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Inflation, Debt, and Default[1]

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Abstract

We study how the co-movement of inflation and the business cycle affects real interest rates and the likelihood of debt crises. First, we show that for advanced economies, periods in which the co-movement between inflation and the business cycle is positive, real interest rates tend to be low. A positive co-movement of inflation with the cycle raises the returns of nominal bonds in bad times, making them a good hedge against aggregate risk. However, such procyclicality also generates default risk, since nominal debt becomes more expensive for the government when the economy deteriorates. In order to evaluate both effects, we develop a model of sovereign default on domestic nominal debt with exogenous inflation risk and domestic risk averse lenders. Countercyclical inflation tends to be *substitute* with default, while procyclical inflation is *complement* with it. In good times, when default is unlikely, procyclical inflation yields lower interest rates. In bad times, when default is possible, procyclical inflation can trigger an increase in default risk and spikes in real interest rates.

Keywords: inflation risk, domestic nominal debt, interest rates, sovereign default
JEL classification codes: E31, F34, G12, H63

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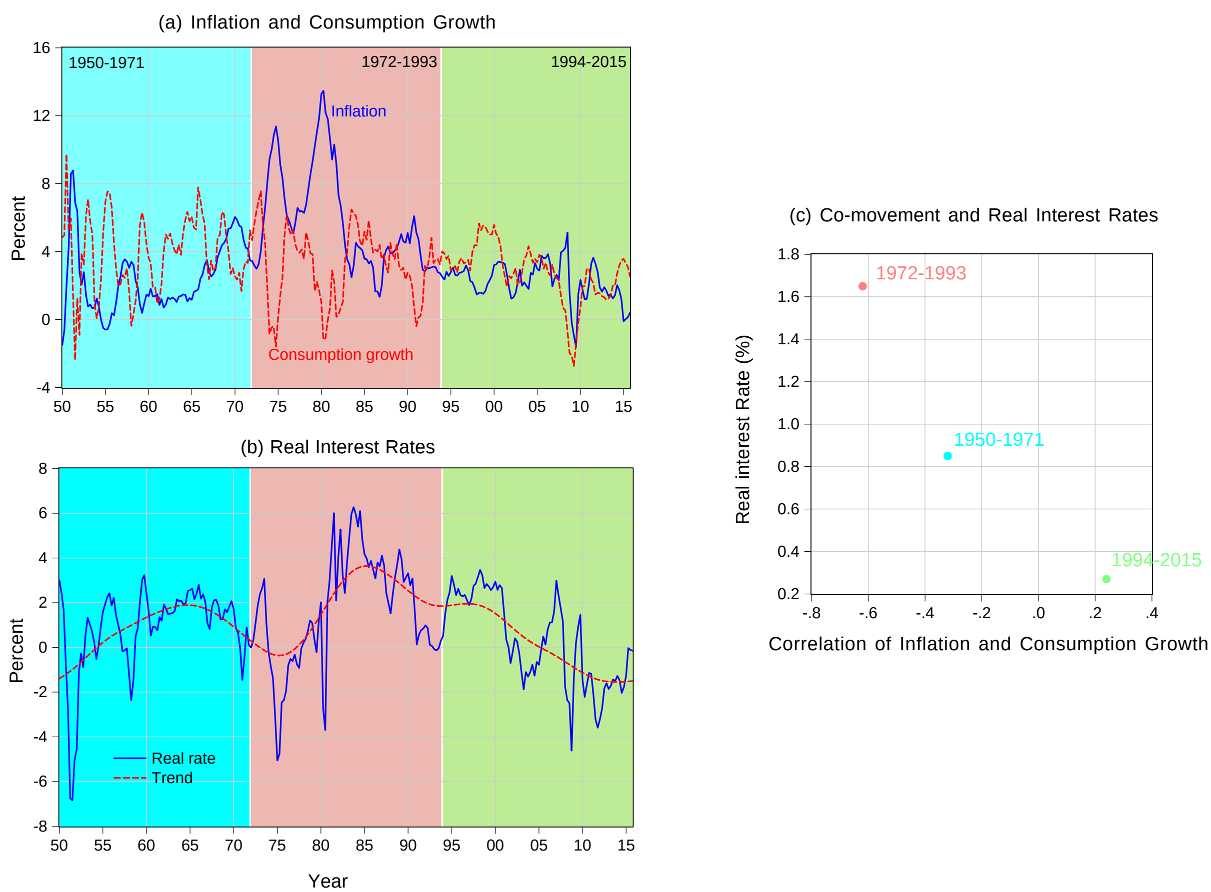
1 Introduction

Over the past 50 years, inflation dynamics over the business cycle in advanced economies has changed quite dramatically, as we have observed periods of highly countercyclical inflation, as well as periods of procyclical inflation. The goal of this paper is to study how changes in the co-movement between inflation and economic activity affect real sovereign yields, debt dynamics, and debt crises. To be more concrete, in Figure 1 we provide some motivating evidence for the mechanism we want to highlight.

Figure 1: Inflation and Consumption Growth and Real Rates in the U.S.



Note: Inflation is the log difference between CPI in quarter t and t-4. Consumption growth is the log difference in real personal consumption expenditures over the same interval. Real interest rates are nominal rates on government securities (from the IMF IFS database) minus expected inflation computed using a linear univariate forecasting model estimated on actual inflation.

In panel (a), we plot quarterly time series for year-on-year U.S. inflation and consumption growth from 1950 to 2015. The point of the panel is to highlight changes in the co-movement of the two series over three equal length sub-samples. It shows how in the first sub-sample (1950–1971), the co-movement between inflation and consumption growth is mildly negative, turns to strongly negative in the second sub-sample (1972–1993), and finally becomes positive in the most recent sample (1994–2015). If inflation co-varies positively with domestic consumption growth, then returns on domestic nominal debt are high (low) when consumption growth is low (high). This feature makes domestic nominal bonds less risky from a domestic investor's perspective, and thus — if government debt is mostly held domestically, as it is in most developed countries — they should trade, *ceteris paribus*, at a lower real interest rate.[2] The second and third panels in Figure 1 show that this indeed is the case. Panel (b) plots the U.S. real interest rate (along with its trend depicted by the dashed line) over the same sample, while panel (c) plots the average real rate and the average co-movement between inflation and consumption growth in each of the three sub-samples. Notice how the middle sample, which displays the most negative inflation consumption growth co-movement, also is the one with the highest real rate. The most recent sample — where the co-movement has turned positive — displays the lowest real rate, while the early sample has intermediate co-movement and an intermediate real rate.

Altogether, this evidence in Figure 1 suggests that the co-movement between inflation and consumption growth is closely connected with the real yield on government debt. The evidence, though striking, is obviously not conclusive as there might be a variety of other factors inducing this pattern. For this reason, in the first part of this paper, we establish this relationship in a more systematic fashion. In particular, we show that for a large sample of advanced economies, in countries and periods in which the co-movement of inflation with domestic consumption growth is high, real interest rates on government bonds tend to be low, even after controlling for a broad array of macroeconomic variables. This suggests that this co-movement is systematically connected to real interest rates. In that sense, the paper also suggests a new channel through which monetary policy may have been a determinant of the secular decline in real interest rates.

[2]For example, as of 2015, the share of public debt held by domestic creditors is 64 percent in the U.S., 69 percent in the United Kingdom, and 78 percent in Canada. Aizenman and Marion (2011) report that the share of U.S. public debt held in Treasury Inflation-Protected Securities (TIPS) is less than 8 percent, as of 2009.

Notice, though, that the same logic that makes nominal debt more attractive to lenders when inflation is procyclical, also suggests that nominal debt is less attractive to the borrower (the government). Consider, for example, a recession which is also accompanied by deflation. In that state, the lenders are happy to receive a large payoff on their nominal assets at the time when their consumption is low (recession). As discussed earlier, this pushes down interest rates. Consider now the point of view of the borrower (the government), which has to make larger payments at exactly the time when its income is low. For this reason, inflation procyclicality tends to make default more likely and this in turn pushes up interest rates. This discussion suggest that the effect of inflation procyclicality on interest rates depends on how likely default is. If default is not likely inflation, procyclicality should result in a discount, but the size of this discount should be smaller when default is more likely. In order to provide evidence for this mechanism, we regress interest rates on procyclicality and on an interaction between procyclicality and dummies that indicates that default is possible.[3] We indeed find that in periods where default is more likely the "procyclicality discount" is significantly reduced.

In the second part of the paper, we develop a very simple two period model of debt and default with stochastic inflation where equilibrium outcomes can be characterized using simple diagrams, and we can provide simple intuition for the relation between inflation cylicality, the real interest rate, and default. We show that when default is not possible, there is indeed a procyclicality discount. However, when default is possible, procylicality can lead to increased interest rates, since procylical inflation tends to make default more likely, as discussed earlier.

In the third part of the paper we develop a quantitative structural model of debt pricing and default. the model serves two purposes. The first is to show that the empirical connection between debt pricing and inflation dynamics can be understood using simple asset pricing logic. The second is to analyze how the original asset pricing logic for debt pricing and its dynamics is modified in the presence of sovereign default risk.[4]

[3]We experiment using both low output and low credit rating as dummies for the likelihood of default

[4]Sovereign default risk, reflected in credit default swap (CDS) spreads, was material even among developed economies during the European Debt Crisis. For instance, Belgium, Greece, Italy, Portugal, and Spain had CDS-implied default probabilities that exceeded 5 percent in 2011 and 2012.

Our model extends existing models of sovereign debt in two directions. First, we introduce domestic risk-averse lenders, in contrast to the common assumption of foreign risk-neutral lenders in the literature on sovereign debt crises in emerging economies. This distinction is important since a large amount of public debt is held domestically in advanced economies.[5] Second, we introduce exogenous stochastic inflation so that government bond rates endogenously reflect both inflation risk and default risk. These two features allow us to explicitly analyze the endogenous connection between stochastic discount factors of the domestic lenders, debt pricing, and default probabilities, and to analyze how this relation changes as the co-movement between inflation and consumption growth varies.

Consistent with the data, our model predicts that borrowing costs fall as the covariance of inflation and consumption growth increases. During normal times, relative to its countercyclical counterpart, the procyclical inflation economy sustains similar levels of debt and default risk, and yet enjoys lower borrowing costs. The procyclicality discount reflects the overall reduction in risk perceived by domestic lenders.

However, for a domestic government, debt becomes less attractive in bad times: deflation makes real government obligations larger in recessions, when the government values consumption more. In contrast, the government in the countercyclical economy benefits from the haircut induced by inflation in bad times: a form of partial default. Thus, the cyclicality of inflation affects the government's incentives to borrow or to repay. In our calibrated model, default risk — and thereby the sovereign real rate — spikes markedly and by more during bad times in the the procyclical economy, compared to the countercyclical economy.

Our exercise highlights that several ingredients are necessary to generate plausible bond prices and, at the same time, replicate our estimated relation between interest rates, inflation cyclicality and likelihood of default. In particular, we find that long-term debt, Epstein-Zin preferences, and very rare occurrences of default are key for quantitative success.

Our paper also has implications for the debate on the costs and benefits of joining or exiting a monetary union. Suppose that the union goes into a recession where some, but not all, members of the union get into fiscal trouble. Then the countries in fiscal trouble would like a more countercyclical monetary policy while the others don't: the contrast over

[5] One could also consider the case where foreign risk-averse lenders experience inflation that is correlated with domestic inflation through financial and trade linkages.

monetary policy increases in a recession. Our paper also suggests that monetary policy may have contributed to the secular decline in real interest rates, while also increasing the likelihood of debt crises during bad times.

Related literature. Our paper is related to several strands of literature. On the empirical side, our findings are related to studies on the importance of the inflation risk premium and its variation, as, for example, Boudoukh (1993) or Ang et al. (2008). Campbell et al. (2009) and Du et al. (2016) focus on the covariance of bond returns and other macroeconomic variables such as consumption growth and equity returns. Song (2016) studies the nature of inflation risk in U.S. bond markets by estimating a model with time variations in the stance of monetary policy as well as the co-movement of inflation and economic activity. On the theoretical side, the backbone of our set-up is a debt default model with incomplete markets as in Eaton and Gersovitz (1981), Aguiar and Gopinath (2006), or Arellano (2008). While these papers focus on foreign debt, Reinhart and Rogoff (2011) suggest that the connection between default, domestic debt, and inflation is an important one. D'Erasmo and Mendoza (2012), Pouzo and Presno (2014), and Arellano and Kocherlakota (2014) tackle the issue of default on domestic debt but do not include inflation.[6] Araujo et al. (2013), Sunder-Plassmann (2016), Mallucci (2015) and Fried (2017) study how the currency composition of debt interacts with default crises in emerging economies while Berriel and Bhattarai (2013), Faraglia et al. (2013), and Ottonello and Perez (2016) study nominal debt with inflation, in the absence of default. Kursat Onder and Sunel (2016) and Nuño and Thomas (2016) consider the interaction of inflation and default on foreign investors.[7] Our paper is also related to Lizarazo (2013) who studies default in the context of risk averse international lenders. Aguiar et al. (2016) provide an excellent compendium on modeling risk averse competitive lenders in the sovereign default literature.

[6] Broner et al. (2010) examine the role of secondary asset markets which make the distinction between foreign and domestic default less stark.

[7] Much of the existing literature has focused on strategic inflation, even hyperinflation, as a countercyclical policy option that governments with limited commitment can use when faced with a high debt burden in bad times. That focus is certainly legitimate for emerging economies but less warranted in the context of advanced economies mainly because of monetary policy independence. Central bank independence makes the cost of hyperinflation higher than the cost of a default, perhaps due to limited participation in bond markets in contrast to the economy-wide effects of hyperinflation.

Our general question is also related to recent work that studies how joining a monetary union can affect the probability of a self-fulfilling crisis in a debt default model (see Aguiar et al. 2013 and Corsetti and Dedola 2016). We complement these papers by highlighting how the cyclicality of inflation impacts fundamental-driven default crises, suggesting a promising extension of existing models of self-fulfilling debt crises.

The paper is structured as follows. In section 2, we discuss our empirical findings. In section 3, we develop a simple model of domestic nominal debt, where we discuss the main mechanisms at work. In section 4, we build a quantitative model of domestic debt and default, and section 5 presents our main results on the impact of inflation cyclicality. Section 6 concludes.

2 Inflation and Real Interest Rates

In this section, we study the empirical relation between several conditional moments of inflation and real interest rates on government debt. The main novel finding of the section is that higher covariance of inflation with economic activity is robustly and significantly associated with lower real interest rates on government debt.

Our dataset includes quarterly observations on real consumption growth, inflation, interest rates on government bonds, and government debt-to-GDP ratios for an unbalanced panel of 19 OECD economies from 1985Q1 to 2015Q4. The countries in the dataset are: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, Korea, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, and the United States.

We mainly use quarterly data from the IMF and the OECD to document our empirical findings. We compute inflation as the change in log GDP deflator using data from the OECD. We use nominal interest rates on government bonds from the IMF International Financial Statistics (IFS). For government debt, we use quarterly series from Oxford Economics on gross government debt relative to GDP, extended with quarterly OECD data on central government debt relative to GDP. Quarterly real consumption is constructed as the sum of private and public real consumption using the data from the OECD.

Using this data, we construct real interest rates using expected inflation and the conditional co-movement between inflation and consumption growth. To do, so we follow Boudoukh (1993) and first formulate a vector auto-regression (VAR) model for inflation and consumption growth. The basic VAR is:

$$\begin{bmatrix} \pi_{it} \\ g_{it} \end{bmatrix} = \mathbf{A_i} \begin{bmatrix} \pi_{it-1} \\ g_{it-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{\pi it} \\ \varepsilon_{git} \end{bmatrix} \tag{1}$$

where π_{it} is inflation, and g_{it} is the change in log consumption in country i in period t, A_i is a country-specific 2-by-2 matrix, and $\varepsilon_{\pi it}$ and ε_{git} are innovations in the two time series. We then estimate the VAR using standard OLS and construct time series for residuals $\varepsilon_{\pi it}$ and ε_{git} for each country.

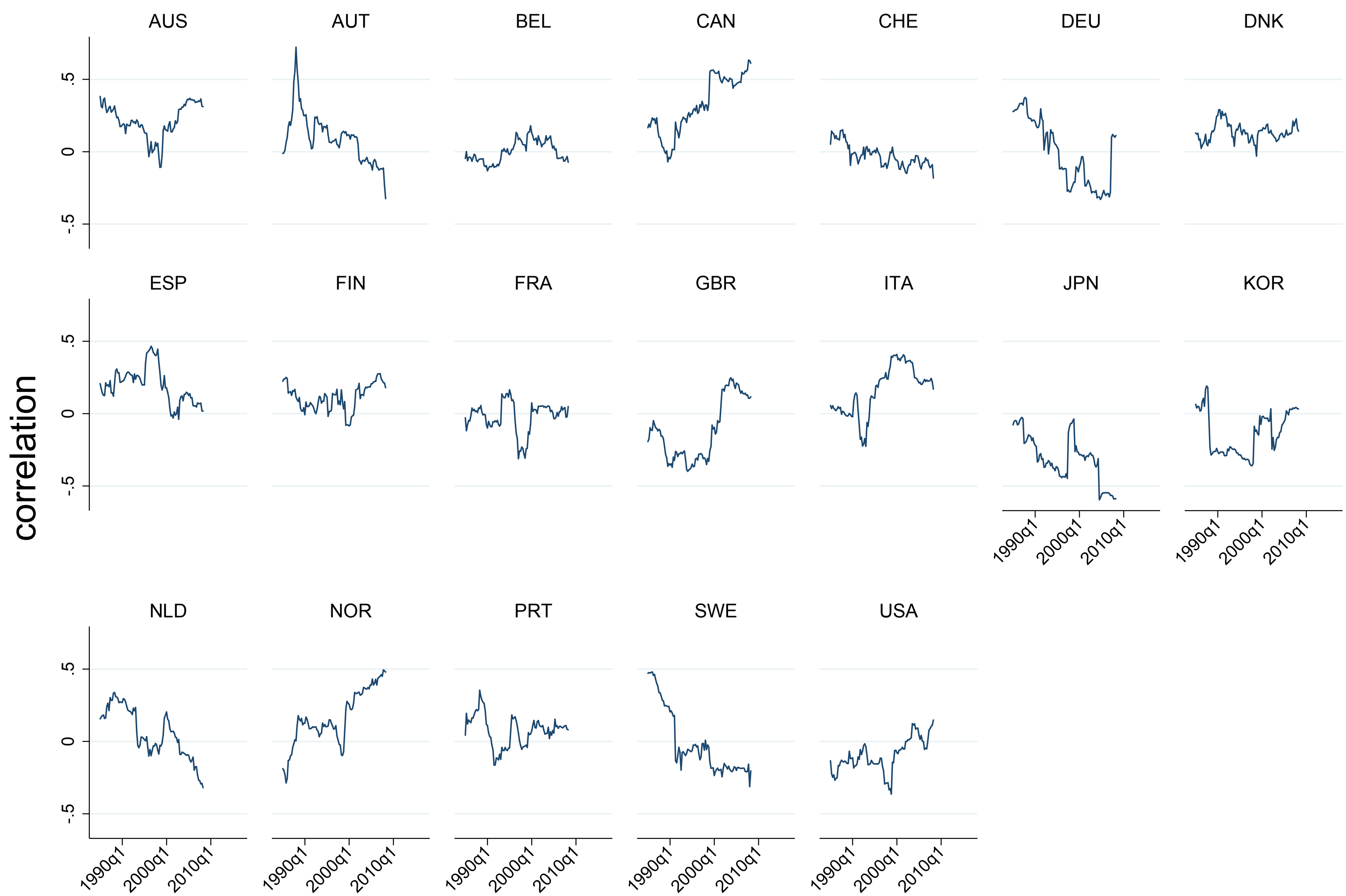
We measure the expected inflation as the forward-looking predicted inflation from the VAR, that is $\mathbf{E}[\pi_{i,t+1}]$. We then derive real rates on government debt as nominal rates less expected inflation. Finally, we measure the conditional co-movement between inflation and consumption growth by measuring the co-variance between the two innovations, $\varepsilon_{\pi it}$ and ε_{git}, in overlapping country-windows, comprised of 40 quarters.

In Figure 2, we plot the path of the conditional correlation for the countries in our sample. It illustrates that the co-movement of inflation and consumption growth varies over time and across countries. In many countries, such as Canada, Italy, Norway, the U.S., or the U.K., the co-movement of inflation and consumption growth has clearly increased since the mid-1980s, while it has sharply decreased or fluctuated in other countries such as Germany.

With this dataset, we estimate how the conditional covariance of inflation and consumption growth relates to interest rates faced by governments. All specifications include a full set of country and time fixed effects.

In Table 1, we regress the real interest rate on the conditional covariance of inflation with consumption growth. The main result from Table 1 is that in periods with higher conditional covariance between inflation and consumption growth, governments face lower interest rates. This finding is robust to the inclusion of the level of government debt and average residual inflation and consumption growth (column 2). This association is also robust to the inclusion of the variances of residual inflation and consumption growth as additional

Figure 2: Conditional correlation between inflation and consumption growth



regressors (columns 3). In the appendix, we also show that the results are robust to using different yield measures and different debt measures.

Table 1: Inflation consumption growth co-movement and real interest rates

	Real yield on government debt			
		covariance		correlation
	(1)	(2)	(3)	(4)
Inflation consumption co-movement	-1.80***	-1.64***	-1.80**	-1.06**
	(0.54)	(0.40)	(0.64)	(0.43)
Lagged government debt	0.02***	0.02***	0.02***	0.02***
	(0.01)	(0.00)	(0.00)	(0.00)
Average inflation residual		2.41**	2.14*	1.91*
		(0.99)	(1.02)	(0.93)
Average cons. growth residual		-1.75	-1.65	-1.52
		(1.07)	(1.04)	(1.08)
Variance of inflation residual			0.30	0.26
			(0.29)	(0.31)
Var. of cons. growth residual			-0.06	0.23*
			(0.18)	(0.12)
standard deviation of co-movement	0.17	0.17	0.17	0.21
adj. R^2	0.88	0.90	0.90	0.90
N	1726	1726	1726	1726

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses. Standard errors clustered by country. All regressions include country and time fixed effects. The data is a quarterly unbalanced panel from 1985Q1 to 2015Q4 including AUS, AUT, BEL, CAN, CHE, DEU, DNK, ESP, FIN, FRA, GBR, ITA, JAP, KOR,NLD, NOR, POR, SWE, USA. All variables are computed over a forward-looking ten-year window. The co-movement of inflation and consumption growth is measured as the covariance of residuals within that window: $\mathbf{cov}_t(\varepsilon_{\pi it}, \varepsilon_{git})$. Other regressors are averages and variances of those residuals in the window and lagged debt.

Overall, our results show that the co-movement of inflation and consumption growth are associated with lower real interest rates that governments face. We call this the *inflation procyclicality discount*. The magnitude of this discount is economically significant. As an illustration of its magnitude, consider moving from a country/time period in which the inflation/consumption correlation is around -0.3 (for example, the U.S. in the 1980s) to a sample period in which the correlation is around 0.1 (for example, the U.S. in the 2000s).

This roughly corresponds to a change in correlation equal to two times the standard deviation of correlation in our sample. Using the coefficient estimated in column (4) of Table 1, we can see that this increase in procyclicality is associated with a lowering of real rates by 42 basis points. Similarly, using the coefficient estimated in column (3) of Table 1, a fall in covariance that is twice as large as our sample standard deviation, is associated with a decrease in real rates by 61 basis points.

Table 2: Inflation procyclicality discount in good times

	Real yield on government debt		
	(1)	(2)	(3)
Good times measure		cons. growth	credit rating
Inflation consumption covariance	-1.80**		
	(0.64)		
Indicator(good times)		-0.23	0.26
		(0.23)	(0.19)
Interaction term (good times)		-2.99***	-2.70***
		(0.70)	(0.91)
Interaction term (bad times)		-1.16	-1.31
		(0.68)	(0.79)
Other controls	Yes	Yes	Yes
adj. R^2	0.90	0.91	0.93
N	1726	1726	1438

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses. Standard errors clustered by country. All regressions include country and time fixed effects. The data is a quarterly unbalanced panel from 1985Q1 to 2015Q4 including AUS, AUT, BEL, CAN, CHE, DEU, DNK, ESP, FIN, FRA, GBR, ITA, JAP, KOR, NLD, NOR, POR, SWE, USA. All variables are computed over a forward-looking ten-year window. The co-movement of inflation and consumption growth is measured as the covariance of residuals within that window: $\mathbf{cov}_t(\varepsilon_{\pi it}, \varepsilon_{git})$. Other regressors are averages and variances of those residuals in the window and lagged debt.

Our second main finding is that the procyclicality discount is a good times discount. This can be seen in Table 2 column (2), which includes an indicator for good times, defined to be a (10-year) window in which the average residual consumption growth is positive, and its interaction with the covariance of inflation and consumption growth. Column (2) shows that the interaction term is negative and statistically significant, while the interaction of covariance and an indicator for bad times (the complement of good times) is not statistically significant, implying that the inflation cyclicality discount is a good times discount. In column (3), we report similar results when the good times indicator is defined as a window in which the average credit rating is AAA, which is the sample median. In both cases, the good times interaction term is negative and statistically significant, while the bad times interaction term is smaller in magnitude and statistically insignificant.

Overall, we find that procyclical inflation episodes are associated with a significant discount on real sovereign yields albeit such ‘‘inflation procyclicality discount’’ vanishes in bad times. The standard consumption-based asset pricing model suggests that the hedging benefits of procyclical inflation rationalize an inflation procyclicality discount. However, the state-dependent nature of the procyclicality discount suggests that bad times are associated with additional credit risk, possibly default risk. From the government's perspective, inflation procyclicality is not desirable in bad times *ceteris paribus* and reduces the government's willingness to pay. In the next section, we develop a simple theory to understand the relation between the inflation-consumption growth co-movement, interest rates, and default.

3 Simple Model

In this section we highlight the main economic mechanism of this paper through a very simple two-period model of inflation and default, where equilibrium outcomes can be characterized using simple diagrams.

3.1 Simple model without default

Consider a two-period, one-good, closed economy with competitive lenders and borrowers. Both borrowers and lenders receive one unit of the good in the first period and an endowment of x in the second period, where x is a random variable with c.d.f. F over X, with finite support $X = [x_{\min}, x_{\max}]$ and $\mathbf{E}(x) = \mu$. The variable x here captures aggregate risk of the economy, to which both lenders and borrowers are exposed. We assume that the only difference between lenders and borrowers (i.e. motive to intertemporal trade) lies in their preferences. In particular, we assume that $\beta_\ell > \beta_b$ are the discount factors of lenders and borrowers, respectively. Lenders and borrowers can trade a nominal bond at price q today, which pays a nominal amount of 1 tomorrow. We normalize the current price level to 1, and assume that the future price level is given by $1 + \pi(x; \kappa) \equiv [1 + \kappa(\mu - x)]^{-1}$, where κ is the key parameter, capturing the cyclicality of inflation. If $\kappa > 0$, prices (and inflation) are procyclical, so the bond pays less in good states of the world (when x is high), while the reverse is true if $\kappa < 0$.

The borrower solves

$$\max_{b_b} u(1 + qb_b) + \beta_b \int_X v\left(x - \frac{b_b}{1 + \pi(x; \kappa)}\right) dF(x), \tag{2}$$

and the lender solves

$$\max_{b_\ell} u(1 - qb_\ell) + \beta_\ell \int_X v\left(x + \frac{b_\ell}{1 + \pi(x; \kappa)}\right) dF(x), \tag{3}$$

Notice that both borrowers and lenders act competitively so that they take the price of bonds as given. An equilibrium is then simply a bond price and bond quantities of borrowers and lenders such that, given prices, bond quantities are optimal for each agent and the bond market clears.

Theorem 1 shows that, under certain conditions, we can demonstrate an inflation cyclicality discount arising from the hedging benefits of inflation procyclicality.

Theorem 1. Inflation procyclicality discount

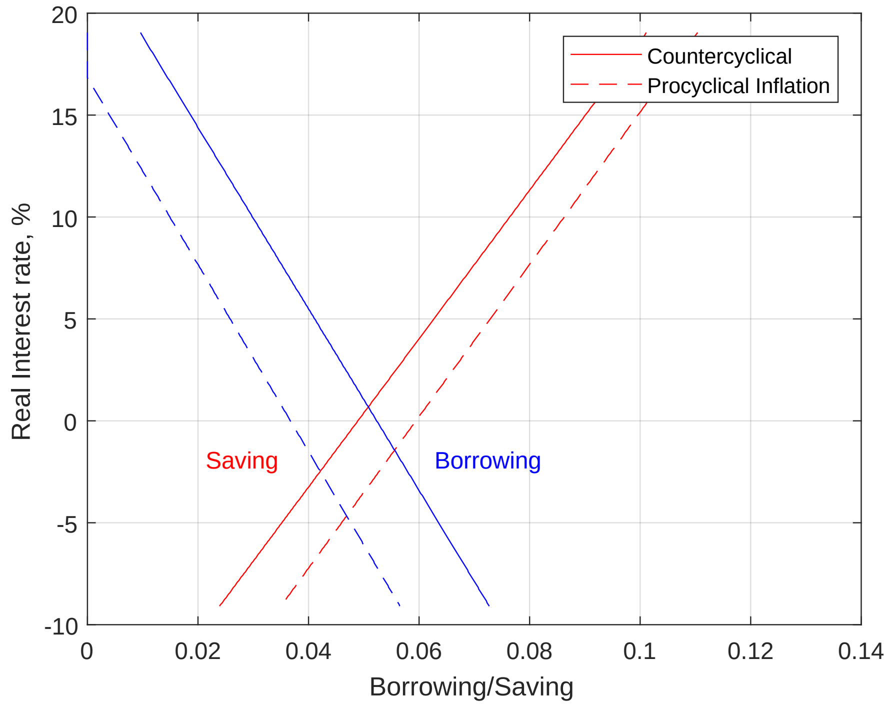
Assume that both borowers and lenders have quasilinear utility, i.e. $u(c) = Ac$ *and* $v(c) = Ac - \frac{\phi}{2}c^2$ *with* $\frac{A}{\phi} > \mu$*. There is an inflation procyclicality discount. That is,*

$$\frac{\partial q}{\partial \kappa} > 0. \tag{4}$$

Proof: See Appendix B.1.

Figure 3 provides some visual intuition for this result. The lines in the figure represent the desired supply of loans from the lender (increasing in the interest rate) and the desired demand for loans by the borrower (decreasing in the interest rate). The solid lines are supply and demand with countercyclical inflation, while the dashed lines are supply and demand

Figure 3: Interest rates and cyclicality of inflation



with procyclical inflation. Note that as inflation goes from counter to pro-cyclical the supply of loans increases, highlighting the hedging effect. While procyclical inflation makes debt less risky for the lender, the opposite is true for the borrower, and this results in the decrease in the demand for borrowing. Since supply increases and demand falls, the equilibrium interest rate unequivocally falls, while the equilibrium level of debt can move in either direction.

3.2 Simple model with default

Now consider the possibility that the nominal contract can be defaulted on. In particular, the borrower can default on its bond payments and if it does so, no payments are made and it incurs a cost $C(x) = \psi(x - x_{\min})^2$. As in Dubey et al. (2005), we keep the assumption of competitive borrowers, so they do not perceive that their borrowing decision affects the equilibrium interest rate they face. In this environment, there will be equilibrium default when default costs are below repayment, hence the default set $\widehat{X}$ is given by

$$x : C(x) < \frac{b_b}{1 + \pi(x;\kappa)} \tag{5}$$

which typically is an interval, i.e. default happens when income is low enough and when debt is high enough. The key observation is that in a world with default, the cyclicality of inflation can change the default set, thereby altering the hedging properties of bonds. Theorem 2 shows that, under certain regularity conditions, the default set $\widehat{X}$ increases with the level of debt (b_b) and the cyclicality of inflation (κ).

Theorem 2. Inflation procyclicality and default

Assume that $-(\mu - x_{\min})^{-1} < \kappa < (x_{\max} - \mu)^{-1}$. *For* ψ *large enough, there exists a unique threshold* $\widehat{x}(\kappa, b_b) \in [x_{\min}, \mu]$ *such that default occurs if and only if* $x \in [x_{\min}, \widehat{x}]$. *Furthermore, the default threshold is increasing in debt* (b_b) *and the cyclicality of inflation* (κ), *ceteris paribus. That is,*

$$\frac{\partial \widehat{x}(\kappa, b_b)}{\partial b_b} > 0 \tag{6}$$

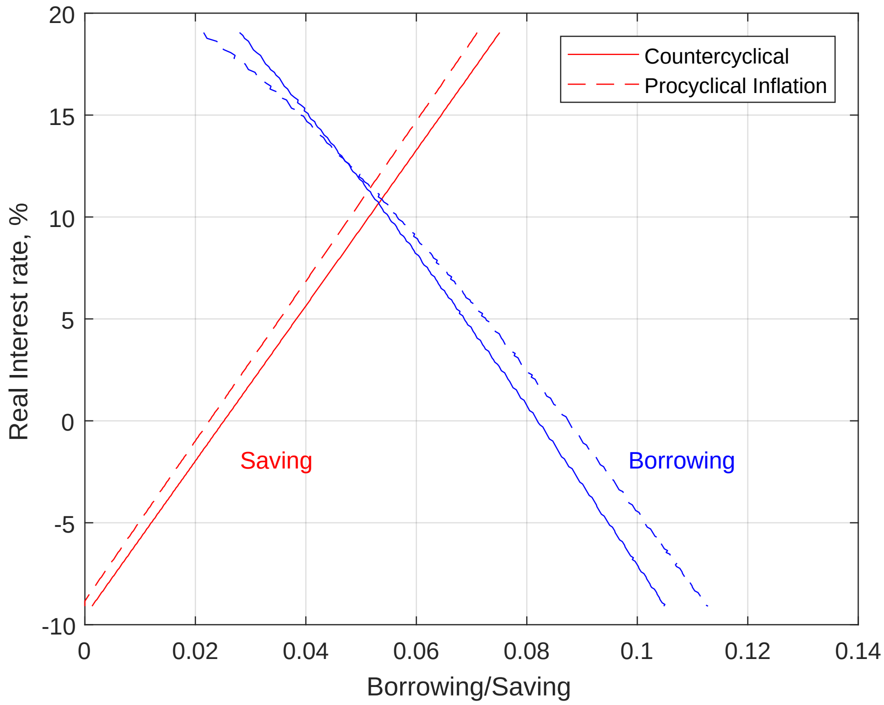
$$\frac{\partial \widehat{x}(\kappa, b_b)}{\partial \kappa} > 0. \tag{7}$$

Proof: See Appendix B.2.

Given this result we can then write the problem of the borrower as

$$\max_{b_b} u\left(1 + q b_b\right) + \beta_b \left(\underbrace{\int_{\widehat{x}(b_b,\kappa)}^{x_{\max}} v\left(x - \frac{b_b}{1 + \pi(x)}\right)}_{\text{Repayment}} + \underbrace{\int_{x_{\min}}^{\widehat{x}(b_b,\kappa)} v\left(x - C(x)\right)}_{\text{Default and suffer cost}} \right) dF\left(x\right) \tag{8}$$

Figure 4: Interest rates and cyclicality of inflation



The lender, taking as given the default threshold $\widehat{x}$, solves

$$\max_{b_\ell} u\left(1 - qb_\ell\right) + \beta_\ell \left(\underbrace{\int_{\widehat{x}}^{x_{\max}} u\left(x + \frac{b_\ell}{1+\pi(x)}\right)}_{\text{Repayment}} + \underbrace{\int_{x_{\min}}^{\widehat{x}} u\left(x\right)}_{\text{Defaulted on}} \right) dF\left(x\right). \tag{9}$$

In the model with default, changes in covariance lead to changes not only to quantities but also to the default threshold, complicating the analysis. Thus, to gain further intuition, we utilize a numerical illustration. Figure 4 shows that, unlike the model without default in which higher inflation procyclicality unequivocally reduced interest rates, in the model with default, higher inflation procylicality can increase real rates. This is because countercyclical inflation, which implies low repayments in bad states, is substitute with default, while procyclical inflation, which implies high repayments in bad states, is complement with default. Thus, a country following procyclical inflation will face a lower interest rate if not at default risk, but might face a sudden spike in rates in bad times. This simple model motivates our quantitative model, in which the cyclicality of inflation is a key driver of real sovereign yields, nominal debt dynamics, and default risk.

4 Quantitative Model

We extend the standard sovereign default model of Eaton and Gersovitz (1981) and Arellano (2008) in two dimensions: exogenous *inflation* and domestic *risk-averse lenders*.

Environment Time is discrete and indexed by $t = 0, 1, 2, ...$ The exogenous states of the world are given by $s = (y, \pi, k)$ where the aggregate endowment y and inflation π follow a joint Markov process and $k \in \{L, H\}$ indexes the default cost regime. The economy is populated by a continuum of lenders and a government. The government receives a constant fraction τ of the aggregate endowment y. The government values government expenditure according to

$$E_0 \sum_{t=0}^{\infty} \beta_g^t \frac{g_t^{1-\gamma_g}}{1-\gamma_g} \tag{10}$$

where $0 < \beta_g < 1$ is the discount factor, g_t is government expenditure at time t, and γ_g is the risk aversion of the government.

Lender preferences As in Arellano (2008), Bocola and Dovis (2016), and Hatchondo et al. (2016), the lenders value flows using a stochastic discount factor $m(y_t, y_{t+1})$, and thus value a sequence of payments $\{x_t\}_{t=0}^{\infty}$ by

$$E_0 \sum_{t=0}^{\infty} m_{0t} x_t \tag{11}$$

where $m_{0t} = \Pi_{j=0}^{t} m_{j-1,j}$.

We assume that $m_{t,t+1}$ takes the form

$$m_{t,t+1} = \beta_\ell \left(\frac{y_{t+1}}{y_t}\right)^{-1} \left(\frac{W_{t+1}^{1-\gamma_\ell}}{\mathbf{E}_t\left[W_{t+1}^{1-\gamma_\ell}\right]}\right) \tag{12}$$

where β_ℓ and γ_ℓ can be interpreted as the lender's discount factor and risk aversion, respectively, and W_t is defined recursively as

$$\log W_t = (1 - \beta_\ell) \log y_t + \frac{\beta_\ell}{1 - \gamma_\ell} \log \left(E_t \left[W_{t+1}^{1-\gamma_\ell} \right] \right). \tag{13}$$

Thus, the lender's stochastic discount factor is derived from recursive preferences as in Epstein and Zin (2013) and Weil (1989).

Market structure. The government has access to debt markets in which it issues noncontingent bonds to the domestic lenders. Bonds are risky because debt contracts are not enforceable, which may lead to government default, and also because they may lose value due to exogenous inflation.

For tractability, bonds are assumed to mature with probability δ, as in Arellano and Ramanarayanan (2012), Hatchondo and Martinez (2009), and Chatterjee and Eyigungor (2013). Setting $\delta = 1$ corresponds to the model with one-period debt and $\delta = 0$ corresponds to the model with consols.

Recursive equilibrium. Given the option to default, $V^o(B, s)$ satisfies

$$V^o(B, s) = \max_{c,d} \left\{ V^c(B, s), V^d(B, s) \right\} \tag{14}$$

where B is incoming government assets, V^c is the value of not defaulting, and V^d is the value of default.

When the government defaults, it defaults on all existing debt, in which case the government is excluded from debt markets for a stochastic number of periods and revenue may fall. During this time, no debt payments are paid. Upon reentry, after k periods, the government's debt obligation is $-\lambda^k B$ where $1 - \lambda$ is the rate at which the government's debt obligation decays each period. This tractable way of modeling partial default is also consistent with the fact that longer default episodes are associated with lower recovery rates, as documented by Benjamin and Wright (2009). Setting $\lambda = 0$ corresponds to the model with full default.

The government's value of default is then given by

$$V^d(B,s) = u_g\left(\tau(y-\phi^d(y,k))\right) + \beta_g \mathbf{E}_{s'|s}\left[\theta V^o\left(\frac{\lambda B}{1+\pi'}, s'\right) + (1-\theta)V^d\left(\frac{\lambda B}{1+\pi'}, s'\right)\right] \quad (15)$$

where $0 < \theta < 1$ is the probability that the government will regain access to credit markets, and $\phi^d(y)$ is the loss in income during default. In particular, we assume a quadratic function

$$\phi^d(y,k) = d_1(k)\max\left\{0, \frac{1}{d_0}y + \left(1-\frac{1}{d_0}\right)y^2\right\}, \quad (16)$$

similar to Chatterjee and Eyigungor (2013), except that the expression has been written such that d_1 is the default cost at mean output ($y=1$) and d_0 determines the output threshold above which the default costs are positive. $k \in \{H, L\}$ governs the magnitude of default costs with $d_1(H) > d_1(L)$.

The value of not defaulting, is given by

$$V^c(B,s) = \max_{B'\le 0}\left\{\begin{array}{l} u\left(\tau y - q(s,B')\left(B'-(1-\delta)B\right) + B(r+\delta)\right) \\ +\beta_g \mathbf{E}_{s'|s}\left[V^o\left(\frac{B'}{1+\pi'}, s'\right)\right] \end{array}\right\} \quad (17)$$

where $q(s,B')$ is the bond price schedule the government faces. Note that the real return on government debt is stochastic, even in the absence of default, due to inflation risk.

In this environment, the bond price schedule satisfies

$$\begin{aligned} q(s,B') &= \mathbf{E}_{s'|s}\left[\frac{1-d'}{1+\pi'}\left(r+\delta+(1-\delta)q\left(s',B''\right)\right)m(s,s')\right] \\ &\quad +\mathbf{E}_{s'|s}\left[\frac{d'}{1+\pi'}q^{def}\left(\frac{B'}{1+\pi'}, s'\right)m(s,s')\right] \end{aligned} \quad (18)$$

where d' and B'' are the optimal default and debt decisions given the state $(\frac{B'}{1+\pi'}, s')$, and q^{def} is the price of a bond in default and is given by

$$\begin{aligned} q^{def}(B,s) &= \lambda\mathbf{E}_{s'|s}\left[\frac{\theta(1-d')}{1+\pi'}\left(r+\delta+(1-\delta)q\left(s',B''\right)\right)m(s,s')\right] \\ &\quad +\lambda\mathbf{E}_{s'|s}\left[\frac{1-\theta+\theta d'}{1+\pi'}q^{def}\left(\frac{\lambda B}{1+\pi'}, s'\right)m(s,s')\right]. \end{aligned} \quad (19)$$

where d' and B'' are the optimal default and debt decisions given the state $(\frac{\lambda B}{1+\pi'}, s')$,

Definition The *recursive equilibrium* for this economy is defined as value functions for the government $\{V^o, V^c, V^d\}$, the associated policy functions $\{B', d\}$, and a pricing function q such that $\{V^o, V^c, V^d, B', d\}$ solve the government's problem in (14), (15), and (17) and q satisfies (18).

Real bond price and spread It is convenient to define the real bond price as

$$\begin{aligned} \widehat{q}(s, B') \quad &= \quad \mathbf{E}_{s'|s}\left[(1-d')\frac{1+\bar{\pi}(s)}{1+\pi'}\left(r+\delta+(1-\delta)\widehat{q}\left(s', B''\right)\right)m(y,y')\right] \\ &\quad +\mathbf{E}_{s'|s}\left[d'\frac{1+\bar{\pi}(s)}{1+\pi'}\widehat{q}^{def}\left(\frac{B'}{1+\pi'}, s'\right)m(y,y')\right] \end{aligned} \tag{20}$$

where lenders adjust for expected inflation, defined as $1+\bar{\pi}(s) \equiv 1/\mathbf{E}_{s'|s}\left[\frac{1}{1+\pi(s')}\right]$. As before, d' and B'' are the optimal default and debt decisions given the state $\left(\frac{B'}{1+\pi'}, s'\right)$, and the real price of a bond in default $\widehat{q}^{def}$ is similarly given by

$$\begin{aligned} \widehat{q}^{def}(B, s) \quad &= \quad \lambda\mathbf{E}_{s'|s}\left[\theta(1-d')\frac{1+\bar{\pi}(s)}{1+\pi'}\left(r+\delta+(1-\delta)\widehat{q}\left(s', B''\right)\right)m(y,y')\right] \\ &\quad +\lambda\mathbf{E}_{s'|s}(1-\theta+\theta d')\left[\frac{1+\bar{\pi}(s)}{1+\pi'}\widehat{q}^{def}\left(\frac{\lambda B}{1+\pi'}, s'\right)m(y,y')\right] \end{aligned} \tag{21}$$

where d' and B'' are the optimal default and debt decisions given the state $\left(\frac{\lambda B}{1+\pi'}, s'\right)$.

In the special case where $\lambda = 0$ and $\delta = 1$, we can express the spread as

$$\begin{aligned} \mathrm{spr}_t \equiv \frac{q_t^{RF} - \widehat{q}_t}{q_t^{RF}} = &\underbrace{\Pr_t\left[d_{t+1} = 1\right]}_{\text{default premium}} \\ &+ \mathbf{cov}_t\left[\frac{m_{t,t+1}}{\bar{m}_{t,t+1}}, d_{t+1}\right] \\ &+ \mathbf{cov}_t\left[\frac{1+\bar{\pi}_{t,t+1}}{1+\pi_{t+1}}, d_{t+1}\right] \\ &\underbrace{- \Pr_t\left[d_{t+1} = 0\right]\mathbf{cov}_t\left[\frac{m_{t,t+1}}{\bar{m}_{t,t+1}}, \frac{1+\bar{\pi}_{t,t+1}}{1+\pi_{t+1}}\right]}_{\text{procyclicality discount}}. \end{aligned} \tag{22}$$

where the risk-free price is defined as the price of a non-defaultable real bond, which is $q^{RF}(s) \equiv \mathbf{E}_{s'|s}\left[\left(\delta + r + (1-\delta)q^{RF}(s')\right) m(y, y')\right]$. The first two terms reflect the probability of default and the compensation for countercyclical default — effects which are standard but are now endogenous to the cyclicality of inflation. The third term compensates lenders for default risk being positively correlated with surprise deflation (high returns). Finally, the last term reflects the comovement between surprise inflation and surprise output growth.

Overall, equation (22) elicits the intuition from the simple model: the cyclicality of inflation in a model with domestic default entails various endogenous channels including, but not limited to, an endogenous default risk and the standard hedging argument. The interplay between these channels also vary over the cycle: inflation procyclicality is likely to be associated with a discount when default risk is low, but not in bad times as default motives are increased with inflation procyclicality. We turn to a quantitative analysis of these forces in the next section and use the model to assess the implications of the ‘‘inflation procyclicality discount’’ we documented.

5 Quantitative analysis

In this section, we use a calibrated version of the model to investigate the role of the inflation process on the dynamics of interest rates, debt, and default crises. We first calibrate the model with zero covariance to generate reasonable default probabilities for advanced economies. We then use the covariance estimates from section 2 to assess the impact of different inflation processes on interest rates, debt dynamics, and default crises.

5.1 Functional forms and calibration

Income and inflation processes Endowments y and inflation π follow a joint process:

$$\begin{bmatrix} \log y' \\ \pi' \end{bmatrix} = \begin{bmatrix} \rho_{y,y} & \rho_{\pi,y} \\ \rho_{y,\pi} & \rho_{\pi,\pi} \end{bmatrix} \begin{bmatrix} \log y \\ \pi \end{bmatrix} + \begin{bmatrix} \epsilon_y \\ \epsilon_\pi \end{bmatrix} \tag{23}$$

where

$$\begin{bmatrix} \epsilon_y \\ \epsilon_\pi \end{bmatrix} \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \sigma_y^2 & \sigma_{\pi,y} \\ \sigma_{\pi,y} & \sigma_\pi^2 \end{bmatrix} \right).$$

Note that since we consider a closed economy environment, output in our model is equal to consumption. We set the persistence of output $\rho_{y,y}$ to 0.8, the persistence of inflation $\rho_{\pi,\pi}$ to 0.8, the spillover terms $\rho_{y,\pi}$ and $\rho_{\pi,y}$ to zero, and both variance terms σ_y and σ_π to 0.010 based on the parameters estimated for the cross section of OECD economies in our dataset. Table 9 in appendix A contains the detailed estimates by country. We consider two values for the covariance of inflation and output $\sigma_{\pi,y}$: $+0.255e^{-4}$ and $-0.255e^{-4}$, which generate a 1.5 standard deviation increase and decrease from the median of the covariance of inflation and consumption residuals computed at 10-year windows, which is close to zero.

Default cost regime switching Next, we calibrate the regime switching process. We assume the default cost regimes $d_1(k)$ follow a Markov switching process with transition matrix

$$P = \begin{bmatrix} p_H & 1-p_H \\ 1-p_L & p_L \end{bmatrix}.$$

We estimate the persistence parameters using spreads relative to German bonds from the subsample of our dataset covering Eurozone countries between 1999 and 2015.[8] We estimate p_H and p_L as the persistence of low spreads and high spreads respectively. We define the cutoff for high and low spreads to capture material changes in the nature of sovereign credit risk. In our benchmark calibration, low spreads and high spreads are defined to be below and above 200 basis points respectively. The estimation yields $p_H = 0.992$ and $p_L = 0.909$.[9]

Preferences We set the discount factor β_ℓ of the lender to be 0.99 to match an implied risk-free rate of 4 percent. We set the lender's risk aversion γ_ℓ to be 59, following Hatchondo et al. (2016). This higher level of risk aversion of the lender is also common in the finance and equity premium puzzle literature (for example, see Bansal and Yaron 2004 and Mehra

[8]Sovereign spreads are computed by subtracting the German nominal rate from the nominal rates of the Eurozone economies in our dataset over the same period.

[9]We present the robustness of our results to changes in this definition in the appendix.

and Prescott 1985). We set the government's risk aversion γ_g to be 2, as is standard in the macro and sovereign debt literature.

Jointly calibrated parameters We jointly choose the mean income loss parameters $d_1(H) = 0.20$ and $d_1(L) = 0.16$ along with the government's discount factor $\beta_g = 0.9875$ to match countercyclical default risk targets across the two default cost regimes.

Specifically, we choose these parameters so that the acyclical economy has (i) an overall default probability of 0.2 percent, (ii) a conditional default probability of 0.3 percent when output is below average in the high default cost regime H, and (iii) a conditional default probability of 0.8 percent when output is below average in the low default cost regime L. By comparison, a standard emerging economy calibration features an unconditional default risk of around 2 percent.[10]

Other externally calibrated parameters We set the default cost parameter $d_0 = -0.0275$, which corresponds to an output threshold of 1.5 standard deviations below mean, above which the default cost is positive. We show in Table 11 of Appendix C that the main results are robust to alternative values. We set δ to be 0.054 to match the average debt maturity of 4.6 years in our sample (1999–2010). We set the tax rate τ to be 19 percent to match the government consumption share of GDP in OECD economies between 1985 and 2015. The probability of re-entry θ is set to match the average exclusion of 10 quarters as documented by Richmond and Dias (2008) and the recovery parameter λ is set to be consistent with the average recovery rate of 50 percent reported by Benjamin and Wright (2009). To compute the average recovery rate, we take the following steps. First, we consider a default to be over when the government regains access to credit, which on average lasts 10 quarters. Second, we discount the payment back to the period of default by an annualized interest rate of 10 percent as in Benjamin and Wright (2009). A summary of our parameters can be found in Table 3.

[10]See for example Aguiar et al. (2016) for a benchmark calibration for emerging economies.

Table 3: Calibration – Baseline economy with acyclical inflation

Parameters	Values	Targets / Source
Gov't discount factor β_g	0.988	Unconditional default probability: 0.2 percent
Default cost at mean $d_1(H)$	0.200	Bad times def. prob. in $H-$regime: 0.3 percent
Default cost at mean $d_1(L)$	0.160	Bad times def. prob. in $L-$regime: 0.8 percent
Lender discount factor β_ℓ	0.990	Risk-free rate: 4 percent
Lender risk aversion γ_ℓ	59	Hatchondo et al. (2016)
Gov't risk aversion γ_g	2	Hatchondo et al. (2016)
Default cost threshold d_0	-0.028	Sensitivity analysis in Appendix C
Probability of re-entry θ	0.100	Average exclusion: 10 quarters†
Recovery parameter λ	0.960	Average recovery rate: 50 percent‡
Tax rate τ	0.193	Government consumption (percent GDP)
Debt maturity δ	0.054	OECD average maturity: 4.6 years
Persistence of $H-$regime p_H	0.992	Persistence of low Eurozone spreads
Persistence of $L-$regime p_L	0.909	Persistence of high Eurozone spreads
Persistence $\rho_{y,y} = \rho_{\pi,\pi}$	0.800	VAR estimates (OECD cross section)
Spillovers $\rho_{\pi,y} = \rho_{y,\pi}$	0.000	VAR estimates
Volatility $\sigma_y = \sigma_\pi$	0.010	VAR estimates
Covariance of innovations $\sigma_{\pi,y}$	0.000	Acyclical baseline $\pm$1.5 s.d. $= \pm$0.255e-4

$\dagger$: See Richmond and Dias (2008). $\ddagger$: See Benjamin and Wright (2009).

Table 4: Baseline results on the procyclicality discount, default risk and debt

	Positive co-movement (+1.5 s.d.)	Negative co-movement (–1.5 s.d.)	Difference
Spreads (percent)	1.25	1.64	–0.39
Default probability (percent)	0.24	0.15	+0.09
Public debt (percent of tax receipts)	63.9	69.7	–5.79

5.2 Quantitative Results

Using the calibrated model, we contrast two default cost regimes and two inflation regimes: a procyclical economy and a countercyclical economy, which correspond to a covariance of inflation and consumption innovations of 1.5 standard deviations above and below zero respectively. The main goal of this exercise is to quantitatively explore the differences between the two inflation regimes and how these differences change with and without material default risk.

Baseline unconditional results First, we present the results from our calibrated benchmark model. In Table 4, we show the equilibrium interest rates, debt, and default risk across inflation regimes. We find that, relative to its countercyclical counterpart, the procyclical economy faces spreads which are 39 basis points lower. Such "procyclicality discount" represents about 40 percent of the discount estimated in the empirical section. Despite such a sizable discount, the procyclical economy is marginally more prone to debt crises and sustains lower debt burdens compared the countercyclical economy.

Baseline results: good versus bad times Moreover, the procyclicality discount is state-contingent as in the data. We first report the spreads and default probabilities in the high default cost regime, conditional on good and bad times, defined as when output is above and below average, respectively. In good times, default risk is immaterial — default probabilities are near-zero — and the conditional procyclical discount is about 85 basis points, 45 basis points larger than the unconditional procyclicality discount. However, in bad times, countercyclical default risk spikes more in the procyclical economy compared to the countercyclical

Table 5: State-contingent procyclicality discount and debt crises under high default costs

	Positive co-movement (+1.5 s.d.)	Negative co-movement (–1.5 s.d.)	Difference
Spreads (high default cost regime)			
in good times (pct)	0.58	1.43	–0.85
in bad times (pct)	1.79	1.77	+0.02
Default prob. (high default cost regime)			
in good times (pct)	0.00	0.00	–0.00
in bad times (pct)	0.40	0.26	+0.15

economy. Even though both economies feature near-zero default risk in good times, default risk spikes to 0.40 percent in bad times in the procyclical economy, about 0.15 percentage points more than the default risk increase in the countercyclical economy. This result contrasts the 'complementarity' of inflation and default in the procyclical economy as opposed to the 'substitution' of inflation and default under countercyclical inflation. Altogether, in bad times, there is no procyclicality discount. In fact, relative to its countercyclical counterpart, spreads are 2 basis points higher in the procyclical economy. We summarize these findings in Table 5.

Baseline results: when default risk is material The previous results highlighted the offsetting nature of the procyclicality hedging discount and default incentives. This effect is even stronger in the low default costs regime because it features relatively more material default risk in bad times. For instance, in bad times, in the low default cost regime, default risk is 0.89 percent in the procyclical economy and about 0.62 percent in the countercyclical economy. This larger default probability more than offsets the sizable good-times procyclicality discount, leading to a 'procylicality premium' of 35 basis points.

Discussion In good times, default risk is immaterial, and the procyclical economy enjoys a large discount, regardless of the default cost regime. However, in bad times, the procyclical economy faces a larger increase in default risk, and can face a premium relative to its countercyclical counterpart, especially in the low default cost regime.

The main finding of stronger procyclical discount in good times is qualitatively robust

Table 6: State-contingent procyclicality discount and debt crises under low default costs

	Positive co-movement (+1.5 s.d.)	Negative co-movement (–1.5 s.d.)	Difference
Spreads (low default cost regime)			
in good times (pct)	0.86	1.68	–0.83
in bad times (pct)	2.68	2.33	+0.35
Default prob. (low default cost regime)			
in good times (pct)	0.00	0.00	0.00
in bad times (pct)	0.92	0.64	+0.28

to alternative preferences, risk aversion, debt maturity, and regime switching assumptions. However, these assumptions are important quantitatively. The good-times procyclical discount is increasing in risk aversion and debt maturity, and is smaller in single default cost regimes. We show that the good times procyclicality discount is robust to using constant relative risk aversion (CRRA) utility, but in this case the calibrated economy features very volatile risk-free rates.

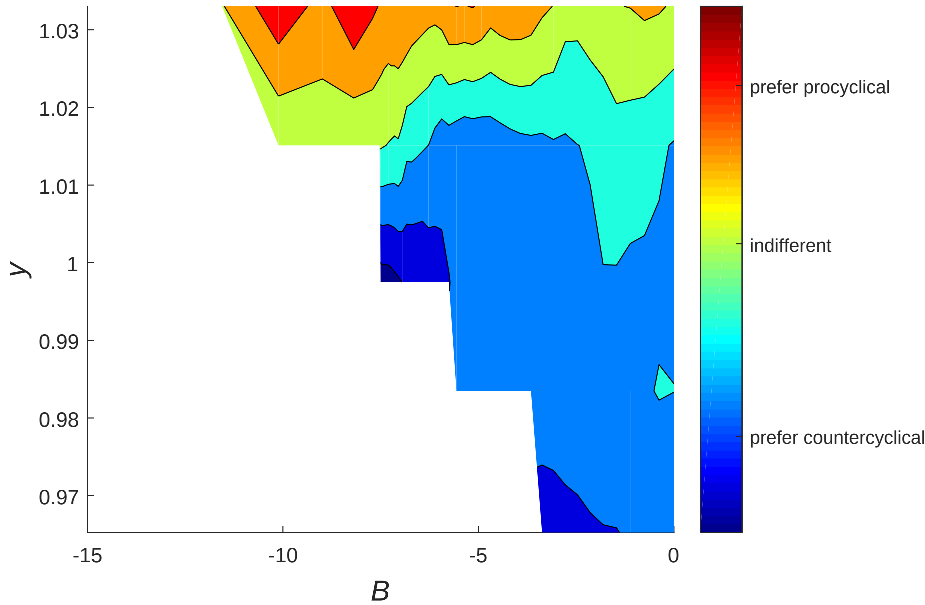
5.3 When is procyclicality preferred?

Since the effect of inflation cyclicality on default and interest rates is state-dependent, it is useful to discuss when the government prefers a procyclical regime. In Figure 5, panel (a) shows which cyclicality regime the government prefers across different states of incoming debt and inflation-output realizations. Panel (b) in Figure 5 shows the lenders' welfare ranking of the inflation cyclicality regimes.

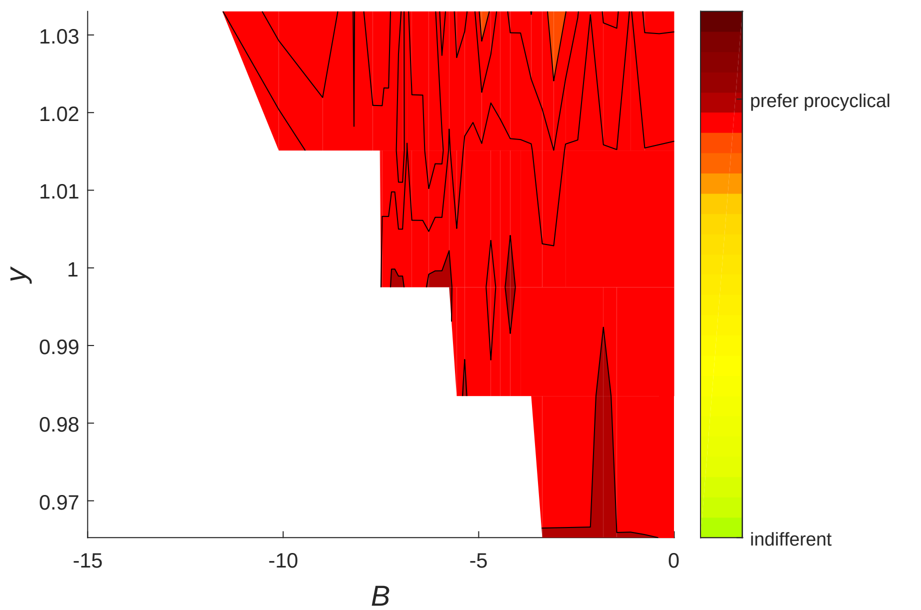
Figure 5 reveals that the government typically prefers the countercyclical regime, especially in bad states of the world and with high debt. The government only prefers procyclicality in good states of the world. Despite offering overall lower interest rates, the procyclical inflation regime is not always preferred by the government. This is consistent with the endogenous state- and regime-dependent default premium present in this model. In contrast, the lenders prefer inflation procyclicality almost everywhere, especially in bad states of the world. The lenders' preference for procyclicality align with the government's only in good states of the world.

Figure 5: Welfare comparison of cyclicality regimes across states

(a) Government



(b) Lender



6 Conclusion

The goal of this paper was to investigate how inflation cyclicality affects borrowing costs, and debt and default dynamics. Empirically, we documented that the co-movement of inflation innovations and consumption growth innovations fluctuates over time across a large number of advanced countries. Moreover, we find that increased co-movement of inflation and consumption growth is associated with lower borrowing costs, especially in good times. Theoretically, we showed that the inflation processes — especially inflation cyclicality — can be important in explaining interest rates and the dynamics of default. In particular, in our benchmark calibration, the procyclical inflation economy faces lower borrowing costs, even as default is more likely. However, when the economy deteriorates, the procyclical economy faces a much higher likelihood of facing a debt crisis, because it is more likely to face lower inflation, possibly even deflation, and thus an increasing real debt burden. Our findings have implications for the debate on the costs and benefits of joining or exiting monetary unions. Our findings also suggest a new channel, the interaction of monetary policy and interest rates in the presence of sovereign credit risk, that can help understand the secular decline in real rates.

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Appendix

A Additional Tables

Table 7: Sensitivity to yield measure

	Real yield on government debt		
	(1)	(2)	(3)
Yield Source	IFS	Fame 5-year	Fame 10-year
Inflation consumption covariance	-1.80**	-1.45	-1.49
	(0.64)	(0.92)	(1.12)
Other controls	Yes	Yes	Yes
adj. R^2	0.90	0.89	0.92
N	1726	1140	1389

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses. Standard errors clustered by country. All regressions include country and time fixed effects. The data is a quarterly unbalanced panel from 1985Q1 to 2015Q4 including AUS, AUT, BEL, CAN, CHE, DEU, DNK, ESP, FIN, FRA, GBR, ITA, JPN, KOR, NLD, NOR, PRT, SWE, USA. All variables are computed over a forward-looking ten-year window. The co-movement of inflation and consumption growth is measured as the covariance of residuals within that window: $\mathbf{cov}_t(\varepsilon_{\pi it}, \varepsilon_{git})$. Other regressors are averages and variances of those redisuals in the window and lagged debt.

Table 8: Sensitivity to debt measure

	Real yield on government debt			
	(1)	(2)	(3)	(4)
Debt Source	Oxford+OECD	OECD	Oxford	OECD+Oxford
Inflation consumption co-movement	-1.80**	-1.35	-1.82***	-1.67**
	(0.64)	(1.59)	(0.56)	(0.64)
Other controls	Yes	Yes	Yes	Yes
adj. R^2	0.90	0.82	0.91	0.91
N	1726	918	1556	1731

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses. Standard errors clustered by country. All regressions include country and time fixed effects. The data is a quarterly unbalanced panel from 1985Q1 to 2015Q4 including AUS, AUT, BEL, CAN, CHE, DEU, DNK, ESP, FIN, FRA, GBR, ITA, JPN, KOR, NLD, NOR, PRT, SWE, USA. All variables are computed over a forward-looking ten-year window. The co-movement of inflation and consumption growth is measured as the covariance of residuals within that window: $\mathbf{cov}_t(\varepsilon_{\pi it}, \varepsilon_{git})$. Other regressors are averages and variances of those redisuals in the window and lagged debt.

Table 9: VAR results

country	$\rho_{\pi\pi}$	$\rho_{c\pi}$	$\rho_{\pi c}$	ρ_{cc}	σ_c	σ_π	$\sigma_{\pi,c}$
USA	0.93	0.06	-0.10	0.86	0.17	0.34	0.00
AUS	0.82	0.10	-0.02	0.67	0.67	0.54	0.07
AUT	0.82	0.04	-0.10	0.65	0.27	0.43	0.00
BEL	0.85	0.02	-0.04	0.77	0.33	0.33	0.00
CAN	0.75	0.18	-0.02	0.72	0.63	0.42	0.06
CHE	0.90	0.09	-0.02	0.83	0.27	0.29	0.01
DEU	0.85	0.10	-0.15	0.49	0.32	0.53	0.02
DNK	0.56	-0.05	-0.25	0.71	0.56	0.66	0.02
ESP	0.87	0.01	-0.04	0.91	0.34	0.59	0.01
FIN	0.67	0.12	-0.01	0.87	0.65	0.73	0.05
FRA	0.89	0.10	-0.18	0.67	0.22	0.32	-0.01
GBR	0.83	0.09	-0.11	0.83	0.56	0.51	-0.06
ITA	0.67	-0.03	-0.01	0.88	0.61	0.44	-0.01
JPN	0.92	0.10	-0.26	0.48	0.37	0.70	-0.11
KOR	0.69	0.10	-0.30	0.81	0.97	1.24	-0.32
NLD	0.67	0.04	-0.05	0.85	0.53	0.44	0.00
NOR	0.81	0.14	-0.02	0.68	1.79	0.80	-0.02
PRT	0.88	-0.04	0.02	0.89	0.68	0.71	-0.02
SWE	0.75	-0.12	-0.02	0.75	0.72	0.52	0.09
average	0.80	0.04	-0.08	0.76	0.56	0.57	-0.01
median	0.82	0.06	-0.04	0.77	0.52	0.56	0.00
min	0.56	-0.12	-0.30	0.48	0.29	0.17	-0.32
max	0.93	0.18	0.02	0.92	1.24	1.79	0.09

The data is a quarterly panel from 1985Q1 to 2015Q4.

B Proofs

B.1 Proof of Theorem 1

Theorem 1. Inflation procyclicality discount

Assume that both borowers and lenders have quasilinear utility, i.e. $u(c) = Ac$ *and* $v(c) = Ac - \frac{\phi}{2}c^2$ *with* $\frac{A}{\phi} > \mu$. *There is an inflation procyclicality discount. That is,*

$$\frac{dq(\kappa)}{d\kappa} > 0.$$

Proof:

Lender. The lender's first order condition is given by

$$-qu'(1-qb)+\beta_\ell \mathbf{E}\left[v'\left(x+\frac{b}{1+\pi(x;\kappa)}\right)\frac{1}{1+\pi(x;\kappa)}\right]=0 \tag{24}$$

which can be written as

$$qA=\beta_\ell\left[A-\phi(\mu+b)+\phi\kappa\sigma^2-\phi b\kappa^2\sigma^2\right]. \tag{25}$$

Rearranging terms in equation (25) yields the optimal debt supply:

$$b_\ell(q;\kappa)=\frac{-\frac{A}{\phi}q+\beta_\ell\left(\frac{A}{\phi}-\mu+\kappa\sigma^2\right)}{\beta_\ell\left(1+\kappa^2\sigma^2\right)} \tag{26}$$

Borrower. The borrower's first order condition is given by

$$qu'(1+qb)+\beta_b \mathbf{E}\left[u'\left(x-\frac{b}{1+\pi(x;\kappa)}\right)\frac{1}{1+\pi(x;\kappa)}\right]=0 \tag{27}$$

which can be written as

$$qA=\beta_b\left[A-\phi(\mu-b)+\phi\kappa\sigma^2+\phi b\kappa^2\sigma^2\right]. \tag{28}$$

Hence, the optimal debt demand is given by

$$b_b(q;\kappa)=\frac{\frac{A}{\phi}q-\beta_b\left(\frac{A}{\phi}-\mu+\kappa\sigma^2\right)}{\beta_b\left(1+\kappa^2\sigma^2\right)}. \tag{29}$$

Inflation Procylicality Discount. The market clearing condition is

$$b_\ell(q;\kappa)=b_b(q;\kappa). \tag{30}$$

Substituting equations (26) and (29), and rearranging terms, we obtain

$$q=\frac{\phi}{A}\frac{2\beta_b\beta_\ell}{\beta_b+\beta_\ell}\left(\frac{A}{\phi}-\mu+\kappa\sigma^2\right) \tag{31}$$

Finally, taking the derivative with respect to κ, we obtain the desired result. $\square$

B.2 Proof of Theorem 2

Theorem 2. Inflation procyclicality and default

Assume that $-(\mu - x_{\min})^{-1} < \kappa < (x_{\max} - \mu)^{-1}$. *For* ψ *large enough, there exists a unique threshold* $\widehat{x}(\kappa, b_b) \in [x_{\min}, \mu]$ *such that default occurs if and only if* $x \in [x_{\min}, \widehat{x}]$. *Furthermore, the default threshold is increasing in debt* (b_b) *and the cyclicality of inflation* (κ), *ceteris paribus. That is,*

$$\frac{\partial \widehat{x}(\kappa, b_b)}{\partial b_b} > 0 \tag{32}$$

$$\frac{\partial \widehat{x}(\kappa, b_b)}{\partial \kappa} > 0. \tag{33}$$

Proof: The borrower defaults when the cost of default is less than cost of repayment, i.e. when

$$C(x) \leq b_b [1 + \pi(x; \kappa)]^{-1}$$

or

$$C(x)[1 + \pi(x; \kappa)] \leq b_b. \tag{34}$$

The proof proceeds in the following steps. First, we show that if a solution exists, it is unique. Second, we show that the unique threshold is increasing in debt and the cyclicality of inflation.

Existence and uniqueness. If a solution exists, it is unique if the left hand side of (34) is strictly increasing,

$$C_x [1 + \pi(x; \kappa)] + C(x) \pi_x(x; \kappa) > 0. \tag{35}$$

We know that

$$\begin{aligned}
\pi\left(x;\kappa\right) &= \frac{-\kappa\left(\mu-x\right)}{1+\kappa\left(\mu-x\right)} \\
\Rightarrow \pi_x\left(x;\kappa\right) &= \frac{\kappa+\kappa\pi\left(x;\kappa\right)}{1+\kappa\left(\mu-x\right)} \\
&= \kappa[1+\pi\left(x;\kappa\right)]^2
\end{aligned}$$

Condition (35) then becomes

$$C_x > -C\left(x\right)\kappa\left[1+\pi\left(x;\kappa\right)\right]$$

which holds since

$$\begin{aligned}
& C_x > -C\left(x\right)\kappa\left[1+\pi\left(x;\kappa\right)\right] \\
\Leftrightarrow & 2\psi\left(x-x_{\text{min}}\right) > -\psi(x-x_{\text{min}})^2\kappa\left[1+\pi\left(x;\kappa\right)\right] \\
\Leftrightarrow & 2\left[1+\kappa\left(\mu-x\right)\right] > -\left(x-x_{\text{min}}\right)\kappa \\
\Leftrightarrow & \kappa\left(\mu-\frac{x+x_{\text{min}}}{2}\right) > -1 \\
\Leftarrow & \frac{-1}{\mu-x_{\text{min}}} < \kappa < \frac{1}{x_{\text{max}}-\mu}
\end{aligned}$$

Hence if a solution exists, it is unique. Since $C(x)$ is continuous, by the intermediate value theorem, a solution exists in $x \in [x_{\text{min}}, \mu]$ if

$$C\left(x_{\text{min}}\right)\left[1+\pi\left(x_{\text{min}};\kappa\right)\right] \leq 0,$$

which holds since $C(x_{\text{min}}) = 0$, and

$$C\left(\mu\right)\left[1+\pi\left(\mu;\kappa\right)\right] \geq b_b$$

which holds for ψ large enough.

Hence, there exists an output threshold

$$\hat{x} \in [x_{\min}, \mu]$$

such that the borrower defaults if and only if $x \leq \hat{x}$.

Comparative Statics. Let $G(\hat{x}; \kappa, b_b) = C(\hat{x}) - b_b(1 + \pi(\hat{x}; \kappa))^{-1} = 0$. By the implicit function theorem,

$$\frac{\partial G(\hat{x}; \kappa, b_b)}{\partial \hat{x}} \frac{d\hat{x}}{db_b} + \frac{\partial G(\hat{x}; \kappa, b_b)}{\partial b_b} = 0$$

and

$$\frac{\partial G(\hat{x}; \kappa, b_b)}{\partial \hat{x}} \frac{d\hat{x}}{d\kappa} + \frac{\partial G(\hat{x}; \kappa, b_b)}{\partial \kappa} = 0.$$

Hence

$$\begin{aligned}
\frac{d\hat{x}}{db_b} &= -\frac{-(1 + \pi(\hat{x}; \kappa))^{-1}}{C_x(\hat{x}) + b_b(1 + \pi(\hat{x}; \kappa))^{-2} \pi_x(\hat{x}; \kappa)} \\
&= \frac{1}{C_x(\hat{x})[1 + \pi(\hat{x}; \kappa)] + b_b[1 + \pi(\hat{x}; \kappa)]^{-1} \pi_x(\hat{x}; \kappa)} \\
&= \frac{1}{C_x(\hat{x})[1 + \pi(\hat{x}; \kappa)] + C(\hat{x}) \pi_x(\hat{x}; \kappa)} > 0
\end{aligned}$$

since

$$C_x[1 + \pi(x; \kappa)] + C(x) \pi_x(x; \kappa) > 0$$

from (35). We also have

$$\begin{aligned}
\frac{d\hat{x}}{d\kappa} &= -\frac{b_b[1 + \pi(\hat{x}; \kappa)]^{-2} \pi_\kappa(\hat{x}; \kappa)}{C_x(\hat{x}) + b_b(1 + \pi(\hat{x}; \kappa))^{-2} \pi_x(\hat{x}; \kappa)} \\
&= -\frac{b_b[1 + \pi(\hat{x}; \kappa)]^{-1} \pi_\kappa(\hat{x}; \kappa)}{C_x(\hat{x})[1 + \pi(\hat{x}; \kappa)] + b_b[1 + \pi(\hat{x}; \kappa)]^{-1} \pi_x(\hat{x}; \kappa)} \\
&= -\frac{b_b[1 + \pi(\hat{x}; \kappa)]^{-1} \pi_\kappa(\hat{x}; \kappa)}{C_x(\hat{x})[1 + \pi(\hat{x}; \kappa)] + C(\hat{x}) \pi_x(\hat{x}; \kappa)} > 0
\end{aligned}$$

since

$$\pi(x;\kappa) = \frac{-\kappa(\mu - x)}{1+\kappa(\mu - x)} \tag{36}$$

$$\Rightarrow \pi_\kappa(\hat{x};\kappa) = \frac{-(\mu-\hat{x}) - (\mu-\hat{x})\,\pi(\hat{x};\kappa)}{1+\kappa(\mu-\hat{x})} \tag{37}$$

$$= \frac{-(\mu-\hat{x})(1+\pi(\hat{x};\kappa))}{1+\kappa(\mu-\hat{x})} \tag{38}$$

$$= -(\mu-\hat{x})\left[1+\pi(\hat{x};\kappa)\right]^2 < 0 \tag{39}$$

This concludes the proof of Theorem 2. □

C Sensitivity Analyses

Table 10: Robustness to government discount factor

	Positive co-movement (+1.5 s.d.)	Negative co-movement (–1.5 s.d.)	Difference
Lower patience ($\beta_g = 0.985$)			
Spreads (pct)	3.68	3.77	–0.09
Spreads in good times (pct)	2.37	3.28	–0.91
Spreads in bad times (pct)	4.94	4.24	+0.70
Def. prob. in good times (pct)	0.00	0.01	–0.00
Def. prob. in bad times (pct)	1.10	0.89	+0.21
Higher patience ($\beta_g = 0.989$)			
Spreads (pct)	0.30	0.86	–0.55
Spreads in good times (pct)	–0.03	0.79	–0.82
Spreads in bad times (pct)	0.62	0.92	–0.29
Def. prob. in good times (pct)	0.00	0.00	0.00
Def. prob. in bad times (pct)	0.20	0.07	+0.12

Table 11: Robustness to default cost threshold d_0

	Positive co-movement (+1.5 s.d.)	Negative co-movement (–1.5 s.d.)	Difference
Lower output threshold ($d_0 = -0.035$)			
Spreads (pct)	1.24	1.63	–0.40
Spreads in good times (pct)	0.57	1.44	–0.87
Spreads in bad times (pct)	1.81	1.80	+0.02
Def. prob. in good times (pct)	0.00	0.00	–0.00
Def. prob. in bad times (pct)	0.44	0.24	+0.19
Higher output threshold ($d_0 = -0.020$)			
Spreads (pct)	1.29	1.62	–0.32
Spreads in good times (pct)	0.64	1.44	–0.80
Spreads in bad times (pct)	1.97	1.80	+0.16
Def. prob. in good times (pct)	0.00	0.00	–0.00
Def. prob. in bad times (pct)	0.41	0.32	+0.09

Table 12: Robustness to utility function

	Positive co-movement (+1.5 s.d.)	Negative co-movement (–1.5 s.d.)	Difference
Epstein-Zin ($\gamma_\ell = 8$)			
Spreads (pct)	1.36	1.41	–0.05
Spreads in good times (pct)	0.79	1.18	–0.39
Spreads in bad times (pct)	1.90	1.62	+0.28
Def. prob. in good times (pct)	0.00	0.00	–0.00
Def. prob. in bad times (pct)	0.43	0.34	+0.09
CRRA ($\gamma_\ell = 8$)			
Spreads (pct)	1.49	2.05	–0.56
Spreads in good times (pct)	1.48	2.38	–0.90
Spreads in bad times (pct)	1.51	1.74	–0.23
Def. prob. in good times (pct)	0.00	0.01	–0.01
Def. prob. in bad times (pct)	0.46	0.37	+0.09

Table 13: Robustness to risk aversion

	Positive co-movement (+1.5 s.d.)	Negative co-movement (–1.5 s.d.)	Difference
Lower risk aversion ($\gamma_\ell = 8$)			
Spreads (pct)	1.36	1.41	–0.05
Spreads in good times (pct)	0.79	1.18	–0.39
Spreads in bad times (pct)	1.90	1.62	+0.28
Def. prob. in good times (pct)	0.00	0.00	–0.00
Def. prob. in bad times (pct)	0.43	0.34	+0.09
Higher risk aversion ($\gamma_\ell = 120$)			
Spreads (pct)	1.07	1.96	–0.89
Spreads in good times (pct)	0.36	1.80	–1.44
Spreads in bad times (pct)	1.74	2.11	–0.38
Def. prob. in good times (pct)	0.00	0.00	–0.00
Def. prob. in bad times (pct)	0.43	0.20	+0.23

Table 14: Robustness to debt maturity

	Positive co-movement (+1.5 s.d.)	Negative co-movement (–1.5 s.d.)	Difference
Shorter debt maturity (4 years)			
Spreads (pct)	0.94	1.37	–0.43
Spreads in good times (pct)	0.39	1.19	–0.80
Spreads in bad times (pct)	1.46	1.54	–0.08
Def. prob. in good times (pct)	0.00	0.00	–0.00
Def. prob. in bad times (pct)	0.38	0.24	+0.14
Longer debt maturity (6 years)			
Spreads (pct)	2.18	2.39	–0.21
Spreads in good times (pct)	1.30	2.19	–0.89
Spreads in bad times (pct)	3.03	2.58	+0.45
Def. prob. in good times (pct)	0.00	0.00	–0.00
Def. prob. in bad times (pct)	0.51	0.31	+0.21

Table 15: Robustness to single default cost regime

	Positive co-movement (+1.5 s.d.)	Negative co-movement (–1.5 s.d.)	Difference
High default cost regime ($p_h = 1$)			
Spreads (pct)	1.31	1.61	–0.30
Spreads in good times (pct)	0.63	1.43	–0.80
Spreads in bad times (pct)	1.97	1.79	+0.18
Def. prob. in good times (pct)	0.00	0.00	–0.00
Def. prob. in bad times (pct)	0.40	0.23	+0.17
Low default cost regime ($p_l = 1$)			
Spreads (pct)	1.65	1.86	–0.22
Spreads in good times (pct)	0.87	1.60	–0.80
Spreads in bad times (pct)	2.39	2.11	+0.28
Def. prob. in good times (pct)	0.00	0.00	–0.00
Def. prob. in bad times (pct)	0.56	0.39	+0.17