The “Mystery of the Printing Press”
Monetary Policy and Self-fulfilling Debt Crises*

Giancarlo Corsetti
Cambridge University and CEPR

Luca Dedola
European Central Bank and CEPR

First Version December 2012. New revised version: August 2014

*We thank, without implicating, Eric Van Wincoop, Guillermo Calvo, Jordi Galí, Ricardo Reis, Pontus Rendhål, Hamid Sabourian, Pedro Teles, Oreste Tristani, Frank Smets and Gilles St. Paul, our discussants Pierpaolo Benigno, Alexander Guembel, Maren Froemel, Ramon Marimon, Gernot Mueller, Philippe Martin, Thepthida Sopraseuth as well as seminar participants at the Bank of England, Columbia University, the European Central Bank, the International Monetary Fund, Paris School of Economics, the 2012 Conference on The Economics of Sovereign Debt and Default at the Banque de France, the 2012 workshop on Fiscal Policy and Sovereign Debt at the European University Institute, the 2012 conference on Macroeconomics after the Financial Flood in memory of Albert Ando at the Banca d’Italia, the T2M Conference in Lyon, the 2013 Banque de France and Bundesbank Macroeconomics and Finance Conference, the 2013 Barcelona Summer Forum: International Capital Flows and the 2014 conference on “The European Crisis — causes and consequence” in Bonn. We thank Anil Ari for superb research assistance. Giancarlo Corsetti acknowledges the generous support of the Keynes Fellowship at Cambridge University, and the Centre For Macroeconomics. The views expressed in this paper are our own, and do not reflect those of the European Central Bank or its Executive Board, or any institution to which we are affiliated.
Abstract

Sovereign debt crises may be driven by either self-fulfilling expectations of default or fundamental fiscal stress. This paper studies the mechanisms by which either conventional or unconventional monetary policy can rule out the former. Conventional monetary policy is modeled as a standard choice of inflation, while unconventional policy as outright purchases in the debt market. By intervening in the sovereign debt market, the central bank effectively swaps risky government paper for monetary liabilities only exposed to inflation risk and thus yielding a lower interest rate. We show that, provided fiscal and monetary authorities share the same objective function, there is a minimum threshold for the size of interventions at which a backstop rules out self-fulfilling default without eliminating the possibility of fundamental default under fiscal stress. Fundamental default risk does not generally undermine the credibility of a backstop, nor does it foreshadow runaway inflation, even when the central bank is held responsible for its own losses.

JEL classification: E58, E63, H63

Key words: Sovereign risk and default, Lender of last resort, Seigniorage, Debt monetization
“[T]he proposition [is] that countries without a printing press are subject to self-fulfilling crises in a way that nations that still have a currency of their own are not.”


“Soaring rates in the European periphery had relatively little to do with solvency concerns, and were instead a case of market panic [...] [These countries] no longer had a lender of last resort, and were subject to potential liquidity crises.”


“OMT has been probably the most successful monetary policy measure undertaken in recent times.”

Mario Draghi, ECB Press Conference (Q&A), June 6, 2013.

1 Introduction

The recent sovereign debt crisis among some members of the euro area is commonly attributed to the inherent vulnerability to destabilizing speculation that follows from the loss of both monetary policy independence and the (government) ability to denominate debt in domestic currency. As exemplified by the Krugman’s quote at the beginning of this paper, a widely entertained hypothesis maintains that countries in control of the “printing press” can always eliminate the possibility of crises driven by self-validating expectations. This option is precluded to countries without a currency of their own.

The historical record, however, shows that outright default on public debt is far from rare, also in countries where debt is denominated in domestic currency and policymakers are in principle in control of the ‘printing press.’ In a long sample ending in 2005, Reinhart and Rogoff (2011) document 68 cases of overt domestic default (often coinciding with external debt default).\footnote{According to the data, domestic default (usually but not necessarily in conjunction with default on external debt) tends to occur under extreme macroeconomic duress — in}
Krugman’s quote: in the data, it is difficult to separate fundamental default from crises generated by self-fulfilling expectations. Eliminating the latter by no means implies that default cannot occur. Rather the evidence emphasizes the need to identify the conditions under which disruptive speculation may emerge in the sovereign debt market, and the mechanisms and policies by which the central bank can stem it—a striking example of an effective backstop to government debt being recently the Outright Monetary Transactions (OMT) program launched by the European Central Bank in September 2012.

In this paper, we develop a model of sovereign default driven by either self-fulfilling expectations, or weak fundamentals, and analyze the mechanisms by which either conventional or unconventional monetary policy can rule out the former. Benevolent fiscal and monetary authorities choose the optimal rate of default under discretion, either imposing “haircuts” on debt holders (outright repudiation) or engineering surprise inflation, or both. We model conventional monetary policy as a standard choice of inflation, and unconventional policy as outright purchases in the debt market.

Using a non-monetary version of our model, we first lay out in detail the main mechanism by which multiple equilibria emerge under lack of fiscal commitment. In doing so, we extend Calvo (1988) to an environment with fundamental and political risk. Different from Calvo’s original contribution, in our model equilibria with self-fulfilling default are distinct from the equilibrium with discretionary default occurring only if fundamental fiscal stress materializes, and can occur only for intermediate levels of public debt. We then show that the same mechanism characterizes a monetary version of the economy where the central bank only relies on conventional policies.

terms of high inflation and negative growth. Reinhart and Rogoff (2011) shows that, in the year in which a crisis erupts, on average, output declines by 4 percent if the country defaults on domestic debt, against a decline of 1.2 percent, if the country defaults on external debt only. The corresponding average inflation rates are 170 percent (in cases of domestic debt default) against 33 percent (external debt default).

We should stress that the ability to prevent self-fulfilling crises does not rule out sovereign default altogether. Ex-post, defaults may be driven by weak fundamentals, and are typically associated with debt monetization and inflation — see the evidence in Reinhart and Rogoff (2009) and (2011) discussed above. As weak fundamentals may interact with self-fulfilling expectations of a crisis in determining sovereign risk, the case for central banks interventions remains strong.

See also Cohen and Villemort (2011) and Cole and Kehoe (2000) among others. In addition to fundamental default and political risk, our model also differs from Calvo (1988) in several other dimensions. In the monetary version of the model, default is not restricted to debasing debt via inflation as in Calvo (1988). Finally, we model the balance sheet of the central bank allowing for interest-bearing liabilities.
The ability to generate seigniorage revenue and debase debt with inflation cannot prevent self-fulfilling default altogether. However, it may affect the range of debt for which the economy becomes vulnerable to it, a point also stressed by Aguiar et al. (2013).4

In the second part of the paper, we model unconventional policies allowing the central bank to purchase government debt, while simultaneously issuing monetary liabilities in the form of interest bearing reserves. In our analysis, this is where the printing press argument by Krugman comes into play. Monetary authorities stand ready to honour their own liabilities — not necessarily government debt — by redeeming them for cash (fiat money) at their nominal value (see also Hall and Reis 2012). Thus, by purchasing government paper, the central bank effectively swaps default-risky public debt for its own liabilities with a guaranteed face value, subject only to the risk of inflation.5 As a result, central bank interventions reduce uncertainty and the overall cost of debt service, altering the trade-offs faced by a discretionary fiscal authority.

On a large enough scale, central bank purchases can keep the cost of servicing the debt below the level at which default would become the preferred policy option, even in the absence of fundamental fiscal stress, relative to the alternative of raising the primary surplus. Specifically, we show that there is a a minimum threshold for debt purchases above which there is no equilibrium with self-fulfilling default. Close to this minimum threshold, a monetary backstop does not eliminate default due to fundamental fiscal stress. Sufficiently above this threshold, it eliminates outright default altogether.

We also show that, to be credible, a backstop cannot have strongly adverse consequences on the future inflation choices by the central bank, a risk that is magnified if the central bank is held responsible for its own balance sheet losses, barring contingent fiscal transfers. The prospects of being forced to run high residual inflation to make good for these losses, i.e. the prospects of large deviations from the overall optimal policy, would ultimately make a backstop a dominated strategy, relative to the alternative of facing an equilibrium with belief-driven speculation. Nonetheless, our analysis emphasizes that, provided fiscal and monetary authorities are benevolent (maximize social welfare), the conditions for a backstop to be

---

4In the monetary economy studied by Calvo (1988), outright default is ruled out by assumption: multiple equilibria then obtain only by virtue of a specific assumption on the costs of inflation.

5See Gertler and Karadi (2012) for a similar notion of unconventional monetary policy applied to outright purchases of private assets.
credible/desirable under budget separation are reasonably mild.

These findings are important in light of concerns that, on the one hand, the central bank may not have the ability to expand its balance sheet on a sufficient scale to effectively backstop government debt. On the other hand, even if a backstop rules out belief-driven crises, large-scale purchases of government debt may foreshadow large losses on the central bank balance sheet, forcing monetary authorities to run suboptimal inflation policies. To rule out belief-driven sovereign default, central bank purchases neither have to match the full scale of the government financing, nor have to guarantee the government in all circumstances, at the cost of high inflation.

The gist of our argument is most easily understood referring to a situation in which the relevant (risk-free) nominal interest rate is at its lower bound. In this case, the central bank would be able to issue fiat money at will to buy government paper, without any impact on current prices. To the extent that markets price the risk of non-fundamental default in sovereign rates, these purchases would arbitrarily reduce the cost of servicing the debt and thus eliminate any self-fulfilling equilibria (because fiat money is subject only to inflation risk). However, to avoid undesirable inflation developments, appropriate fiscal and monetary policy would be required in the future to deal with the increased monetary stock.

Our model of unconventional monetary policy can be viewed as an extension to the case in which central bank liabilities are issued at the equilibrium interest rate — namely, at a rate consistent with expectations of future inflation. Also in this case, the central bank can expand its balance sheet, issuing interest-bearing monetary liabilities (that will always be convertible into cash/fiat money at face value), with no immediate inflationary consequences. As discussed above, in doing so the monetary authority fully accounts for the implications of its purchases on the future optimal choice of primary surpluses and inflation.

While our analytical framework is close to Calvo (1988), our model and results also build on a vast and consolidated literature on self-fulfilling debt crises, most notably Cole and Kehoe (2002) and more recently Roch and Uhlig (2011), as well as sovereign default and sovereign risk, see e.g. Arellano (2008) and Uribe (2006) among others. A few recent papers and ours complement each other in the analysis of sovereign default and monetary policy. Jeanne (2011) addresses issues in lending of last resort where, in case of default, the government repudiates its entire stock of debt, while Reis (2013) discusses debt crises by modelling the central bank balance sheet in a similar way as ours. In a dynamic continuous time framework, Aguiar, Amador, Farhi and Gopinath (2012) analyze a similar problem as in our
paper (abstracting however from unconventional policies involving interventions in the sovereign debt market). Cooper (2012) and Tirole (2012) study debt guarantees and international bailouts in a currency union.

By the same token, while we encompass trade-offs across different distortions in a reduced-form fashion, in doing so we draw on a vast literature, ranging from the analysis of the macroeconomic costs of inflation, in the Kydland-Prescott but especially in the new-Keynesian tradition (see e.g. Woodford 2003), to the analysis of the trade-offs inherent in inflationary financing (e.g. Barro 1983), or the role of debt in shaping discretionary monetary and fiscal policy (e.g. Diaz et al. 2008 and Martin 2009), and, last but not least, the commitment versus discretion debate (e.g. Persson and Tabellini 1993).

The text is organized as follows. Section 2 revisits the logic of self-fulfilling sovereign debt crises in a non-monetary model. Section 3 shows that, in the absence of a monetary backstop, the same mechanism studied in the real economy of Section 2 is at work in economies with non-indexed debt. Section 4 and 5 analyze monetary backstop strategies. Section 6 concludes.

2 The logic of self-fulfilling sovereign debt crises

As in Calvo (1988), our main question concerns the determinants of the market price at which a government can borrow a given amount $B$ from private investors at a point in time, and the consequences of agents expectations (determining this price) on the ex-post fiscal choices by the government. The model is solved under the maintained assumption that with some probability policymakers are unable to commit in a credible way to a fiscal plan, detailing how public debt will be serviced and public spending financed in future periods, under different contingencies. Ex post, the government may choose to default, partially or fully, on its liabilities.\footnote{In the model, under commitment there are no self-fulfilling default crises, — as shown by Calvo (1988). For an analysis of default under commitment, see Adam and Grill (2011).}

Since we are interested in the mechanism by which, given the government financing needs, default is precipitated by agents expectations (rather than, say, in the determinants of public debt accumulation), we find it useful to carry out our analysis in a two-period economy.\footnote{In our two-period economy, the financial need of the government in the first period coincides with the stock of public debt. In multiperiod models, there would be a fundamental distinction between the stock of debt $B$, on which the government may impose haircuts, and the short-term financial needs of the public sector, which determine the ex-}

---

6\footnote{In the model, under commitment there are no self-fulfilling default crises, — as shown by Calvo (1988). For an analysis of default under commitment, see Adam and Grill (2011).}

7\footnote{In our two-period economy, the financial need of the government in the first period coincides with the stock of public debt. In multiperiod models, there would be a fundamental distinction between the stock of debt $B$, on which the government may impose haircuts, and the short-term financial needs of the public sector, which determine the ex-}
mechanism as clearly as possible, we initially abstract from the monetary dimension of the analysis: the central bank and a demand for its liabilities will be introduced from the next section on.

2.1 Model setup

Consider a two-period economy, populated by a continuum of risk-neutral agents who derive utility from consuming in period 2 only. The government is benevolent but, for reasons that will become apparent later in the text, we allow for political uncertainty about its type. Specifically, we assume that, in period 1, the government announces fiscal plans that rule out default altogether. In period 2, with probability $1 - \gamma$ the government will stick to its fiscal plans and honor its liabilities entirely. With probability $\gamma$, instead, the government will act under discretion and reoptimize: it will choose taxes and a default rate that maximize current agents’ utility, taking market expectations and interest rates as given. The level of output in the second period is also subject to uncertainty. Output may be High or Low with probability $\mu$ and $(1 - \mu)$, respectively.

The timeline is as follows. In the first period, private agents can invest a given stock of financial wealth $W$ either in domestic public debt $B$, at the gross market interest rate $R$, or in a real asset $K$, with an infinitely elastic supply, yielding an exogenously given “safe” real interest rate $\tilde{R}$. Consumers’ wealth in the first period is thus equal to $W = B + K$. The fiscal authority announces tax plans consistent with no default, which will honor with probability $1 - \gamma$.

In the second period, uncertainty about output and the type of government is resolved. If the government does not reoptimize, taxes will be adjusted to the solvency requirement of the public sector. If the government instead acts under discretion and reoptimizes, as in Calvo (1988) it may impose a haircut on the owners of government debt at the rate $\theta \in [0, 1]$, inducing distortions that affect net output and aggravate the budget — to be discussed below. Different from Calvo (1988), however, we explicitly allow for the possibility that default be driven by fundamental imbalances in states of fiscal and economic distress, in addition to self-fulfilling expectations.

In the spirit of Calvo (1988), we proceed by specifying the relevant distortions in reduced-form, referring to the relevant literature which has provided micro-foundations to them. First, in light of the literature on tax smooth-

---

The posure of the government to a self-fulfilling crisis — including the primary deficit, interest payments, as well as the rollover of outstanding bonds and bills coming to maturity during the period.
ing, we posit that taxation \( T_i \) results in a dead-weight loss of output indexed by \( z(T_i; Y_i) \), where from now on a subscript \( i \) will refer to the output state \( i = L, H \). Given the level of gross output \( Y_i \), the function \( z(.) \) is convex in \( T \), satisfying standard regularity conditions. We realistically assume that, to raise a given level of tax revenue, dead-weight losses are larger, and grow faster in \( T \), if the economy is in a recessionary state, that is:

\[
\begin{align*}
    z(T; Y_L) &> z(T; Y_H), \\
    z'(T; Y_L) &> z'(T; Y_H).
\end{align*}
\] (1)

Since what matters in our analysis is the size of the primary surplus, rather than the individual components of the budget, for simplicity we posit that government spending \( G \) is invariant across states of nature — an assumption that is not consequential for our main results.

Second, default entails costs that, without loss of generality, we assume falling on the budget, proportional to the size of the ex-post haircut, that is \( \theta_i B \tilde{R} \).\(^8\) Upon defaulting, the government incurs a financial outlay equal to a fraction \( \alpha \in (0, 1) \) of the size of default.\(^9\)

Under these assumptions, the budget constraint of the government in period 2 for \( i = L, H \) is

\[
T_i - G = (1 - \theta_i) B \tilde{R} + \alpha \theta_i B \tilde{R}, \quad \alpha, \theta_i \in [0, 1]
\] (2)

where \( \tilde{R} \) is the market interest rate on public debt, set in period 1. The primary surplus — defined as the difference between taxes \( T \) and government spending \( G \) — finances debt repayment net of the haircut \( \theta_i B \tilde{R} \), but gross of the transaction costs of defaulting \( (\alpha \theta_i B \tilde{R}) \).\(^{10}\)

\(^8\)Our results would go through if the variable costs of default were in output, rather than in the budget.

\(^9\)Sovereign default may entail different types of costs, including output and revenue losses associated with a contraction of economic activity, as well as transaction costs in the repudiation of government liabilities. In the theoretical literature, some contributions (see e.g. Arellano 2008 and Cole and Kehoe 2000) posit that a default causes output to contract by a fixed amount; in other contributions (see e.g. Calvo 1988) the cost of default falls on the budget and is commensurate to the extent of the haircut imposed on investors. Calvo (1988) refers to legal and transaction fees associated to default. In a broader sense, one could include disruption of financial intermediaries (banks and pension funds) that may require government support. The relative weight of different default costs is ultimately an empirical matter — see e.g. Cruces and Trebesch 2012.

\(^{10}\)From an accounting perspective, the budget costs of default due to legal fees should be part of the the primary surplus. In what follows, we find it expositionally convenient to consider them as part of the debt service, hence we include them in the net interest bill of the government.
Consumption and the budget constraint of the country’s residents is
\[ C_i = U_i = [Y_i - z(T_i; Y_i)] - T_i + KR + (1 - \theta_i) B \hat{R} \]  

(3)

Consumption is equal to output, \( Y \), net of losses from distortionary taxes, \( z(T_i; Y_i) \), minus the tax bill, \( T \), plus the revenue from portfolio investment. Consumers earn the safe (gross) interest rate \( \hat{R} \) on their holdings of \( K \), and the net (ex haircut) payoffs \( (1 - \theta_i) \hat{R} \) on their holding of public debt \( B \). Under risk neutrality, consumption coincides with agents’ utility \( U \) and thus defines the objective function of the benevolent government.

2.2 Optimal choice between taxes and haircuts

In our model, with probability \( 1 - \gamma \) the government sticks to its pre-announced “no default policy” in period 2, and raises taxes as to satisfy the budget constraint in all states of nature

\[ \tilde{T}_i - G = B \hat{R} = \tilde{T} - G, \quad i = L, H \]  

(4)

where \( \tilde{T}_i \) denotes taxes in a no-default (\( \theta_i = 0 \)) equilibrium. It is worth stressing that, under mild conditions, this policy plan that we posit as a simplifying assumption will coincide with the optimal plan under commitment. This result can be derived by solving the problem of a benevolent government (with a probability \( 1 - \gamma \) of being in charge in period 2) that internalizes the effects of its decisions on expectations and thus on \( \hat{R} \).

Default is instead a possibility if the government turns out to be discretionary — an event which occurs with probability \( \gamma \). The optimal plan by the discretionary government is derived by maximizing agents’ utility, \( C_i \), subject to its budget constraint and the constraint on the default rate \( \theta \in [0, 1] \), taking \( \hat{R} \) as given.\(^{12}\) Let a hat above a variable, e.g., \( \hat{T}_i \), denote

\(^{11}\)The proof is available upon request. The economic logic of this result is as follows. As is well understood, a government acting under commitment could in principle make plans with contingent default (see Adams and Grill 2012). Yet, in our setting, this government will be aware that the rate \( \hat{R} \) is already high, in anticipation of default by the discretionary government in charge in period 2 with probability \( \gamma \). With \( \hat{R} \) sufficiently high, the benefits from reducing the ex-ante market rates exceed the gains from committing to ex-post contingent default: it will be optimal to set \( \theta = 0 \) in all states of nature, as to compensate for the adverse effects on expectations of prospective default under discretion. In light of this result, our modelling assumption is a good approximation to the behavior of a government under commitment — which allows us to simplify considerably the algebra and the analysis in the main text.

\(^{12}\)A \( \theta \) outside the range \([0, 1]\) would be tantamount to assuming that the government is able to subsidize bond holders or tax them without incurring the output distortions associated to net taxes \( T \).
an equilibrium with outright default. Conditional on default, the optimality condition for taxes is:
\[ z' \left( \hat{T}_i; Y_i \right) = \frac{\alpha}{1 - \alpha}. \] (5)

The government chooses an optimal tax level \( \hat{T}_i \) trading-off the economic costs associated with raising revenue \( z \left( T; Y_i \right) \), with the variable budget cost of default, indexed by the parameter \( \alpha \). Note that this trade-off is independent of the interest rate and the size of debt. Given \( G \), the optimal taxation level \( \hat{T}_i \) determines the maximum primary surplus that the country finds it optimal to generate conditional on default, \( \hat{T}_i - G \), in turn pinning down net output \( Y_i - z \left( \hat{T}_i; Y_i \right) \) as well as the optimal haircut rate:

\[ \hat{\theta}_i = \frac{B\bar{R} + G - \hat{T}_i}{(1 - \alpha) B\bar{R}}, \quad i = L, H. \] (6)

Observe that \( \text{sign} \left( \frac{\partial \hat{\theta}_i}{\partial \bar{R}} \right) = \text{sign} \left( \hat{T}_i - G \right) \): in an interior equilibrium with a default rate \( \hat{\theta}_i \in (0, 1) \), the haircut is increasing in the level of the interest rate — provided the country runs a primary surplus.

Observe also that with a sufficiently low sovereign rate \( \bar{R} \), were the discretionary government to set its preferred tax rate \( T_i = \hat{T}_i \), the default rate \( \theta_i \) would be negative. But since haircuts can only be positive, the optimum is to repay obligations in full and set \( \hat{\theta}_i = 0 \).

Using (6) together with the constraint on admissible default rates \( \theta \in [0, 1] \), the optimal policy under discretion can be written compactly as follows:

- if \( \hat{\theta}_i < 0 \) \( \theta_i = 0 \) \( T_i = \hat{T}_i = G + B\bar{R} \) (7)
- if \( \hat{\theta}_i \in (0, 1) \) \( \theta_i = \hat{\theta}_i \) \( T_i = \hat{T}_i = z' \left( \frac{\alpha}{1 - \alpha}; Y_i \right) \) (8)
- if \( \hat{\theta}_i \geq 1 \) \( \theta_i = 1 \) \( T_i = \hat{T}_i^+ = G + \alpha B\bar{R} \) (9)

Note that, when the constraint \( \theta_i \leq 1 \) is binding in equilibrium, the government optimally defaults on all its liabilities, but its current non-interest expenditure (including the variable budget costs of default evaluated at \( \theta_i = 1 \)) may exceed \( \hat{T}_i \) — hence the notation \( \hat{T}_i^+ \).

The above conditions are defined up to the size of the haircuts, to be determined jointly with equilibrium pricing by private markets, discussed below.
2.3 Debt pricing and equilibrium

The price of debt is pinned down by the interest parity condition, equating (under risk neutrality) the expected real returns on domestic bonds to the safe interest rate:

$$\tilde{R} \{(1 - \gamma) + \gamma [\mu (1 - \theta_H) + (1 - \mu) (1 - \theta_L)]\} = R$$  \hspace{1cm} (10)$$

Under rational expectations, agents anticipate the optimal discretionary plan of the government conditional on the market interest rate $\tilde{R}$.

A rational-expectation equilibrium is defined by the above condition (10), together with the conditionally optimal tax rates (5) or (9) and (4) and associated default rates, and the government budget constraint (2).

We are interested in studying economies where, in equilibrium, fundamental default may be optimal for low realizations of output, but there is no fundamental reason for defaulting in the high-output state. Using the expression for the optimal haircuts in the two states (6) with $0 = \hat{\theta}_H < \hat{\theta}_L \leq 1$, it is easy to verify that in these economies the size of the initial $B$ has to satisfy the following inequalities:

$$0 < \left(\hat{T}_L - G\right) < BR \leq (1 - \gamma (1 - \mu)) \left(\hat{T}_H - G\right).$$  \hspace{1cm} (11)$$

In words: the initial level of $B$ is large enough that, in the low output state, the (positive) primary surplus under default $\left(\hat{T}_L - G\right)$ will fall short of the interest bill of the government valued at the risk-free rate, $BR$. At the same time, $B$ is small enough that, in the high output state, the (positive) primary surplus $\left(\hat{T}_H - G\right)$ that would be optimally chosen under default can comfortably finance the largest possible interest bill— corresponding to the case in which agents anticipate total repudiation in the low-output state, setting $\tilde{R} = R/(1 - \gamma (1 - \mu))$.\(^{13}\) In the rest of this section, we will impose (11), together with the following:

$$1 - \alpha > \gamma > 0; \hspace{0.5cm} 1 \geq \mu \geq \alpha > 0.$$  \hspace{1cm} (12)$$

As further discussed below, the condition $1 - \alpha > \gamma$ ensures that multiple equilibria emerge only for relatively highly levels of $B$ in the range (11). Moreover, imposing $\mu \geq \alpha$ conveniently simplifies our analysis by excluding

\(^{13}\)Observe that a countercyclical $G$ would increase ‘fiscal stress’ in the low output state, while raising fiscal surplus in the good output state. Generalizing our model in this direction would aggravate notation, without producing additional insight.
corner solutions with $\theta_L = 1$ and $\theta_H = 1$. It is worth noting that, with the above restrictions in place,

$$BR < \frac{1 - \gamma}{\alpha} \left( \hat{T}_H - G \right),$$

implying that the optimal rate of default in the high output state is always below 100 percent.\textsuperscript{14} These conditions are stricter than we need to prove our results, but allow us to formulate our main propositions in a tighter and therefore more accessible fashion.

### 2.4 Weak fundamentals and self-validating expectations as drivers of sovereign debt crises

Our first proposition establishes that, in our model, the equilibrium is generally not unique. With this proposition, we extend the main result by Calvo (1988) to a stochastic setting with fundamental and political risk, and derive a novel result relative to this author’s contribution. Namely, provided that the probability of a discretionary government in period 2 is not too high ($\gamma < 1 - \alpha$), self-fulfilling crises are possible only when the government financing needs $B$ are relatively high in the relevant range (11).\textsuperscript{15}

Namely, there is a threshold for $B$ below which the economy only admits a fundamental equilibrium (denoted with the superscript $F$), in which the interest rate charged on debt reflects anticipations of default in the low-output state of nature in period 2— based on the correct probability that the low-output state materializes ($\mu$) and the discretionary government is in charge ($\gamma$). For $B$ above such threshold, there is also a second, non-fundamental equilibrium (denoted with $N$), in which market participants coordinate their expectations on default occurring in both the high and low output state — and thus charge a higher equilibrium interest rate than in $F$.

**Proposition 1** *Holding the conditions (11) and (12), there will be either one or two rational expectations equilibria which satisfy the pricing condition (10), together with the government optimizing conditions (7) through (9) and*

\textsuperscript{14}See the expression for the equilibrium haircut in (17) below.

\textsuperscript{15}In Calvo (1988), there are two equilibria for any level of $B$, no matter how small. The solution in Calvo (1988) is a special case of our analysis if we let $\mu \rightarrow 1$ (output is non-stochastic) and $\gamma = 1$. In the non-stochastic version of the model, the equilibrium may be unique for a special combination of parameters’ values.
(2), depending on whether B is below or above the following threshold

\[ B \leq \frac{(1 - \alpha - \gamma (1 - \mu)) \left( \hat{T}_H - G \right) + \gamma (1 - \mu) \left( \hat{T}_L - G \right)}{(1 - \alpha) R}. \]  

(14)

When B is below the threshold (14), there will be a unique fundamental equilibrium in which default will occur only in the low output state of the world if the government is discretionary. In this equilibrium the haircuts are set to \( \theta^F_H = 0 \) and

\[ 0 < \theta^F_L = \frac{B \tilde{R}^F - \left( \hat{T}_L - G \right)}{(1 - \alpha) B \tilde{R}^F} < 1 \]  

(15)

with the equilibrium interest rate given by

\[ \tilde{R}^F = \frac{(1 - \alpha) RB - \gamma (1 - \mu) \left( \hat{T}_L - G \right)}{[(1 - \gamma) (1 - \alpha) + \gamma (\mu - \alpha)] B}. \]  

(16)

When B is above the threshold (14), there will be a second equilibrium, driven by self-validating expectations, with default in both states under the discretionary government, with \( \tilde{\theta}^F_L < \tilde{\theta}^N_L \) and \( 0 < \tilde{\theta}^N_H < \tilde{\theta}^N_L \). The rates of default in each state are given by:

\[ 0 < \tilde{\theta}^N_H = \frac{B \tilde{R}^N - \left( \hat{T}_H - G \right)}{(1 - \alpha) B \tilde{R}^N} < 1 \]  

(17)

\[ 0 < \tilde{\theta}^N_L = \frac{B \tilde{R}^N - \left( \hat{T}_L - G \right)}{(1 - \alpha) B \tilde{R}^N} < 1, \]

with equilibrium interest rate given by:

\[ \tilde{R}^N = \frac{(1 - \alpha) RB - \gamma (\mu \left( \hat{T}_H - G \right)) + (1 - \mu) \left( \hat{T}_L - G \right)}{(1 - \alpha - \gamma) B}. \]  

(18)

Both haircuts and taxation vary across equilibria. In the fundamental equilibrium, the discretionary government only defaults in the low output state \( Y_L \); in the non-fundamental equilibrium, it imposes haircuts in both states of the world. The equilibrium interest rate will thus generally be higher than the safe rate R. In the F-equilibrium, the difference is determined by rational expectations of default in the weak state. In the
N-equilibrium, the difference is driven by self-confirming beliefs that the discretionary fiscal authority will always default. Non-fundamental equilibria are welfare-dominated because the level of taxation is higher in each state of nature (whether or not the government defaults), and so are the overall tax-related distortions reducing output.

2.5 A graphical illustration

The logic of belief-driven debt crises can be illustrated graphically, as shown by Figures 1a and 1b. Each figure plots the best-response default rate $\theta$ that satisfies the budget constraint and the optimality conditions of the discretionary government against the market determined rate $\tilde{R}$ (light-colored line) together with the equilibrium $R$ charged by investors against the government-determined haircut rate (dark-colored line). The two figures refer to the high-output and the low-output state, respectively.

In either state, the government best-response under discretion depends on the haircut in the other states only through the market interest rate $e_R$. Thus, in either figure, there is only one government reaction function, which, for $0 \leq \theta_i \leq 1$, can be written as follows:

$$\theta_i \text{-Government} = \max \left\{ 0, \min \left\{ \frac{BR - (T_i - G_i)}{(1 - \alpha) BR}, 1 \right\} \right\}$$

Conversely, from (10), the contingent haircut expected by investors in one state depends explicitly on the expected haircut in the other state. In either figure, we present two investors’ best responses to $R$, conditional on the two possible equilibrium haircut rates in the other state.

Figure 1a is drawn for the high output state. The investors’ response

$$\theta_H \text{-Investors} = \max \left\{ 0, \min \left\{ 1 - \frac{1}{\gamma \mu} \left[ \frac{R}{R} - (1 - \gamma) - \gamma (1 - \mu) (1 - \theta_L) \right], 1 \right\} \right\}$$

is plotted for two different values of $\theta_L$. The curve to the right is drawn conditional on the non-fundamental equilibrium default in the low-output state ($\theta_L = \theta_L^N$); the curve to the left for $\theta_L = \theta_L^F$. Only the former curve crosses the government best response at a positive haircut rate. This illustrates that default in the high-output state is affected by self-validating expectations of fiscal stress in the low-output state, driving up $R$ for each $\theta_H$.\(^{16}\)

\(^{16}\)The two lines also cross at zero default rate $\theta_H = 0$, but this cannot be an equilibrium because $R$ would be too low to cause non-fundamental default in the L-state.
The curve to the left, i.e. the investors’ best response for $\theta_L = \tilde{\theta}_L^F$, crosses the government’s on the x-axis (where $\theta_H = 0$) at the equilibrium rate $\tilde{R}^F$. Note that this is an equilibrium because the government best response for some $\tilde{R} < \tilde{R}^N$ hits the non-negativity constraint on $\theta_H$. Multiplicity arises specifically because of this non-negativity constraint on $\theta$.

The Figure 1b is drawn for the low-output state. Here, the government best response under discretion crosses both best responses by the investors at positive default rates. Of course, the default rate and the market interest rates on debt are higher conditional on private agents coordinating on the non-fundamental equilibrium. Comparing the two figures also makes it clear that the conditions for equilibrium multiplicity coincide with the conditions for default in the high state.

### 2.6 The comparative statics of debt and notional interest bills

A policy-relevant question is whether countries that have a higher initial level of liabilities $B$ would also face higher notional interest bills $B\tilde{R}$. The answer is far from obvious because the optimal default rate and thus the market interest rate are both endogenous in equilibrium, and may actually be falling in $B$.

We first note that $\mu \geq \alpha$ is a sufficient condition for the notional interest
bill $B\tilde{R}$ in the fundamental interior equilibrium

$$B\tilde{R}^F = \frac{(1 - \alpha) RB - \gamma (1 - \mu) (\tilde{T}_L - G)}{[1 - \gamma (1 - \alpha) + \gamma (\mu - \alpha)]}$$

(19)

to be unambiguously rising in $B$. However, the same condition is not sufficient to ensure that $B\tilde{R}$ will also be rising in $B$ in the non-fundamental equilibrium:

$$B\tilde{R}^N = \frac{(1 - \alpha) RB - \gamma (1 - \mu) (\tilde{T}_H - G) + (1 - \mu) (\tilde{T}_L - G)}{(1 - \alpha - \gamma) B}$$

(20)

The sign of the derivative $\partial B\tilde{R}^N / \partial B$ crucially depends on the probability of the government reneging on its fiscal commitments. It is positive for $\gamma < 1 - \alpha$, that is,

$$\frac{\partial B\tilde{R}^N}{\partial B} > 0 \iff \gamma < 1 - \alpha.$$ 

To gain intuition, let $\mu = 1$ and $\gamma = 1$, as in the original contribution by Calvo (1988): there is no random variation in output, and $\tilde{T}$ and $G$ are invariant to $B$. This is equivalent to assuming that the primary surplus under default is invariant to $B$ as well — implying that the expression $(1 - \theta (1 - \alpha)) B\tilde{R}^N$ is equal to a constant, see (2) evaluated at $\gamma = 1$. Since
a higher $B$ tends to reduce the endogenous default rate $\theta$, with both $B$ and $(1 - \theta (1 - \alpha))$ rising, $\tilde{R}^N$ must fall more than proportionally. The original Calvo setup indeed predicts that the notional interest rate $\tilde{R}^N$ as well as the notional interest bill $B\tilde{R}^N$ generating a belief-driven debt crisis are lower, the higher the initial stock of debt $B$.

This admittedly counterintuitive feature of Calvo (1988) follows from the modelling assumption restricting the primary surplus upon default to be independent of the amount of debt in the market. In our model, we remove this restriction, and allow for a weak dependence between primary surpluses and $B$ by stipulating that, with some large enough probability, the government will not default in any state of the world. When $1 - \gamma > \alpha$, in our model the notional interest bill $B\tilde{R}^N$ is rising with the level of initial debt, ensuring that the equilibrium is unique at relative low values of $B$.

2.7 Fixed vs variable costs of default

We conclude this section by noting that our results would go through qualitatively if the model featured also fixed costs of default (as is standard in the literature, see e.g. Cole and Kehoe 2000), in addition to variable costs. Introducing fixed costs in our setting would have two implications. First, the equilibrium would continue to be characterized by a threshold value for debt defining two regions of $B$, one in which the equilibrium is unique, the other in which it is not — this threshold would obviously be different from the one characterized in our first proposition. Second, in the range of debt where equilibrium is unique, default may not occur at all, not even in the low-output state. Fixed costs may discourage debt repudiation even when the macroeconomic outcome turns out to produce fiscal stress — as outright default may reduce welfare more than the distortions of running high fiscal surpluses in a downturn.

In the literature, fixed costs are typically motivated with the observation that default is not frequent at low level of debt. But (differently from Calvo 1988) in our model self-fulfilling crises are already ruled out at low level of debt by virtue of variable costs of default only. Hence, because of the substantial algebraic complications that fixed costs would introduce in our analysis, we prefer to pursue expositional and analytical clarity by abstracting from them altogether — they would obviously be relevant from a quantitative perspective.
3 Sovereign default in a monetary model with non-indexed debt

In Section 2, we have analyzed the main mechanism by which discretionary fiscal policy can make a country vulnerable to self-fulfilling sovereign debt crises in an economy with real debt. The question we address in the rest of the paper is whether the central bank qualifies as an institution that can rule out self-fulfilling sovereign debt crises under any circumstances.

Specifically, we ask whether countries with non-indexed public debt denominated in domestic currency are shielded from belief-driven crises, thanks to the policymakers’ use of either conventional or unconventional monetary policy. With the first, we refer to the control of inflation, giving the monetary authorities the option to inflate away public liabilities and raise revenue through an inflation tax. With the second, we refer to central bank purchases in the public debt market without an immediate effect on inflation.

In this section, we will show that, under conventional monetary policy, the same non-uniqueness of equilibria analyzed in Section 2 also characterizes a monetary version of our economy where public debt is nominal and not indexed. In the next section, we will then characterize a non-conventional backstop policy with central bank purchases of public debt, and analyze conditions under which this will be successful.

3.1 Model setup

As stressed by Calvo (1988), some degree of repudiation is a natural outcome in a monetary economy, because unexpected changes in inflation rates affect the ex-post real returns on assets which are not indexed to the price level. Consistently, in our monetary model, repudiation in period 2 will take the form of either outright default on debt holdings, or a reduction in the real value of debt through inflationary surprises, or both.\footnote{This is different from the monetary model analyzed by Calvo (1988), where partial repudiation exclusively takes the form of inflation.}

Relative to the model specification in Section 2, our model set up changes as follows. First, to minimize the use of new notation from now on we redefine government liabilities $B$ and the notional interest rate $\tilde{R}$ in nominal, rather than in real terms. As before, variables in the last period are indexed to the random realization of the high- and low-output states of the world, i.e., $i = L, H$. So, $P_1$ denotes the price level in the first period. $P_1 > 0$ and $\pi_1 (\infty > \pi_1 > -1)$ are the price level and the inflation rate in period 2, in either the low- or the high-output state.
Second, as in Calvo (1988), we model the demand for (non-interest bearing) fiat money $M$ restricting our attention to the case of a constant velocity:

$$M_1/P_1 = M_i/P_i = \kappa,$$  \hspace{1cm} (21)

The seigniorage revenue — the amount of real resources the monetary authorities can obtain by increasing the stock of fiat money — will thus be:

$$\frac{M_i - M_1}{P_i} = \frac{\pi_i}{1 + \pi_i} \kappa,$$  \hspace{1cm} (22)

where we posit that $M_1$ and $P_1$ are exogenously given and conveniently normalized as follows: $M_1/\kappa = P_1 = 1$.\(^{19}\) Similarly to taxes and default, inflation is distortionary. Namely, we posit a reduced-form convex cost of inflation $C()$, normalized such that $C(0) = C''(0) = 0$  — a standard instance being $C(\pi) = \frac{\lambda}{2} \pi^2$.

Third, different from the government, whose type in period 2 is subject to uncertainty, we assume that the central bank always acts under discretion.

Finally, in a nominal economy with non-indexed debt, the optimal policy plans in period 2 will be defined over $T_i, \theta_i,$ and $\pi_i$. Since these instruments are typically controlled by different policymakers, their analysis generally raises complex issues in the specification of objective functions and constraints across fiscal and monetary authorities, and the way they interact strategically. For our purpose, however, a natural benchmark scenario is one in which both are benevolent (i.e. they maximize the same objective function), consolidate their budget constraints, but may make their optimal plans independently, taking each other instruments as given.\(^{20}\) Our analysis thus provides a reference allocation, against which one can assess the consequences of alternative policy scenarios — revolving around political economy considerations or institutional settings that differentiates the objectives and constraints of the monetary and fiscal authorities.

\(^{18}\) As a simplification, the money demand (21) from Calvo implicitly bypasses the need to impose a transversality condition on $M$. Note that the setup can be easily generalized to encompass an inflation Laffer curve, by positing that $\kappa$ is a function of expected inflation.

\(^{19}\) As shown below, we stipulate that the budget constraint has to be satisfied for every policy strategy, consistent with the assumptions in the literature on discretionary policy and default. We also intentionally abstract from issues in the determination of the value of nominal liabilities in the first, initial period, of the kind analyzed by the fiscal theory of the price level and related literature (see e.g. Uribe 2006 for a related approach).

\(^{20}\) We should stress that a common objective function and budget constraint fundamentally narrow the scope for opportunistic behavior, even when the monetary and fiscal authorities are operationally independent. It can be shown that, under discretion, the policy plan derived below will be the same under coordination.
3.2 Budget constraints

With any seigniorage revenue rebated to fiscal authorities, we can write the consolidated budget constraint of the government and the central bank in period 2 as follows:

\[ T_i - G = [1 - \theta_i (1 - \alpha)] \frac{B}{1 + \pi_i} \tilde{R} - \frac{\pi_i}{1 + \pi_i} \kappa, \quad \alpha, \theta_i \in [0, 1] \]  

Note that government spending can be financed at least in part through seigniorage, as well as via an inflationary debasement of outstanding (ex-default) public liabilities.

The consumption/budget constraint of the country residents is

\[ C_i = [Y_i - z(T_i; Y_i)] - C(\pi_i) - T_i - \frac{\pi_i}{1 + \pi_i} \kappa + KR + (1 - \theta_i) \frac{B}{1 + \pi_i} \tilde{R}, \]  

Consumption is equal to output \( Y_i \) net of losses from raising taxes and inflation, minus the tax bill \( T_i \) including the inflation tax \( \frac{\pi_i}{1 + \pi_i} \kappa \), plus the revenue from portfolio investment. The net real payoffs on public debt is \( (1 - \theta_i) \frac{B}{1 + \pi_i} \tilde{R} \).

The timeline follows closely Section 2. In the first period, private agents can invest either in a real asset \( K \), yielding an exogenously given safe real interest rate \( R \), or in domestic nominal public debt \( B \), at the gross nominal market interest rate \( \tilde{R} \). As before, the fiscal authority announces tax plans consistent with no default, which will honor with probability \( 1 - \gamma \).

In the second period, uncertainty about the type of government is resolved. If the government acts under discretion and reoptimizes (a circumstance which occurs with probability \( \gamma \)), it may impose a haircut on the owners of government debt at the rate \( \theta \in [0, 1] \). Whether or not the government re-optimizes, the central bank chooses the rate of inflation in period 2 under discretion, by maximizing agents’ consumption.

3.3 Optimal choice of inflation, taxation and default

The optimal discretionary plan is now defined over \( T_i, \theta_i, \) and \( \pi_i \) — it thus displays a key difference relative to the real economy studied in the previous section. A new condition states that inflation is chosen by trading off the output benefits from reducing distortionary income taxation net of the costs of default (if any), with the output cost of inflation:

\[ z'(T_i; Y_i) \left( B \tilde{R} + \kappa \right) - \theta_i B \tilde{R} \left[ \alpha - z'(T_i; Y_i) (1 - \alpha) \right] = (1 + \pi_i)^2 C'(\pi_i) \]  

19
Observe that the inflation rate would not be equal to zero even if printing money generated no seigniorage revenue ($\kappa = 0$). This is because a discretionary monetary authority will not resist the temptation to inflate nominal debt, if only moderately so according to the condition above. Positive costs of inflation indeed prevent policymakers from attempting to wipe away the debt with infinite inflation.

Conditional on default, however, the optimal rate of taxation is identical to the case of the economy with real debt (5), corresponding to the optimal default rate

$$\hat{\theta}_i = \frac{1}{1 - \alpha} \left[ 1 - \frac{(1 + \hat{\pi}) \left( \hat{T}_i - G \right) + \hat{\pi} \kappa}{B \hat{R}} \right]$$

Using these expressions, we can then write the analogs of the conditions (7) through (9) together with the associated optimal inflation (as special cases of (25)), as follows:

If $\hat{\theta}_i < 0$ \hspace{2cm} $\theta_i = 0$ \hspace{2cm} $T_i = \hat{T}_i = \frac{B \hat{R}}{1 + \hat{\pi}_i} + G - \frac{\pi_i}{1 + \pi_i} \kappa$ \hspace{2cm} (27)

and \hspace{2cm} $z'(\hat{T}_i; Y_i) \left( B \hat{R} + \kappa \right) = (1 + \hat{\pi}_i)^2 C' \left( \hat{\pi}_i \right)$ \hspace{2cm} (28)

If $\hat{\theta}_i \in (0, 1)$ \hspace{2cm} $\theta_i = \hat{\theta}_i$ \hspace{2cm} $T_i = \hat{T}_i = z'^{-1} \left( \frac{\alpha}{1 - \alpha}; Y_i \right)$ \hspace{2cm} (29)

and \hspace{2cm} $\frac{\alpha}{1 - \alpha} \left( B \hat{R} + \kappa \right) = (1 + \hat{\pi})^2 C' \left( \hat{\pi} \right)$ \hspace{2cm} (30)

If $\hat{\theta}_i \geq 1$ \hspace{2cm} $\theta_i = 1$ \hspace{2cm} $T_i = \hat{T}_i = G + \alpha \frac{B \hat{R}}{1 + \pi_i} - \frac{\pi_i}{1 + \pi_i} \kappa$ \hspace{2cm} (31)

and \hspace{2cm} $z'(\hat{T}_i^+; Y_i) \left( B \hat{R} + \kappa \right) = (1 + \pi_i)^2 C' \left( \pi_i \right)$ \hspace{2cm} (32)

If no default ($\theta_i = 0$), the revenue from taxation and seigniorage needs to finance the government real expenditure and interest bill in full. The tax and the inflation rates are set according to (27) and (28). Both $\hat{T}_i$ and $\hat{\pi}_i$ are always state-contingent in this case.\(^{22}\) Note that these choices are the same

\(^{21}\)Under commitment the monetary authority would choose a lower inflation rate. However, it would not be able to undo the multiplicity due to the lack of commitment by the fiscal authority in choosing the size of the haircuts.

\(^{22}\)To see this, rewrite the implicit condition for inflation replacing $\hat{T}_i$:

$$z' \left( B \hat{R} + G - \frac{\pi_i}{1 + \pi_i} \kappa, Y_i \right) \left( B \hat{R} + \kappa \right) = (1 + \pi_i)^2 C' \left( \pi_i \right).$$

Since the function $z' \left( \hat{T}_i, Y_i \right)$ is state contingent, also the left-hand-side has to be state contingent.
whether the fiscal authority sticks to the plans announced in period 1 and does not reoptimize (occurring with probability \(1 - \gamma\)) or the government turns out to be discretionary.

Conditional on default \((\theta_i > 0)\), if the constraint \(\theta_i \leq 1\) is not binding, by the two conditions (29) and (30) the optimal inflation rate is identical across states of the world, i.e., \(\hat{\pi}_H = \hat{\pi}_L = \hat{\pi}\).\(^{23}\) If the constraint \(\theta_i \leq 1\) is binding in equilibrium, inflation rates are instead state dependent. When the optimal default rate is 100 percent, taxes and seigniorage will have to cover current non-interest expenditure, according to (31) and (32).

### 3.4 Debt pricing and equilibrium

Under risk neutrality, expected real returns are the same on government bonds and on the real asset:

\[
\hat{R} \left\{ (1 - \gamma) \left[ \frac{\mu}{1 + \hat{\pi}_H} + \frac{1 - \mu}{1 + \hat{\pi}_L} \right] + \gamma \left[ \mu \left( \frac{1 - \theta_H}{1 + \hat{\pi}_H} \right) + (1 - \mu) \left( \frac{1 - \theta_L}{1 + \hat{\pi}_L} \right) \right] \right\} = R.
\]  
(33)

The interest parity condition pins down the price of government debt as a function of both expected default and expected inflation rates.

The rational-expectation equilibrium is defined by these pricing conditions, together with the budget constraint (23), the optimal tax rates, either (29) or (31), or (27), and the optimal inflation, either (30) or (32).

As discussed in Section 2, we also assume conditions ensuring that an equilibrium with no default in the high-output state exists, and the set of equilibria is increasing in \(\hat{\theta}_H^F < 1\). In this nominal economy, the analog of conditions (11) and (12) are:

\[
\Pi_H \left( 1 + \hat{\pi}_H^F \right) \left( \hat{T}_H - G + \frac{\kappa \hat{\pi}_H^F}{1 + \hat{\pi}_H^F} \right) \geq BR > \Pi_L \left( 1 + \hat{\pi}_L^F \right) \left( \hat{T}_L - G + \frac{\kappa \hat{\pi}_L^F}{1 + \hat{\pi}_L^F} \right) > 0,
\]  
(34)

\[
1 - \alpha > \gamma > 0; \quad 1 \geq \mu \geq \alpha > 0.
\]

where \(\Pi_H\) and \(\Pi_L\) are defined as follows

\[
\Pi_L \equiv (1 - \gamma) \left( \mu \frac{1}{1 + \hat{\pi}_H} + (1 - \mu) \frac{1}{1 + \hat{\pi}_L} \right) + \gamma \left( \mu \frac{1}{1 + \hat{\pi}_H} + (1 - \mu) \frac{1}{1 + \hat{\pi}_L} \right).
\]  
(35)

\(^{23}\)This property of the optimal inflation rate depends on the simplifying assumption that the cost of inflation does not vary with the state of the world. It would be easy to relax this assumption, at the cost of cluttering the notation without much gain in terms of economic intuition.
Interpreting the first set of inequalities: the level of debt is sufficiently high that, in the low state, the government revenue under fundamental default (including seigniorage) will fall short of the interest bill of the government valued at the nominal risk-free rate. Conversely, in the high-output state, there will be no fundamental reason for defaulting: we posit that the primary surplus net of the inflation tax revenue will be above the largest possible interest bill, corresponding to expectations of total repudiation in the low-output state. Moreover, we restrict $\mu$ (the probability of the good output state) and $1 - \gamma$ (the probability of the fiscal authority to honor commitments) to be higher than $\alpha$ (the proportional budget cost of default). 24

3.5 Self-validating expectations of sovereign default and macroeconomic resilience with non-indexed debt

Our second proposition below establishes that, relative to the real economy studied in Section 2, debt-monetization and seigniorage obviously affect the equilibrium policy trade-offs. But per se the option to print money does not rule out multiplicity.

**Proposition 2** Holding the conditions (34), there will be either one or two rational expectations equilibria which satisfy the pricing condition (33), together with the government budget constraint (2) and its optimizing conditions for taxes (either (29) or (31), or (27)) and for inflation (either (30) or (32)), depending on whether $B$ is below or above the following threshold

$$BR \leq \left[ (1 - \gamma) \left( \mu \frac{1 + \hat{\pi}_F^T}{1 + \hat{\pi}_H^T} + (1 - \mu) \frac{1 + \hat{\pi}_F^T}{1 + \hat{\pi}_L^T} \right) - \frac{\gamma(\alpha - \mu)}{1 - \alpha} \right] \left( \hat{T}_H - G + \frac{\hat{\pi}_F^T}{1 + \hat{\pi}_L^T} \kappa \right)$$

$$\quad + \frac{\gamma(1 - \mu)}{1 - \alpha} \left( \hat{T}_L - G + \frac{\hat{\pi}_F^T}{1 + \hat{\pi}_L^T} \kappa \right).$$

(37)

For $B$ below the threshold (37), there will be a unique fundamental equilibrium in which default occurs only in the low output state of the world, i.e., $\theta_H^F = 0$ and $0 < \hat{\theta}_L^F$, with the equilibrium haircut given by:

$$\hat{\theta}_L^F = \frac{BR - \Pi_L \left( 1 + \hat{\pi}_L^F \right) \left[ \left( \hat{T}_L - G \right) + \frac{\hat{\pi}_F^T}{1 + \hat{\pi}_L^T} \kappa \right]}{(1 - \alpha) BR - \gamma (1 - \mu) \left( \hat{T}_L - G + \frac{\hat{\pi}_F^T}{1 + \hat{\pi}_L^T} \kappa \right)};$$

(38)

24Once again these conditions are stricter than we need to prove our results. They nonetheless allow us to formulate our main propositions in a tighter and therefore more accessible fashion, ruling out corner solutions.
inflation rates given by

\[ z'(\tilde{T}_i; Y_H) \left( B\tilde{R}^F + \kappa \right) = (1 + \tilde{\pi}_i)^2 C' (\tilde{\pi}_i), \]  

and the equilibrium interest bill determined as follows:

\[ B\tilde{R}^F = \frac{(1 - \alpha) BR - \gamma (1 - \mu) \left( \tilde{T}_L - G + \frac{\tilde{\pi}_L^F}{1 + \tilde{\pi}_L^N} \kappa \right)}{(1 - \gamma)(1 - \alpha) \left( \frac{\mu}{1 + \tilde{\pi}_H} + \frac{(1 - \mu)}{1 + \tilde{\pi}_L} \right) + \gamma \left[ \frac{\mu(1 - \alpha)}{1 + \tilde{\pi}_H} - \frac{\alpha(1 - \mu)}{1 + \tilde{\pi}_L} \right]} \]  

For \( B \) above the threshold (37), there will be a second equilibrium, driven by self-validating expectations, where the default rates are positive in both states:

\[ 0 < \hat{\theta}_L^N = \frac{B\tilde{R}^N - (1 + \tilde{\pi}_L^N) \left( \tilde{T}_L - G \right) - \tilde{\pi}_L^N \kappa}{(1 - \alpha) B\tilde{R}^N} < 1 \]  

\[ 0 < \hat{\theta}_H^N = \frac{B\tilde{R}^N - (1 + \tilde{\pi}_L^N) \left( \tilde{T}_H - G \right) - \tilde{\pi}_L^N \kappa}{(1 - \alpha) B\tilde{R}^N} < 1; \]

and the interest bill \( B\tilde{R}^N \) is given by:

\[ B\tilde{R}^N = \frac{(1 - \alpha) BR - \gamma \left[ \mu \left( \tilde{T}_H - G \right) + (1 - \mu) \left( \tilde{T}_L - G \right) + \frac{\tilde{\pi}_L^N}{1 + \tilde{\pi}_L^N} \kappa \right]}{(1 - \gamma)(1 - \alpha)(1 - \gamma) \left( \frac{\mu}{1 + \tilde{\pi}_H^N} + \frac{(1 - \mu)}{1 + \tilde{\pi}_L^N} \right) - \frac{\alpha \gamma}{1 + \tilde{\pi}_L^N}} \]  

Multiplicity is actually of exactly the same kind as in the real economy, with partial repudiation via haircuts differing across equilibria. However, note that, for a given default rate \( \theta \), the inflation rate is uniquely determined — there is no multiplicity in debt monetization. In practice, a unique inflation rate conditional on a realized haircut rate rules out the possibility
of high interest rates and taxation in the presence of sound fiscal funda-
mentals and no default. This result obtains under more general conditions 
than the standard convex costs of inflation we assume in our model.25 Yet, 
it may not hold for some speciﬁcations of these costs, for instance, if \( \alpha > 0 \) 
is bounded for large but ﬁnite values of the inﬂation rate.26
An intriguing question is whether, everything else equal, the debt thresh-
old for which the equilibrium is unique is higher in a monetary economy 
than in an economy without inﬂation-related beneﬁts (seigniorage) and dis-
tortions. A positive answer would imply that, even if ineﬀective in ruling out 
selﬁshing crises, inﬂationary ﬁnance may nonetheless increase resilience 
to them. Comparing Propositions 1 and 2, the question boils down to iden-
tifying the conditions under which the following holds:

\[
\left[ (1 - \gamma) (1 - \alpha) \left( \mu \frac{1 + \pi_L^F}{1 + \pi_H} + (1 - \mu) \frac{1 + \pi_L^F}{1 + \pi_L} \right) - \gamma (\alpha - \mu) \right] \left( \hat{T}_H - G + \frac{\pi_L^F}{1 + \pi_L^F} \right) + \\
+ \gamma (1 - \mu) \left( \hat{T}_L - G + \frac{\pi_L^F}{1 + \pi_L^F} \right) > \\
[ (1 - \gamma) (1 - \alpha) - \gamma (\alpha - \mu) ] \left( \hat{T}_H - G \right) + \gamma (1 - \mu) \left( \hat{T}_L - G \right).
\]

Sufficient conditions for the latter to hold are either that \( \hat{\pi}_L^F > \pi_L \geq \pi_H \), 
which is always the case since \( \hat{R}^N > \hat{R}^F \), or that \( \kappa > 0 \). On the one hand,

25 To see this note that under default we can rewrite the condition for optimal inﬂation 
determination as follows:

\[
\frac{\alpha \beta R + \kappa}{1 - \alpha} = C' (\hat{\pi}_i).
\]

Clearly the left-hand-side is falling in inﬂation, as the numerator is at most a linear 
function of inﬂation through the nominal interest rate \( \hat{R} \). Under convexity of inﬂation 
costs \( C' (\cdot) \), the right-hand-side is instead non-decreasing in inﬂation, resulting in a unique 
equilibrium inﬂation level (recall that we also assume \( C' (0) = 0 \)). However, for uniqueness it 
would be enough to assume that for some \( \pi > \hat{\pi}_i \), \( C' (\cdot) \) falls at a rate lower than the 
left hand side (roughly given by \( (1 + \pi)^{-1} \)).

A similar argument applies for inﬂation determination the case without default, as on 
the right hand side \( \alpha (1 - \alpha) \) would be generally lower than \( \alpha / (1 - \alpha) \), and decreasing in inﬂation.

26 Calvo (1988) provides an example of a monetary economy with multiple equilibria 
and selﬁshing expectations of inﬂationary debasement of debt. Our results diﬀer in 
two crucial dimensions. First, in the monetary version of our model the government may 
still choose to impose haircuts on the holders of public debt — a possibility that is instead 
ruled out by assumption in the monetary economy studied by Calvo. Second, as already 
explained, inﬂation costs are convex. In contrast, Calvo (1988) speciﬁes suﬃciently non-
convex costs \( C (\pi) \), yielding multiplicity in the rate of inﬂation itself. See also Obstfeld 
(1994) for a similar assumption.
by reducing ex-post the real value of outstanding public liabilities, inflation surprises raise the debt threshold for which equilibrium is unique in the monetary economy. On the other hand, the government can now count on the additional revenue from the inflation tax, which has the same effect. Note that a key reason for this result is that, in the model, the maximum level of taxes under default, $T_i$, is independent of inflation.

We conclude this section by stressing that, similar to the previous section, the conditions (34) are sufficient for the notional interest bill $B\overline{R}$ in nominal terms to be increasing in the initial level of nominal liabilities $B$. Namely, in the interior, fundamental equilibrium, given that $\pi_i^F > \pi_i$ (inflation in the state $L$ under default is higher than inflation without default), $\mu \geq \alpha$ is a sufficient condition for $B\overline{R}^F$ in (40) to be increasing in $B$. By the same token, in the interior non-fundamental equilibrium, $1 - \alpha > \gamma$ is a sufficient condition for $B\overline{R}^N$ in (43) to be increasing in $B$.²⁷

### 4 Policy options to stem self-fulfilling crises

When multiple equilibria are possible, differences in welfare across equilibria are driven by differences in output and budget losses caused by taxation, inflation and default. Specifically, the increase in the interest rate due to self-fulfilling expectations causes unnecessary disruption not only in the low-output state, but also in the high-output state.

The fact that equilibria with non-fundamental default are detrimental to social welfare raises the issue of what kind of policies can be deployed to prevent it. Calvo (1988), for instance, endorses the view that self-fulfilling debt crises can be prevented if in period 1 an institution could credibly set a ceiling $\overline{R}$ on the interest rate, at which it would stand ready to buy any amount of government debt.²⁸ The main idea is that, by setting a ceiling $\overline{R} < \overline{R}^N$, this institution would essentially coordinate agents’ expectations

²⁷It can be shown that, when $\theta_L^N = 1$ binds, a sufficient condition consists of the following:

$$\frac{1 - \alpha}{1 - \alpha (1 - \mu)} > 1 - \alpha > \gamma$$

$$= > (1 - \gamma)(1 - \alpha)\left(\mu \frac{1 + \pi_i^N}{1 + \pi_H^N} + (1 - \mu) \frac{1 + \pi_H^N}{1 + \pi_L^N}\right) > \gamma \alpha \mu.$$  

²⁸Many policy analysts have recently made use of this argument, to advocate interventions by the European Central Bank, likened to a "lender of last resort"; see e.g. De Grauwe (2011).
on the fundamental equilibrium.\textsuperscript{29} If the market interest rate cannot rise to the level $\bar{R}^N$ — the argument goes — the only possible market equilibrium, in which private agents hold any government debt at all, is one in which they optimally bid $\bar{R}^F$.\textsuperscript{30}

However, a key feature of an intervention policy providing a backstop to government debt is that, to be effective, it should be credible. This is especially important in models attributing multiplicity of equilibria to discretionary policymaking. Clearly, a government unable to commit to future policies (as we have assumed in our analysis so far) would not be able to coordinate market expectations on its own, by offering to pay an interest rate not higher than $\bar{R}$. If investors believe there will be default, they will simply refuse to buy debt at a price inconsistent with their expectations, independently of any government announcement.

Under discretion, prospective interventions are a sustainable belief if they are (i) feasible and (ii) welfare-improving from the perspective of the intervening institution. Assuming that such an institution is benevolent, this means that welfare conditional on interventions must be higher than in the non-fundamental equilibrium in which markets charge $\bar{R}^N$, taking into account future discretionary policy choices.

\section{Monetary backstops}

In Section 3 we have discussed the limits of conventional monetary policy (or inflationary debt financing). In this section we analyze unconventional policies whereby the central bank purchases government debt and expands its balance sheet by issuing its own liabilities. What makes this question particularly intriguing is that, from an aggregate perspective, any purchase of government debt by the monetary authorities is at best backed by their consolidated budget with the fiscal authorities — i.e. there are no additional resources to complement tax and seigniorage revenues.

In light of the classic Wallace (1981) irrelevance result, a prerequisite for these policies to be successful is that central bank liabilities be different

\textsuperscript{29}In Corsetti and Dedola (2011), we show that, in contrast to a transfer implicit in an intervention rate below the fundamental rate, liquidity support does not discourage costly reforms that improve government budget (see also Corsetti et al. 2005 and Morris and Shin 2006).

\textsuperscript{30}The introduction of this institution in the model affects the set of possible equilibria. To wit: even if an equilibrium with $\bar{R}^N$ cannot occur, in the model there is another equilibrium in which agents refuse to buy government paper at $\bar{R}^F$, and all public debt ends up being held by the intervening institution at the rate $\bar{R}$.
from government debt along some dimension. This prerequisite is already entertained in virtually all monetary models, where fiat money, the core central bank liability, earns a lower interest rate than government debt, and is exposed to inflation risk, but not to overt default risk. Monetary models take for granted that central bank liabilities are a claim to cash, and there would be no discretionary attempts at tampering with the face value of the monetary base.\footnote{Nonetheless, there are historical examples to the contrary (see e.g. Velde 2007), raising interesting research questions.}

Our analysis of monetary backstops emphasizes that it is by virtue of an interest rate differential in issuing liabilities, reflecting different underlying risks, that monetary authorities may redress belief-driven runs in the public debt market. The gist of our argument is most easily understood referring to a situation in which the relevant, risk-free nominal interest rate is at its lower bound. In this case, the central bank would be able to issue fiat money at will to buy government paper without any impact on current prices. If markets price in a risk of non-fundamental sovereign default, these purchases would arbitrarily reduce the costs of servicing the debt and eliminate self-fulfilling equilibria, because fiat money is subject only to inflation risk. However, to avoid undesirable inflation developments, appropriate fiscal and monetary policy would be required in the future to deal with the increased monetary stock.

Our model of unconventional monetary policy can be viewed as an extension to the case in which monetary reserves are issued at an equilibrium interest rate — namely, at a rate reflecting expectations of future inflation. In our specification, the central bank can expand its balance sheet, issuing interest-bearing monetary liabilities (that will always be convertible into cash/ fiat money at face value) with no immediate inflationary consequences. As discussed above, our analysis fully accounts for the implications of central bank purchases on the future optimal choice of primary surpluses and inflation.

5.1 A setup with fiat money and central bank reserves

Hereafter, we extend our model allowing the central bank to purchase a share $\omega$ of government debt $B$ at some pre-announced rate $\bar{R}$ in period 1. The central bank finances its debt purchases by issuing, in addition to $M$, monetary liabilities in the form of “reserves” $H$, remunerated at the default-free nominal rate $(1+i)$. As discussed above, while ex-post inflation surprises affect the real value of all outstanding nominal liabilities (at the
price of distortions induced by inflation), outright haircuts $\theta$ are applied to $B$ only (at the price of budget costs).

The motivation for distinguishing between $M$ and $H$ in our framework is twofold. First, from a modelling perspective, assuming interest-bearing reserves $H$ allows us to introduce a demand for central bank liabilities for a given price level in the first period, consistent with the discretionary choice of inflation (the monetary policy “instrument”) in the second period. By modelling $H$, we also abstract from the possibility of a surprise devaluation of nominal public liabilities $B$ in the initial period. In Section 3, we have already shown that inflationary debt financing consistent with rational expectations (in the second period) can affect the range for which sovereign debt is vulnerable to self-fulfilling default—but cannot rule this out. The model nonetheless fully accounts for the possibility that a backstop to the government impact expectations of future (period 2) inflation, to the extent that the central bank is anticipated to make good on its eventual losses via inflationary financing. These expectations in turn drive up the interest rate $i$: the larger the anticipated monetary expansions in period 2, the higher the market-determined nominal rate at which the central bank can issue reserves in period 1.

Second, from a policy perspective, our treatment of $H$ reflects a key institutional feature of modern central bank liabilities. In practice, central banks have been able to expand their balance sheet without feeding inflationary pressures and expectations, even when operating away from the lower bound on riskless short term interest rates — by remunerating reserves in line with prevailing market rates.

### 5.2 Budget constraints

Allowing for the possibility that the central bank buys and holds debt on its balance sheet raises two issues relevant to the specification of the government budget constraint. The first is whether a government that opts for default is able/willing to discriminate between private investors and monetary authorities, applying different haircuts. The second concerns the costs of defaulting on the central bank. For clarity of exposition, we find it analytically convenient to proceed under the assumptions that the government applies the same haircut $\theta_i$ rate to all debt holder — corresponding to a ‘pari

---

32 In dynamic monetary models, buying government debt by increasing the money stock does not necessarily result in higher current inflation, as the latter mainly reflects future money growth (see e.g. Diaz et al. (2008) and Martin (2009), placing this consideration at the heart of their analysis of time inconsistency in monetary policy).
passu' clause in government paper; second, that the cost of defaulting is isomorphic for the central bank and private investors, i.e. it is a budget cost proportional to the haircut rate. We nonetheless allow for a quantitative difference between the two, positing $1 > \alpha > \alpha_{CB} \geq 0$.

Under a ‘pari passu’ rule, the budget constraint of the central bank in the second period is:

$$T_i = \frac{\pi_i}{1 + \pi_i} + \frac{(1 - \theta_i)\omega BR}{1 + \pi_i} - \frac{(1 + \delta_i)}{1 + \pi_i}$$

$$= \frac{\pi_i}{1 + \pi_i} + \left(\frac{(1 - \theta_i)R}{1 + \pi_i} - \frac{(1 + \delta_i)}{1 + \pi_i}\right) \omega B.$$  \hspace{1cm} (44)

where $T_i$ denotes transfers from the central bank to the fiscal authority in state $i = L, H$. Allowing for $\alpha_{CB} < \alpha$, the government budget constraint in period 2 then reads:

$$T_i - G = [1 - \theta_i (1 - \alpha)] \frac{R}{1 + \pi_i} (1 - \omega) B + [1 - \theta_i (1 - \alpha_{CB})] \frac{R}{1 + \pi_i} \omega B - T_i$$

$$= \left[1 - \theta_i (1 - \alpha)\right] \frac{R}{1 + \pi_i} (1 - \omega) B + \theta_i \alpha_{CB} \frac{R}{1 + \pi_i} \omega B + \frac{(1 + \delta_i)}{1 + \pi_i} \omega B.$$  \hspace{1cm} (45)

where $\tilde{R}$ is the market interest rate at which agents are willing to buy the share of government debt $(1 - \omega) B$ not purchased by the central bank.

Consolidating the budget of the fiscal and the monetary authorities yields the following key expression:

$$T_i - G + \frac{\pi_i}{1 + \pi_i} \kappa =$$

$$[1 - \theta_i (1 - \alpha)] \frac{R}{1 + \pi_i} (1 - \omega) B + \theta_i \alpha_{CB} \frac{R}{1 + \pi_i} \omega B + \frac{(1 + \delta_i)}{1 + \pi_i} \omega B.$$  \hspace{1cm} (46)

Ultimately, the primary budget surplus (the difference between taxation and final spending $T_i - G$) augmented with seigniorage finances (i) the (gross) interest payments by the government to private investors (net of default but gross of the transaction costs associated to it); and (ii) the (gross) interest bill of the central bank—always paid in full under our assumptions.

As in Section 3, the government spending can be financed at least in part through seigniorage, and via an inflationary debasement of outstanding (ex-default) public liabilities. It does not follow, however, that there is a mechanical relation between central bank purchases of government debt financed by issuing reserves today and higher inflation in the future. Given a desired target of inflation, this is inconsistent with the above budget constraint only if, after repaying the bonds in the hands of private investors (the first bracket on the right hand side), what is left of the primary surplus
falls short of the interest bill on reserves. Inflation is ultimately driven by fiscal choices, not by the size of the central bank balance sheet.

The budget constraint of the representative agent is

\[ C_i = Y_i - z(T_i; Y_i) - T_i - \frac{\pi_i}{1 + \pi_i} \kappa + KR + (1 - \theta_i)(1 - \omega) \frac{B}{1 + \pi_i} \tilde{R} + (1 + \bar{i}) \frac{1}{1 + \pi_i} \mathcal{H} - \mathcal{C} (\pi_i), \]

Consumption is equal to output \( Y_i \) net of losses from raising taxes and inflation, minus the tax bill \( T_i \) including the inflation tax \( \frac{\pi_i}{1 + \pi_i} \kappa \), plus the revenue from portfolio investment. Note that the net real payoffs are determined by the realization of default and inflation. Namely, they are \((1 - \theta_i) \frac{B}{1 + \pi_i} \tilde{R}\) for the public debt, and \((1 + \bar{i}) \frac{1}{1 + \pi_i}\) for the central bank liabilities.

Combining the three constraints above we can write private consumption as follows:

\[ C_i = Y_i - z(T_i; Y_i) - G - \mathcal{C}(\pi_i) - \left[ (1 - \omega) \alpha \tilde{R} + \omega \alpha_{CB} \tilde{R} \right] \frac{\theta_i B}{1 + \pi_i}. \quad (47) \]

Under linear utility, this is the objective function of the policymakers.

The timeline is summarized as follows. Relative to our previous model specification, in the first period, the central bank may intervene in the debt market, buying a share \( \omega \) of \( B \) against issuance of reserves for \( \mathcal{H} = \omega B \). Private agents can thus invest their financial wealth in the safe asset \( K \), yielding \( R \) in real terms; domestic nominal public debt \( B \), at the gross nominal market interest rate \( \tilde{R} \); and (if any supplied) ‘reserves’, yielding \( i \). As before, the fiscal authority announces tax plans consistent with no default, which will honor with probability \( 1 - \gamma \).

In the second period, uncertainty about the type of government is resolved. If the government acts under discretion and reoptimizes (a circumstance which occurs with probability \( \gamma \)), it may impose a haircut on the owners of government debt at the rate \( \theta \in [0, 1] \). The central bank chooses the rate of inflation and always repay its own liabilities in full.

### 5.3 Fiscal and monetary policy reaction functions

Consistent with our argument in Section 3, we now characterize the discretionary policy plan under a policy scenario in which fiscal and monetary authorities maximize the same objective function under a consolidated budget constraint. In doing so, they take as given each other instruments, as
well as the intervention rate $\omega$ and all the rates of return set in period 1. Hereafter, a bar above a variable (e.g., $\tilde{T}_i$) refers to an allocation conditional on positive debt purchases by the central bank, i.e., $\omega > 0$.

As before, inflation is chosen by trading off the output benefits from reducing the need for distortionary income taxation and the costs of default (if any), with the output cost of inflation. So, if no default takes place, taxes satisfy the budget constraint (45) (or equivalently (46)) with $\theta = 0$:

$$
\tilde{T}_i = G - \frac{\tilde{\pi}_i}{1 + \tilde{\pi}_i} \kappa + \frac{\tilde{R}}{1 + \tilde{\pi}_i} (1 - \omega) B + \frac{(1 + i)}{1 + \pi_i} \omega B
$$

and the inflation rate is set according to:

$$
z'(\tilde{T}_i; Y_i) \left[ B\tilde{R} + \kappa - \left( \tilde{R} - (1 + i) \right) \omega B \right] = \left( 1 + \tilde{\pi}_i \right)^2 C' \left( \tilde{\pi}_i \right).
$$

Conditional on a government default, in the case of an interior solution for $\theta_i$, taxes are set according to:

$$
z'(\tilde{T}_i; Y_i) = \frac{\alpha(1 - \omega)\tilde{R} + \omega \alpha CB \tilde{R}}{(1 - \alpha)(1 - \omega)\tilde{R} - \omega \alpha CB \tilde{R}}
$$

and the optimal default rate will be:

$$
\hat{\theta}_i = \frac{(1 - \omega) B\tilde{R} + \omega (1 + i) B - \left( 1 + \tilde{\pi}_i \right) \left( \hat{T}_i - G \right) - \tilde{\pi}_i \kappa}{(1 - \alpha)(1 - \omega)B\tilde{R} - \alpha CB \omega B}\tilde{R}
$$

Note that (50) is identical to (5) when $\alpha CB = 0$. In this case, $z'(\tilde{T}_i; Y_i) = \alpha / (1 - \alpha)$, as in the case without interventions.

In turn, with an interior solution for $\tilde{T}_i$, the optimal inflation rate satisfies:

$$
z'(\tilde{T}_i; Y_i) \left[ B\tilde{R} + \kappa - \left( \tilde{R} - (1 + i) \right) \omega B \right] = \left( 1 + \tilde{\pi}_i \right)^2 C' \left( \tilde{\pi}_i \right);
$$

conditional on an interior solution for default $(0 < \theta_i < 0)$, by (50) and (52) the optimal inflation rate is identical across states of the world, i.e. $\tilde{\pi}_H = \tilde{\pi}_L = \tilde{\pi}$.

In the case of complete default, at a corner solution with $\theta_i = 1 (\hat{\theta}_i > 1)$, taxes adjust residually to satisfy the budget (including default costs):

$$
\hat{T}_i \leq \hat{T}_i^+ = G + \alpha \frac{\tilde{R}}{1 + \tilde{\pi}_i} (1 - \omega) B + \alpha CB \frac{\tilde{R}}{1 + \tilde{\pi}_i} \omega B
$$
The optimal (unconstrained) inflation satisfies the analog of (52) evaluated at $\hat{T}_i^+$. Observe that, for $\omega = 0$, the above optimal plan is identical to the one derived in section 3.

Not surprisingly, the optimal haircut rate will generally be dependent on the level of interventions, in turn affecting the interest bill of the government. Note that, for a given sovereign rate $\widetilde{R}$, a large enough size of interventions $\omega$ results in a negative desired haircut $\hat{\theta}_i$. In this case, no default takes place in equilibrium. Purchases of debt on a sufficient scale can rule out default as an optimal policy outcome under discretion. This is a key property of the the optimal plan that lies at the core of the mechanism by which a monetary backstop works.

5.4 Interest rate determination and equilibrium

As in section 3, the interest parity condition (33) pins down the price of government debt as a function of both expected default and expected inflation rates. When both $B$ and $\mathcal{H}$ are held by the private sector, however, there is another equilibrium interest parity conditions. In addition to (33), the interest rate on reserves $1 + i$, free from the outright default risk, must equal the real rate $R$, adjusted by expected inflation:

$$
(1 + i) \left[ (1 - \gamma) \left( \mu \frac{1}{1 + \pi_H} + (1 - \mu) \frac{1}{1 + \pi_L} \right) + \gamma \left( \mu \frac{1}{1 + \pi_H} + (1 - \mu) \frac{1}{1 + \pi_L} \right) \right] = R.
$$

Comparing this expression with (33), it is apparent that, as long as the central bank does not buy up all outstanding government liabilities, i.e. provided that $0 < \omega < 1$, the interest rate on government debt required by the private sector must exceed the interest paid on central bank’s liabilities by the expected rate of default.

The rational-expectation equilibrium is defined by these pricing conditions, together with the budget constraint (45), the optimal tax rates, either (50) or (53), or (48), and the optimal inflation, either (52) or its analog evaluated at $\hat{T}_i^+$. With the objective of focusing on economies with the properties described in Section 2, we again impose the conditions (34).

5.5 A fundamental equilibrium with credible backstops

We now establish that, when the central bank purchases enough government bonds, there is a unique fundamental equilibrium in which default occurs only in the low output state under discretion. When $\omega$ is large enough, the
non-fundamental equilibrium with default in all states of the world characterized in Proposition 2 is ruled out.

Our main result is summarized in Proposition 3 below. In writing this proposition, we find it useful to simplify the characterization of the equilibrium by positing \(\alpha_{CB} = 0\) — there are no budget costs implied by defaulting on the central bank.\(^{33}\)

**Proposition 3** If central bank purchases \(\omega\) are above the following threshold:

\[
1 > \omega \geq \omega = \frac{(1 - \alpha) BR - \gamma (1 - \mu)(\widehat{T}_L - G + \frac{\pi^N}{1 + \pi}) -}{(1 - \alpha)(1 - \gamma)(\mu \frac{1 + \pi^N}{1 + \pi} + (1 - \mu) \frac{1 + \pi^N}{1 + \pi})} \frac{(1 - \alpha)(1 - \gamma)(\mu \frac{1 + \pi^N}{1 + \pi} + (1 - \mu) \frac{1 + \pi^N}{1 + \pi})}{\gamma \mu + (1 - \gamma)(\mu \frac{1 + \pi^N}{1 + \pi} + (1 - \mu) \frac{1 + \pi^N}{1 + \pi})} [\widehat{T}_H - G + \frac{\pi^N}{1 + \pi}] \]

A unique rational expectations equilibrium exists satisfying pricing conditions (33) and (54), where fiscal and monetary authorities act independently pursuing the same objective function (47) subject to their consolidated budget constraint (46), and with the government optimally choosing taxes according to (50) in case of default. In this equilibrium default occurs only in the low output state of the world, with equilibrium haircuts given by \(\theta^F_H = 0\) and \(0 < \widehat{\theta}^F_L < 1\):

\[
\widehat{\theta}^F_L = \frac{BR - \left(1 - \gamma \left(\mu \frac{1 + \pi^F}{1 + \pi} + (1 - \mu) \frac{1 + \pi^F}{1 + \pi}\right) + \gamma \left(\mu \frac{1 + \pi^F}{1 + \pi} + 1 - \mu\right)\right) \left[\widehat{T}_L - G + \frac{\pi^F}{1 + \pi}\right]}{\left(1 - \alpha - \left(\frac{\mu \frac{1 + \pi^F}{1 + \pi} + 1 - \mu}{\mu \frac{1 + \pi^F}{1 + \pi} + 1 - \mu}\right) + (1 - \mu) \frac{1 + \pi^F}{1 + \pi}\right) (1 - \gamma) \left(\mu \frac{1 + \pi^F}{1 + \pi} + 1 - \mu\right) \left[\widehat{T}_L - G + \frac{\pi^F}{1 + \pi}\right]}
\]

\(^{(56)}\)

\(^{33}\) The same equilibrium characterization in Proposition 3 is obtained for \(\alpha_{CB} > 0\) if we posit that

\[
\alpha_{CB} R = \alpha \widehat{R}
\]

The intervention rate \(\widehat{R}\) is set proportionally to the market rate of debt, depending on the ratio between the variable budget costs of default (under our assumptions, \(\overline{R} > \widehat{R}\)).
inflation rates are given by:

\[
\begin{align*}
\frac{\alpha}{1-\alpha} \left( B\tilde{R}^F + \kappa - \left( \frac{\alpha \mu (\gamma \frac{1-\gamma \alpha}{1+\gamma} + \frac{1-\gamma}{1+\gamma} C)}{1-\alpha - \omega} \right) \omega \right) \end{align*}
\]

while the equilibrium interest bill is determined as follows:

\[
B\tilde{R}^F = \left[ 1 - \alpha - \left( \frac{\mu (\gamma \frac{1-\gamma \alpha}{1+\gamma} + \frac{1-\gamma}{1+\gamma} C)}{1-\alpha - \omega} \right) \omega \right] B - \gamma (1-\mu) \left( \left( \frac{\alpha \mu (\gamma \frac{1-\gamma \alpha}{1+\gamma} + \frac{1-\gamma}{1+\gamma} C)}{1-\alpha - \omega} \right) \omega \right) - \gamma \frac{\alpha (1-\mu)}{1+\gamma};
\]

where \( B\tilde{R}^F > R^F \).

The success of the backstop rests on the fact that debt purchases by the central bank affect the trade-offs faced by the discretionary government in a favorable way. Raising the size of interventions progressively reduces the overall costs of servicing the public debt. A falling interest rate bill in turn progressively reduces the temptation to resort to a haircut rather than improving the primary surplus — \( \tilde{\theta}_i^N \) falls in \( \omega \). For large enough interventions, \( \tilde{\theta}_H^N \leq 0 \) : default in the high state becomes a welfare-dominated option—recall from our discussion in Section 2, that preventing default in the high-output state is tantamount to rule out non-fundamental equilibria.\(^34\)

Compared with the non-fundamental equilibrium with default in both the high and the low output state characterized by Proposition 2, the unique fundamental equilibrium with positive interventions characterized by Proposition 3 features lower taxes in all states of the world without default, and also lower inflation (and thus related distortions) across the board, as a by-product of a lower interest rate bill. Because of the lower interest bill, it may even be possible for the unique equilibrium with positive interventions in Proposition 3 to be welfare-improving relative to the fundamental allocation characterized in Proposition 2.

\(^{34}\)Note that our result goes through even if, provided \( \alpha > \alpha_{CB} = 0 \), central bank purchases tend to reduce the cost of default faced by the government.
5.6 The case of a (near) full backstop

Proposition 3 establishes that the size of interventions required to rule out the adverse non-fundamental equilibrium does not need to cover the entire financing need of the government. In particular, the minimum effective backstop is not large enough to rule out default in a situation of fiscal stress. By the logic of the model, however, it is easy to show that there is a threshold for $\omega$ higher than $\overline{\omega}$, beyond which the monetary backstop ends up ruling out default in both the high and the low output state — for the case $\alpha_{CB} = 0, \overline{\omega} = 1$. A near full backstop of public debt ($\omega > \overline{\omega}$) means that the central bank essentially redresses the commitment problem at the root of the equilibrium multiplicity, with the interest bill falling below the fundamental level (without interventions):

$$(1 + i)B < \tilde{R}F \quad B$$

Ruling out default under fiscal stress crucially affects the trade-off in welfare levels across states of nature. In the high output state, a lower interest bill will imply that taxes and inflation be lower than in the fundamental equilibrium without interventions. Conversely, in the low output state, no default means that taxes are bound to be higher, exacerbating distortions. In light of the properties of (1), the fundamental equilibrium with very large interventions will not necessarily be welfare improving, relative to a fundamental equilibrium without or with limited interventions.\(^{35}\)

5.7 Central bank losses on sovereign debt holdings

Proposition 3 is derived for the limiting case in which the two authorities consolidate their intertemporal budget constraints. In this case, the central bank implements interventions of the required scale ($\omega \geq \overline{\omega}$) with the understanding that, in case of large balance sheet losses, the fiscal authorities are willing to underwrite monetary liabilities with positive contingent transfers. Haircuts on the debt held by the central bank (if any) would be at best a wash for the consolidated budget, as they would generate the need for higher transfers to the central bank and possibly higher taxes to cover default costs. With these contingent transfers in place, monetary authorities can always set inflation according to the optimal condition (49).

\(^{35}\)The problem is that the loss of one instrument — outright haircuts on public liabilities — would generally imply suboptimal adjustment in the other instruments (taxes and inflation).
Interactions between the two authorities, however, are regulated by institutions and rules that, most often, constrain budget consolidation. In the actual conduct of monetary policy, indeed, central banks are typically held responsible for backing their own liabilities. The question is whether budget separation may undermine the results derived so far in our analysis. The problem at hand is compelling because, in practice, it is difficult to exclude a positive probability of fundamental fiscal stress. By intervening around the minimum threshold, the central bank exposes its balance sheet to potential losses ex-post, since ruling out belief-driven debt runs does not necessarily rule out default. In case fundamental losses materialize, either taxes or seigniorage, or possibly both, must adjust, in line with the classical analysis by Sargent and Wallace (1981). The issue is the extent to which balance sheet losses translate into suboptimal adjustment in these instruments, up to reducing the welfare incentives for the central bank to intervene and thus undermining the credibility of the backstop.

Relative to the policy scenario assumed so far, we now replace a consolidated (intertemporal) budget constraint with separate constraints. Specifically, the transfers from the central bank to the government are constrained to be non-negative, i.e., $T_i \geq 0$, de facto making the central bank responsible for fully absorbing any losses it makes. As before, the fiscal and monetary authorities act independently pursuing the same objective — maximizing the residents’ welfare ex post.

Under the constraint $T_i \geq 0$, since seigniorage revenue is bounded (in our model $\lim_{\pi \to \infty} \frac{\pi_i}{1+i} \kappa = \kappa$), unless $\kappa$ is implausibly large, or $B$ too small to create a situation of fiscal stress, large interventions may foreshadow large contingent losses on the central bank balance sheet. If monetary authorities need to absorb these losses without help from the treasury, they will have to resort heavily to the printing press, with two key implications. First, to the extent that inflation is anticipated by rational agents, prospective debt monetization will drive up the interest on reserves $1+i$, exacerbating the central bank balance sheet problem. Second, in the presence of (convex) inflation costs, a heavy resort to the printing press may not entail an improvement over the N-equilibrium. If markets coordinate on charging $\tilde{R}^N$ on public debt, the central bank may be reluctant to buy debt on a large scale, on anticipation of large losses forcing highly inefficient inflationary policies.

---

36 It is sometimes argued that the central bank need not raise inflation because 'it can talk banks to hold reserves indefinitely.' This would be equivalent to exercise the option of restructuring monetary liabilities. If markets anticipate default on monetary liabilities, their demand for reserves will be affected. Note that our analysis emphasizes the absence of default risk on reserves as one of the main benefits from the printing press.
It is important to stress that, with separate budget constraints, the backstop strategy is not at stake because of concerns about central bank ‘bankruptcy’. Rather, the core argument is that, in general, it is optimal to use all instruments – taxes, default and inflation – to minimize their combined distortions. A break-even constraint on the central bank, requiring positive remittances $T_i \geq 0$ in $i = H, L$, interferes with the monetary authorities’ ability to set inflation rates that minimize distortions. With the social costs of this inefficiency rising non-linearly with inflation (and a large $B$), the credibility of large-scale interventions may be ultimately jeopardized.

As a corollary of Proposition 3, we state the condition under which a break-even constraint on the central bank would not impinge on the equilibrium allocation.  

**Corollary 4** The unique equilibrium characterized in Proposition 3 continues to exist under a central bank break-even constraint $T_i \geq 0$, provided the following condition holds:

$$0 \leq T_L = \frac{\tilde{\pi}^F}{1 + \tilde{\pi}^F} \kappa + \left( \frac{1 - \tilde{\theta}_L}{1 + \tilde{\pi}^F} R - \frac{(1 + i)}{1 + \tilde{\pi}^F} \right) \omega B, \quad (59)$$

The corollary suggests that a high intervention rate $R$ can contain the risk that the break-even constraint be binding. As a limiting case, under the assumptions underlying Proposition 3 (that $\alpha_{CB} = 0$, and the the fiscal authority cannot discriminate across creditors upon default), the central bank can always set $R$ high enough to satisfy the above inequality in all circumstances. For any given anticipated default rate in the low output state, there is an intervention rate that is high enough to compensate for central bank losses if this state of the world materializes.

---

37The corollary applies to the case of interventions around the minimum threshold. As discussed above, a near-full backstop, with $\omega \to 1$, rules out outright default on private investors in all states of the world. In this case, provided that the monetary and fiscal authorities share the same objective function, budget separation cannot be a problem. With a common objective of maximizing household’s consumption, the same marginal conditions characterized under budget consolidation also hold under separation. Defaulting on the central bank up to causing the constraint $T_i \geq 0$ to be binding would force monetary authorities to pursue a suboptimal inflation. In addition, with $\alpha_{CB} > 0$, it would also would create a net budget loss. Hence it would never be optimal for the discretionary government to default and make $T_i \geq 0$ binding in equilibrium.

38In this case the intervention rate $R$ does not impinge on any of the conditions defining the equilibrium.
But there is a second, more crucial, observation. When the constraint in the corollary above is binding, the equilibrium allocation is different from the case in which the two authorities consolidate their budget. However, a binding constraint does not necessarily imply that the central bank would be unwilling to implement the backstop. Consider an equilibrium with a small violation of (59). In the low output state, losses from interventions would force the monetary authorities to accept an inefficiently high adjustment of inflation, in violation of the marginal conditions for optimal taxation and inflation (52). Yet, to the extent that the adjustment is contained, the equilibrium with interventions ruling out belief-driven debt runs will still be preferred over the non-fundamental equilibrium without interventions. A monetary backstop will be granted, as long as the deviation of inflation and taxation from their optimal rates is not too large.

6 Conclusions

This paper has reconsidered the question of whether and why the central bank can provide a backstop to the government, as to rule out self-fulfilling sovereign debt crises. Our main conclusions resonate with the widespread policy view that under appropriate conditions, a central bank has indeed the power to backstop the government debt, although for different reasons that many observers invoke. Our model highlights three crucial conditions. Firstly, a monetary backstop is successful to the extent that the central bank is able to issue liabilities at a lower interest rate than the government. A key message from our analysis is that successful intervention strategies rest on a swap of (default-) risky government debt with nominal liabilities which can always be redeemed against currency.

Secondly, monetary policy making should not be itself a source of multiple equilibria in inflation and interest rates, thus undermining any welfare gains from a monetary backstop. Namely, conditional on a realized haircut, inflation rates should be uniquely determined, ruling out the possibility of high interest rates and taxation in the presence of sound fiscal fundamentals and no default. While this result obtains under more general conditions than the convex inflation costs we assume in our analysis, it may not hold for some specifications of these costs, for instance if the latter are bounded for large but finite values of the inflation rate.

Lastly, a successful monetary backstop is greatly facilitated when the fiscal and monetary authorities share the same objective function. Provided that fiscal and monetary authorities are both benevolent (i.e. they both
maximize social welfare), a monetary backstop is effective under reasonably mild conditions, even when the central bank is held responsible for its own balance sheet losses, barring contingent fiscal transfers. While in this case the two authorities would act independently without consolidating their budget constraints, the optimal discretionary plan internalizes the effects of own policy choices on overall distortions. By the same token, our analysis suggests that a monetary backstop may be called into question when political economy or distributional considerations cause the two authorities to trade-off self-interested objectives with socially efficient policies.

Our results are at odds with views often voiced in the public debate, claiming that the central bank is ‘a lender of last resort to the government’ because it is not subject to a budget constraint. These views stress, alternatively, that a central bank can always consolidate its liabilities and force private banks to hold them indefinitely, or debase them by a bout of unexpected inflation. In light of our analysis, both views have fundamental weaknesses. The view stressing the need for the central bank to impose financial repression over private banks by forcing them to hold reserves, de facto introduces the possibility of default on monetary liabilities, without however working out its consequences. If the central bank is expected to tamper with its liabilities, it is easy to see that the arbitrage condition relating the rate on monetary liabilities and the risk free rate would have to include terms in the anticipated central bank’s haircut \( \theta_i^{CB} \): the optimal monetary policy would have to account for the optimal haircut on the holders of reserves. The logic of self-fulfilling beliefs would then apply to a discretionary central bank as well as to the government, extending the results in the paper to the case of central bank interventions.

The alternative, inflation-debasement view downplays the social costs of running high inflation, historically conducive to financial and macro instability. If anything, our analysis shows that even a central bank’s willingness to provide a monetary backstop may be at stake in situations when monetary authorities fear they will be forced into residual adjustment in the rate of inflation, to absorb balance sheet losses. Exactly because high inflation is costly, in some circumstances the provision of a monetary backstop covering a large share of the government financing needs may be welfare dominated by the alternative of letting market coordinate on a non-fundamental equilibrium.\(^\text{39}\) Our analysis, nonetheless, also calls attention on the fact that

\(^{39}\)The fact that, at the time of the writing, as a consequence of the current crisis inflation is at low or even negative rates and therefore its costs are low relative to the costs of unemployment, is irrelevant for the argument: what matters is an assessment of the cost of prospective inflation on a path of monetary debasement of debt.
inflation rates are higher in an equilibrium with belief-driven outright defaults: an effective monetary backstop prevents high (let alone runaway) inflation, rather than creating price instability.

Although our analysis is carried out in closed economy, it bears lessons for a currency union. As already mentioned, a common objective function among fiscal and monetary authorities, and some fiscal support to the central bank (if only limited to financial stress situations) greatly enhance the ability of a central bank to provide a monetary backstop. In a monetary union among essentially independent states, it may be possible that national governments pursue different, inward-looking objectives and/or be adverse to extending large-scale fiscal backing to the common central bank. Our analysis, however, suggests that the conditions under which a common central bank has the ability to engineer a successful backstop to member states are fairly unrestrictive. This is especially true if, as is the case for the OMTs, governments can benefit from the backstop only provided they agree to strict conditionality, ensuring stability of public finances and possibly eliciting stricter cross-border cooperation.

References


