds b^I and risk-free assets k so that $s = b^I + k$, where b^I denotes the per-capita holding of government debt of domestic rich agents. Government debt is nominal and pays an interest rate i' next period if there is no default. When old, these agents supply labor n' , contingent on the realization of A' and the tax rate τ' . Consumption in old age depends on the decision $D \in \{r, d\}$ of the government to repay or default on its debt, captured here by the operator $\mathbb{1}_D$ in (8): $\mathbb{1}_r=1$ and $\mathbb{1}_d=0$.

Finally, given linear utility of consumption, the portfolio decision between intermediated saving s and money holding m is only driven by expected returns. As long as expected return on money holding $\tilde{\pi}^e$ is strictly inferior to the real return R on the risk-free asset, rich households do not hold money. The portfolio for intermediated savings will include both nominal government debt and risk-free asset as long as the expected return on government debt equals that on the asset:

$$(1 + i')\tilde{\pi}^e(1 - P^d) = R, \quad (9)$$

where P^d is the probability of default, determined in equilibrium, and $\tilde{\pi}^e$ the expected inflation over states where debt is repaid. We refer to this as the ‘no-arbitrage condition’.

Denote by n_y^I and n_o^I the optimal labor supply decisions of intermediated agents in young and old age. The solution to (5) with $u(c) = c$ and $g(n) = \frac{n^2}{2}$ implies:

$$n_y^I = Rz \quad \text{and} \quad n_o^I = A'(1 - \tau'). \quad (10)$$

Labor supply n_y^I of young agents is determined by the expected return R on intermediated savings. In old age though, the effective return on intermediated savings will depend on the realized inverse inflation rate $\tilde{\pi}'$, the nominal interest rate i' and the default decision of the government.

2.1.3 Foreign Households

In addition to domestic agents, there are also foreign households who hold domestic debt. The details of the foreign economy are not important for this analysis except that foreign households are risk neutral and have access to certain return of R as an alternative store of value. In equilibrium, they hold a fraction $(1 - \theta)$ of domestic debt.¹³

¹³Given the indifference of risk neutral agents regarding their portfolio of government debt and storage, θ is not determined in equilibrium. Thus equilibria will be characterized for given values of θ . This is used to assess the robustness of our results to domestic holding of public debt.

2.2 The Government

The government is composed of a treasury and a central bank. Every period, it has to finance a constant and exogenous flow of real expenses g . Government expenditures do not enter into agents utility. To finance these expenses, it issues nominal debt B' . The government uses revenue from labor taxes and seignorage from printing money to repay principal and interests on debt.¹⁴ Alternatively, it can default on its inherited debt obligation.

Throughout the analysis, the fiscal authority chooses taxes and default given transfers from the monetary authority. That is, the fiscal policy decisions are made after the monetary interventions.

Under repayment, the real budget constraint of the government is:

$$(1 + i)\tilde{\pi}b = \tau(\nu^m An_o^m(\tau) + \nu^I An_o^I(\tau)) + \frac{\Delta M}{P}. \quad (11)$$

The left hand side contains the real liabilities of the government, net of realized inflation $\tilde{\pi}$, where b is real debt outstanding. On the right hand side, $n_o^j(\tau)$ is the labor supply decision of old agents of type $j \in \{I, m\}$, ΔM is the change in the total money supply (M) and P is the price level. Denote by σ the rate of money creation that implements the change in money supply ΔM .

Instead of repayment, the government can fully renege on its debt. But there are two costs of default for domestic agents. First, direct costs of default are born by old rich agents, who hold a fraction θ of government debt. Second, if the government repudiates its debt, the country suffers from a deadweight loss, as commonly assumed in the literature on strategic default.¹⁵ Formally, aggregate productivity contemporaneously drops by a proportional factor γ . The model excludes punishments involving exclusion from future capital markets. This is partly to ensure that default effects are contained within a generation but also reflects the quantitative finding that the main force preventing default is the direct output loss.¹⁶

As the government budget constraint holds over time for a given generation, a decision to default on period t debt has no direct effect on future generations. That is, default affects only the welfare of current old agents, who otherwise are taxed via seignorage or labor tax.¹⁷

The government weights the welfare burden of tax distortions against the direct costs and penalty induced by the default decision. Denote by $W^r(\cdot)$ the welfare of the economy under *repayment* and by $W^d(\cdot)$ under *default*. The decision to default is optimal whenever $\Delta(\cdot) = W^d(\cdot) - W^r(\cdot) \geq 0$.

Given aggregate productivity A , nominal interest rate i , real money tax base m_{-1} , tax rate τ , money printing

¹⁴The assumption that new expenses are financed exclusively by new debt allows us to focus on how the debt is repaid rather than its magnitude. This use of generational budget balance appears in Chari and Kehoe (1990) and Cooper, Kempf, and Peled (2010), for example. An alternative, as in Cole and Kehoe (2000), could add more strategic uncertainty through debt rollover.

¹⁵Penalties and direct sanctions are central theoretic concepts for enforcement of international asset trade. See the seminal work by Eaton and Gersovitz (1981). For an extensive review, see Eaton and Fernandez (1995).

¹⁶Empirical evidence regarding reputation costs of default are mixed: exclusion from international credit markets are short-lived and premium following defaults are usually found to be negligible. An extensive discussion can be found in Trebesch, Papaioannou, and Das (2012). From a theoretical point of view, Bulow and Rogoff (1989) show that reputation mechanisms cannot enforce international asset trade, if the government can buy foreign assets as an alternative source of insurance.

¹⁷The assumption of no taxation of income when young is just a simplification that allows us to neatly disentangle demand for money, for intermediated claims and labor supply driven by taxation.

rate σ that satisfy (11) and the induced inverse inflation rate $\tilde{\pi}$, the welfare criterion $W^D(\cdot)$ for $D \in \{r, d\}$ is:

$$W^D(A, i, m_{-1}, \tau, \sigma, \tilde{\pi}) = \nu^m \left(c_o^m(D) - \frac{n_o^m(D)^2}{2} \right) + \nu^I \left(c_o^I(D) - \frac{n_o^I(D)^2}{2} \right). \quad (12)$$

The levels of $\tilde{\pi}$ are chosen under each of the options, as a function of the monetary regime under which the economy operates. Specifically, under repayment, $D = r$, the welfare of old agents is:

$$W^r(A, i, m_{-1}, \tau, \sigma, \tilde{\pi}^r) = \frac{[A(1 - \tau)]^2}{2} + \nu^m m_{-1} \tilde{\pi}^r + ((1 + i)\tilde{\pi}^r - R)\theta b + \nu^I R(Rz^2 - \Gamma). \quad (13)$$

Here the inflation is created by the printing of money that is transferred directly to the treasury.

The option to default, $D = d$, triggers penalties but no tax need be raised. In keeping with the generational view of the budget constraint, any money creation in the current period is transferred lump-sum to the current old. The amount of this transfer will depend on the monetary regime. In this case, the welfare of old agents becomes:

$$W^d(A, i, m_{-1}, \sigma, \tilde{\pi}^d) = \frac{[A(1 - \gamma)]^2}{2} + \nu^m m_{-1} \tilde{\pi}^d - R\theta b + \nu^I R(Rz^2 - \Gamma) + T(\sigma, m_{-1}, \tilde{\pi}^d), \quad (14)$$

where $T(\sigma, m_{-1}, \tilde{\pi}^d)$ is the aggregate lump sum transfer to old agents that implements $\tilde{\pi}^d$.¹⁸

2.3 Assumptions

The following two assumptions are used for characterizing equilibria. The first places a lower bound on γ so that default is costly, especially when no debt is held by domestic agents.

Assumption 2.

$$\frac{A_l^2 \gamma (2 - \gamma)}{2} > \nu^m. \quad (\mathbf{A.2})$$

Under this assumption, default is not a desirable option when seignorage revenue alone could service principal and interest on debt.¹⁹ The next assumption ensures that the fundamentals of the economy are compatible with a risk-free outcome, i.e. given the real level of debt b , a real interest rate of R , the debt will be repaid for all A . That is, there is a solution to (9) without default. Formally,

Assumption 3. $b < \bar{b}$ where

$$\bar{b} = \frac{A_l^2 (1 - \gamma) \gamma}{R}. \quad (\mathbf{A.3})$$

Note that Assumption 3 is stated in the extreme case where there is no seignorage revenue, and all debt is held by foreigners.²⁰ The presence of an equilibrium without default provides a convenient benchmark for the analysis.

¹⁸Computations to derive (13) and (14) are detailed in Appendix 6.1.

¹⁹This is established in the construction of equilibria.

²⁰This assumption is derived using the government budget constraint with no inflation, no fiscal revenue from seignorage and all debt is held by foreigners ($\theta = 0$). It implies that there will be an equilibrium without default risk when some of the debt is held by domestic agents and when money printing does provide resources to the fiscal authority. Indeed, domestic holding of public debt or a higher money printing rate relaxes the willingness of the fiscal authority to default rather than repay its debt.

2.4 State Variables and Equilibrium Definition

The strategic uncertainty is modeled through a sunspot variable, denoted s , that corresponds to confidence of domestic and foreign households about the repayment of government debt next period.

- If $s = s^o$, agents are “optimists” : they coordinate on the risk free (fundamental) price of the government debt.
- If $s = s^p$, agents are “pessimists” : they coordinate on a higher risk / lower price equilibrium with state contingent default.

The distribution of sunspot shocks is i.i.d. Denote by $p \in (0, 1)$ the probability of optimism, i.e. $s = s^o$. In the event there is a unique equilibrium price, then the fundamental price obtains regardless of the sunspot realization. Note that we only consider cases where debt has value.²¹

The state of the economy is $\mathcal{S} = (A, i, m_{-1}, s, s_{-1})$. Aggregate productivity, A , is realized and directly affects the productivity of the old. There are two endogenous predetermined state variables, m_{-1} and i , respectively real money holdings of current old agents, and the nominal interest rate on outstanding public debt. Both the sunspot shock last period, s_{-1} , and the current realization, s , may impact fiscal policy, monetary policy and the choices of private agents.

To define a Stationary Rational Expectations Equilibrium (SREE), it is necessary to be precise about market clearing conditions and the link between money printing, inflation and seignorage revenue. These conditions are used in the equilibrium definition and in constructing various types of equilibria.

2.4.1 Market Clearing

In every state, the markets for money and bonds must clear. The condition for money market clearing is

$$\nu^m m(\mathcal{S}) = \frac{M(\mathcal{S})}{P(\mathcal{S})} \quad \forall \mathcal{S}, \quad (15)$$

where $P(\mathcal{S})$ is the state dependent money price of goods and $M(\mathcal{S})$ is the stock of fiat money. This equation implies that the real money demand of the current young equals the real value of the supply.

The market for government debt clears if the no-arbitrage condition (9) holds and the savings of the rich plus the demand from the foreigners is not less than the real stock of government debt. We assume that the foreigners' endowment is large enough to clear the market for bonds as long as (9) is met.

2.4.2 Government Budget Constraint, Inflation and Seignorage

The SREE version of the government budget constraint, (11), requires a couple of building blocks. The inverse inflation rate, $\tilde{\pi}$, is given by:

$$\tilde{\pi}(\mathcal{S}) = \frac{P(\mathcal{S}_{-1})}{P(\mathcal{S})} = \frac{m(\mathcal{S})}{m(\mathcal{S}_{-1})} \frac{1}{1 + \sigma(\mathcal{S})}, \quad (16)$$

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²¹The case of “market shutdown”, where debt has no value, is not of direct interest for our analysis.

using (15). Revenue from seignorage is:

$$\frac{\Delta M}{P(\mathcal{S})} = \sigma(\mathcal{S})\nu^m m(\mathcal{S}_{-1})\tilde{\pi}(\mathcal{S}) = \nu^m m(\mathcal{S}) \left(\frac{\sigma(\mathcal{S})}{1 + \sigma(\mathcal{S})} \right). \quad (17)$$

Here $m(\mathcal{S}_{-1})$ represents the real money holdings of the current old. Importantly, these equations imply a one-to-one mapping between the rate of money creation $\sigma(\mathcal{S})$ and realized inverse inflation $\tilde{\pi}(\mathcal{S})$. This reflects the fact that $m(\mathcal{S}_{-1})$ is given in (16) and that employment and money demand for the current generation, $m(\mathcal{S})$, is, as we verify below, independent of the current rate of money creation. Accordingly, our equilibrium definition is stated with the government setting inflation $\tilde{\pi}(\mathcal{S})$.

Embedded in (17) is an interaction between inflation expectations, that determines the real money holding $m(\mathcal{S}_{-1})$, and realized inflation. This element will give rise to strategic interactions between expected inflation and delivered inflation. This interaction rests on the endogeneity of money demand.

Substituting these expressions for seignorage and the inverse inflation rate into (11), we can write the government budget constraint as:

$$(1 + i)\tilde{\pi}(\mathcal{S})b = A^2(1 - \tau(\mathcal{S}))\tau(\mathcal{S}) + \nu^m m(\mathcal{S}) \left(\frac{\sigma(\mathcal{S})}{1 + \sigma(\mathcal{S})} \right). \quad (18)$$

As alternative models of monetary interventions are developed, the determination of $\tilde{\pi}(\mathcal{S})$ and hence $\sigma(\mathcal{S})$ is made explicit.

2.4.3 Stationary Rational Expectations Equilibrium

Definition 1. A Stationary Rational Expectations Equilibrium (SREE) is given by:

1. The labor supply and savings decisions of private agents, $(n_y^m(\mathcal{S}), n_o^m(\mathcal{S}), n_y^I(\mathcal{S}), n_o^I(\mathcal{S}), m(\mathcal{S}), k(\mathcal{S}), b(\mathcal{S}))$, who form rational expectations in youth, supply labor in young and old age, solve (1) and (5) subject to their respective budget constraints (2),(3) and (6),(8), given state contingent monetary and fiscal policies $(\tau(\mathcal{S}), \tilde{\pi}(\mathcal{S}), D(\mathcal{S}))$, for all $\mathcal{S}$.
2. The government maximizes its welfare criterion by choosing a policy $(\tau(\mathcal{S}), \tilde{\pi}(\mathcal{S}), D(\mathcal{S}))$ subject to the government budget constraint, (18) for all $\mathcal{S}$.
3. All markets clear (goods, money, bonds) for all $\mathcal{S}$.

The choice problem of the government will depend on the monetary policy framework, as detailed below. The conduct of monetary policy determines what the government takes as given in choosing its policy.²² Also, we characterize equilibria for given θ , share of government debt held by domestic agents, as its value is not pinned down in equilibrium.

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²²Aguiar, Amador, Farhi, and Gopinath (2013) and Corsetti and Dedola (2013) study discretionary monetary authorities. Our analysis will also highlight particular forms of commitment by the central bank as well as the role of reputation forces to implement policies without commitment.

3 Monetary Interventions under Commitment

This section studies the interaction of monetary interventions and debt fragility in a setting where the central bank is endowed with a commitment technology. Two cases are considered.

The first is inflation targeting, a common form of intervention. This discussion highlights the origins of debt fragility in our model and shows that inflation targeting alone does not eliminate this form of strategic uncertainty. To overcome debt fragility requires more than a simple form of commitment by the monetary authority.

The second case enriches the policy to allow for state dependent interventions, while maintaining an inflation target on average. We argue that this second policy is effective to eliminate debt fragility.

As this policy requires partial commitment by the monetary authority, Section 4 provides conditions such that this outcome can be achieved without commitment as long as reputation effects are strong enough.

3.1 Strict Inflation Targeting

Strict inflation targeting is our starting point for the study of how monetary interventions can stabilize sovereign debt markets. In this institutional structure, the treasury has discretionary power over fiscal policy, choosing fiscal policy *ex post* given the monetary intervention. In contrast, the monetary authority is endowed with a commitment technology and is bound to deliver unconditionally an inflation target. We find that under this arrangement, debt valuations are sensitive to investors sentiment, as in the real economies of Calvo (1988) and Cooper (2012). The intuition behind this result is that strict inflation targeting turns a nominal bond into a real debt contract.

Specifically, the central bank commits to an inflation target $0 < \tilde{\pi}^* \leq 1$ and delivers it by printing money. By doing so, the central bank does not accommodate productivity shocks nor does it respond to sunspots. Revenue from seignorage is transferred to the treasury, which in turn decides to repay or default on its outstanding debt obligation.²³ Formally, the policy of the central bank is:

$$\tilde{\pi}(\mathcal{S}) = \tilde{\pi}^* \quad \forall \mathcal{S}. \quad (19)$$

As the central bank is bound to deliver its inflation target $\tilde{\pi}^*$, agents' expectations are $\tilde{\pi}^e = \tilde{\pi}^*$.²⁴ In a stationary equilibrium, there is a stationary rate of money creation, σ^* , directly linked to the target inflation: $\frac{1}{1+\sigma^*} = \tilde{\pi}^*$.

Using (17), modified to reflect the equilibrium under an inflation target $\tilde{\pi}^*$, revenue obtained from seignorage is:

$$\frac{\Delta M}{P(\mathcal{S})} = \nu^m m(\mathcal{S}) \left(\frac{\sigma(\mathcal{S})}{1 + \sigma(\mathcal{S})} \right) = \nu^m \tilde{\pi}^* (1 - \tilde{\pi}^*), \quad (20)$$

as $m = m_{-1} = \tilde{\pi}^e = \tilde{\pi}^*$.²⁵ Within this monetary set-up, the government budget constraint under repayment

²³This institutional arrangements refers to item 2 in Definition 1.

²⁴In particular, if there is default, the monetary authority prints money and transfers it to old agents to meet this target.

²⁵Revenue from seignorage is maximized at $\tilde{\pi}^L \equiv \frac{1}{2}$ which is the top of the seignorage "Laffer curve". At $\tilde{\pi}^* > \tilde{\pi}^L$, a reduction in $\tilde{\pi}^*$ (i.e. an increase in the rate of inflation) will increase revenue. The determination of the optimal inflation target $\tilde{\pi}^*$ is not part of the present analysis. The model could provide a positive theory of inflation, where the inflation target would be set to minimize distortions associated to tax revenue. Given the Laffer curve property of seignorage, any inflation target $0 < \tilde{\pi}^* < \tilde{\pi}^L$ is inefficient, but this does not affect the essential results regarding debt fragility.

becomes:

$$(1+i)\tilde{\pi}^*b = A^2(1-\tau)\tau + \nu^m\tilde{\pi}^*(1-\tilde{\pi}^*). \quad (21)$$

To formally derive the result that self-fulfilling debt crisis can arise under this monetary regime, we establish the existence of several interest rates that solve investors pricing equation (9). To do so, we first verify that the default decision in the monetary economy has the following monotonicity property: if the government defaults for a given realization of technology $\bar{A}$, then it would default for any lower realization $A \leq \bar{A}$.

Lemma 1. *Under Assumption 2, given a level of real obligations $(1+i)\tilde{\pi}^*b$, there is a unique $\bar{A}(i) \in [A_l, A_h]$ such that if $A \leq \bar{A}(i)$, then the treasury defaults on its debt. Otherwise it repays its debt.*

Proof. Given a nominal interest rate i , the decision to repay or default on debt is given by $\Delta(\cdot) = W^d(\cdot) - W^r(\cdot)$, where the relevant welfare criteria are given by (13) and (14) and the lump-sum transfer under default by $T(\tilde{\pi}^*) = \nu^m\tilde{\pi}^*(1-\tilde{\pi}^*)$. Hence, a point of indifference between default and repayment, $\bar{A}(i)$ solves:

$$\frac{[A(1-\gamma)]^2}{2} - \frac{[A(1-\tau)]^2}{2} = (1+i)\tilde{\pi}^*\theta b - \nu^m\tilde{\pi}^*(1-\tilde{\pi}^*), \quad (22)$$

where τ satisfies the government budget constraint (21). Denote by $G(A)$ the left side of (22). Clearly if $G(A)$ is monotonically decreasing in A , then the default decision satisfies the desired cut-off rule. Rewrite $G(A)$ as follow:

$$G(A) = \frac{[A(1-\gamma)]^2}{2} - \frac{A^2}{2} - \frac{A^2\tau(\tau-2)}{2}. \quad (23)$$

Using the government budget constraint, (23) rewrites:

$$G(A) = \frac{A^2\gamma(\gamma-2)}{2} - [(1+i)\tilde{\pi}^*b - \nu^m\tilde{\pi}^*(1-\tilde{\pi}^*)] \frac{(\tau-2)}{2(1-\tau)}. \quad (24)$$

The first term is negative since $\gamma < 1$. If seignorage revenue is enough to service debt, then no tax need be raised and $\bar{A}(i) = A_l$, by Assumption 2.²⁶ Otherwise, $(1+i)\tilde{\pi}^*b - \nu^m\tilde{\pi}^*(1-\tilde{\pi}^*) > 0$. Finally, we need to derive the monotonicity of $\frac{\tau-2}{1-\tau}$ with respect to A . Its derivative is:

$$\frac{-1}{(1-\tau)^2} \frac{d\tau}{dA} > 0, \quad (25)$$

which is positive since $\frac{d\tau}{dA} < 0$ for the lowest value of τ that solves the budget constraint. Overall, we have $G'(A) < 0$. Hence, the cut-off value $\bar{A}(i)$ is unique and default occurs if and only if $A \leq \bar{A}(i)$.

Note that if $\bar{A}(i) \leq A_l$, then debt is risk free. Finally, $\bar{A}(i) = A_h$ is inconsistent with the assumption that debt has value. ■

From this result, the probability of default P^d becomes $F(\bar{A}(i))$. Altogether, an interest rate for the government

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²⁶To see this, set $\theta = 0$, $m = 1$ and $\tilde{\pi}^r = 0$ in (13) and (14) and verify that $\Delta(\cdot) = W^d(\cdot) - W^r(\cdot) < 0$ under Assumption 2.

debt solves:

$$(1+i)\tilde{\pi}^*(1-F(\bar{A}(i))) = R. \quad (26)$$

This equation may have several solutions, stemming from the interplay between beliefs of investors, probability of default and best-response of the government. Default arises both because of fundamental shocks (low A) and strategic uncertainty: the probability of default depends on the interest rate, and in equilibrium on the beliefs of investors which determine this probability. It forms the basis for multiple valuations of government debt.

Lemma 2. *Under Assumptions 2 and 3, for any inflation target $0 < \tilde{\pi}^* \leq 1$, there are multiple interest rates that solve the no-arbitrage condition (26).*

Proof. An equilibrium of the debt financing problem is characterized by an interest rate i and a default threshold $\bar{A}$. Importantly, an equilibrium is such that *beliefs* of investors are consistent with the *best response* of the government.

Investors believe that the government defaults with probability $P^d = F(\bar{A})$. This belief induces $\bar{A}^b(i)$, the default threshold consistent with P^d :

$$(1+i)\tilde{\pi}^*(1-F(\bar{A})) = R \Rightarrow \bar{A}^b(i). \quad (27)$$

Given i , the government decision to repay or default induces $\bar{A}^g(i)$, the realization of A for which the government is indifferent between default and repayment:²⁷

$$\Delta(A, i) = W^d(A, i) - W^r(A, i) = 0 \Rightarrow \bar{A}^g(i). \quad (28)$$

An equilibrium requires $\bar{A}^b(i) = \bar{A}^g(i)$. The nominal interest rate i can take value on $[\underline{i}, +\infty)$ where $\underline{i}$ is the nominal interest rate consistent with risk-free debt. Formally, it satisfies $(1+\underline{i})\tilde{\pi}^* = R$. We study the monotonicity properties of $\bar{A}^b(\cdot)$ and $\bar{A}^g(\cdot)$.

The default threshold $\bar{A}^b(i)$ induced by belief of investors has the following properties. First, $\bar{A}^b(\underline{i}) = A_l$: if investors charge $\underline{i}$, it means that they expect no default. Second, differentiating (27) with respect to $\bar{A}$ and i , one gets:

$$\frac{d\bar{A}^b(i)}{di} = \frac{(1-F(\bar{A}))}{f(\bar{A})(1+i)} > 0, \quad (29)$$

since $f(\cdot) > 0$. Finally, $\lim_{i \rightarrow +\infty} \bar{A}^b(i) = A_h$.

The best response of the government to i is captured by $\bar{A}^g(i)$, the default threshold. Given Assumption 3, for low values of i , debt is risk free.²⁸ Hence, there is $\epsilon > 0$ such that $\bar{A}^g(\underline{i} + \epsilon) = A_l$. Second, by differentiating (22)

²⁷Lemma 1 established that this threshold is unique. To determine $\Delta(A, i)$ from (13) and (14), set $\tilde{\pi} = m = \tilde{\pi}^*$ and set τ from (21) if the government decides to repay.

²⁸Relaxing Assumption 3 and allowing a fundamental equilibrium with positive probability of default does not change the central result that several interest rates are compatible with the no-arbitrage condition.

with respect to $\bar{A}$ and i , one gets:

$$\tilde{\pi}^* b \left[\frac{1-\tau}{1-2\tau} - \theta \right] di + \bar{A} \left[(1-\gamma)^2 - \frac{(1-\tau)^2}{1-2\tau} \right] d\bar{A} = 0. \quad (30)$$

The factor of di is positive since $\frac{1-\tau}{1-2\tau} > 1$ and the factor of $d\bar{A}$ is negative since $\frac{(1-\tau)^2}{1-2\tau} > 1$. Hence:

$$\text{if } \bar{A}^g(i) \in (A_l, A_h), \text{ then } \frac{d\bar{A}^g(i)}{di} > 0. \quad (31)$$

Finally, there is an upper bound $\bar{i}$ such that default occurs for all A if $i \geq \bar{i}$:

$$\forall i > \bar{i}, \bar{A}^g(i) = A_h. \quad (32)$$

By continuity of the functions $\bar{A}^g(\cdot)$ and $\bar{A}^b(\cdot)$, there is a value $i > \underline{i}$ that satisfies $\bar{A}^g(i) = \bar{A}^b(i)$. ■

The monotonicity properties of $\bar{A}^g(i)$ and $\bar{A}^b(i)$ are summarized in Figure 1. Under Assumption 3, there is always an equilibrium with certain repayment, where the nominal interest rate is $\underline{i}$. In addition, there will exist an equilibrium in which the debt is never repaid and, accordingly, investors place zero probability on repayment.²⁹ Lemma 2 characterizes additional interior equilibria in which default arises with a positive probability: there is $\bar{A} \in (A_l, A_h)$ and $i > \underline{i}$ that satisfy the no-arbitrage condition with state contingent default. Figure 1 illustrates the multiplicity of equilibria, including three interior equilibria.³⁰

This lemma provides the basis for the existence of a SREE in which sunspots matter under strict inflation targeting, i.e. the value of government debt is dependent upon the beliefs of investors. In equilibrium there are sunspot dependent variations in employment, output and consumption.

Proposition 1. *Under Assumption 2 and 3, for any $0 < \tilde{\pi}^* \leq 1$, there is a SREE with the following characteristics:*

1. *If $s_{-1} = s^o$, the government security is risk free and the treasury reimburses with probability 1.*
2. *If $s_{-1} = s^p$, the interest rate incorporates a risk-premium and the treasury defaults on its debt with positive probability.*

Proof. The characterization of the SREE directly comes from Lemma 2 and the existence of several interest rates compatible with the no-arbitrage condition in equilibrium. We describe the optimal behavior of agents consistent with the equilibrium definition.

As $\tilde{\pi}^e = \tilde{\pi}^* \in (0, 1]$, poor agents save only with money holding and rich young agents invest in intermediated claims. Indeed, consider a young household with productivity z . It can either save with money holding or via the financial sector, incurring the fixed cost Γ .

²⁹As mentioned previously, we discard this “market shutdown” case, which always exists.

³⁰The equilibrium ★ of the debt financing problem with a positive probability of default is a locally stable equilibrium under “best response dynamics”. Specifically, “best response dynamics” points to the dynamics induced by investors responding to the treasury, followed by the treasury responding to investors. To see why the equilibrium ★ is locally stable, suppose the interest rate i is lower than the equilibrium value. Given i , the treasury decision is captured by a threshold level for default, $\bar{A}^g(i)$, along the solid line. Given this, investors will ‘set’ an interest rate such that the no-arbitrage conditions holds, i.e. $\bar{A}^b(i)$ along the dashed line. Following this dynamic will lead to the locally stable equilibrium.

Figure 1: Multiplicity of Interest Rates under Strict Inflation Targeting

This figure represents the mapping from interest rate i to default threshold $\bar{A}$, both for investors and the fiscal authority. Investors associate an interest rate i to a default threshold via the probability of default in the no-arbitrage condition. This is the dashed line. Given the interest rate i , the optimal decision of the fiscal authority to service its debt or default is captured by the default threshold, indicated by the solid line. An equilibrium is reached when beliefs of investors are consistent with the best-response of the fiscal authority. The figure highlights the existence of several equilibria, one of them being risk-free. The equilibrium indicated with a ★ is locally stable under best response dynamics.

If it chooses to hold money, its labor supply when young is $n = z\tilde{\pi}^e$, its real demand for money holding is $zn = z^2\tilde{\pi}^e$ and the net expected contribution to consumption: $(z\tilde{\pi}^e)^2$. If it chooses the intermediated savings, its labor supply when young is $n = Rz$, its savings net of the intermediation cost $s = Rz^2 - \Gamma$ and the net expected contribution to consumption: $R(Rz^2 - \Gamma)$. Hence, intermediated saving dominates money holding if and only if:

$$z^2 > \frac{R\Gamma}{R^2 - (\tilde{\pi}^e)^2}, \quad (33)$$

which is true for any $\tilde{\pi}^e \in (0, 1]$ as long as Assumption 1 holds. An aggregate fraction $\theta \in [0, 1]$ of the government security is being held by domestic rich agents.

If $s_{-1} = s^o$, then young agents form expectations $P^d = 0$ and $\tilde{\pi}^e = \tilde{\pi}^*$. They supply labor accordingly. Consequently, the interest rate on debt satisfies the no-arbitrage condition (9) with $P^d = 0$ and $\tilde{\pi}^e = \tilde{\pi}^*$. Given i , seignorage revenue $\nu^m \tilde{\pi}^*(1 - \tilde{\pi}^*)$ and using Assumption 3, the optimal policy of the treasury is then to raise labor taxes τ for all A so as to satisfy its budget constraint and repay its debt.

All markets clear. The money demand of the young poor agents is constant at $\tilde{\pi}^*$. The price level adjusts to ensure market clearing. From this, $\tilde{\pi}^* = \frac{1}{1+\sigma^*}$. In this equilibrium, inflation targeting and setting fixed money growth rate are equivalent. Given the no-arbitrage condition, the bond market clears assuming the foreign lenders have enough endowment to buy the government debt not purchased by domestic rich agents.

For the case $s_{-1} = s^p$, we outline only differences with the previous case. From Lemma 2, there is an interest rate i that carries a risk premium and satisfy the no-arbitrage condition, such that $(1+i)\tilde{\pi}^* > R$. Young agents form expectations $P^d > 0$ and $\tilde{\pi}^e = \tilde{\pi}^*$. They price the government debt according to $P^d > 0$ and $\tilde{\pi}^e = \tilde{\pi}^*$. Given i

and seignorage revenue $\nu^m \tilde{\pi}^*(1 - \tilde{\pi}^*)$, there is a unique threshold $\bar{A}(i)$ such that the optimal policy of the treasury is to raise labor taxes τ for all $A \geq \bar{A}(i)$ to satisfy its budget constraint and default otherwise. Finally, expectations are consistent with the best response of the government: $P^d = F(\bar{A}(i))$. ■

By making the sunspot binary (optimism or pessimism), we restrict attention to equilibria with potentially at most two levels of the nominal interest rate. As shown in Figure 1, there could be more self-fulfilling levels of interest rates associated with different default thresholds. Allowing the sunspot variable to have more than two realizations could capture these outcomes, without changing the essential nature of the analysis.

Overall this section, particularly Proposition 1, makes clear that debt fragility, identified in real economies as in Calvo (1988) or Cooper (2012), extends to economies with nominal debt. In effect, the inflation target of the monetary authority converts the nominal obligation into a real non contingent security. Seignorage does reduce the real debt burden left to the fiscal authority, but without eliminating the underlying strategic uncertainty. The choice of the inflation target does not allow the monetary authority to peg the real interest rate. Instead the real interest rate on debt continues to reflect the sentiments of investors.

Naturally, whichever of the nominal interest rate is being selected is not neutral on welfare: the lower the nominal interest rate, the higher the welfare of a given generation. From a life-time perspective, the welfare $V^{sit}(\tilde{\pi}^*, p)$ of a given generation under “strict inflation targeting” is negatively related to the probability of pessimism p . Using (12) and (28):

$$\begin{aligned} V^{sit}(\tilde{\pi}^*, p) = & p \left[\int_{A_l}^{A_h} W^r(A, \underline{i}) dF(A) \right] \\ & + (1 - p) \left[\int_{A_l}^{\bar{A}} W^d(A, i) dF(A) + \int_{\bar{A}}^{A_h} W^r(A, i) dF(A) \right] - \sum_{j \in \{m, I\}} \nu^j \frac{(n_y^j)^2}{2}. \end{aligned} \quad (34)$$

The first term corresponds to the expected welfare of old agents under optimism, when the nominal interest rate $\underline{i}$ induces repayment for any realization of technology A . The second term is the expected welfare under pessimism, where the risk premium included in the nominal interest rate $i > \underline{i}$ leads the treasury to default for low realizations of $A \in [A_l, \bar{A}]$. Finally, as inflation expectations are anchored, the third term that captures young agents’ disutility of labor is independent of the realization of the sunspot shock.³¹

Importantly, the welfare of a generation under monetary delegation is increasing in the probability of optimism p and decreasing with the nominal interest rate i associated with pessimism. Indeed, as discussed above, the equilibrium under optimism Pareto dominates the coordination failure outcome, and the higher the risk premium under pessimism, the lower is welfare.³²

Finally, Proposition 1 is stated for any level of inflation target $\tilde{\pi}^*$. This does not imply though that the equilibrium is independent of the inflation target. The inflation target will influence seignorage revenue, the nominal interest rate and the fiscal burden. The size and magnitude of these effects will depend on the target inflation relative to the peak of the seignorage “Laffer curve” and the local stability property of the equilibrium.³³

³¹Formally, $\tilde{\pi}^e = \tilde{\pi}^*$, $n_y^m = \tilde{\pi}^*$ and $n_y^I = Rz$ from (4) and (10).

³²In Section 4.2, this stationary equilibrium is used as a threat point to support the credibility of an alternative monetary regime.

³³These elements are discussed in more detail in the working paper.

Next, we allow the monetary authority to design state-contingent interventions and show how it is effective to stabilize debt valuations and deter debt fragility.

3.2 “*Whatever it takes*” - State Contingent Interventions

Instead of imposing an inflation target, suppose the central bank chooses a state-contingent inflation policy that alters the real debt burden and distributes resources from seignorage across states. As in Chari, Christiano, and Eichenbaum (1998) this is a one period commitment, allowing the monetary authority to announce a policy and implement it next period, contingent on the current state. By carefully choosing the distribution of realized future inflation, the central bank can provide a shield against debt fragility.

Consider a rule given by $\tilde{\pi}(A, i, s_{-1})$: the rate of inflation in the current period depends on current productivity, the interest rate on outstanding debt as well as the sunspot realization from previous period.³⁴ This rule is devised with a couple of key properties. First, to induce agents to hold money, the rule will deliver a target rate of inflation. Second, it will support the fundamental equilibrium by using monetary tools to counter pessimistic expectations so that equilibria with strategic uncertainty no longer exist.³⁵ In this way, the monetary authority responds to variations in current beliefs, reflected in the sunspot and the interest rate, by appropriately setting policy for the future.

Importantly, the characterization of this policy stresses that if investors were pessimistic in the previous period, the monetary authority responds to variations in productivity: the rate of inflation is inversely related to current productivity. Specifically, when A is high, the rate of inflation is relatively low and fiscal policy, through the setting of tax rates, bears more of the burden of financing debt obligations. But during times of low productivity, when default is likely, the monetary authority inflates the real value of debt and generates seignorage revenue. Both effects allow the fiscal authority to set low taxes and avoid default.

We first describe the desired properties of this policy, derive its existence and properties in Lemma 3. Then, we characterize the stationary equilibrium of the economy under $\tilde{\pi}(A, i, s_{-1})$ and argue that such monetary policy rule stabilizes debt valuations.³⁶

Specifically, suppose the central bank commits to a rule in which $\tilde{\pi}(A, i, s^o) = \tilde{\pi}^*$ for all (A, i) : under optimism, there is an inflation target as in Section 3.1. Delivered inflation $\tilde{\pi}^*$ is independent of both current productivity A and the interest rate on debt. When $s_{-1} = s^p$, the central bank implements a state dependent monetary policy. This policy satisfies two key properties.

First, given pessimism the policy rule anchors inflation expectations. $\tilde{\pi}(A, i, s^p)$ meets the inflation target $\tilde{\pi}^*$ *on average*:

$$\int_A \tilde{\pi}(A, i, s^p) dF(A) = \tilde{\pi}^*, \quad (35)$$

³⁴This commitment is independent of other elements of the state vector.

³⁵To be clear, the policy is designed to eliminate equilibria with state contingent default. “Market shutdown” remains.

³⁶As written, the intervention depends on (A, i, s_{-1}) . In the equilibrium constructed below, optimism is equivalent to an interest rate satisfying $(1 + i)\tilde{\pi}^* = R$. Hence there is only one interest rate conditional on optimism. If there is pessimism, we condition monetary policy on the interest rate on outstanding debt in order to specify the monetary intervention both on and off the equilibrium path. An alternative would write the equilibrium conditions solely as a function of the interest rate, not the sunspots. This is used in the discussion of the policy implementation.

for all i . Combined with the policy under optimism, $\tilde{\pi}(A, i, s^o) = \tilde{\pi}^*$, unconditional inflation expectations are anchored at $\tilde{\pi}^*$. Thus, the real money tax base is invariant and resources from seignorage are given by:

$$\frac{\Delta M}{P} = \nu^m \tilde{\pi}^* (1 - \tilde{\pi}(A, i, s^p)). \quad (36)$$

The government budget constraint under repayment becomes:

$$(1 + i)\tilde{\pi}(A, i, s^p)b = A^2(1 - \tau)\tau + \nu^m \tilde{\pi}^* (1 - \tilde{\pi}(A, i, s^p)). \quad (37)$$

Second, $\tilde{\pi}(A, i, s^p)$ is designed to deter state contingent default: given A and i , the treasury either reimburses its debt with probability 0 or 1. For low values of debt obligations, the fiscal authority will choose to repay its debt, for all A . For high values of these obligations, the fiscal authority will default, again for all A . Of course, the size of the debt obligations are determined in equilibrium, based upon investor beliefs and central bank policy. Formally, Lemma 3 establishes that there is a monetary policy rule $\tilde{\pi}(A, i, s^p)$ that satisfies these two properties.

Lemma 3. *Given an inflation target $0 < \tilde{\pi}^* \leq 1$, there is a monetary policy rule $\tilde{\pi}(A, i, s^p)$, that satisfies the inflation target and deters state contingent default. Moreover, $\tilde{\pi}(A, i, s^p) > 0$ for all (A, i) and is increasing in A .*

Proof. We derive a state-contingent monetary policy rule $\tilde{\pi}(A, i, s^p)$ that satisfies (35) and deters state contingent default. Consider the case $\theta = 0$, where all debt is held abroad, and $\nu^m \approx 0$, which makes seignorage a negligible source of income for the fiscal authority. The proof is extended to the general case $\theta \geq 0$ and $\nu^m \geq 0$ in Appendix 6.2.

Given pessimism, consider a state contingent rule $\tilde{\pi}(A, i, s^p)$, denoted $\tilde{\pi}_A^p$ in the following analysis. This rule induces a unique interest rate cut-off i^δ such that if $i < i^\delta$ then the fiscal authority is induced to repay its debt for all A , i.e. with probability 1. If $i > i^\delta$, then the fiscal authority defaults for all A , i.e. with probability 0. For $i = i^\delta$, the fiscal authority is indifferent between repayment and default for all A . This condition for indifference is:

$$\Delta(A, i^\delta, m_{-1}, \tau, \tilde{\pi}_A^p) = W^d(\cdot) - W^r(\cdot) = 0 \quad \forall A, \quad (38)$$

where $m_{-1} = \tilde{\pi}^*$ using the inflation target condition (35) and τ satisfies the government budget constraint (37) given $(A, i^\delta, \tilde{\pi}_A^p)$:

$$(1 + i^\delta)\tilde{\pi}_A^p b = A^2(1 - \tau)\tau. \quad (39)$$

Using $\theta = 0$ and $\nu^m \approx 0$, (38) implies $\tau = \gamma$ for all A . From the government budget constraint:

$$\tilde{\pi}_A^p = \frac{A^2(1 - \gamma)\gamma}{(1 + i^\delta)b} \quad \forall A. \quad (40)$$

Applying the inflation target requirement (35), the nominal interest rate cut-off i^δ is:

$$1 + i^\delta = \frac{(1 - \gamma)\gamma}{\pi^* b} \int_A A^2 dF(A), \quad (41)$$

which gives:

$$\tilde{\pi}_A^p = \frac{A^2 \pi^*}{\int_A A^2 dF(A)}. \quad (42)$$

We verify that this monetary rule deters state contingent default:

$$\frac{d\Delta(A, i, m, \tau, \tilde{\pi}_A^p)}{di} = A^2(1 - \tau) \frac{d\tau}{di}, \quad (43)$$

where $\frac{d\tau}{di} = \frac{\tilde{\pi}_A^p b}{A^2(1-2\tau)} > 0$ from (39). As $\Delta(A, i^\delta, \tilde{\pi}^*, \tau, \tilde{\pi}_A^p) = 0$ for all A , we get that for all A and all $i < i^\delta$, $\Delta(\cdot) < 0$ and for all $i > i^\delta$, $\Delta(\cdot) > 0$. Hence there is no nominal interest rate $i > 0$ that induces the fiscal authority to default on its debt in a state-contingent manner. Finally, from (42), we get $\tilde{\pi}_A^p > 0$ and $\frac{d\tilde{\pi}_A^p}{dA} > 0$. ■

The lemma establishes two critical properties of the policy rule $\tilde{\pi}(A, i, s^p)$. First, for all A , $\tilde{\pi}(A, i, s^p) > 0$, which rules out any issue of demonetization of the economy and potential complete default via inflation. Second, the policy rule is countercyclical: $\tilde{\pi}(A, i, s^p)$ is increasing in A , i.e. the lower the technology realization, the higher is inflation and seignorage revenue. As the proof made clear though, seignorage revenue can be negligible³⁷ and still the intervention of the central bank is effective to deter debt fragility. Accordingly, the effectiveness of the monetary intervention relies on the unique capacity of the central bank to generate state contingent inflation and turn a non-state contingent nominal bond into a state contingent real asset.³⁸

When the central bank commits to $\tilde{\pi}(A, i, s_{-1})$, there is a unique price for debt, namely the fundamental price under inflation targeting. That is, there is no sunspot equilibrium affecting the valuation of debt. Formally,

Proposition 2. *Under Assumptions 2, 3, when the monetary authority commits to $\tilde{\pi}(A, i, s_{-1})$, with $\tilde{\pi}(A, i, s^p)$ given in Lemma 3, debt is uniquely valued and risk-free. Debt fragility is eliminated.*

Proof. Under Assumption 3, there is a risk-free outcome under strict inflation target $0 < \tilde{\pi}^* \leq 1$. Hence, there is an equilibrium nominal interest rate $\underline{i}$ under optimism that satisfies $(1 + \underline{i})\tilde{\pi}^* = R$. Now under pessimism, the monetary authority commits to $\tilde{\pi}(A, i, s^p)$ as defined in Lemma 3. As seen in the proof of this lemma, this rule delivers inflation as a function of the technological shock A . It is noted $\tilde{\pi}_A^p$ in the following developments. We verify that under this rule, the best response of the treasury is to repay its debt for all A and that the equilibrium interest rate is $\underline{i}$.

A central property of $\tilde{\pi}_A^p$ is that it delivers the inflation target on average. By continuity and monotonicity of $\tilde{\pi}_A^p$ in A , there is a realization $\tilde{A}$ such that $\tilde{\pi}_{\tilde{A}}^p = \tilde{\pi}^*$. In this case, the best-response of the fiscal authority is to raise taxes and repay its debt. Second, $\tilde{\pi}_A^p$ is such that if the fiscal authority repays its debt with positive probability, it repays its debt with probability 1. Hence, under $\tilde{\pi}_A^p$, the fiscal authority repays its debt for all A : debt is risk-free. Finally, the no-arbitrage condition under inflation target $\tilde{\pi}^*$ uniquely pins down the nominal interest rate. Hence,

³⁷The proof in the text focuses on the case of ν^m near zero, where seignorage resource is negligible.

³⁸Whenever all debt is held abroad, $\theta = 0$, the fiscal-monetary mix under $\tilde{\pi}(A, i, s^p)$ could generate an allocation which coincides with the allocation under the optimal policy with commitment, as in Calvo and Guidotti (1993): the inflation tax should absorb all source of variation in technology A . Our analysis stresses that the benefits of countercyclical monetary policy extend to the prevention of self-fulfilling crises. Domestic holding of public debt modifies the repayment / default decision and hence the profile of $\tilde{\pi}(A, i, s^p)$.

under $\tilde{\pi}_A^p$, the nominal interest rate is $\underline{i}$:

$$(1 + \underline{i}) \int_A \tilde{\pi}_A^p dF(A) = (1 + \underline{i}) \tilde{\pi}^* = R. \quad (44)$$

■

This proposition makes clear that the commitment of the central bank rules out the effect of pessimism on the value of debt. The key to this result is the relaxation of the incentive to default by the fiscal authority through the erosion of the real return to debt in low productivity states.

Figure 2 displays the equilibrium monetary policy rule and the induced tax policy, as described in Proposition 2.³⁹ In the case $s_{-1} = s^p$, note the distribution of inflation over realization of A : for low A , high inflation, i.e. low real value of debt and high seignorage revenue. Hence, in case of pessimism, the monetary authority implements a countercyclical policy that stabilizes the price of debt and provides fiscal relief for low values of A , compensated by lower inflation for higher realizations of A . A critical element of this policy is the commitment of the central bank so that inflation expectations are anchored and the real money tax base is not sensitive to variations in private agents' sentiments. It illustrates how the central bank can alter the real value of debt, and incidentally distribute income from seignorage, so as to contain the fiscal pressure that weights on the fiscal authority. In this sense, the monetary authority *leans against the winds* of pessimism as well as those associated with low productivity.

The analysis has so far maintained Assumption 3, where the fundamental equilibrium is risk-free. It is straightforward to extend the analysis to a situation where the fundamental equilibrium is associated with a positive probability of default: self-fulfilling variations in the price of debt would reflect investors' sentiment under strict inflation targeting; the monetary intervention characterized in Lemma 3 would only eliminate non-fundamental equilibria.⁴⁰

As written, the monetary intervention depends jointly on the sunspot from the previous period as well as the interest rate on outstanding debt. Along the equilibrium path, from Proposition 2, only the fundamental price of debt will be observed. Though extraneous uncertainty may still exist, it will not be reflected in the equilibrium interest rate. With this in mind, it may be more natural to condition monetary interventions on interest rates so that along the equilibrium path, no actual intervention is needed. But, the monetary authority stands ready to intervene in response to higher interest rates that reflect investors pessimism. This is, in effect, a threat of the monetary authority off the equilibrium path to intervene either to support the fiscal authority or, if interest rates are too high, to allow default with probability one.

Formally, in this case, the monetary authority commits to the following policy, labelled “*wit*”, for “*whatever it takes*”:

$$\begin{aligned} \text{if } i = \underline{i}, \quad \text{then} \quad \forall A \quad \tilde{\pi}(A, i) &= \tilde{\pi}^* \\ \text{if } i > \underline{i}, \quad \text{then} \quad \forall A \quad \tilde{\pi}(A, i) &= \tilde{\pi}_A^p, \end{aligned} \quad (45)$$

where $\tilde{\pi}_A^p = \tilde{\pi}(A, i, s^p)$, as defined in Lemma 3.

³⁹The dependence on i is not explicit as these are the policy functions along the equilibrium path.

⁴⁰Formally, if the fundamental equilibrium is associated with a default threshold $\bar{A}$, then $\tilde{\pi}(A, i, s^p) = \tilde{\pi}^*$ if $A < \bar{A}$ and, conditional on $A \geq \bar{A}$, $\tilde{\pi}(A, i, s^p)$ meets the inflation target and eliminates equilibria with default thresholds higher than $\bar{A}$.

Figure 2: State Dependent Monetary and Fiscal Policy

The left panel represents the state dependent monetary policy to which the central bank commits. The right panel represents the induced fiscal policy. The dependence of the policies on the sunspot and realized productivity are displayed.

With this implementation, the central bank commits to a strategy conditional on the nominal interest rate and ensures that private investors coordinate on the fundamental price of debt $\underline{i}$. In equilibrium, only the fundamental price of debt is observed and the central bank implements its unconditional inflation target.⁴¹

Under this rule, given an inflation target $\tilde{\pi}^*$, debt fragility is eliminated and the expected life-time welfare of private agents is given by:

$$V^{wit}(\tilde{\pi}^*) = \int_{A_l}^{A_h} W^r(A, \underline{i}) dF(A) - \sum_{j \in \{m, I\}} \nu^j \frac{(n_y^j)^2}{2} \geq V^{sit}(\tilde{\pi}^*, p), \quad (46)$$

where $V^{sit}(\cdot)$ is the lifetime welfare under strict inflation targeting, defined in (34). The inequality is strict whenever the probability of optimism p is lower than 1.

4 Monetary Interventions under Discretion

The preceding analysis assumes that the monetary authority is granted a commitment technology and argues that this power can eliminate multiplicity. This section relaxes the assumption of commitment, allowing the monetary authority to operate under discretion. In this case, inflationary expectations are determined through the equilibrium interaction of money demand and *ex post* optimal policy. The endogeneity of money demand is important for the determination of the equilibrium level of expected inflation, and thus output, as well as the base for the inflation tax. There are two main results.

First, there is a response to deviations from the “*wit*” policy that can support this intervention without commit-

⁴¹This approach is reminiscent of the analysis in Bassetto (2005). Indeed, committing to a specific strategy rather than to a policy rule allows the monetary authority to react to deviations from private agents and ensures a unique equilibrium outcome. In other words, committing to a strategy allows the monetary authority a second mover-advantage in this dynamic game while anchoring expectations.

ment, as a sub-game perfect Nash equilibrium. The argument uses a version of the grim trigger strategy in repeated games, as in Rubinstein (1979). We focus on certain features of the economy, such as the presence of strategic uncertainty, that make deviations from policy “*wit*” costly and thus support the elimination of debt fragility as an equilibrium without commitment.

Second, absent reputation effects, debt fragility cannot be prevented by monetary interventions under discretion. Despite having the ability to stabilize fluctuations in debt prices, the monetary authority lacks the credibility to do so. Instead it relies as much as possible on the inflation tax. This leads to an adjustment of inflation expectations and generates both self-fulfilling debt crisis and inflationary policies under pessimism.

For this analysis, fiscal and monetary choices are both undertaken without commitment. As in the earlier analysis, monetary policy is implemented prior to fiscal policy. There is an asymmetry: reputation building is considered only for the monetary authority. This reflects our desire to study monetary interventions that stabilize debt markets otherwise subject to strategic uncertainty. If fiscal reputation effects were sufficiently strong, default would never occur, and the “*wit*” policy would not have been necessary in the first place.

To establish these results, we extend our analysis to encompass discretionary monetary policy with reputation. First, we characterize the properties of the static optimal policy, as a building block for the analysis. Then, we derive conditions such that reputation effects are sufficient to support the “*wit*” policy. Finally, we study the equilibrium outcome absent reputation effects. We show in this case that monetary interventions are ineffective to contain pessimism. The essence of these contrasting results underlines why anchoring inflation expectations is critical for monetary interventions to eliminate debt fragility.

4.1 Static Optimal Choice

This section characterizes the optimal policy choice that maximizes current welfare in any state of the economy. This decision is static in that there are no reputation effects. The analysis is the basis for constructing equilibria with policy discretion. As we shall see, it also provides a building-block for constructing equilibria with reputation effects since the static choice captures an optimal deviation.

In this setting, the central bank moves first, setting the inflation rate and anticipating the best response of the treasury to raise labor taxes or default on its debt obligations. As the effect of these choices are contained within generation, the central bank designs the policy $(\tau(\mathcal{S}), \tilde{\pi}(\mathcal{S}), D(\mathcal{S}))$ as a best response to realized productivity shock A , the sunspots (s_{-1}, s) and predetermined variables of the economy m_{-1} and i . This is, in effect, the same as minimizing the cost of the policy to taxpayers, hence to old agents, since they contribute to government’s resources via the tax on labor income and seignorage on money holding.⁴²

Given the productivity shock A , real money holding m_{-1} and nominal interest rate i on debt, the central bank chooses the money printing rate σ and whether the treasury defaults ($D = d$) or raises taxes τ and repays its debt ($D = r$). Hence, the central bank solves

$$D \in \{r, d\} = \operatorname{argmax} \left[\max_{\tau, \sigma^r} W^r(A, i, m_{-1}, \tau, \sigma^r, \tilde{\pi}^r), \max_{\sigma^d} W^d(A, i, m_{-1}, \sigma^d, \tilde{\pi}^d) \right], \quad (47)$$

subject to its budget constraint (11), $\tau \geq 0$ and $\tilde{\pi} \geq \tilde{\pi}$.

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⁴²The following developments establish formally that the effect of such policy are contained within a generation.

Following Calvo (1978), we introduce a positive lower bound $\underline{\pi} > 0$ on the inverse inflation rate, to ensure that our results do not hinge upon the implausible capacity of the central bank to generate infinite inflation and eliminate the burden of debt.⁴³

The solution to (47) generates a default choice as well as a tax rate τ in the event of repayment and money growth rates σ^D dependent on the default decision, $D = d, r$. As mentioned in Section 2.4.1, the money growth rate induces a realization of the inflation rate, hence we describe monetary policy as the choice of inflation $\tilde{\pi}^D(\cdot)$.

If the government chooses to repay the debt, the real money tax base m_{-1} is given. In that case, money creation provides an *ex post* source of revenue without generating any distortion to current labor supply decisions of money holders. If this tax revenue is sufficient to cover its obligations, there is no labor tax imposed, and, using Assumption 2, repayment is preferred over default. Else, if seignorage does not generate enough revenue to cover its obligations, the government must impose a labor tax if it chooses to avoid default.

In the event of default, the choice of the inflation rate is welfare neutral: when default occurs, monetary policy is implemented via lump-sum transfers which are purely redistributive, and consequently has no influence on the choices of the government. We set $\tilde{\pi}^d = \underline{\pi}$ in the event of default so that this rate is consistent with the inflation chosen whenever the government is indifferent between default and repayment.

The following lemma summarizes the state contingent static choices of monetary and fiscal policy.

Lemma 4. *Under Assumption 2:*

1. *if the government chooses to repay its debt, then*

- a. $\tilde{\pi}^r = \max \{ \underline{\pi}, \Pi(\mathcal{S}) \}$, where $\Pi(\mathcal{S}) = \frac{\nu^m m(\mathcal{S})}{\nu^m m_{-1} + (1+i)b}$,
- b. $\tau > 0$ and solves the government budget constraint (48) if and only if $\tilde{\pi}^r = \underline{\pi}$.

2. *if the government chooses to default, then $\tau = 0$ and $\tilde{\pi}^d = \underline{\pi}$.*

3. *the government chooses to default if and only if*

$$\Delta(\cdot) = \frac{[A(1-\gamma)]^2}{2} - \frac{[A(1-\tau)]^2}{2} - (1+i)\underline{\pi}\theta b + T(\mathcal{S}, \underline{\pi}) > 0,$$

where τ solves the government budget constraint given $\tilde{\pi}^r = \underline{\pi}$ under repayment, and $T(\cdot)$ is the lump-sum transfer that implements $\underline{\pi}$ under default.

Proof. If the government repays, it will first use the inflation tax to obtain revenue since this tax is not distortionary. It will use labor taxation only if needed to repay the debt. Hence, if the real inflation tax base is large enough to service debt, then its labor tax policy is $\tau = 0$.

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⁴³Chari, Christiano, and Eichenbaum (1998) impose a similar restriction on the highest inflation regime that the central bank can implement. In the appendix of that paper, this restriction is rationalized by the presence of an alternative technology such that agents can bypass the cash-in-advance constraint. In effect, the return on this alternative technology pins down the worst sustainable equilibrium and thus $\underline{\pi}$. In our framework, the poor could store at a return of $r < 1$ instead of holding money and a parallel argument could be made for $\underline{\pi}$. Corsetti and Dedola (2013) and Aguiar, Amador, Farhi, and Gopinath (2013) adopt an *ex post* cost of inflation to limit money creation.

We derive first the condition under which seignorage alone is enough to service debt. Using (15), the government budget constraint under repayment is:

$$(1+i)\tilde{\pi}^r b = A^2(1-\tau)\tau + \nu^m m_{-1} \sigma^r \tilde{\pi}^r. \quad (48)$$

From this expression, if $\tau = 0$, then $(1+i)\tilde{\pi}^r b = \nu^m \tilde{\pi}^r m_{-1} \sigma$ implying $\sigma = \frac{(1+i)b}{\nu^m m_{-1}}$. Using (16), under repayment $\tilde{\pi}^r = \frac{m(\mathcal{S})}{m_{-1}} \frac{1}{1+\sigma}$, where m_{-1} is real money held by the old and $m(\mathcal{S})$ is the level of real money demand of the current young.⁴⁴ The resulting inverse rate of inflation is given by $\Pi(\mathcal{S}) = \frac{\nu^m m(\mathcal{S})}{(1+i)b + \nu^m m_{-1}}$. Hence, resource from seignorage is enough to service debt if $\Pi(\mathcal{S}) \geq \tilde{\pi}$.

We next verify that $\Pi(\mathcal{S}) \geq \tilde{\pi}$ implies the treasury chooses to service its debt rather than default, i.e. $\Delta(\cdot) \equiv W^d(\cdot) - W^r(\cdot) < 0$. With $\tau = 0$, $\Delta(\cdot)$ is:

$$\Delta(\cdot) = \frac{[A(1-\gamma)]^2}{2} - \frac{A^2}{2} + \nu^m m_{-1}(\tilde{\pi} - \tilde{\pi}^r) - (1+i)\tilde{\pi}^r \theta b + T(\mathcal{S}, \tilde{\pi}). \quad (49)$$

Here $T(\cdot) = \nu^m m_{-1} \sigma^d \tilde{\pi}$ is the lump-sum transfer that implements $\tilde{\pi}^d = \tilde{\pi}$, with $\sigma^d = \frac{m(\mathcal{S})}{\tilde{\pi} m_{-1}} - 1$. Also, as seignorage is sufficient to service principal and interest on debt, $(1+i)b = \sigma^r \nu^m m_{-1}$, with $\sigma^r = \frac{m(\mathcal{S})}{\tilde{\pi}^r m_{-1}} - 1$. Finally, by the definition of $\tilde{\pi}^D$, $\nu^m m_{-1} \tilde{\pi}^D (1 + \sigma^D) = \nu^m m(\mathcal{S})$ for $D = r, d$. Rearranging (49), one gets:

$$\Delta(\cdot) = \frac{[A(1-\gamma)]^2}{2} - \frac{A^2}{2} - \nu^m m(\mathcal{S}) \frac{\sigma^r}{1 + \sigma^r} (\theta - 1). \quad (50)$$

This is negative by Assumption 2 as long as $\frac{m(\mathcal{S})\sigma^r}{1+\sigma^r}(1-\theta) < 1$. With $\theta \leq 1$ and $\sigma \geq 0$ under both optimism and pessimism, $\tilde{\pi} \leq 1$ so that $m(\mathcal{S}) = \tilde{\pi}^e(\mathcal{S}) \leq 1$. Hence $\frac{m(\mathcal{S})\sigma}{1+\sigma}(1-\theta) < 1$. We get $\Delta(\cdot) < 0$, i.e. when seignorage is enough to service principal and interest, the government chooses not to default.

If resource from seignorage is not enough to service principal and interest on debt, then positive labor taxes are implemented: $\tau > 0$ if and only if $\tilde{\pi} > \Pi(\mathcal{S})$. In this case, default is possible. Using these elements together with (13) and (14), one gets the expression for $\Delta(\cdot)$ stated in the Lemma. ■

Denote by $W^{dev}(A, i, m_{-1})$ the welfare of the old agents when the tax rate, inverse inflation rates and repayment decision $(\tau, \tilde{\pi}, D)$ are set according to Lemma 4. The analysis of equilibria under discretion builds on this lemma to study two cases: (i) the outcome for a patient central bank able to build a reputation and (ii) an equilibrium without any reputation effect.

4.2 Supporting “*wit*” through reputation

Can the central bank rely on its *reputation* to make “*wit*” credible? The monetary authority has an incentive to deviate from its stabilization policy to take advantage of the non-distortionary nature of the inflation tax and inflate beyond expectations. To counter this short-term gain, we construct an equilibrium in which any deviations from “*wit*” are met by a strict application of the inflation targeting regime described in Section 3.1. Hence, this analysis combines the two cases studied in Section 3 as the inflation target outcome becomes a threat point to

⁴⁴As seen in (4), the money demand of the young is driven by inflation expectations that are entirely independent of the current choices of the policy maker.

support the incentive to implement the state dependent policy that deters debt fragility.⁴⁵ In effect, our analysis investigates whether the central bank can credibly announce the “*wit*” policy, i.e. anchor interest rates, by relying on its *institutional spine*, i.e. its long-acquired credibility to anchor inflation expectations.

The construction of the equilibrium goes as follow. The monetary authority seeks to implement the policy “*wit*” described in (45). This generates lifetime welfare of $V^{wit}(\tilde{\pi}^*)$, given by (46). In a given state, the central bank could renege on its promise and consider any policy whatsoever. After that deviation, the “*whatever it takes*” type intervention is no longer credible. The monetary authority returns to its essential mandate of strict inflation targeting.

Recall that “*wit*” describes policy as long as $i \in [\underline{i}, i^\delta]$, where i^δ is an upper bound on nominal interest rates associated to the policy.⁴⁶ If the interest rate on debt exceeds i^δ , the monetary authority cannot prevent a certain default, and debt is not issued in the first place.⁴⁷ Thus we explore credibility only for $i \in [\underline{i}, i^\delta]$. Further, we do not consider deviations in inflation expectations, consistent with the idea that the central bank enforces “*wit*” by relying on its capacity to anchor inflation expectations through an inflation target.⁴⁸

In normal times, i.e. $i = \underline{i}$, the central bank implements its strict inflation target $\tilde{\pi}^*$. Whenever the nominal interest rate is above its fundamental value, the central bank implements the countercyclical policy rule $\tilde{\pi}(A, i, s^p)$ defined in Lemma 3. The associated tax rates solve the government budget constraint (11) given the monetary intervention.

Accordingly, the incentive for maintaining policy “*wit*” is characterized by the following difference in welfare:

$$\Delta(A, i, m_{-1}, p) = [W^{wit}(A, i, m_{-1}) - W^{dev}(A, i, m_{-1})] + \frac{\beta}{1 - \beta} [V^{wit}(\tilde{\pi}^*) - V^{sit}(\tilde{\pi}^*, p)]. \quad (51)$$

Here $W^{wit}(A, i, m_{-1}) - W^{dev}(A, i, m_{-1})$ is the immediate gain to old agents from deviating from “*wit*”.⁴⁹ This is a gain since relying on the non-distortionary inflation tax is desirable *ex post*, particularly when agents are holding large money balances. Since inflation expectations are anchored here, the tax base for seignorage is $m_{-1} = \tilde{\pi}^*$. For any $i \in [\underline{i}, i^\delta]$, the monetary intervention induces repayment of debt. The welfare of old agents writes:

$$W^{wit}(A, i, m_{-1}) = \begin{cases} \frac{[A(1-\tau)]^2}{2} + \nu^m m_{-1} \tilde{\pi}^* + ((1+i)\tilde{\pi}^* - R)\theta b + \nu^I R(Rz^2 - \Gamma), & \text{if } i = \underline{i} \\ \frac{[A(1-\tau)]^2}{2} + \nu^m m_{-1} \tilde{\pi}_A^p + ((1+i)\tilde{\pi}_A^p - R)\theta b + \nu^I R(Rz^2 - \Gamma), & \text{if } i > \underline{i} \end{cases} \quad (52)$$

where $\tilde{\pi}_A^p = \tilde{\pi}(A, i, s^p)$, as defined in Lemma 3.

Any deviation from “*wit*” is met with the policy characterized in Lemma 4. Since it provides higher seignorage revenue and lower the real value of debt, this deviation relaxes the incentives to default, hence repayment is ensured under “*dev*”. The payoff $W^{dev}(\cdot)$ is thus given by (13), evaluated at the policy choice characterized in Lemma 4.⁵⁰

⁴⁵Importantly, inflation targeting could be sustained with a similar reputational mechanism, where the threat point would be the demonetization of the economy. Naturally, the welfare in the real economy is lower than the welfare in the monetary economy under strict inflation targeting.

⁴⁶See Lemma 3.

⁴⁷Again, the “market shutdown” case is of no interest for the present analysis.

⁴⁸The case where the central bank loses its capacity to anchor inflation expectations is the purpose of the analysis next section.

⁴⁹As discussed in 4.1, this deviation has welfare consequences that are contained within a generation.

⁵⁰Especially, we implicitly assume that the lower bound on the inverse inflation rate $\underline{\pi}$ is low enough so that $\tilde{\pi}_{A_l}^p > \underline{\pi}$. Again, the precise value of $\underline{\pi}$ is not relevant for our analysis.

The punishment to the deviation arises from the second term in (51), $\frac{\beta}{1-\beta} [V^{wit}(\tilde{\pi}^*) - V^{sit}(\tilde{\pi}^*, p)]$, where $\beta \in (0, 1]$ is the rate at which the monetary authority discounts successive generations. Here the punishment for deviating from policy “*wit*” is the continuing operation of the monetary authority under strict inflation targeting. In fact, resorting to the inflation target is a punishment precisely because of the possibility of self-fulfilling debt crisis. The lifetime welfare for each successive generation is $V^{sit}(\tilde{\pi}^*, p)$, given by (34), which depends positively on p , the probability of optimism. Hence, as $V^{wit}(\tilde{\pi}^*) = V^{sit}(\tilde{\pi}^*, 1)$, we have $V^{wit}(\tilde{\pi}^*) > V^{sit}(\tilde{\pi}^*, p)$ for $p < 1$.

If $\Delta(A, i, \tilde{\pi}^*, p) \geq 0$, then policy “*wit*” is incentive compatible in state (A, i) . Using this construction, the “*wit*” policy can be supported in an equilibrium without commitment if the costs of deviating from it are sufficiently high. Formally,

Proposition 3. *If the probability of pessimism is sufficiently high and β close enough to unity, then the monetary authority will pursue the “*wit*” policy in all states, i.e. $\Delta(A, i, \tilde{\pi}^*, p) \geq 0$ for all A and $i \in [\underline{i}, i^\delta]$. Debt fragility is eliminated.*

Proof. Clearly $W^{wit}(A, i, \tilde{\pi}^*) - W^{dev}(A, i, \tilde{\pi}^*) \leq 0$ since the monetary authority deviating from its pre-announced policy could replicate policy “*wit*”. In fact from Lemma 4, it will choose to generate some additional inflation to take advantage of the non-distortionary nature of this source of revenue. The inflation rate is higher than that under policy “*wit*” for any (A, i) . Higher inflation relaxes the debt burden left to be serviced with distortionary taxation and unambiguously increases welfare. Also note that by construction “*wit*” deters state-contingent default. A fortiori, no default is possible under the deviation.

As $V^{sit}(\tilde{\pi}^*, p)$ is increasing in p , $\Delta(A, i, \tilde{\pi}^*, p)$ is decreasing in p . So for low enough p , $V^{wit}(\tilde{\pi}^*) - V^{sit}(\tilde{\pi}^*, p)$ can be large. Further, for β close to unity, $\frac{\beta}{1-\beta} [V^{wit}(\tilde{\pi}^*) - V^{sit}(\tilde{\pi}^*, p)]$ can be arbitrarily large. Hence for p sufficiently small and β close enough to unity, $\Delta(A, i, \tilde{\pi}^*, p) > 0$ for all A . ■

The conditions for supporting policy “*wit*” have two components. The first is the usual condition that the monetary authority does not discount the future too heavily. The second is not standard and involves the strategic uncertainty of the model. A gain from policy “*wit*” is the elimination of debt crisis that do arise with probability $(1 - p)$ under the strict inflation target regime. As the probability of pessimism increases, the penalty associated with sticking to the inflation target regime is larger. Accordingly, the higher the risk of coordination failure under inflation targeting, the more credible it is for the central bank to promise to undertake “*whatever it takes*” to counter pessimistic beliefs.

This proposition nests two types of deviations from the equilibrium path. First, suppose investors in period $t - 1$ believe in policy “*wit*”, charge the fundamental interest rate $\underline{i}$ and expect the unconditional inflation target $\tilde{\pi}^*$ in all states. Still in period t the monetary authority operating under “*wit*” can choose to deviate and implement a policy of the type characterized in Lemma 4. The gain from this is the use of the non-distortionary inflation tax, which is the highest for $A = A_l$. The cost is that “*whatever it takes*” is no longer credible. But the foundation of the monetary authority as following strict inflation targeting is not altered. If the conditions of Proposition 3 are satisfied, the monetary authority does not deviate along the equilibrium path.

Providing incentives for the monetary authority along the equilibrium path is necessary but not sufficient for “*whatever it takes*” to be incentive compatible. Consider a deviation by investors in which they believe there is

a positive probability of default implying $i > \underline{i}$. We maintain the integrity of the monetary authority and thus anchor inflationary expectations at $\tilde{\pi}^*$.⁵¹ In this case, “*wit*” implements $\tilde{\pi}(A, i, s^p)$ as described in Lemma 3. Here, the credibility of “*wit*” is not necessarily at stake for low values of A but precisely for high realization of technology. Indeed, to deliver the inflation target *on average*, the central bank tightens monetary policy whenever the realization of technology is high. Still, if the conditions for Proposition 3 hold, the monetary authority will have an incentive to implement $\tilde{\pi}(A, i, s^p)$ to preserve its reputation and continue with policy “*wit*”. In this case, the pessimism of investors is not warranted, whatever the realization of A .

Note that our construction considers the most profitable short-term deviation and a conservative long term punishment. Any alternative specification would make the possibility to sustain “*wit*” easier. For instance, the deviation from “*wit*” to “*dev*”, i.e. to full discretion, could be replaced by a deviation to the inflation target. This would generate a smaller short term gain, making it easier to support “*wit*”. Further, we are not considering a deviation in which investors no longer trust the monetary authority to meet the inflation target on average. Otherwise, investors may hold arbitrary expectations about future inflation, which is studied in next section.

4.3 Full Discretion

If the conditions for Proposition 3 fail, then concerns about its reputation will not constrain the central bank. In this case, do monetary interventions insulate against debt fragility? Intuitively, the central bank could adjust inflation and seignorage to accommodate variations in the price of government debt driven by strategic uncertainty and avoid default. But, as we shall see, the central bank, absent reputation effects, loses the ability to do so. The result is that debt fragility remains.

An essential element of this environment is the interaction between expected and realized inflation and the associated effects on the demand for money and the price of nominal debt. Specifically, if agents anticipate high inflation (low $\tilde{\pi}^e$), they would reduce labor supply in youth and their real money holdings m_{-1} accordingly.

To collect revenue from seignorage, the central bank then has to deliver a higher inflation rate (low $\tilde{\pi}$), consistent with the beliefs of agents. The same applies to the nominal interest rate on government debt. Hence, the capacity of the central bank to support a stressed fiscal authority may be compromised by strategic complementarities between expected and delivered inflation: if agents anticipate the willingness of the central bank to resort to inflation, the real money tax base would decrease, which in turn reduces the capacity of the central bank to intervene. This is where the endogeneity of money demand is particularly important in the analysis. Similarly, investors anticipating a *monetary bailout* would charge a higher nominal interest rate, reflecting higher anticipated inflation rates.

The formation of expectations by young agents reflects these *ex post* policy choices. Let $\tilde{\pi}^e(\mathcal{S})$ denote the expectation of future (inverse) inflation given the current state $\mathcal{S}$. Then the requirement of rational expectations is $\tilde{\pi}^e(\mathcal{S}) = E_{\mathcal{S}'|\mathcal{S}}\tilde{\pi}(\mathcal{S}')$ where the expectation is over the future state given $\mathcal{S}$. This condition will be used in the construction of equilibria under discretion.

To characterize a SREE under this regime, we build upon the policy choices analyzed in Section 4.1 and characterized in Lemma 4: we study the debt pricing dimension of the equilibrium and the associated stationary inflation expectations. The equilibrium combines these essential elements.

⁵¹As discussed earlier, policy “*wit*” applies only for interest rates below a level denoted i^δ . For pessimism sufficiently high so that $i > i^\delta$, “*wit*” prescribes default with probability one. In that situation, there is no credibility to evaluate.

4.3.1 Multiple interest rates

First, we investigate whether debt fragility arises under this regime. We show that the multiplicity of interest rates consistent with the no-arbitrage condition (9) persists and interacts with inflation expectations.

Lemma 5. *Under Assumptions 2 and 3, under full discretion, there are multiple interest rates that solve the no-arbitrage condition (9).*

Proof. Consider the debt pricing building block of the equilibrium. We show that there are several possible outcomes, and consistent with our equilibrium definition, these different outcomes are driven by the realization of the sunspot s_{-1} . Using Assumption 3 and Lemma 4, there is a risk-free equilibrium of the debt financing problem, with inflation expectations $\tilde{\pi}^e(s^o) \geq \tilde{\pi}$.⁵² This may arise with $\tau = 0$ and $\tilde{\pi}^e(s^o) \geq \tilde{\pi}$ or, from Lemma 4, with $\tau > 0$ and $\tilde{\pi}^e(s^o) = \tilde{\pi}$.

Suppose investors believe the government will default on its debt with positive probability. If the belief is self-fulfilling, then the optimal policy of the central bank is to set the inflation level to $\tilde{\pi}$ for all A whether it reimburses its debt or defaults (see Lemma 4). Otherwise, resources from seignorage would be enough to cover principal and interest on debt, and default would be avoided for all realization of A . Hence, inflation expectations of agents are consistent with the best response of the government at $\tilde{\pi}^e(s^p) = \tilde{\pi}$. The no-arbitrage condition pricing public debt becomes:

$$(1+i)\tilde{\pi}(1-F(\bar{A}(i))) = R, \quad (53)$$

where $\bar{A}(i)$, defined in Lemma 1, is the boundary of the default region given i .

From Lemma 2, we know that there are at least two interest rates i that are consistent with this equilibrium condition, one of which carries a risk-premium and induces the government to default for some realizations of A . Hence the initial pessimistic beliefs are self-fulfilling and support the existence of an interest rate that carries a positive probability of default. ■

The key is that inflation expectations and probability of default are jointly linked by the anticipation of the best response of the discretionary central bank. In particular, the interest rate with a risk-premium that solves the no-arbitrage condition is systematically associated with the lowest real money tax base $m = \tilde{\pi}^e(s^p) = \tilde{\pi}$, which in turn prevents the central bank from inflating away the real value of debt.⁵³

4.3.2 Stationnary inflation expectations

As shown in the proof of Lemma 5, in the event of pessimism, young agents expect high inflation, i.e. $\tilde{\pi}^e(s^p) = \tilde{\pi}$. Indeed, whenever the equilibrium of the debt financing problem induces state-contingent default, the inflation rate is maximal. That is, regardless of the current state $\mathcal{S}$, given pessimism in the previous period, $s_{-1} = s^p$, the inverse inflation rate is $\tilde{\pi}(\mathcal{S}) = \tilde{\pi}$.

⁵²In general $\tilde{\pi}^e(\mathcal{S})$ denotes expected (inverse) inflation. The notation $\tilde{\pi}^e(s)$ highlights the dependence of expectations on the sunspot, s . This is the expectation held by young agents regarding the future value of $\tilde{\pi}$. This value determines the labor supply and real money demand of young poor agents. It also influences the nominal interest rate, see (9).

⁵³This characterization does rely on the existence of the lower bound $\tilde{\pi}$, but not its exact value. The assumption that the central bank cannot print an infinite amount of money and generate an unbounded level of inflation within period, is essential for debt to have value, especially under pessimism. Without this bound, debt would not be issued in the first place under pessimism.

The issue of existence of inflation expectations arises when $s_{-1} = s^o$. From Lemma 5, young agents anticipate the government will service its debt obligation for all $\mathcal{S}$. Given the bias toward inflationary financing of debt, what determines $\tilde{\pi}^e(s^o)$ is whether seignorage resource is enough to service principal and interest on debt for all (A, s) . Formally, Lemma 4 established that with $s_{-1} = s^o$, given the real money tax base $\nu^m m_{-1} = \nu^m \tilde{\pi}^e(s^o)$, the inflation delivered by the discretionary government satisfies:

$$\tilde{\pi}^r(A, s, \cdot) = \max \left\{ \frac{\nu^m \tilde{\pi}^e(s)}{\nu^m \tilde{\pi}^e(s^o) + (1+i)b}; \tilde{\pi} \right\} \quad \forall A \quad \forall s \in \{s^o, s^p\}, \quad (54)$$

where the max operator captures whether seignorage resource is enough to service principal and interest on debt, and $\tilde{\pi}^e(s) = m(\mathcal{S})$ is the real money demand of current young agents, conditional on the realization of the current sunspot s .⁵⁴

The following lemma establishes the existence of stationary inflation expectations under optimism that are consistent with the policy choice (54) of the government for all $b \in (0, \bar{b})$ and all $p \in [0, 1]$.

Lemma 6. *Given Assumptions 2 and 3, under monetary discretion, there is a debt threshold $\hat{b} = \frac{\nu^m \tilde{\pi}(1-\tilde{\pi})}{R}$ such that:*

1. *If $0 < b < \hat{b}$, then $\tilde{\pi}^e(s^o) > \tilde{\pi}$ is consistent with the government choice $\tilde{\pi}^r(A, s, \cdot) > \tilde{\pi}$, for all (A, s) .*
2. *If $\hat{b} \leq b < \bar{b}$, then $\tilde{\pi}^e(s^o) = \tilde{\pi}$ is consistent with the government choice $\tilde{\pi}^r(A, s, \cdot) = \tilde{\pi}$, for all (A, s) .*

Proof. Computation details are provided in Appendix 6.3. ■

In the first case, the level of debt and inflation expectations are such that seignorage is sufficient to service debt for any realization of s . In the second case, the level of debt and inflation expectations are such that seignorage is not sufficient to service debt, and must be complemented with labor taxes for any realization of s .⁵⁵

Lemma 6 is silent on the uniqueness of inflationary expectations under optimism. In fact, complementarities between expected and delivered inflation rates can give rise to multiple stationary levels of inflation expectations.⁵⁶

4.3.3 Equilibrium characterization

The analysis has established the potential for multiple solutions to the debt valuation equation and the existence of inflation expectations consistent with monetary policy. Taken together, these elements create the basis for sunspot equilibria associated with the valuation of government debt under full discretion. Formally,

Proposition 4. *For any $\tilde{\pi} > 0$, under Assumptions 2 and 3, there is a SREE under discretion with the following properties:*

1. *If $s_{-1} = s^o$, government debt is risk free as the treasury reimburses with probability 1, with either:*

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⁵⁴If the debt is not too large, then the inflation tax alone is sufficient to cover debt obligations: i.e. $\tilde{\pi}^r(A, s, \cdot) > \tilde{\pi}$ for all (A, s) and $\tilde{\pi}^e(s^o) > \tilde{\pi}$. In this case, $\tau(A, s) = 0$ for all (A, s) . Else, the inflation tax will be maximal, $\tilde{\pi}^e(s^o) = \tilde{\pi}$, and supplemented by a labor tax. In both cases $D(A, s) = r$ for all (A, s) .

⁵⁵We do not impose further parametric restriction to ensure that $\hat{b} < \bar{b}$, where $\bar{b}$ is defined by Assumption 3. This requires the lower bound on productivity A_l or the cost of default γ to be high enough or the share of money holder ν^m to be low enough. If it were the case that $\hat{b} \geq \bar{b}$, then only case 1 of Lemma 6 would apply, our results would not be affected.

⁵⁶This possibility is not explored further as our results are independent of this form of multiplicity.

- a. if $0 < b < \hat{b}$, then $\tilde{\pi}^e(s^o) > \tilde{\pi}$ and for all A all s , $\tilde{\pi}(A, s, \cdot) > \tilde{\pi}$, $\tau(A, s, \cdot) = 0$, $D(A, s, \cdot) = r$,
  - b. if $\hat{b} \leq b < \bar{b}$, then $\tilde{\pi}^e(s^o) = \tilde{\pi}$ and for all A all s , $\tilde{\pi}(A, s, \cdot) = \tilde{\pi}$, $\tau(A, s, \cdot) > 0$, $D(A, s, \cdot) = r$.
2. If $s_{-1} = s^p$, the interest rate incorporates a risk-premium. For all A , $\tilde{\pi}(A, \cdot) = \tilde{\pi}$. The treasury defaults on its debt for all $A < \bar{A}$ where $\bar{A} \in (A_l, A_h)$ and $\tilde{\pi}^e(s^p) = \tilde{\pi}$.

Proof. We describe the optimal behavior of agents consistent with the equilibrium definition. This proof builds on Lemma 5 and the existence of several interest rates (and associated inflation expectations) consistent with the equilibrium definition.

If $s_{-1} = s^o$, then by Assumption 3, debt is risk free. Two cases need to be distinguished, as established in Lemma 6. If $b < \hat{b}$, then inflation expectations under optimism $\tilde{\pi}^e(s^o)$ allow seignorage resource to be sufficient to service principal and interest on debt. Young agents form expectations of no default and $\tilde{\pi}^e(s^o) > \tilde{\pi}$. They supply labor accordingly, young agents with low productivity save with money, young rich agents save via intermediated claims; the interest rate i on the government security satisfies the no-arbitrage condition (9) with a zero probability of default, i.e. $P^d = 0$, and $\tilde{\pi}^e(s^o)$. The optimal policy of the government is then to set for all A , all s , $\tilde{\pi}(A, s, \cdot) > \tilde{\pi}$, $\tau(A, s, \cdot) = 0$ and repay the debt.

On the other hand, if $\hat{b} \leq b < \bar{b}$, then there is an equilibrium with $\tilde{\pi}^e(s^o) = \tilde{\pi}$, seignorage resource is not sufficient and taxes need be raised to service debt. Using Lemma 4 and Assumption 3, for all A , all s , $\tilde{\pi}(A, s, \cdot) = \tilde{\pi}$, $\tau(A, s, \cdot)$ solves the government budget constraint (48) and debt is repaid. Accordingly, young agents form expectations $P^d = 0$, $\tilde{\pi}^e(s^o) = \tilde{\pi}$, the government security is priced according to (9). In both cases, all markets clear.

For $s_{-1} = s^p$, we detail only the differences with the previous case. Independently of the level of b , young agents form rational expectations in which there is a positive probability of default, i.e. $P^d > 0$, and $\tilde{\pi}^e(s^p) = \tilde{\pi}$. The government security is priced accordingly. Given i and seignorage revenue $\nu^m \tilde{\pi}(1 - \tilde{\pi})$, there is a unique threshold $\bar{A}(i) > A_l$ such that the optimal policy is to raise labor taxes τ for all $A \geq \bar{A}(i)$ so as to satisfy the budget constraint (48) and default otherwise. Finally, expectations are consistent with the best response of the government: $P^d = F(\bar{A}(i))$. ■

Does full discretion in monetary policy provide a shield against debt fragility? Can the government inflate the real value of debt and generate additional resources to service its debt? When the central bank loses the ability to anchor inflation expectations, the answer is negative. As the proposition makes clear, this result does not hinge upon a particular inflation ceiling $\tilde{\pi}$.⁵⁷ Indeed, when pessimism hits the economy, the interplay between inflation expectations and real money tax base *corners* the central bank into a high inflation regime with no more capacity to inflate debt or provide additional resources to the treasury. Hence, under a regime of full discretion, the sunspot shock to investors confidence triggers a joint shift in inflation expectations and debt sustainability. This shift in inflation expectations is the driving force that neutralizes the strategy of the discretionary government to print money and collect seignorage to service its debt.

Our results under full discretion contrast with the analysis conducted in Corsetti and Dedola (2013) and Aguiar, Amador, Farhi, and Gopinath (2013). The inability of the central bank to address non-fundamental variations in debt prices under full discretion lies in the endogenous adjustment of inflation expectations. Monetary interventions

⁵⁷Specifically, it holds for $\tilde{\pi}$ arbitrarily close to 0, i.e. an inflation ceiling arbitrarily high.

are effective to deter debt fragility only if the central bank prevents the real money tax base and the nominal interest rate to be sensitive to inflation expectations, something one would miss in a model without money.

5 Conclusions

The goal of this paper is to determine whether monetary policy enhances or mitigates fiscal fragility. A committed central bank can deter debt fragility by designing a specific monetary policy rule. The policy requires the monetary authority to implement a countercyclical policy, that erodes the real value of debt and provides resources, through seignorage, in times of low productivity and thus low revenue. By supporting the fiscal authority in these states, the incentive for default is eliminated. Sovereign debt is no longer subject to multiple valuations driven by investors' sentiments.

Absent commitment, if reputation effects are strong enough, this policy can be an equilibrium outcome even if the monetary authority acts solely under discretion. Interestingly, the credibility of this monetary strategy increases with the risk of self-fulfilling debt crisis.

Otherwise, debt fragility is not eliminated by monetary interventions. In particular, if the central bank is committed to an inflation target, then debt fragility remains. At the other extreme, if the central bank is allowed complete discretion and discounts the future heavily, then money holdings become too tempting as an inelastic source of finance. This seignorage is internalized by private agents as this temptation to inflate the real value of debt is anticipated. Debt fragility remains.

6 Appendix

6.1 Welfare under Repayment and under Default

As explained in section (2.2), the repayment vs. default decision in this environment is a discrete choice that affects only the welfare of old agents. Hence, the welfare criteria of interest for $D \in \{r, d\}$ is:

$$W^D(A, i, m_{-1}, \tau, \sigma, \tilde{\pi}) = \nu^m \left[c_o^m(D) - \frac{n_o^m(D)^2}{2} \right] + \nu^I \left[c_o^I(D) - \frac{n_o^I(D)^2}{2} \right]. \quad (55)$$

Using the labor supply policy functions from (4) and (10), we get the following consumption and labor supply vectors:

$$\begin{aligned} c_o^m(r) &= An_o^m(r)(1 - \tau) + m_{-1}\tilde{\pi}^r & c_o^m(d) &= An_o^m(d)(1 - \gamma) + m_{-1}\tilde{\pi}^d + t \\ n_o^m(r) &= A(1 - \tau) & n_o^m(d) &= A(1 - \gamma) \\ c_o^I(r) &= An_o^I(r)(1 - \tau) + (1 + i)\tilde{\pi}^r b^I + Rk & c_o^I(d) &= An_o^I(d)(1 - \gamma) + Rk + t \\ n_o^I(r) &= A(1 - \tau) & n_o^I(d) &= A(1 - \gamma). \end{aligned}$$

Using $\nu^I b^I = \theta b$, one can solve for k , the risk-free component of individual portfolio of rich agents from their budget constraint:

$$zn_y^I = Rz^2 = b^I + k + \Gamma \Rightarrow \nu^I Rk = \nu^I R(Rz^2 - \Gamma) - R\theta b. \quad (56)$$

We derive the expressions for $W^r(\cdot)$ and $W^d(\cdot)$:

$$W^r(A, i, m_{-1}, \tau, \sigma, \tilde{\pi}^r) = \frac{[A(1 - \tau)]^2}{2} + \nu^m m_{-1} \tilde{\pi}^r + ((1 + i)\tilde{\pi}^r - R)\theta b + \nu^I R(Rz^2 - \Gamma) \quad (57)$$

$$W^d(A, i, m_{-1}, \sigma, \tilde{\pi}^d) = \frac{[A(1 - \gamma)]^2}{2} + \nu^m m_{-1} \tilde{\pi}^d - R\theta b + \nu^I R(Rz^2 - \Gamma) + T(\cdot), \quad (58)$$

where τ solves the government budget constraint under repayment and $T(\cdot) = \nu^m m_{-1} \sigma \tilde{\pi}^d$ is a lump sum transfer that implements $\tilde{\pi}^d$ under default.

Default is optimal whenever $\Delta(\cdot) = W^d(\cdot) - W^r(\cdot) \geq 0$.

6.2 Proof Lemma 3

This section details the proof of Lemma 3 in the general case $\theta \in [0, 1]$ and $\nu^m \geq 0$.

We adopt the following notations. Consider the central bank committing to a policy contingent on A , noted $\tilde{\pi}_A$, and such that $\int_A \tilde{\pi}_A dF(A) = \tilde{\pi}^*$. Given $m_{-1} = \tilde{\pi}^e(\cdot) = \tilde{\pi}^*$, where $\tilde{\pi}^*$ is the inflation target of the central bank, the discretionary default decision of the treasury is captured by:

$$\begin{aligned} \Delta(A, i, \tilde{\pi}^*, \tau, \tilde{\pi}_A) &= W^d(\cdot) - W^r(\cdot) \\ &= \frac{[A(1 - \gamma)]^2}{2} - \frac{[A(1 - \tau)]^2}{2} + \nu^m \tilde{\pi}^*(1 - \tilde{\pi}_A) - (1 + i)\tilde{\pi}_A \theta b, \end{aligned} \quad (59)$$

where τ solves the government budget constraint given $\tilde{\pi}_A$:

$$G(A, i, \tilde{\pi}^*, \tau, \tilde{\pi}_A) = A^2(1 - \tau)\tau + \nu^m \tilde{\pi}^*(1 - \tilde{\pi}_A) - (1 + i)\tilde{\pi}_A \theta b = 0. \quad (60)$$

Moreover, in the economy with $\theta > 0$, default occurs for two reasons: either it is the best response of the treasury: $\Delta(\cdot) > 0$, or the fiscal capacity of the country cannot service debt, since $\tau \leq \frac{1}{2}$.

We show that there is a unique state-dependent inflation policy $\tilde{\pi}(A, i, s^p)$, noted $\tilde{\pi}_A^p$ in the following developments, and an induced interest rate cut-off i^δ such that the policy delivers the inflation target on average, and, if the central bank commits to $\tilde{\pi}_A^p$, then the fiscal authority services its obligation for all A if and only if $i < i^\delta$.

We proceed in two steps: first we show that for any i^t , there is a unique policy $\tilde{\pi}_A(i^t)$ such that the treasury reimburses its debt if and only if $i < i^t$. Second, we show that there is a unique i^δ such that $\tilde{\pi}_A(i^\delta)$ satisfies the inflation target. The desired policy is given by $\tilde{\pi}_A^p = \tilde{\pi}_A(i^\delta)$ for all A .

Part I. Consider a nominal interest rate i^t such that $1 + i^t > 0$ and a realization $A \in [A_l, A_h]$.

(i) The following elements establish that there is a unique inflation level $\tilde{\pi}_A(i^t)$ such that the fiscal authority is indifferent between repayment and default.

First, there is an inverse inflation rate $\tilde{\pi}_A^1(i^t)$ such that debt is serviced with no taxes on labor income.

$$G(A, i^t, \tilde{\pi}^*, \tau, \tilde{\pi}_A^1(i^t)) = 0 \Rightarrow \tau = 0. \quad (61)$$

In this case, using Assumption 2, $\Delta(\cdot) < 0$. Using the government budget constraint with $\tau = 0$, one gets:

$$\tilde{\pi}_A^1(i^t) = \frac{\nu^m \tilde{\pi}^*}{\nu^m \tilde{\pi}^* + (1 + i^t)b} > 0. \quad (62)$$

Similarly, the central bank can set the inverse inflation rate to $\tilde{\pi}_A^2(i^t)$ so that if the treasury desires to service its debt, it has to set $\tau = \frac{1}{2}$. Formally:

$$\tilde{\pi}_A^2(i^t) = \frac{\frac{A^2}{4} + \nu^m \tilde{\pi}^*}{\nu^m \tilde{\pi}^* + (1 + i^t)b}. \quad (63)$$

Importantly, for any inflation rate between these two cases, the lower the inflation, i.e. the higher $\tilde{\pi}_A$, the higher the tax rate to service debt. Formally, differentiating the government budget constraint w.r.t. τ and $\tilde{\pi}_A$:

$$\forall \tilde{\pi}_A \in [\tilde{\pi}_A^1(i^t), \tilde{\pi}_A^2(i^t)], \quad \frac{d\tau}{d\tilde{\pi}_A} = \frac{\nu^m \tilde{\pi}^* + (1 + i^t)b}{A^2(1 - 2\tau)} > 0. \quad (64)$$

Moreover, the lower the inflation, i.e. the higher $\tilde{\pi}_A$, the higher the value of $\Delta(\cdot) = W^d(\cdot) - W^r(\cdot)$:

$$\frac{d\Delta(\cdot)}{d\tilde{\pi}_A} = \frac{1 - \tau}{1 - 2\tau}(\nu^m \tilde{\pi}^* + (1 + i^t)b) - (\nu^m \tilde{\pi}^* + (1 + i^t)\theta b) > 0, \quad (65)$$

since $\frac{1 - \tau}{1 - 2\tau} > 1$ for $\tau \in [0, \frac{1}{2})$.

Hence, there is a unique $\tilde{\pi}_A(i^t)$ that has the desired property to make the treasury indifferent between repayment and default. Especially,

- if $\Delta(A, i^t, \tilde{\pi}^*, \frac{1}{2}, \tilde{\pi}_A^2(i^t)) > 0$, then $\tilde{\pi}_A^1(i^t) < \tilde{\pi}_A(i^t) < \tilde{\pi}_A^2(i^t)$,
- if $\Delta(A, i^t, \tilde{\pi}^*, \frac{1}{2}, \tilde{\pi}_A^2(i^t)) \leq 0$, then $\tilde{\pi}_A(i^t) = \tilde{\pi}_A^2(i^t)$.

(ii) Next, we verify that for any $i < i^t$, the fiscal authority services its debt, otherwise for any $i > i^t$, it defaults. Given $\tilde{\pi}_A(i^t)$, we have:

$$\frac{d\Delta(\cdot)}{di} = A^2(1 - \tau)\frac{d\tau}{di} - \tilde{\pi}_A(i^t)\theta b = \frac{1 - \tau}{1 - 2\tau}\tilde{\pi}_A(i^t)b - \tilde{\pi}_A(i^t)\theta b > 0. \quad (66)$$

(iii) Also, we establish the following properties of $\tilde{\pi}_A(i^t)$:

$$\frac{d\tilde{\pi}_A(i^t)}{dA} > 0 \quad \frac{d\tilde{\pi}_A^p(i^t)}{di^t} < 0. \quad (67)$$

If $\tilde{\pi}_A(i^t) = \tilde{\pi}_A^2(i^t)$, these properties are straightforward. In the case $\tilde{\pi}_A(i^t) < \tilde{\pi}_A^2(i^t)$, first differentiate the govern-

ment budget constraint w.r.t. $(A, i, \tau, \tilde{\pi}_A)$ to get:

$$\frac{d\tau}{dA} = -\frac{2(1-\tau)\tau}{A(1-2\tau)} \quad \frac{d\tau}{di} = \frac{\tilde{\pi}_A b}{A^2(1-2\tau)} \quad \frac{d\tau}{d\tilde{\pi}_A} = \frac{\nu^m \tilde{\pi}^* + (1+i)b}{A^2(1-2\tau)} \quad (68)$$

Then differentiate $\Delta(A, i, \tilde{\pi}^*, \tau, \tilde{\pi}_A)$ w.r.t to its arguments and using the derivative of τ w.r.t $(A, i, \tilde{\pi}_A)$, one gets:

$$\left[A(1-\gamma)^2 - A \frac{(1-\tau)^2}{1-2\tau} \right] dA + \left[\frac{1-\tau}{1-2\tau} (\nu^m \tilde{\pi}^* + (1+i)b) - (\nu^m \tilde{\pi}^* + (1+i)\theta b) \right] d\tilde{\pi}_A = 0 \quad (69)$$

$$\left[\frac{1-\tau}{1-2\tau} \tilde{\pi}_A b - \tilde{\pi}_A \theta b \right] di + \left[\frac{1-\tau}{1-2\tau} (\nu^m \tilde{\pi}^* + (1+i)b) - (\nu^m \tilde{\pi}^* + (1+i)\theta b) \right] d\tilde{\pi}_A = 0. \quad (70)$$

Since $\frac{1-\tau}{1-2\tau} > \frac{(1-\tau)^2}{1-2\tau} > 1$ for all $0 \leq \tau \leq \frac{1}{2}$ and $0 \leq \theta \leq 1$, we get the desired results.

(iv) Finally, the limits behavior of $\tilde{\pi}_A(i^t)$ are derived from the inequality

$$\tilde{\pi}_A^1(i^t) < \tilde{\pi}_A(i^t) \leq \tilde{\pi}_A^2(i^t), \quad (71)$$

which gives $\lim_{i^t \rightarrow +\infty} \tilde{\pi}_A(i^t) = 0$ and $\lim_{i^t \rightarrow -1} \tilde{\pi}_A(i^t) > 1$.

Part II. By applying the inflation target requirement (35), we show that there is a unique $i^\delta > 0$ such that:

$$\int_A \tilde{\pi}_A(i^\delta) dF(A) = \tilde{\pi}^*. \quad (72)$$

Note $H(i) = \int_A \tilde{\pi}_A(i) dF(A)$, which is defined for all i such that $1+i > 0$. The properties of $\tilde{\pi}_A(i)$ naturally convey to $H(i)$: $H(i)$ is strictly decreasing in i ; $\lim_{i \rightarrow +\infty} H(i) = 0$; $\lim_{i \rightarrow -1} H(i) > 1$.

Hence there is a unique i^δ such that $H(i^\delta) = \tilde{\pi}^*$.

Overall, the monetary policy rule $\tilde{\pi}(A, i, s^p)$ that meets the inflation target and deters state contingent default, exists, and satisfies:

$$\tilde{\pi}(A, i, s^p) = \tilde{\pi}_A^p(i^\delta), \quad \forall A. \quad (73)$$

6.3 Proof Lemma 6

The no-arbitrage condition gives: $(1+i)\tilde{\pi}^e(s^o) = R$. Accordingly, $\tilde{\pi}^e(s^o) \geq \underline{\tilde{\pi}}$ can be part of a stationary equilibrium under full discretion if and only if it satisfies:

$$\tilde{\pi}^e(s^o) = p \max \left\{ \frac{\nu^m \tilde{\pi}^e(s^o)}{\nu^m \tilde{\pi}^e(s^o) + \frac{R}{\tilde{\pi}^e(s^o)} b}; \underline{\tilde{\pi}} \right\} + (1-p) \max \left\{ \frac{\nu^m \tilde{\pi}^e(s^p)}{\nu^m \tilde{\pi}^e(s^o) + \frac{R}{\tilde{\pi}^e(s^o)} b}; \underline{\tilde{\pi}} \right\}, \quad (74)$$

where p is the stationary probability of optimism.

First consider the situation in which seignorage alone is not sufficient to service principal and interest on debt. In this case, the government sets $\tilde{\pi}^r(s, \cdot) = \underline{\tilde{\pi}}$ for all s , and raises additional labor taxes. Agents form expectations accordingly and (74) writes:

$$\tilde{\pi}^e(s^o) = (1-p)\underline{\tilde{\pi}} + p\underline{\tilde{\pi}} = \underline{\tilde{\pi}}. \quad (75)$$

This case emerges whenever $\frac{\nu^m \tilde{\pi}}{\nu^m \tilde{\pi} + \frac{R}{\tilde{\pi}} b} \leq \tilde{\pi}$, which rewrites:

$$b \geq \hat{b} = \frac{\nu^m \tilde{\pi}(1 - \tilde{\pi})}{R}. \quad (76)$$

Next, we show that whenever $0 < b < \hat{b}$, there is a level of inflation expectation under optimism, $\tilde{\pi}^e(s^o)$, such that seignorage alone is sufficient to service principal and interest on debt for all (A,s). (74) writes then:

$$\tilde{\pi}^e(s^o) = p \frac{\nu^m \tilde{\pi}^e(s^o)}{\nu^m \tilde{\pi}^e(s^o) + \frac{R}{\tilde{\pi}^e(s^o)} b} + (1-p) \frac{\nu^m \tilde{\pi}}{\nu^m \tilde{\pi}^e(s^o) + \frac{R}{\tilde{\pi}^e(s^o)} b}. \quad (77)$$

Multiply both sides by $\nu^m \tilde{\pi}^e(s^o) + \frac{R}{\tilde{\pi}^e(s^o)} b$ and get:

$$\nu^m \tilde{\pi}^e(s^o)^2 - p \nu^m \tilde{\pi}^e(s^o) + Rb - (1-p) \nu^m \tilde{\pi} = 0. \quad (78)$$

Hence, (77) has at least a positive solution if $b \leq b^\alpha$, where:

$$b^\alpha = \frac{p^2 \nu^m + 4(1-p) \nu^m \tilde{\pi}}{4R}. \quad (79)$$

Under this condition, the solution to (78) that is necessarily positive⁵⁸ is given by:

$$\tilde{\pi}^e(s^o) = \frac{p + \sqrt{p^2 + 4(1-p) \tilde{\pi} - 4 \frac{Rb}{\nu^m}}}{2}. \quad (80)$$

This solution is compatible with (74) if it satisfies the following two conditions:

$$\frac{\nu^m \tilde{\pi}^e(s)}{\nu^m \tilde{\pi}^e(s^o) + \frac{R}{\tilde{\pi}^e(s^o)} b} \geq \tilde{\pi} \quad \forall s \in \{s^o, s^p\}, \quad (81)$$

We verify that $b^\alpha \geq \hat{b}$ and that for all $b < \hat{b}$, when $\tilde{\pi}^e(s^o)$ is given by (80), then the conditions (81) are satisfied. Note $F(p) = 4R(b^\alpha - \hat{b})$. Substituting and rearranging:

$$F(p) = p^2 \nu^m - p 4 \nu^m \tilde{\pi} + 4 \nu^m \tilde{\pi}^2 = \nu^m (p - 2 \tilde{\pi})^2 \geq 0, \quad (82)$$

which gives $b^\alpha \geq \hat{b}$.

Next, note $G(p, b) \equiv \tilde{\pi}^e(s^o)$, where $\tilde{\pi}^e(s^o)$ is given by (80). The feasibility condition (81) for $s = s^p$ then reads:

$$G(b, p) = \frac{p + \sqrt{p^2 + 4(1-p) \tilde{\pi} - 4 \frac{Rb}{\nu^m}}}{2} \geq \sqrt{\frac{Rb \tilde{\pi}}{\nu^m (1 - \tilde{\pi})}}. \quad (83)$$

In this expression, the left side $G(b, p)$ is decreasing in b , whereas the right side is increasing in b ; $G(0, p) > 0$ and the right side is equal to 0 for $b = 0$; $G(\hat{b}, p) \geq \tilde{\pi}$ and the right side is equal to $\tilde{\pi}$, for $b = \hat{b}$. Hence for all $b < \hat{b}$,

⁵⁸The other solution to the polynomial can be both positive and feasible, hence there is possibly multiple stationary inflation regimes due to the Laffer curve property of seignorage.

(83) is satisfied.

Finally, the feasibility condition (81) for $s = s^o$ requires $b \leq b^\delta = \frac{\nu^m}{4R}$ and:

$$\frac{1 - \sqrt{1 - 4\frac{Rb}{\nu^m}}}{2} \leq G(b, p) \leq \frac{1 + \sqrt{1 - 4\frac{Rb}{\nu^m}}}{2}. \quad (84)$$

Since $\tilde{\pi}(1 - \tilde{\pi}) \leq \frac{1}{4}$, we have $\hat{b} \leq b^\delta$. Note $\mathcal{B}_l(b)$ and $\mathcal{B}_u(b)$ the lower and upper bounds of this inequality.

$\mathcal{B}_l(b)$, is increasing in b , $\mathcal{B}_l(0) = 0$, $\mathcal{B}_l(\hat{b}) = \frac{1 - \sqrt{1 - 4\tilde{\pi}(1 - \tilde{\pi})}}{2} = \frac{1 - \sqrt{(1 - 2\tilde{\pi})^2}}{2} \leq \tilde{\pi}$ for all $\tilde{\pi} \in [0, 1]$. As $G(b, p)$ is decreasing in b and $G(\hat{b}, p) \geq \tilde{\pi}$, we have that for all $b \in [0, \hat{b}]$, $G(b, p) \geq \mathcal{B}_l(b)$.

We finally verify that $G(b, p) \leq \mathcal{B}_u(b)$ for all $b < \hat{b}$. Taking the derivatives of $G(b, p)$ w.r.t. p :

$$\frac{dG(\cdot)}{dp} = \frac{1}{2} \left(1 + \frac{p - 2\tilde{\pi}}{\sqrt{p^2 + 4(1 - p)\tilde{\pi} - 4\frac{Rb}{\nu^m}}} \right). \quad (85)$$

If $p - 2\tilde{\pi} > 0$, then $\frac{dG(\cdot)}{dp} > 0$. If $p - 2\tilde{\pi} < 0$, then verify that $-1 \leq \frac{p - 2\tilde{\pi}}{\sqrt{p^2 + 4(1 - p)\tilde{\pi} - 4\frac{Rb}{\nu^m}}} \leq 0$, so that again $\frac{dG(\cdot)}{dp} > 0$. Hence, for all $p \in [0, 1]$, all $\tilde{\pi} \in [0, 1]$, all $b \in [0, \hat{b}]$:

$$G(b, p) \leq G(b, 1) = \frac{1 + \sqrt{1 - 4\frac{Rb}{\nu^m}}}{2} = \mathcal{B}_u(b). \quad (86)$$

Overall, we have shown that for all $b \leq \hat{b}$, there is $\tilde{\pi}^e(s^o)$ that satisfies (80) and solves (74).

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