Erschienen in: Journal of International Economics. Elsevier. 2020, 123, 103293
https://doi.org/10.1016/j.jinteco.2020.103293

Sovereign and private default risks over the business cycle

Leo Kaas [a], Jan Mellert [b], Almuth Scholl [c,*]

[a] Goethe University Frankfurt, House of Finance, Theodor-W.-Adorno-Platz 3, D-60323 Frankfurt am Main, Germany
[b] Technical University Dortmund, Faculty of Business, Economics and Social Science, Vogelpothsweg 87, D-44227 Dortmund, Germany
[c] University of Konstanz, Postbox 132, D-78457 Konstanz, Germany

A B S T R A C T

Sovereign debt crises are often accompanied by deep recessions with sharp declines in external credit to the private sector. In a sample of emerging economies we find that both, sovereign and private interest rate spreads are countercyclical. This paper presents a model of a small open economy that accounts for these empirical regularities. It includes private firms, which finance a fraction of imports by external debt and are subject to idiosyncratic productivity risk, and a government, which borrows internationally and taxes firms to finance public expenditures. The model gives rise to endogenous private and sovereign interest rate spreads and a dynamic feedback mechanism between sovereign and private default risks through the endogenous response of fiscal policy to adverse productivity shocks.

Keywords:
Sovereign default
Corporate borrowing
Interest rate spreads
Fiscal policy

1. Introduction

Sovereign default is a recurrent phenomenon in emerging economies. Default episodes are typically associated with severe recessions, characterized by sharp drops in output, investment, and imports. Recent empirical studies further suggest that sovereign default is followed by worsening conditions for external finance for the private sector. Arteta and Hale (2008) show that foreign credit to non-financial firms contracts sharply in the aftermath of sovereign debt crises.[1] Ağca and Celasun (2012) find that higher external sovereign debt in emerging markets translates into higher borrowing costs for the private sector, and much more so in countries that have experienced sovereign default episodes in the past. What is the explanation for these links between sovereign debt and the private sector's access to foreign credit? And how do these relations affect macroeconomic conditions around default episodes?

To address these questions, we investigate the dynamic interrelations between sovereign and private credit risks in emerging economies and their effects on macroeconomic outcomes. We first document several business-cycle facts about interest rate spreads on sovereign and private external debt for a sample of emerging market economies, and we consider the behavior of these interest rate spreads during Argentina's sovereign debt crisis in 2002. In line with earlier literature, the default crisis was accompanied by strong declines in government spending and imports and by an increase in sovereign and private interest rate spreads. Over the business cycle, private and sovereign spreads are countercyclical, which is a robust phenomenon that is independent of the inclusion of default episodes.

We then build a dynamic, stochastic model of a small open economy to account for these observations. Our modeling approach follows the recent quantitative literature on sovereign debt in incomplete markets economies with an endogenous default choice of the government, e.g., Aguiar and Gopinath (2006) and Arellano (2008). The model has domestic households, domestic firms producing final goods and intermediate goods, a domestic government and foreign lenders. Final goods firms produce their output with imperfectly substitutable domestic and foreign intermediate goods. A fraction of imported intermediate goods must be financed by external credit. Since firms face idiosyncratic productivity and default cost shocks, their credit is subject to default risk, so that risk-neutral international investors charge a premium on

* Corresponding author.
E-mail addresses: kaas@wiwi.uni-frankfurt.de (L. Kaas), jan.mellert@tu-dortmund.de (J. Mellert), almuth.scholl@uni-konstanz.de (A. Scholl).

[1] See also Das et al. (2010) who obtain similar results for a broader data set.

private debt. Households value private consumption, leisure and a public good provided by the government. The government acts in the interest of domestic households, it levies a linear sales tax and borrows internationally so as to smoothen the provision of the public good and to balance fluctuations in tax revenues over the business cycle. In any period, the government has the option to default on the outstanding debt, which gives rise to an endogenous interest rate spread on sovereign debt. In the event of default, the government is temporarily excluded from international financial markets, in which case it must finance public expenditures solely from taxes.

In a quantitative application to Argentina we show that our theoretical framework mimics the empirical facts of a typical emerging market economy, in particular countercyclical sovereign and private spreads, volatile imports, and deep recessions in default. Moreover, and in line with the empirical evidence of procyclical fiscal policy in emerging market economies (e.g., Talvi and Vegh, 2005; Ilzetzki and Vegh, 2008), taxes are countercyclical and government spending is procyclical.

Similar to Cuadra et al. (2010),[2] the procyclicality of fiscal policy is a direct consequence of countercyclical sovereign default risk. If the economy enters a recession, external public debt becomes more expensive due to the higher sovereign default risk, and this induces the government to raise tax rates so as to finance public expenditures. This procyclicality of fiscal policy is important for macroeconomic amplification in our model: Higher tax rates in recessions depress firms' profitability even further and induce more firms to default on their external debt, which endogenously lowers aggregate productivity. Moreover, higher private spreads reduce import demand. Both effects deepen the recession and amplify sovereign default risk. In case of a default, by not repaying debt the government is able to reduce tax rates, which stimulates profitability, reduces the private interest rate spread and fosters the recovery of the economy.

To explore the quantitative importance of the dynamic feedback mechanism between tax policy and private credit risk, we run a counterfactual experiment and shut down the endogenous tax response. Our simulations show that an exogenously fixed tax rate strongly decreases the variance of the private interest rate as well as the variance of aggregate productivity. As a result, imports, output, and private consumption become substantially less volatile. In the absence of an endogenous tax response, default events are characterized by less severe recessions, but the recovery after a default is slower. We find that in a typical default event, the endogenous interaction between tax policy and credit risks reduces aggregate productivity by additional 1.8 percentage points. The private spread increases by additional 4.8 percentage points, imports drop by additional 10.1 percentage points, and output falls by additional 3.3 percentage points.

Our paper builds on the classic paper by Eaton and Gersovitz (1981) and the quantitative contributions of Arellano (2008) and Aguiar and Gopinath (2006) and introduces firm heterogeneity and private default into a model of sovereign debt and default.[3] We contribute to the literature by quantifying the macroeconomic amplification generated by the endogenous interaction between fiscal policy and credit risks. Our framework is closely related to Mendoza and Yue (2012) who focus on the question why sovereign default episodes are associated with deep recessions. They consider a model of sovereign debt, in which firms produce final output from domestically produced and imported intermediate goods. A share of the imported intermediate goods is financed by external debt. Different from our setup, they abstract from endogenous tax policy and endogenous private default risk and assume that firms are always able to borrow at the risk-free rate, which is at odds with the evidence.[4] Furthermore, all firms and the government are simultaneously excluded from international financial markets if the government chooses to default. This in turn causes firms to substitute away from imports towards domestically produced goods, generating output costs and severe recessions. In our model, sovereign defaults are also associated with severe contractions in imports and output. However, these factual reactions do not require to shut all firms out of financial markets together with the defaulting government. Instead, the default decisions of private firms make aggregate productivity an endogenous outcome. In recessions, more private firms default, which reduces aggregate productivity and generates an endogenous output cost of sovereign default. Importantly, the endogenous reaction of fiscal policy amplifies this mechanism: As the government raises taxes in response to higher sovereign borrowing costs, the default rate of private firms increases, which in turn reduces aggregate productivity and deepens the recession.

Similar to our paper, Arellano et al. (2019) explore the consequences of the joint dynamics of sovereign and private default risk for real economic activity, but in contrast to our paper they focus on the role of financial intermediation and apply their model to Italy. In a related contribution, de Ferra (2018) develops a two-sector framework with a labor income tax to study the dynamic interaction between fiscal policy and corporate credit risk for the case of Italy. Arellano et al. (2016) argue that the risk of government interference in private debt markets creates a link between sovereign and private borrowing costs which is in accordance with the experience in the European debt crisis. Similar to our model, Aguiar et al. (2009) show that governments in closer proximity to default raise taxes with adverse consequences for the private sector, but they do not consider private default.

We abstract from the role of domestically held debt, often on the balance sheet of banks, that is also discussed as a potential source of amplification. For instance, in theoretical contributions based on finite–horizon economies, Brutti (2011) and Gennaioli et al. (2014) argue that sovereign default harms the balance sheets of domestic banks or private investors, which triggers contractions in credit and investment. Engler and Große-Steffen (2016), Niemann and Pichler (2017), and Sosa-Padilla (2018) build quantitative stochastic general equilibrium models with a similar feature. While this channel may be important in several developed and emerging economies, Arteta and Hale (2008) show that the decline in external credit during sovereign debt crises is concentrated in the non-financial sector, which motivates why we abstract from financial intermediaries in our model.

Besides the banking channel, other contributions also consider spillover effects of sovereign default on external credit of firms. Andreasen (2015) suggests a signaling mechanism, based on the idea that the government's repayment decision provides new information regarding the institutional quality (such as recovery rates), which affects the financial conditions of private firms. Sandleris (2014) argues that sovereign default can trigger a collapse of private credit even when no debt is held domestically. In his model, a sovereign default reduces the firms' collateral value, which limits their borrowing capacity. Arellano and Kocherlakota (2014) propose a reverse mechanism: due to informational frictions in private credit markets, private default crises can emerge as a coordination equilibrium, which possibly triggers a sovereign debt crisis.

The remainder of this paper is organized as follows. In the next section, we document empirical evidence about sovereign and private credit risk in emerging market economies. In Section 3, we describe the model framework, define the recursive equilibrium and explain the main determinants of sovereign and private default risks. In

[2] Cuadra et al. (2010) analyze the properties of optimal tax policy in the presence of sovereign default risk.

[3] The broader literature on sovereign debt in quantitative macroeconomic models considers political uncertainty (e.g., Cuadra and Sapriza, 2008; Scholl, 2017), debt renegotiations (e.g., Yue, 2010), the maturity structure of debt (e.g., Hatchondo and Martinez, 2009; Arellano and Ramanarayanan, 2012; Chatterjee and Eyigungor, 2012), or bailouts (e.g., Roch and Uhlig, 2018; Fink and Scholl, 2016; Kirsch and Rühmkorf, 2017). In all these papers, there is no credit to the private sector.

[4] In an earlier working paper version (NBER Working Paper No. 17151), Mendoza and Yue (2012) assume that private firms borrow at the same rate as the government and default simultaneously, which is also counterfactual. Pancrazi et al. (2017) consider a dynamic general equilibrium model with sovereign default and private credit granted by domestic banks that borrow internationally. As Mendoza and Yue (NBER Working Paper), they assume that banks borrow at the same rate as the government from international creditors.

Section 4 we calibrate the model to the Argentine economy to illustrate the quantitative significance of the interplay between sovereign and private credit risks that our model generates. Section 5 concludes.

2. Empirical facts

In this section, we first document the cyclical properties of private and sovereign credit spreads in emerging market economies. Second, we document facts about these spreads and about macroeconomic and fiscal variables around Argentina's default episode in 2002. These facts are important for our quantitative model analysis that we conduct in Section 4.

2.1. Cyclical properties

We document empirical regularities of private and sovereign interest rate spreads in emerging market economies. Our sample consists of Argentina, Brazil, Chile, Ecuador, Korea, Malaysia, Mexico, Peru, Philippines, Russia, and Venezuela.[5] Our sample covers the period from the early 1990s until the second quarter of 2013. Due to data availability, the sample periods for the individual countries differ in their starting and end dates. More details on calculations, data sources, and further statistics can be found in Appendix B and Appendix C.

We follow Arellano and Kocherlakota (2014) and calculate interest rate spreads as the spread between the dollar domestic lending rate and the interest rate on a U.S. bond with similar maturity. If foreign currency lending rates are not available, we use the spread between the local currency domestic lending rate and the local currency domestic deposit rate.[6] Sovereign interest rate spreads are obtained from JP Morgan's Emerging Market Bond Index (EMBI).[7]

In Table 1 we summarize the business-cycle properties of sovereign and private interest rate spreads for our sample of emerging market economies, excluding default events in order to provide meaningful comparisons. The business-cycle statistics reveal several empirical regularities. First, the sovereign interest rate spread tends to be lower and less volatile than its private counterpart. This result is in line with the hypothesis that the sovereign rating provides a ceiling to private company ratings.[8] Second, the sovereign interest rate spread is strongly countercyclical. Third, private interest rates tend to be countercyclical, too, but to a lesser extent compared to sovereign spreads.[9]

Table 1
Sovereign and private interest spreads over the business cycle.

	$E(s)$	$E(s^p)$	$\sigma(s)$	$\sigma(s^p)$	$\rho(s,s^p)$	$\rho(s,y)$	$\rho(s^p,y)$
Argentina	5.97	8.45	2.75	4.81	0.87***	0.83***	0.79***
Brazil	4.80	39.73	3.49	9.39	0.54***	0.59***	0.21**
Chile	1.47	1.96	0.55	0.88	0.63***	0.40***	0.34***
Ecuador	9.37	7.52	3.69	1.84	0.69***	0.34**	0.18
Korea	1.94	1.11	1.61	0.87	0.55***	0.75***	0.65***
Malaysia	1.92	3.10	1.47	0.75	0.38***	0.47***	0.06
Mexico	2.50	6.66	1.03	4.63	0.71***	0.49***	0.19
Peru	3.58	7.68	1.97	1.69	0.46***	0.75***	0.11
Philippines	3.43	4.10	1.44	1.07	0.11	0.75***	0.02
Russia	3.53	6.97	2.69	2.96	0.81***	0.53***	0.25**
Venezuela	7.36	8.03	1.48	2.74	0.33	0.53***	0.21
Average	4.17	8.66	2.02	2.88	0.53	0.59	0.26

Notes: s denotes the annualized sovereign interest rate spread while s^p refers to the annualized private interest rate spread. y denotes real GDP. Interest rate spreads are demeaned and GDP is log-linearly detrended before business-cycle statistics are calculated. Argentina, Ecuador, Russia and Venezuela had default episodes during the time period that we consider. To calculate business-cycle statistics we exclude the default events and consider the following restricted samples: Argentina 1994Q1–2001Q4, Ecuador 2000Q4-2008Q3, Russia 2000Q4-2012Q3, Venezuela 1999Q1-2004Q4. Significance is denoted by stars ('*' 10%,'**' 5%,'***' 1%).

2.2. Dynamics around default

While our analysis of the cyclical properties of sovereign and private spreads explicitly abstracts from default events, we now focus on the dynamics of key macroeconomic variables during the sovereign default episode of Argentina (2002Q1). We consider real GDP, imports, consumption, government expenditures, and the sovereign and private interest rate spreads.[10] Since our model in Section 3 highlights a feedback mechanism between tax policy and private credit risk, our analysis includes tax revenues and a proxy for the corporate tax rate, defined as tax revenues from corporate earnings divided by the operating surplus.[11] In Fig. 1 we plot the patterns of the variables eight quarters before and after the default event in $t = 0$. GDP, imports, consumption, government expenditures, and tax revenues are shown as percentage deviations from a linear trend while the corporate tax rate and the interest rate spreads are depicted in percent. Since data on corporate taxation is only available on an annual frequency, we plot the evolution of the corporate tax rate two years before and after the default.

First, we observe a deep recession with a substantial drop in imports around the default event. Relatedly, Gopinath and Neiman (2014) show that the recession in the course of Argentina's default was accompanied by a substitution of imported intermediate goods by domestic intermediate goods. The deep fall in output is accompanied by a substantial decrease in consumption. Furthermore, we observe a strong and persistent increase of the sovereign spread during the default episode. Private credit costs increase as well, but the rise in the private spread is less pronounced and more transitory. However, the pattern after the sovereign default may be partly driven by sample selection.[12] Therefore, we focus on the pre-default behavior of private spreads in our quantitative analysis. Overall, the findings are in line with Ağca and Celasun (2012) who show that private credit costs increase during sovereign debt crises.

The default event is characterized by a large and persistent decrease in government expenditures. Due to the substantial drop in output, tax revenues decrease substantially, whereas the corporate tax rate increases in the two years prior to the default. The observed patterns in government expenditures and taxation indicate a proyclical fiscal policy in Argentina, which is in line with the findings of Sturzenegger and Zettelmeyer (2006) who document several rounds of tax increases and spending cuts to reduce the deficit prior to the default. Moreover, Cuadra et al. (2010) discuss several episodes, in which the Argentine government implemented a countercyclical tax policy. For example, tax rates were significantly reduced during the economic boom in 1991–1994 and increased at the beginning of the recession in 1995. When economic growth resumed in 1996, the government lowered tax rates.

[5] The choice of countries is based on the sample analyzed by Neumeyer and Perri (2005), but we add emerging market economies for which we have at least ten years of data.

[6] See Table 7 in Appendix C for a detailed description of the computation of the private interest rate spreads.

[7] We use the interest rate spread calculated by JP Morgan instead of the difference between the EMBI yield to maturity and a US bond, because JP Morgan's spread is adjusted for different payment streams. However, the difference between EMBI spreads and the difference between the EMBI yield to maturity and a five-year U.S. bond is negligible.

[8] See also Borensztein et al. (2013) who provide further evidence on the sovereign ceiling.

[9] Our results are in line with the evidence in Bai and Wei (2014), Bedendo and Colla (2015) and Klein and Stellner (2014). They show that corporate and sovereign CDS spreads in Europe comove closely.

[10] Ultimately, for the quantitative evaluation of our model, we are interested in imports of intermediate goods, but since data on them is available only on an annual basis, we use overall imports as a proxy. Following Mendoza and Yue (2012) in the definition of intermediate goods, we calculate the share of intermediate goods in imports. On average these imports account for around 58% of total imports in emerging markets.

[11] Corporate tax revenues are taken from the Argentine Ministry of the Treasury and gross operating surplus is taken from the National Institute of Statistics and Census of Argentina. See Appendix C for details.

[12] After the default, less creditworthy firms might be excluded from US$ credit markets. The remaining firms are more creditworthy and therefore the interest rate may fall.

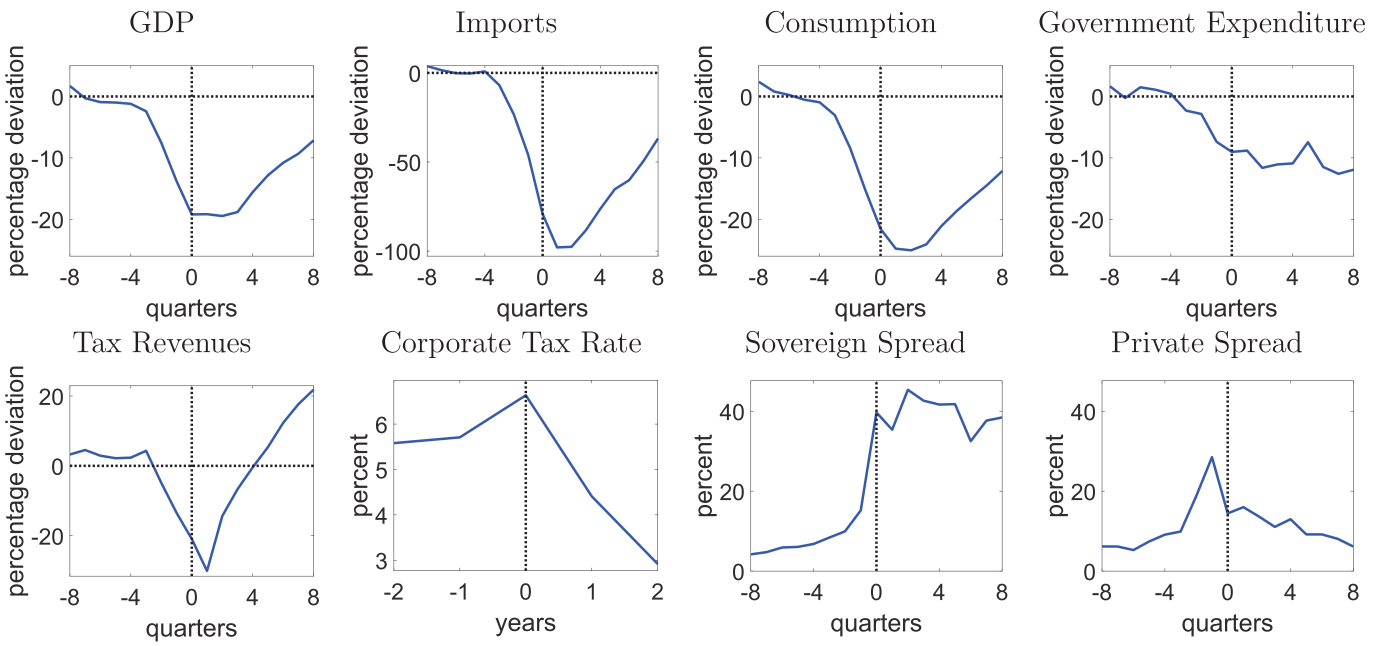

Fig. 1. Argentina's default in 2002.
Notes: The figure shows the dynamic patterns of real GDP, imports, consumption, government expenditures, tax revenues, a proxy of the corporate tax rate, the annualized sovereign interest rate spread, and the annualized private interest rate spread 8 quarters before and after Argentina's default in 2002. The proxy of the corporate tax rate is defined as tax revenues from corporate earnings divided by the operating surplus. The sovereign spread is the EMBI Global spread, and the private spread is calculated as the difference between short-term bank credit interest rate in U.S.$ and the 3-month U.S. T-Bill. Data on corporate taxes are available on an annual frequency only. All other variables are quarterly. Interest spreads and the corporate tax are displayed in %. GDP, imports, consumption, government expenditures, and tax revenues are log-linearly detrended, using data until the quarter before the default. For the quarterly variables, the default period $t = 0$ is set to Q1 2002. For the annual variable the default period is set to 2001.

3. A model of sovereign and private default risk

To capture the facts described in the previous section, we develop a model featuring endogenous sovereign and private default risks and endogenous fiscal policy. We consider a small open economy inhabited by many firms, which are hit by productivity shocks that consist of an idiosyncratic firm-specific component and an aggregate component, which is common for all firms. The firms borrow internationally and decide to default if productivity is sufficiently low, which generates an endogenous premium on private external debt. The government borrows abroad to smoothen the provision of a public good, and it also has the option to voluntarily default on its debt, which gives rise to an interest rate spread on public debt.

Our small open economy comprises four types of agents: a representative household, final goods firms, intermediate goods firms and the domestic government. Foreign investors lend to the government and to private firms.

The domestic household owns firms and supplies labor. All firms are perfectly competitive. Final goods firms produce output from two differentiated intermediate goods. One of them is an import good, the other is produced domestically by intermediate goods firms employing labor. A fraction of imported intermediate goods is financed by external private debt. As it is standard in the quantitative macroeconomic literature the working-capital loan is intraperiod[13] and final goods firms make their borrowing decision before they are hit by idiosyncratic productivity shocks and idiosyncratic default cost shocks.[14] Instead of redeeming their debt, firms can opt to default if the default payoff is larger than the redemption payoff.

The representative household enjoys utility from consumption, leisure and from a public good. The government provides the public good, taxes sales[15] and finances deficits by issuing external debt. Following Arellano (2008), if the government chooses to default, it is excluded from international borrowing for a stochastic number of periods. In addition, during exclusion, the country suffers an exogenous output loss. Even when the government is excluded from international borrowing, private firms retain access to external credit.[16]

The timing within each period is as follows. First, the aggregate component of productivity, which is common across firms, is realized. The government decides whether to default on its external debt and it adjusts current policies, i.e., the sales tax, expenditures for the public good, and debt issuance. Final goods firms make import decisions and borrow abroad. Intermediate goods firms hire workers and produce. Second, final goods firms are hit by idiosyncratic productivity and default cost shocks and decide whether to default or to repay their outstanding debt obligations. Active (non-defaulting) firms buy domestic intermediate goods and produce output.

[13] Compare, e.g., Neumeyer and Perri (2005), Jermann and Quadrini (2012) and Mendoza and Yue (2012).

[14] As in Arellano et al. (2019), there are two types of idiosyncratic shocks affecting the production activity and default behavior of firms. In our model they are required to match different aggregate statistics on private spreads and to be compatible with micro evidence on corporate default, as we explain in Section 4.2.

[15] For simplicity, a sales tax is the only tax instrument of the government. Other distortionary taxes should have similar implications, as long as they reduce the profitability of firms.

[16] Therefore, any spillover from sovereign default on the private credit market is not assumed exogenously but is the outcome of an endogenous equilibrium response. We also do not allow the government to impose capital controls to restrain the borrowing of domestic firms. Whether or not the government would want to make use of such policy tools would be an interesting question for future research.

3.1. Households

The representative household has preferences

$$\mathbb{E}\sum_{t\geq 0}\beta^t u(c_t - v(\ell_t), g_t) \ ,$$

where c_t and g_t are consumption of the private and the public good, and ℓ_t is labor supply. $0<\beta<1$ denotes the discount factor, u is strictly increasing and concave and v is strictly increasing and convex. The household does not borrow or lend internationally and thus consumes all labor and profit income. Therefore, the household's budget constraint is $c_t = \Pi_t + w_t\ell_t$, where Π_t are aggregate profits and w_t is the real wage. As implied by this notation, the gross price of the consumption good is normalized to unity.

3.2. Firms

Intermediate goods firms produce the domestic intermediate good from labor with linear technology $m_t = \ell_t$. Since firms operate under perfect competition, the price of the domestic intermediate good equals the real wage w_t.

Let $s_t \in \{N,D\}$ denote whether the country is in a normal state (N) or in a sovereign default episode (D). In a normal state $s_t = N$, final goods firms produce output from domestic and foreign intermediate goods, m_t and m_t^*, with technology $x_t z_t f(m_t, m_t^*)$. x_t denotes the idiosyncratic component of productivity, which is firm-specific, whereas z_t refers to the aggregate component of productivity, which is common across all firms. f has constant returns to scale and is concave. While z_t follows a Markov process and is known at the beginning of the period, idiosyncratic productivity is realized after firms make import decisions and borrow but before they buy domestic intermediate goods. Then x_t is drawn i.i.d. from cumulative distribution $X(.)$. If the country is in a sovereign default episode, $s_t = D$, the country faces exogenous output costs such that output is $x_t h(z_t) f(m_t, m_t^*) \leq x_t z_t f(m_t, m_t^*)$ with function $h(.) \leq 1$. With τ_t denoting the sales tax, we write the firm's net revenue as $x_t\tilde{z}_t f(m_t, m_t^*)$ with $\tilde{z}_t \equiv (1-\tau_t)z_t$ for $s_t = N$ and $\tilde{z}_t \equiv (1-\tau_t)h(z_t)$ for $s_t = D$.

Imported intermediate goods are bought at the world price p^*. We assume that firms must finance the fraction ξ of imports by external debt and the remaining fraction by domestic funds. International credit markets are incomplete, so that external private debt has gross interest rate R_t, which is unconditional on idiosyncratic productivity realizations and which reflects the firms' default risk. If a firm imports m_t^*, its external debt is $R_t\xi p^* m_t^*$.

After these decisions have been made, final good firms receive two types of idiosyncratic shocks: Idiosyncratic productivity x_t realizes, and the firm learns at which discount price $\vartheta_t p^*$ it is able to liquidate its imported intermediate goods if it decides to default. $\vartheta_t \leq 1$ is drawn i.i.d. and independent of x_t from cumulative distribution $\Theta(.)$.

The firm has two options. Either it stays in business and repays the international debt. Such a firm optimally buys domestic intermediate goods proportional to imports, $m_t = \Phi\left(\frac{x_t\tilde{z}_t}{w_t}\right)m_t^*$, where Φ is an increasing function whose functional form depends on the production function f. Its profit before interest payments is also linear in m_t^*, namely $\pi(x_t\tilde{z}_t, w_t)m_t^*$, where π is increasing (decreasing) in the first (second) argument. Hence, the shareholders' redemption profit is $\pi^R \equiv \pi(x_t\tilde{z}_t, w_t)m_t^* - R_t\xi p^* m_t^* - (1-\xi)p^* m_t^*$.

Alternatively, the firm may opt to default, in which case the firm's creditors are able to recover $\eta\xi p^* m_t^*$, where η is a recovery parameter. The payout to shareholders, net of the sunk expenses for the imported goods, is then $\pi^D \equiv \vartheta_t p^* m_t^* - \eta\xi p^* m_t^* - (1-\xi)p^* m_t^*$.

Therefore, the firm defaults whenever the default payout is larger than the redemption profit, $\pi^D > \pi^R$. This is the case when $x_t < \bar{x}_t(\vartheta_t)$ where the default productivity threshold (a function of the idiosyncratic price discount ϑ_t) is defined by

$$\pi(\bar{x}_t(\vartheta_t)\tilde{z}_t, w_t) = p^*[(R_t - \eta)\xi + \vartheta_t] \ , \tag{1}$$

for all ϑ_t in the support of Θ. Evidently, $\bar{x}_t(.)$ increases in ϑ_t (a larger discount price induces more firms to default), it decreases in $\tilde{z}_t$ (less firms default when productivity z_t is high or taxes are low) and it increases in (w_t, R_t) (more firms default when labor or credit costs are large). On the other hand, the constant-returns specification implies that the default threshold is independent of the amount of imports m_t^*. In general equilibrium, however, there is an indirect effect of the import volume on default risk via domestic intermediate goods and labor markets.

At the beginning of the period, final goods firms choose imports m_t^* to maximize the expected profit value

$$\int\left[\int_{\bar{x}_t(\vartheta)}^{\infty}[\pi(x\tilde{z}_t, w_t) - R_t\xi p^*]m_t^* \ dX(x) + X(\bar{x}_t(\vartheta))(\vartheta - \xi\eta)p^* m_t^*\right]d\Theta(\vartheta) - (1-\xi)p^* m_t^* \ .$$

Because this objective is linear in m_t^*, the first-order condition implies zero expected profits,

$$(1-\xi)p^* = \int\left[\int_{\bar{x}_t(\vartheta)}^{\infty}[\pi(x\tilde{z}_t, w_t) - R_t\xi p^*] \ dX(x) + X(\bar{x}_t(\vartheta))(\vartheta - \xi\eta)p^*\right]d\Theta(\vartheta). \tag{2}$$

While some firms default, new firms may enter the economy in any period. Due to the constant-returns specification, the number of firms is irrelevant. Without loss of generality, we set the mass of firms to one and interpret m_t^* as either aggregate or firm-level imports. Because firms are ex-ante homogeneous, they are all affected by sovereign default events in the same way. Introducing richer firm heterogeneity may be helpful to address additional interesting questions but is beyond the scope of this paper.

3.3. International investors

Risk-neutral international investors have access to an international bond market with constant gross interest rate $\bar{R}$. They lend to domestic firms if the expected gross return of credit equates the safe return. In the event of a private default, which happens with probability $\delta_t = \int X(\bar{x}_t(\vartheta))d\Theta(\vartheta)$, lenders are able to recover the fraction η of the value of credit-financed import goods. The investors' arbitrage condition therefore states that

$$\bar{R} = \int R_t[1 - X(\bar{x}_t(\vartheta))] + \eta X(\bar{x}_t(\vartheta)) \ d\Theta(\vartheta) \ . \tag{3}$$

3.4. Private sector equilibrium

Note that labor supply is $(v')^{-1}(w_t)$ and that labor demand for any firm with idiosyncratic productivity $x \geq \bar{x}_t(\vartheta)$ is equal to this firm's demand for domestic intermediate goods, which is $\Phi\left(\frac{x\tilde{z}_t}{w_t}\right)m_t^* = m_t$. Therefore, the labor market clears in period t if

$$\int\int_{\bar{x}_t(\vartheta)}^{\infty}\Phi\left(\frac{x\tilde{z}_t}{w_t}\right)m_t^* \ dX(x)d\Theta(\vartheta) = \ell_t, \tag{4}$$

$$(v')^{-1}(w_t) = \ell_t \ . \tag{5}$$

Households consume all their income, and since aggregate profit income is zero,

$$c_t = w_t \ell_t \ . \tag{6}$$

Given current productivity z_t, the sales tax τ_t, and the default state s_t, the private sector equilibrium $(w_t, \bar{x}_t(.), \ell_t, R_t, m_t^*, c_t)$ solves the six eqs. (1)–(6). We write $c_t = \mathcal{C}(z_t, \tau_t, s_t)$ and $\ell_t = \mathscr{L}(z_t, \tau_t, s_t)$ for equilibrium consumption and employment, and we assume that a solution of the private sector equilibrium exists for the range of admissible values for (z_t, τ_t, s_t).[17] We further write aggregate output as $y_t = \mathcal{Y}(z_t, \tau_t, s_t)$, which is

$$y_t = \int \int_{\bar{x}_t(\vartheta)}^{\infty} [z_t + \mathbb{I}_{s_t = D}(h(z_t) - z_t)] x f\left(\Phi\left(\frac{x\tilde{z}_t}{w_t}\right), 1\right) m_t^* \ dX(x) d\Theta(\vartheta) \ , \tag{7}$$

and we denote the private sector interest rate by $R_t = \mathscr{R}(z_t, \tau_t, s_t)$.

Because of our assumption that private credit is repaid at the end of the period, the private sector equilibrium does not depend on any endogenous state variables, such as the firms' net worth, which simplifies the model. Including such state variables would complicate the solution of the model considerably, as it would involve intertemporal decisions of firms that have to forecast future tax policies of the government.

3.5. The government

The government maximizes expected utility of the representative household without commitment over future policy choices. At the beginning of period t, it decides whether to default on its external debt obligation. If it does so, it is excluded from international borrowing in the default period. In any future period, it regains access to international credit with exogenous probability θ. In a period of market exclusion, the government finances expenditures for the public good by the sales tax revenues, $g_t = \tau_t y_t$. If the government can borrow internationally, it issues new debt $b_{t+1} < 0$ at price $q(z_t, b_{t+1})$, facing the flow budget constraint $g_t = \tau_t y_t + b_t - q(z_t, b_{t+1}) b_{t+1}$. The price of debt reflects the default-risk adjusted rate of return of foreign lenders. The government takes the private sector's responses as given.

The relevant state variables for the government at the beginning of any period are (z, b, s), with $s \in \{N, D\}$. The government's value function in any period with access to international financial markets is

$$V(z, b, N) = \ \max\left\{V^N(z, b), V^D(z)\right\} \ , \tag{8}$$

where V^N (V^D) are continuation utilities after no default (default). If the government stays solvent, the recursive formulation of its problem is

$$V^N(z, b) = \max_{g, \tau, b_+} \ u(c - v(\ell), g) + \beta \mathbb{E}_z V(z_+, b_+, N) \ , \tag{9}$$

subject to

$$g = \tau y + b - q(z, b_+) b_+ \ ,$$

$$c = \mathcal{C}(z, \tau, N), \ \ \ell = \mathscr{L}(z, \tau, N), \ \ y = \mathcal{Y}(z, \tau, N) \ .$$

The first condition is the budget constraint of the government. The other three equations express the private sector equilibrium in reduced form, as derived in the previous subsection.

If the government has defaulted in some period and is excluded from international bond markets, the recursive problem is

$$V^D(z) = \max_{g, \tau} \ u(c - v(\ell), g) + \beta \mathbb{E}_z \Big[\theta V(z_+, 0, N) + (1 - \theta) V^D(z_+)\Big] \ , \tag{10}$$

subject to $g = \tau y$ and

$$c = \mathcal{C}(z, \tau, D), \ \ \ell = \mathscr{L}(z, \tau, D), \ \ y = \mathcal{Y}(z, \tau, D) \ .$$

The set of default states is

$$\Sigma^D = \left\{(z, b) \ | \ V^D(z) > V^N(z, b)\right\} \ . \tag{11}$$

The government's default probability is

$$\lambda(z, b_+) \equiv \text{Prob}\left((z_+, b_+) \in \Sigma^D \ \ |z\right) \ .$$

International investors lend to the government if

$$q(z, b_+) = \frac{1 - \lambda(z, b_+)}{\bar{R}} \ . \tag{12}$$

The bond price function reflects the endogenous sovereign default risk.[18]

3.6. Equilibrium definition

Definition. *A recursive equilibrium is given by*

(i) *value functions* $V(z, b, s)$, $V^D(z)$, $V^N(z, b)$ *and policy functions* $b_+ = \mathscr{B}(z, b, s)$, $\tau = \mathcal{T}(z, b, s)$, $g = \mathcal{G}(z, b, s)$ *of the government, solving problems (8)–(10), and a default set* Σ^D *satisfying (11).*
(ii) *a pricing function* $q(z, b_+)$ *satisfying the arbitrage condition of foreign lenders (12).*
(iii) *a private sector equilibrium, defining consumption* $c = \mathcal{C}(z, \tau, s)$, *employment* $\ell = \mathscr{L}(z, \tau, s)$, *output* $y = \mathcal{Y}(z, \tau, s)$, *and the private interest rate* $R = \mathscr{R}(z, \tau, s)$ *for* $s = N, D$, *satisfying (1)–(7).*

A solution to a recursive equilibrium specifies optimal plans for the government and for all private agents in this economy. It includes situations with and without sovereign default. The bond pricing function and the private sector interest rate reflect the interest rate spreads associated with optimal default choices of the government and of the private sector.

4. Quantitative analysis

In this section, we solve the model numerically to study its quantitative properties. We apply the model to the Argentine economy, which is often used as the benchmark for studies on sovereign default given its default history and data availability. We calibrate the model at quarterly frequency and choose parameters to match several empirical targets.

4.1. Calibration

4.1.1. Functional forms

We choose a CES production function of final goods:

$$f(m, m^*) = \left[(1 - \omega)(m)^{\rho} + \omega (m^*)^{\rho}\right]^{1/\rho} \ ,$$

---

[17] We also make sure that the equilibrium interest rate is the stable solution of eq. (3); namely, deviations to a lower rate may not raise investors' expected return. This requirement is meaningful because eq. (3) typically has two solutions, the larger of which is unstable. For the parameterization that we use in the next section, we confirm that there is a unique stable solution.

[18] While the government borrows at the end of period t 1 to repay debt in period t, domestic firms borrow within period t. For foreign investors, this difference is irrelevant as long as both loans have the same maturity (i.e., one model period). Furthermore, as in any model set in discrete time, the difference in timing of the intraperiod versus interperiod loans can be made arbitrarily small.

with substitution parameter $\rho < 1$ and $\omega \in (0,1)$ controlling the share of import goods in production. This implies that the demand for domestic input per unit of foreign input is

$$\Phi(q) = \omega^{1/\rho}\left[\left(q(1-\omega)\right)^{\frac{\rho}{\rho-1}} - 1 + \omega\right]^{-1/\rho}, \quad q = \frac{x\tilde{z}}{w} .$$

Profits (before interest) per unit of imports are

$$\pi(x\tilde{z}, w) = w\left(\frac{\omega}{1-\omega}\right)^{1/\rho}\left[\left(\frac{x\tilde{z}}{w}\right)^{\frac{\rho}{\rho-1}}(1-\omega)^{\frac{1}{\rho-1}} - 1\right]^{\frac{\rho-1}{\rho}} .$$

Both Φ and π are defined for $q = x\tilde{z}/w < (1-\omega)^{-1/\rho}$ if $\rho > 0$ and for $q = x\tilde{z}/w > (1-\omega)^{-1/\rho}$ if $\rho < 0$.

The firms' idiosyncratic productivity is uniformly distributed in the interval $[1-\zeta, 1+\zeta]$. The idiosyncratic default cost is uniformly distributed in the interval $[\xi\eta, \overline{\vartheta}]$ where $\overline{\vartheta} \leq 1$. The lower bound $\eta\xi$ ensures that creditors are able to recover the fraction η of the loan volume for all realizations of the discount price ϑ. The parameters ζ and $\overline{\vartheta}$ control the dispersion of these two idiosyncratic shocks.

We employ the GHH preferences (Greenwood et al., 1988):

$$u(c - v(\ell), g) = \frac{\left(c - \frac{\psi}{1+\psi}\ell^{\frac{1+\psi}{\psi}}\right)^{1-\gamma}}{1-\gamma} + \alpha\frac{g^{1-\mu}}{1-\mu} ,$$

where $\gamma > 0$ and $\mu > 0$ denote the parameters of relative risk aversion for private and public consumption and $\psi > 0$ is the Frisch elasticity of labor supply. Note that this specification implies that the marginal rate of substitution between private consumption and labor is independent of consumption. $\alpha \geq 0$ is a preference weight for public consumption.

The aggregate productivity component z follows an AR(1) process:

$$\log(z_t) = \varphi \log(z_{t-1}) + \varepsilon_t ,$$

where ε_t is i.i.d. $N(0, \sigma_\varepsilon^2)$.

Following Arellano (2008) we employ asymmetric output costs:

$$h(z) = \begin{cases} \phi\mathbb{E}z & \text{if } z > \phi\mathbb{E}z , \\ z & \text{else} , \end{cases}$$

with $\phi \in (0,1)$.

4.1.2. Parameters

All calibrated parameters and the associated targets and sources are listed in Table 2. The parameters of the CES production function ω and ρ are set at the same values as in Mendoza and Yue (2012) who choose these parameters to match regression estimates for the domestic/imported intermediate goods' demand elasticity.

The parameters for the exogenous aggregate productivity process are set to match the empirical autocorrelation and volatility of linearly detrended Argentine GDP. The Frisch elasticity is chosen to be 2.22, which is a standard value in international macroeconomics (cf. Mendoza and Yue, 2012; Neumeyer and Perri, 2005; Cuadra et al., 2010). The coefficient of risk aversion with respect to private consumption is set to $\gamma = 2$. The coefficient of risk aversion with respect to government consumption is calibrated to $\mu = 9$ to match the volatility of public consumption. The preference parameter referring to the weight on public consumption is chosen to generate the empirical mean share of public consumption (12.9%).

As in Mendoza and Yue (2012) the share of credit-financed imports is set to match a 6% share of working capital in GDP. The choice of the risk-free interest rate corresponds to a standard value in international macroeconomics. The import price is set to a value that implies a 11.8% share of imports as observed in the data. The recovery rate parameter η is set to 43.5%, which corresponds to the recovery rate for senior secured bonds in Latin America, 1990–2017 (see Moody's, 2017) and which is also similar to recovery rates for defaulted U.S. corporate bonds (see e.g., Jankowitsch et al., 2014, and Cui and Kaas, 2020).

Table 2
Parameter choices.

Parameter		Parameter values	Target statistics/source
Frisch elasticity	ψ	2.22	Mendoza and Yue (2012)
Risk aversion c	γ	2	Standard value
Risk aversion g	μ	9	Volatility of government consumption ($\sigma_g/\sigma_y = 0.47$)
Weight on public good	α	4.2-e07	Government consumption share (12.9%)
Weight on imports	ω	0.38	Mendoza and Yue (2012)
CES curvature	ρ	0.65	Mendoza and Yue (2012)
Share of credit-financed imports	ξ	0.495	Working-capital to GDP (6%)
Import price	p^*	3.3475	Import share (11.8%)
Risk-free rate	$\overline{R}$	1.01	Standard value
Discount factor	β	0.90	Debt-service to GDP (3.0%)
Re-entry probability	θ	0.282	Arellano (2008)
Output cost	ϕ	0.9856	Mean sovereign spread (5.97%)
Recovery rate	η	0.435	Moody's (2017)
Dispersion of idios. Prod.	ζ	0.16509	Mean private spread (8.45%)
Dispersion of discount price	$\overline{\vartheta}$	0.2655	Volatility private spread (4.81%)
Persistence of z	φ	0.95	Autocorrelation of GDP (0.84)
Variance of z shocks	σ_ε	0.0025	Volatility of GDP (4.9%)

Regarding idiosyncratic shocks, the two parameters ζ (controlling the variance of idiosyncratic productivity) and $\overline{\vartheta}$ (controlling the variance of the idiosyncratic discount price) are both critical for the level and the volatility of the private spreads (see the discussion in Section 4.2.1). We set these two parameters to match the annual mean private spread of 8.4% and the standard deviation of private spreads of 4.8%.

We follow Arellano (2008) and set the discount factor β so as to match the average public debt service payments as a share of GDP (3%). In our calibration, the probability of re-entering international financial markets after a default is set to 0.282 (Arellano, 2008). The exogenous output cost is set to 1.44% to match the mean of the sovereign spread (5.9%).

4.2. Results

We now study the quantitative properties of our simulated model economy. First, we discuss the properties of the firms' default behavior. Second, we analyze the properties of the policy functions to highlight the main economic mechanism that drives the interactions between sovereign and private default risks. Third, we discuss the business-cycle properties of the simulated model economy. Fourth, we perform an event study and explore the macroeconomic dynamics before and after a sovereign default. Finally, we assess the quantitative importance of the endogenous feedback mechanism between sovereign and private default risks.

4.2.1. Default in the private sector

Fig. 2 visualizes the firms' default productivity threshold $\bar{x}(\vartheta)$, which increases in the firm's price discount upon default ϑ, see Section 3.2 and eq. (1). Firms with idiosyncratic productivity $x \geq \bar{x}(\vartheta)$ repay and those with idiosyncratic productivity $x < \bar{x}(\vartheta)$ default.

The default productivity threshold implicitly depends on the exogenous aggregate productivity component z and on the tax rate τ. If the tax

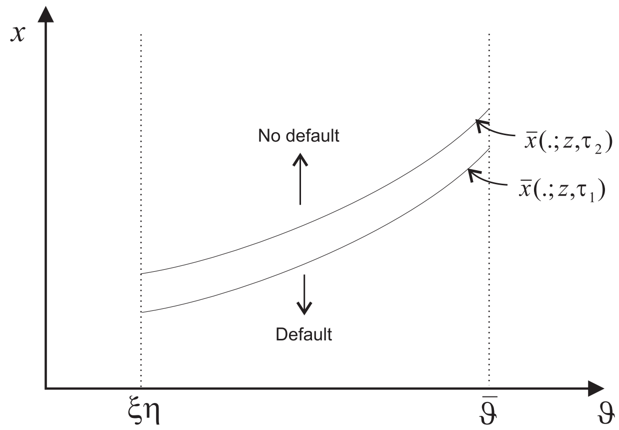

Fig. 2. Firms' default decision.
Notes: This figure shows the firms' default productivity threshold $\bar{x}(\vartheta)$ for varying default price discount parameters ϑ. Firms with idiosyncratic productivity $x \geq \bar{x}(\vartheta)$ repay and those with idiosyncratic productivity $x < \bar{x}(\vartheta)$ default. An increase in the tax rate from τ_1 to τ_2 increases the default productivity threshold such that more firms default.

rate is increased, the number of additional firms defaulting is proportional to the area between the two upward-sloping curves in Fig. 2 (because we calibrate the distribution of (x, ϑ) to be uniform). Importantly, changes in z and τ have a direct (partial equilibrium) effect, via the firm's default decision expressed in eq. (1), and a general equilibrium effect through the wage w and the private interest rate R. An increase in the tax rate (or a reduction in productivity z) reduces the profitability of firms and leads more firms to default (partial equilibrium effect). Higher default risk in turn raises the private interest rate (eq. (3)). But since less firms are active, and also active firms produce at a smaller scale at the lower profitability, the wage rate falls (eq. (4)). Hence, the general equilibrium adjustments of R and w have opposite effects on the default productivity threshold $\bar{x}$.

In Table 3, we employ our calibration and quantify the partial and general equilibrium effects on private default risk. For different realizations of $\tilde{z} = (1-\tau)z$, we report the increase in the quarterly private default rate $\Delta\delta$ in percentage points if $\tilde{z}$ decreases by 1%. In partial equilibrium PE, we keep the private interest rate and the wage fixed whereas they are allowed to adjust in general equilibrium GE. To get meaningful numbers, we consider values of $\tilde{z}$, which are the 25th, 50th, and 75th percentiles of the distribution obtained from a simulation used to compute the business-cycle statistics in Section 4.2.3. Table 3 reveals that for the median realization of $\tilde{z}$, in general equilibrium, the private default probability increases by 1.66 percentage points if $\tilde{z}$ is reduced by 1%. In partial equilibrium, the increase is about 0.5 percentage points higher indicating that in general equilibrium falling wages dampen private default risk. In contrast, for low realizations of $\tilde{z}$, in partial equilibrium, the private default probability increases less in response to a 1% reduction of $\tilde{z}$ than in general equilibrium because the higher private interest rate reinforces default risk and dominates the mitigating effect of lower wages. Hence, private default risk is amplified in severe recessions.

Our analysis of the default productivity threshold implies that the private interest spread is critically determined by the relevant range of idiosyncratic productivity x (controlled by parameter ζ) and by the discount price upon default ϑ (controlled by parameter $\bar{\vartheta}$). We calibrate these two parameters to be in line with *aggregate* facts on private interest spreads. In particular, we match the mean annualized private spread of 8.45% and the volatility of 4.8% (see Table 2).

In the following, we argue that also the *microeconomic* responsiveness of corporate default to variations in firm's profitability is broadly in line with empirical findings. We base this comparison on the study of Campbell et al. (2008) who estimate a logit model of corporate

Table 3
Default risk in the private sector.

Percentile of $\tilde{z}$ distribution	$\tilde{z}$	δ in %	$\Delta\delta^{PE}$ in pp	$\Delta\delta^{GE}$ in pp
25th	0.864	4.51	2.54	2.59
50th	0.872	3.02	2.17	1.66
75th	0.881	1.97	1.80	1.10

Notes: This table reports the quarterly private default rate δ in % evaluated at different realizations of $\tilde{z} = (1 \quad \tau)z$. The last two columns show the increase in the private default rate in percentage points if $\tilde{z}$ is reduced by 1%. $\Delta\delta^{PE}$ is the partial equilibrium change at constant wage and interest rate, and $\Delta\delta^{GE}$ is the general equilibrium response. The realizations of $\tilde{z}$ are the 25th, 50th, and 75th percentiles of the distribution obtained from a simulation used to compute the business-cycle statistics in Section 4.2.3 (with sovereign default episodes excluded).

bankruptcy for U.S. firms on several firm-level variables. Specifically, Campbell et al. (2008) estimate

$$P_{t-1}(d_{i,t} = 1) = \frac{1}{1 + e^{-\beta_0 - \beta_1 Y_{i,t-1}}},$$

where $d_{i,\,t}$ is an indicator that equals one if firm i goes bankrupt in period t and $Y_{i,t-1}$ is a vector of explanatory variables known at period $t-1$, among which is the net income to asset ratio (NITA). Lacking comparable data or research on corporate default in Latin American countries, we use their estimates as a benchmark against which we evaluate our model. Campbell et al. (2008) find that the coefficient on the profitability measure NITA in the logit regression is -14. This implies that a one-percentage point increase of NITA reduces the default probability by roughly 22 basis points.[19] In our model, we proceed similarly and estimate a logit model on a simulated cross section of firms. In the model, we define NITA as profits divided by the firms' assets, which are the equity financed imported goods:

$$NITA = \frac{\pi(x\tilde{z})m^* - (1 - \xi + \xi R)p^* m^*}{(1-\xi)p^* m^*}.$$

The estimation of the logit model delivers a coefficient on NITA equal to -61. That is, a one percentage-point higher NITA lowers the default rate by about 96 basis points, i.e. four times larger than the U.S. estimate suggests. This discrepancy could reflect important differences between the distributions of NITA across Argentine firms relative to U.S. firms, or a stronger responsiveness of corporate default to changes in profitability. As we are not aware of any micro data and empirical studies on these issues, we cannot properly assess the impact of such factors.

Similar to Campbell et al. (2008), our estimate implies that the median firm in our sample faces basically no default risk. To get a sense of the sensitivity of the default probability of a firm to changes in profitability, we also calculate the marginal effects at different percentiles of the distribution of NITA. We consider firms with NITA positions at the 25th, 20th, 15th, 10th, and 5th percentile of the distribution and calculate the change in the firm's default probability in response to a marginal increase in NITA. The corresponding marginal effects are -0.000059, -0.002, -0.0548, -1.1131, and -11.4077 percentage points. These findings highlight that default risk of firms at the low end of the distribution is highly sensitive to changes in NITA, generated e.g. by tax changes, whereas default risk of firms above the 20th percentile of the NITA distribution are barely affected by changes in profitability.

[19] The logit model implies that $dP \approx P(1 \quad P)\beta dNITA$. With $\beta = \quad 14$, $dNITA = 0.01$ and $P = 0.016$ (average annual corporate default rate in the U.S., cf. Cui and Kaas (2018)) follows $dP \approx \quad 0.22\%$.

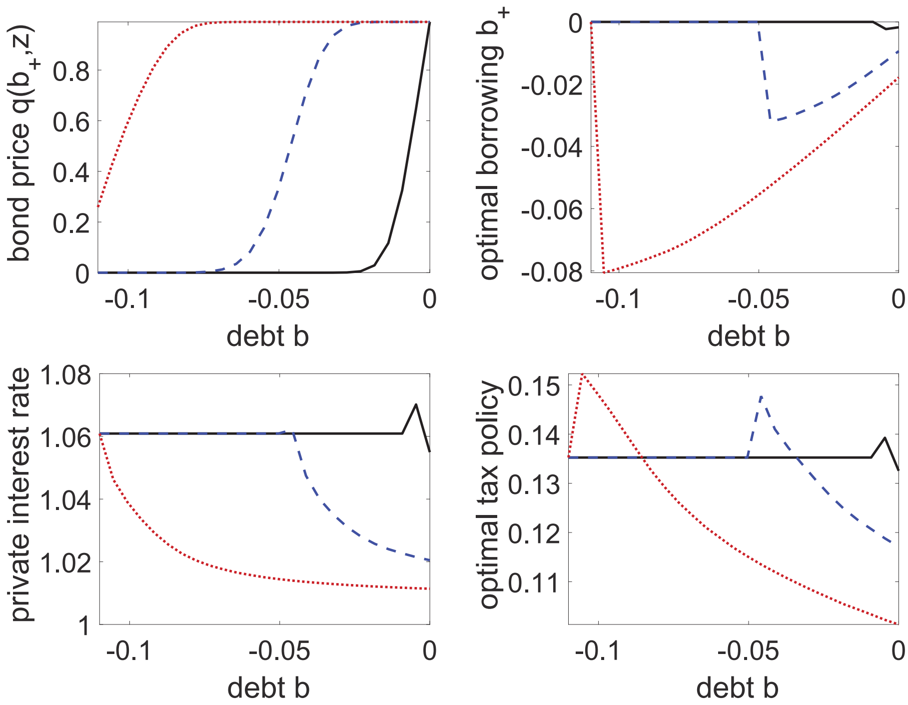

Fig. 3. Policy functions.

Notes: This figure shows the sovereign bond price function $q(z,b_+)$, debt policy $\mathscr{B}(z,b,s)$, tax policy $\mathcal{T}(z,b,s)$ and the quarterly private interest rate $\mathscr{R}(z,\tau,s)$ for productivity realizations of 1.4% (solid line), 0% (dashed line) and +1.4% (dotted line) around the mean value of z.

4.2.2. Policy functions

In this section, we shed light on the optimal decision of the government whether to repay or to default on its outstanding external debt and the implied sovereign credit costs. In Fig. 3 we consider realizations of the exogenous aggregate productivity parameter z of $\pm$1.4% around its mean value and show optimal debt and tax policies together with the associated quarterly private interest rates.

The upper left panel of Fig. 3 shows the sovereign bond price $q(z,b_+)$. It is evident that, first, the bond price is decreasing in debt (i.e. $-b$). For low levels of debt the government always repays and the bond price is equal to the inverse of the risk-free rate. With higher debt levels, foreign creditors incorporate the rising sovereign default probability in their pricing decision and charge a larger price on public debt. Second, the bond price decreases if the economy is hit by adverse shocks to productivity z. Since a government is less able to service its external debt in bad times, the sovereign spread reflects the increased risk of a sovereign default.

The upper right panel of Fig. 3 shows the government's debt policy. For high levels of public external debt and in times of recessions the government becomes borrowing constrained due to prohibitive external credit costs. The lower right panel reveals that the optimal sales tax is increasing in debt and decreasing in productivity z. This pattern implies that fiscal policy is procyclical[20]: In times of recessions the government can become borrowing constrained so that it increases tax rates to finance public expenditures. In default, however, public debt is not repaid such that the government is able to reduce the tax rate. The theoretical prediction regarding the cyclical properties of taxes is in line with the broad empirical literature showing that developing countries and emerging market economies are characterized by procyclical fiscal policies, see, e.g., Talvi and Vegh (2005), Ilzetzki and Vegh (2008).

The cyclical pattern of taxes intensifies the countercyclicality of private interest rates. In a recession, the tax rise amplifies private default risk and increases the private interest rate, which is shown in the lower left panel of Fig. 3. We elaborate on this amplification mechanism in Section 4.2.5 below.

4.2.3. Cyclical properties

In Table 4 we show the business-cycle properties implied by our theoretical framework. For comparison, we report the empirical statistics of the Argentine economy for the period 1994.Q1–2001.Q4. We report the statistical moments based on simulated time series that exclude default events. All variables are logged before they are linearly detrended, except the tax rate, the sovereign spread, and the private spread.

A comparison of the simulated and the empirical cyclical properties reveals that our model captures the co-movements between the variables and the overall macroeconomic volatility. In particular, the model replicates the countercylicality of sovereign and private spreads and the procyclicality of consumption, imports, and public expenditures. The model also mimics the empirical fact that imports are more volatile than output. While the model replicates the volatility of the private spread, it overstates the standard deviation of the sovereign spread. The high volatility of sovereign credit costs is due to the occurrence of "near default states", in which adverse realizations of productivity z substantially increase the default risk so that foreign creditors charge high sovereign interest rates. In spite of high credit costs, the government finds it still optimal to repay because the exclusion from international financial markets imposes a severe punishment.

Table 4 also reports the standard deviation of aggregate productivity $z\hat{x}$, which is similar to the calibrated standard deviation of the TFP parameter in Mendoza and Yue (2012) (1.7%).[21] Importantly,

[20] A similar procyclical pattern can be observed in the policy functions for government expenditures.

[21] Aggregate productivity as defined here corresponds to the total factor productivity (TFP) parameter in Mendoza and Yue's (2002) model. However, we do not refer to TFP because our variable does not apply the appropriate factor-input weights for firms.

Table 4
Business-cycle statistics.

	Argentina	Baseline model	Exogenous tax rate
Business cycle statistics			
$\sigma(y)$	4.94	4.61	2.52
$\sigma(c)/\sigma(y)$	1.05	0.92	0.82
$\sigma(g)/\sigma(y)$	0.47	0.51	1.40
$\sigma(m)/\sigma(y)$	3.09	2.42	2.10
$\sigma(s)$	2.75	8.78	10.11
$\sigma(s^p)$	4.81	4.41	1.87
$\sigma(z\hat{x})$		1.84	1.13
$\rho(c,y)$	0.99	0.99	0.99
$\rho(g,y)$	0.64	0.98	0.91
$\rho(tr,y)$	0.94	0.21	1.00
$\rho(m,y)$	0.99	0.99	0.99
$\rho(s,y)$	0.83	0.73	0.57
$\rho(s^p,y)$	0.79	0.95	0.98
$\rho(s,s^p)$	0.87	0.86	0.62
$\mathbb{E}(s)$	5.97	5.89	5.29
$\mathbb{E}(s^p)$	8.45	8.57	7.61
$\mathbb{E}$(debt service)	3.03	2.8	2.12
$\mathbb{E}(m/y)$	11.76	11.82	11.85
$\mathbb{E}(g/y)$	12.89	12.72	12.72
Default episodes			
Aggregate productivity		5.43	3.62
Imports	79.19	25.71	15.58
Output	19.21	10.37	7.03
Consumption	21.57	8.94	5.66
Government spending	9.02	4.58	6.86
Tax revenues	20.93	4.78	7.03
Pre-default sovereign spread	15.19	18.62	25.10
Pre-default private spread	28.50	14.44	9.67

Notes: This table reports the business-cycle statistics of output y, consumption c, labor ℓ, public expenditure g, tax revenue tr, imports m, the annualized sovereign and private spread s and s^p, and aggregate productivity $z\hat{x}$. All variables are logged except interest rate spreads before they are linearly detrended. Mean values of spreads are in %. Mean values of imports, government spending and debt service payments are given in percentage shares of output. Statistics of the theoretical model refer to a simulation of 50,000 quarters where the first 5,000 quarters are discarded. Default episodes (including one quarter before the default event and the subsequent quarters without external borrowing) are excluded. The second column refers to the baseline model whereas the third column refers to a counterfactural economy, in which the tax rate is fixed. With respect to the default episodes, the table reports the variables' percentage deviations from their linear trends in the period of default, except for the sovereign and private spreads, which are reported in % in the period before a default takes place.

aggregate productivity in our model is endogenously determined and given by $z\hat{x}$ where $\hat{x}$ is average firm-specific productivity which is zero for defaulting firms and $x \geq \overline{x}(\vartheta)$ for non-defaulting firms. If exogenous productivity z is larger, $\hat{x}$ also becomes larger because fewer firms default. In our simulations, z and $\hat{x}$ are positively correlated with $\rho(z,\hat{x}) = 0.86$, which in turn implies that a relatively small calibrated standard deviation of z (see Table 2) results in a much larger standard deviation of endogenous aggregate productivity.

4.2.4. Dynamics around default

To understand the interaction of sovereign and private default risk and their impact on macroeconomic outcomes, we perform an event study and show the dynamics of the economy six quarters before and after a sovereign default. We assume that the government is in a good credit standing in $t < 0$ but defaults at date $t = 0$. In Fig. 4 the solid lines show the percentage deviations from a linear trend for exogenous productivity z, endogenous aggregate productivity $z\hat{x}$, output, imports, consumption, public expenditures, and tax revenues while the sovereign and private spreads and the tax rate are in %. In order to compare the model with the Argentine default episode, Table 4 reports the percentage deviations of endogenous aggregate productivity $z\hat{x}$, imports, output, consumption, government spending, and tax revenues from their linear trends in the default period as well as the mean sovereign and private spread in % in the period before a default takes place.

The dynamic patterns suggest that the economy is in a recession prior to a sovereign default. In the quarters before the default takes place, exogenous productivity z decreases, generating a fall in output. Low output raises the risk of a sovereign default, which is reflected in an increase in the sovereign interest spread in the quarters before the default takes place. Due to high credit costs, the government becomes borrowing constrained and raises the tax rate to finance public expenditures such that tax revenues are flat in the quarters prior to default in spite of the falling tax base (output). The tax increase leads to an endogenous amplification mechanism: Higher tax rates in a recession lower the profitability of private firms so that private default increases and aggregate productivity $z\hat{x}$ declines. Foreign creditors incorporate the default risk in their pricing decision and charge a higher interest rate on private external debt. Import demand falls and the recession deepens. In turn, low output reinforces the risk of a sovereign default, and the sovereign spread increases further. After the default, the government is excluded from international financial markets. Since debt service obligations are not fulfilled, the government budget constraint relaxes such that the tax rate can be reduced. The private spread decreases and imports as well as output recover.

Overall, the model generates dynamics around default events that are broadly in line with the empirical evidence observed in Argentina. In particular, the model implies a sovereign spread of 18.6% in the period before the default, which is close to the empirical counterpart in the Argentine economy. The model generates a private spread of about 14.4%, which underestimates the increase in the private interest before the Argentine default. Note that our theoretical model assumes that after a sovereign default the government is excluded from international financial markets; this is why the sovereign spread is infinite.

The model also replicates the facts that the import drop is a multiple of the output drop and that the fall in government spending is less pronounced than the fall in private consumption. Note, however, that the model underestimates the severity of the recession, see Table 4. During the Argentine default output, imports, consumption, government spending and tax revenues decreased by 19.2%, 79.2%, 21.6%, 9.00%, and 20.9% respectively. In the simulated economy the recession is less severe and we observe a decline of 10.3% for output, 25.7% for imports, 8.9% for consumption, 4.6% for government expenditures and 4.8% for tax revenues. The empirical patterns of these variables are affected by additional factors that are not included in our model, such as exchange rate dynamics and the sovereign-bank nexus as emphasized in, e.g., Engler and Große Steffen (2016), Niemann and Pichler (2017), and Sosa-Padilla (2018). Therefore, our model isolates the endogenous amplification generated by the dynamic interaction between sovereign and private default risks through the response of fiscal policy to adverse productivity shocks.

4.2.5. The feedback mechanism between fiscal policy and default risks

To study the quantitative importance of the dynamic feedback mechanism between sovereign and private default risks through fiscal policy, we conduct a counterfactual experiment, in which we shut down the endogenous tax response and fix the tax rate at the simulated mean of the baseline model (12.74%).

Fig. 5 considers the baseline economy (solid lines) and the counterfactual economy (dashed lines) and displays the sovereign bond price function, the debt policy, the private interest rate and the tax policy at the mean value of productivity z. In comparison with the baseline economy, for a given debt policy, the counterfactual economy is characterized by a lower bond price (upper left panel). The intuition

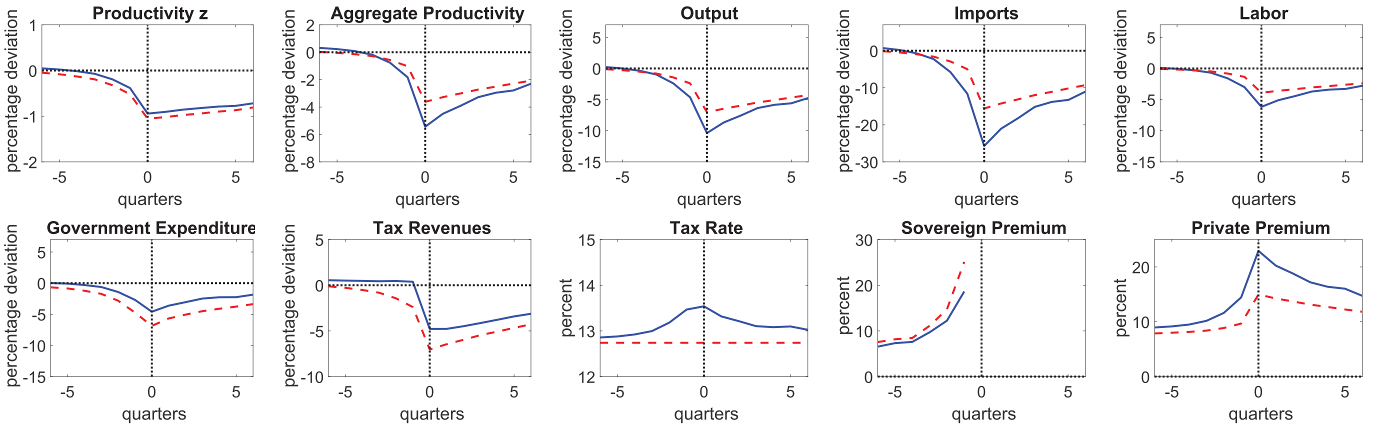

Fig. 4. Default event.

Notes: This figure shows the dynamic pattern of productivity z, aggregate productivity $\hat{x}z$, output y, imports m, labor ℓ, public expenditures g, tax revenues τy, the tax rate τ, the annualized sovereign spread s, and the annualized private spread s^p six quarters before and after a default. The government is in a good credit standing in $t<0$ and defaults at quarter $t=0$. All variables are shown as percentage deviations from their linear trend, except the interest rate spreads and the tax rate which are shown in %. The results are based on a simulation of 50,000 quarters where the first 5,000 quarters are discarded. We include default events if the government has been in a good credit standing for at least 40 quarters before the default takes place. For all variables the mean values over all default events are shown. The dashed lines refer to the dynamics of the counterfactual economy in which the tax rate is exogenously fixed.

behind this result is that a fixed tax rate forces the government to implement larger spending cuts in times of recessions. The decrease in government spending, in turn, raises the sovereign's incentive to default on public debt. Foreign creditors incorporate the increased sovereign default risk such that the counterfactual economy faces higher public credit costs than the baseline economy. Consequently, with a fixed tax rate the government becomes more borrowing constrained (upper right panel). Since the counterfactual economy does not exhibit an endogenous feedback mechanism between fiscal policy and private default risk, the private interest rate is constant for varying debt levels, given that public debt is repaid (lower left panel). If debt is so high that the government decides to default, the private interest rate exhibits a jump increase due to the exogenous output cost. It is evident from this graph that the private interest rate varies less when the tax rate is exogenously fixed.

The business-cycle statistics of the counterfactual economy (third column of Table 4) reflect these findings. We report the statistical moments of simulated time series that exclude default events. Shutting down the endogenous amplification through fiscal policy substantially decreases the standard deviation of the private interest rate. Because private default is much less volatile, aggregate productivity $z\hat{x}$ is also more stable, which in turn implies that output becomes half as volatile as in the baseline economy. Importantly, while the relative standard deviations of imports and private consumption decrease somewhat,

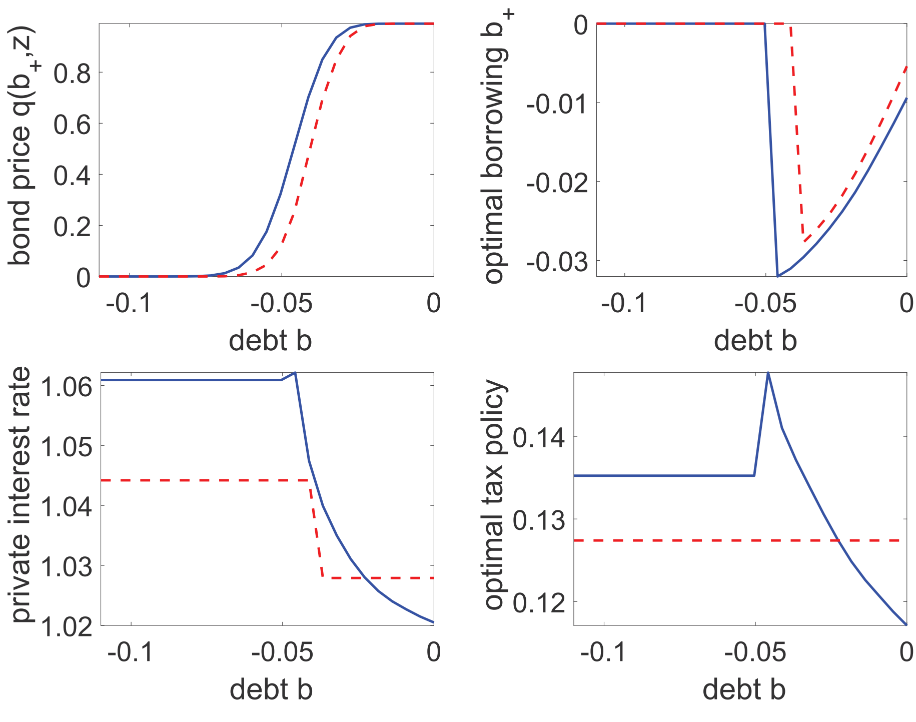

Fig. 5. Endogenous vs. exogenous tax rate: policy functions.

Notes: This figure shows the sovereign bond price function $q(z,b_+)$, debt policy $\mathscr{B}(z,b,s)$, the quarterly private interest rate $\mathscr{R}(z,\tau,s)$ and the tax policy $\mathcal{T}(z,b,s)$ for the mean of productivity z. The solid line refers to the benchmark economy with an endogenous tax policy whereas the dashed line refers to the counterfactual economy in which the tax rate is exogenously fixed.

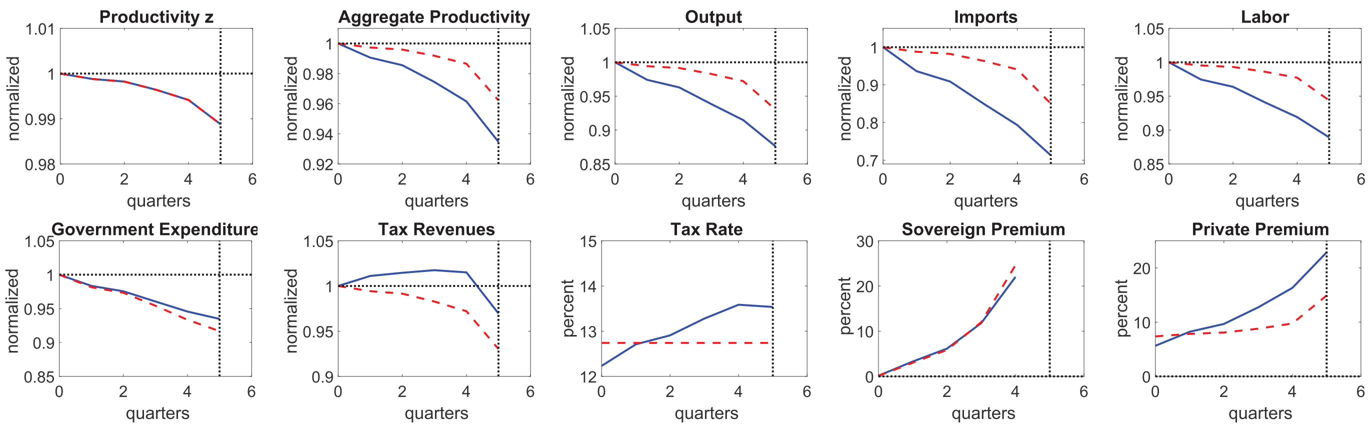

Fig. 6. Endogenous vs. exogenous tax rate: dynamics prior to default.

Notes: This figure compares the dynamics prior to a default event of the baseline economy (solid lines) and the counterfactual economy (dashed lines), in which the tax rate is exogenously fixed. Both economies start with the same initial $b = 0.015$ and are fed with the same series of exogenous productivity z. We collect those episodes, in which both economies default in quarter $t = 5$. The figure shows the dynamic pattern of productivity z, aggregate productivity $\hat{x}z$, output y, imports m, labor ℓ, government expenditures g, tax revenues τy, the tax rate τ, the annualized sovereign and private spread s and s^p. The government is in a good credit standing in $t < 5$ and defaults at quarter $t = 5$. All variables are normalized to 1 in period 0, except the interest rate spreads and the tax rate which are shown in %. For all variables the mean values of the default events are shown.

government spending becomes much more volatile. Likewise, the volatility of the sovereign spread is higher when tax rates are fixed. Since in the counterfactual economy sovereign default risk does not affect private default risk through fiscal policy, the movements of the private interest rate are solely driven by exogenous productivity changes. Consequently, sovereign and private spreads are less correlated than they are in the data and in the baseline model with endogenous fiscal policy.

The dashed lines in Fig. 4 refer to the default dynamics of the counterfactual economy. As in the baseline model, default events are associated with low realizations of exogenous productivity z. Note, however, that with an exogenous tax rate, default events are characterized by worse realizations of z compared to the baseline model (solid line). This is due to the fact that with a fixed tax rate the government is more borrowing constrained. The lower equilibrium level of debt implies that worse realizations of z are required to trigger a default. Moreover, the fixed tax rate generates a fall in tax revenues such that government spending has to be cut substantially. As in the baseline economy, low productivity raises the private spread, which reduces imports. But since the amplification mechanism is shut down by the fixed tax rate, the increase in the private interest rate and the downturn in imports are smaller than in the baseline model. Importantly, aggregate productivity $z\hat{x}$ decreases less compared to the baseline economy. Consequently, the recession is less severe when the tax rate is fixed. Furthermore, the recession starts later: The downturn accelerates only one quarter prior to the default whereas in the baseline model output starts to fall significantly three quarters prior to the default, which is in line with the dynamics in Fig. 1. However, the recovery after the default is slower if the tax rate is exogenously fixed.

Table 4 provides a comparison of the reactions of the variables in a typical default event. On average, incorporating the endogenous feedback mechanism between tax policy and credit risks generates an additional reduction in aggregate productivity of 1.8 percentage points. The private spread increases by additional 4.8 percentage points, imports drop by additional 10.1 percentage points, and output falls by additional 3.3 percentage points.

In Fig. 4 the default events of the two economies are triggered by different realizations of exogenous productivity z, such that the macroeconomic amplification generated by the interplay between sovereign and private default risks cannot be isolated. To facilitate a quantitative assessment of the importance of this feedback mechanism, in Fig. 6 we assume that in period $t = 0$ the baseline economy and the counterfactual economy start with the same initial level of b and feed both economies with the same series of exogenous productivity z. We collect those simulations, in which a sovereign default occurs in quarter $t = 5$ in both economies. Fig. 4 displays the variables of interest normalized to one in period $t = 0$, except for the interest rate spreads and the tax rate which are shown in %. Since both economies face the same productivity realizations z, we expect that the quantitative impact of the endogenous feedback mechanisms is larger compared to Fig. 4. The dynamics shown in Fig. 6 confirm this intuition. The fixed tax rate implies that the increase in the private spread is solely driven by exogenous productivity z. In contrast, with endogenous taxes, the amplification mechanism between fiscal policy and private default reduces aggregate productivity by additional 2.7 percentage points and increases the pre-default private spread by additional 6.5 percentage points, generating a stronger fall in imports and a deeper recession.

5. Conclusions

In this paper we analyze how sovereign and private default risks interact. We develop a stochastic general equilibrium model of a small open economy featuring endogenous private and sovereign default risks. Private sector firms use imperfectly substitutable domestic and imported intermediate goods to produce a final consumption good, where part of the imports need to be financed by external debt. The economy also features a benevolent government providing a public good, financed by taxing firms and borrowing from abroad. The model accounts for several empirical regularities in emerging market economies, namely countercyclical private and sovereign spreads, procyclical fiscal policy, and deep recessions with large drops in imports during default events.

Our results suggest that endogenous fiscal policy creates a stronger correlation between sovereign and private default spreads. It further provides an amplification mechanism reinforcing the effects of adverse productivity shocks. Whenever the government faces higher borrowing costs in a recession, it raises tax rates so as to reduce external credit costs, which decreases firms' profitability and leads to higher private default risk. In turn, aggregate productivity decreases and firms cut their demand for imported inputs, which deepens the recession. While our study highlights this particular mechanism, other channels should also matter to explain the deep recessions around sovereign default events. Future research may explore how exchange rate movements

Table 5
Business-cycle statistics.

	$\sigma(y)$	$\frac{\sigma(c)}{\sigma(y)}$	$\frac{\sigma(g)}{\sigma(y)}$	$\frac{\sigma(m)}{\sigma(y)}$	$\frac{\sigma(x)}{\sigma(y)}$
Argentina	4.94	1.05	0.47	3.09	1.49
Brazil	3.22	1.57	0.92	5.67	3.11
Chile	2.65	1.62	1.30	3.74	2.79
Ecuador	1.75	0.62	1.60	3.06	2.74
Korea	13.09	0.89	0.45	1.13	0.93
Malaysia	4.89	1.23	1.74	2.50	2.68
Mexico	3.05	1.26	1.12	4.48	3.61
Peru	14.34	0.81	1.53	1.70	1.32
Philippines	7.57	0.62	1.71	2.22	1.45
Russia	5.25	1.00	1.13	2.86	1.52
Venezuela	7.71	0.73	0.59	2.59	1.53
Average	6.22	1.04	1.14	3.00	2.11

Notes: y refers to real GDP, c and g denote real consumption and real public expenditures, respectively. m and x are real imports and exports. All series are log-linearly detrended.

(Asonuma, 2016), debt renegotiations (Yue, 2010), long run growth (Gorneman, 2015) or secondary debt markets (Broner et al., 2010) interact with private and sovereign credit risks.

Acknowledgements

We thank the editor and two anonymous referees for excellent comments that substantially improved the paper. We thank Gernot Müller and Thomas Steger for helpful comments. We are grateful to conference audiences at the Colloquium 2018 of the DFG-Priority Program 1578, the Colloquium 2016 of the CRC 649, Verein für Socialpolitik 2016, EEA 2015, T2M 2015, Workshop on Dynamic Macroeconomics in Strasbourg 2014 and the Workshop 2014 of the DFG-Priority Program 1578. We thank the German Research Foundation (grant No. KA/1519-4 and No. SCHO 1442/1-2) for financial support. Jan Mellert gratefully acknowledges the Collaborative Research Center SFB-823 for financial support. The usual disclaimer applies.

Appendix A. Numerical algorithm

The private sector equilibrium can be calculated on a grid for (z,τ). The solution is used to solve the government's problem and to determine the risk-neutral pricing of government bonds via value function iteration.

The numerical algorithm builds on Hatchondo et al. (2010) and employs cubic spline interpolations so that optimal policies are chosen from a continuous set and productivity realizations are allowed that do not lie on the grid. We approximate the equilibrium as the equilibrium of the finite-horizon economy and iterate simultaneously on the value and the bond price functions.

We define evenly distributed grid vectors for bond holdings $b\in[\underline{b},\overline{b}]$ with 25 grid points and productivity realizations $z\in[\underline{z},\overline{z}]$ with 19 grid points. Let $V^{N(0)}(z,b)$ and $V^{D(0)}(z)$ denote the initial guesses for the value functions. For every grid point $(z,b)\in[\underline{z},\overline{z}]\times[\underline{b},\overline{b}]$ and given the initial guesses $V^{N(0)}(z,b)$ and $V^{D(0)}(z)$ we first find candidate values for $\tau^{(0)}$ and $b_+^{(0)}$ by employing a global search procedure. These candidate values are then taken as initial guesses for the FORTRAN optimization routine BCPOL from the IMSL library to find $\tau^{(0)}$ and $b_+^{(0)}$ via eq. (9), (10) where $V_{(0)}^{0}(z,b,s)$ satisfies eq. (8). Given the initial guess, eqs. (11) and (12) determine the the default probability $\lambda^{(0)}(z,b_+^{(0)})$ and the bond price function $q^{(0)}(z,b_+^{(0)})$, respectively. Expected continuation values are computed using Gauss-Hermite quadrature points and weights. To evaluate the expected continuation values for policies and productivity realizations that do not lie on the grid we employ cubic spline interpolations using the algorithm of Akima (1996). The solutions found at each grid point are used to update the value functions $V^{N(1)}(z,b)$ and $V^{D(1)}(z)$. We iterate until the value functions converge.

Appendix B. Further empirical findings

Table 5 reports the business-cycle statistics of the countries contained in our sample. Default episodes are excluded. We observe that consumption is on average slightly more volatile than GDP and that imports and exports are on average two to three times more volatile than GDP. Our observations are in line with results found by Neumeyer and Perri (2005).

Appendix C. Data

The sample of emerging market economies is chosen according to JP Morgan's characterization and data availability. More precisely, we restrict the sample to include countries for which at least 10 years of

Table 6
Data sources for GDP, consumption, government expenditures, tax revenues, imports and exports.

Country	Data source	Sample	Currency	Adjustment	Basis year deflator	Information
Argentina	Ministero de Economica y Production MECON	Q1 1993-Q2 2013	NCU		1993	
Brazil	Instituto Brasileiro de Geografia e Estatistica	Q1 1995-Q2 2013	NCU	SA	2005	
Chile	OECD Outlook	Q1 1995-Q2 2013	NCU		2008	GDP deflator is calculated from nominal and real GDP.
Ecuador	Banco Central del Ecuador	Q1 1990-Q1 2012	US-$	SA	2000	Discontinued after Q1 2012
Korea	Bank of Korea	Q2 1972-Q2 2013	NCU		2005	
Malaysia	Department of Statistics, Malaysia	Q1 1991-Q2 2013	NCU	R	2005	GDP deflator is taken from Oxford Economics.
Mexico	Instituto Nacional de Estadistica, Geografia e Informatica, Mexico	Q1 1993-Q2 2013	NCU		2008	
Peru	Central Reserve Bank of Peru	Q1 1980-Q2 2013	NCU	SA	1994	GDP deflator is calculated from nominal and real GDP.
Philippines	National Statistical Coordination Board (NSCB), Philippines	Q1 1981-Q2 2013	NCU	SA,R	2000	
Russia	Federal State Statistics Service, Russia	Q1 1995-Q2 2013	NCU	SA,R	2005	GDP deflator is taken from Oxford Economics.
Venezuela	Banco Central de Venezuela	Q1 1998-Q2 2013	NCU	SA	1997	GDP deflator is taken from Oxford Economics.

Table 7
Data sources for interest rates.

Country	Data source sovereign spread	Sample sovereign spread	Sample lending rate	Sample risk free rate	Lending rate	Risk free rate
Argentina	JP Morgan, EMBI Global	Q1 1994- Q2 2013	Q2 1993- Q2 2013	Q2 1972- Q2 2013	US$ denominated with 30 days maturity.	US-bond with 3 month maturity.
Brazil	JP Morgan, EMBI Global	Q3 1994-Q2 2013	Q1 1997 -Q2 2013	Q4 1982-Q2 2013	Domestic currency with average maturity.	Domestic currency borrowing rate with average maturity.
Chile	JP Morgan, EMBI Global	Q3 1999-Q2 2013	Q3 1992-Q2 2013	Q2 1972-Q2 2013	US$ denominated with 30–89 days maturity.	US-bond with 3 month maturity.
Ecuador	JP Morgan, EMBI Global	Q2 1995-Q2 2013	Q1 1980-Q3 2008	Q1 1983-Q4 2011	Domestic currency with 90–172 days maturity.	Domestic currency borrowing rate with 30–83 days maturity.
Korea	JP Morgan, EMBI Global	Q1 1994-Q3 2002	Q3 1980-Q2 2013	Q2 1972-Q2 2013	Domestic currency with maturity less 1 year.	Domestic currency borrowing rate with maturity 1–2 years.
Malaysia	JP Morgan, EMBI Global	Q1 1997-Q2 2013	Q4 1986-Q2 2013	Q2 1972-Q2 2013	Domestic currency with 3 month maturity.	Domestic currency borrowing rate with average maturity.
Mexico	JP Morgan, EMBI Global	Q1 1994-Q2 2013	Q4 1993-Q2 2013	Q1 1976-Q2 2013	Domestic currency with unknown maturity.	Domestic currency borrowing rate with 60 days maturity.
Peru	JP Morgan, EMBI Global	Q2 1997-Q2 2013	Q1 1992-Q2 2013	Q2 1972-Q2 2013	US$ denominated with maturity less than 1 year.	US-bond with 3 month maturity.
Philippines	JP Morgan, EMBI Global	Q1 1998-Q2 2013	Q1 1976-Q2 2013	Q1 1976-Q2 2013	Domestic currency with average maturity.	Domestic currency borrowing rate with 61–90 days maturity.
Russia	JP Morgan, EMBI Global	Q1 1998-Q2 2013	Q1 1998-Q2 2013	Q1 1998-Q2 2013	Domestic currency with less than 1 year maturity.	Domestic currency borrowing rate with less than 1 year maturity.
Venezuela	JP Morgan, EMBI Global	Q1 1994-Q2 2013	Q1 1984-Q2 2013	Q1 1984-Q2 2013	Domestic currency with average maturity.	Domestic currency borrowing rate with 90 days maturity.

quarterly data are available until 2013Q2. Korea is the only exception. We add Korea because it is also in the sample of Neumeyer and Perri (2005).

We employ the Census X12 method from the U.S. Census Bureau to seasonally adjust the time series. Nominal time series are deflated using the GDP deflator. For imports and exports we use the import and export price deflators. Tables 6 and 7 give more details on data sources and transformations, where 'SA' stands for 'seasonally adjusted' and 'R' denotes the transformation of nominal variables into real variables.

We follow Neumeyer and Perri (2005) and Arellano and Kocherlakota (2014) and use the emerging markets sovereign interest rate spreads provided by JP Morgan. In most cases private interest rate spreads are calculated by subtracting the local currency deposit rate from the lending rate. Whenever the U.S.$ lending rate is available, a U.S. government debt interest rate with similar maturity is used as the risk-free rate.[22]

In order to show that total imports are an acceptable proxy for intermediate good imports we calculate their share in total imports. In this we follow Mendoza and Yue (2012) and define intermediate goods imports as all imports falling into the following product categories of the COMSTAT dataset: (111*) Food and beverages, primary, mainly for industry; (121*) Food and beverages, processed, mainly for industry; (21*) Industrial supplies not elsewhere specified, primary; (22*) Industrial supplies not elsewhere specified, processed; (31*) Fuels and lubricants, primary; (322*) Fuels and lubricants, processed (other than motor spirit); (42*) Parts and accessories of capital goods (except transport equipment); (53*) Parts and accessories of transport equipment. On average these imports are responsible for around 58% of total imports in emerging market economies.

As a proxy of the corporate tax rate, we consider tax revenues from corporate earnings divided by the operating surplus. Historical corporate tax revenues are taken from the web page of Argentine Ministry of the Treasury[23] and gross operating surplus is taken from the web page of the National Institute of Statistics and Census of Argentina.[24]

[22] See Table 7 for a detailed description of how the interest rate spreads are calculated.
[23] See *www.argentina.gob.ar/hacienda/ingresospublicos/recaudaciontributaria* (last access 29.10.2019).
[24] See *www.indec.gob.ar/indec/web/Institucional-Indec-InformacionDeArchivo-5* (last access: 29.10.2019).

References

Ağca, S., Celasun, O., 2012. Sovereign debt and corporate borrowing costs in emerging markets. J. Int. Econ. 88 (1), 198–208.
Aguiar, M., Gopinath, G., 2006. Defaultable debt, interest rates and the current account. J. Int. Econ. 69 (1), 64–83.
Aguiar, M., Amador, M., Gopinath, G., 2009. Investment cycles and sovereign debt overhang. Rev. Econ. Stud. 76 (1), 1–31.
Akima, H., 1996. Algorithm 760: rectangular-grid-data surface fitting that has the accuracy of a Bicubic polynomial. ACM Trans. Math. Softw. (TOMS) 22 (3), 357–361.
Andreasen, E., 2015. Sovereign default, enforcement and the private cost of capital. Int. Rev. Econ. Financ. 39, 411–427.
Arellano, C., 2008. Default risk and income fluctuations in emerging economies. Am. Econ. Rev. 98 (3), 690–712.
Arellano, C., Kocherlakota, N., 2014. Internal debt crises and sovereign defaults. J. Monet. Econ. 68, S68–S80.
Arellano, C., Ramanarayanan, A., 2012. Default and the maturity structure in sovereign bonds. J. Polit. Econ. 120 (2), 187–232.
Arellano, C., Atkeson, A., Wright, M., 2016. External and public debt crises. NBER Macroecon. Annu. 30 (1), 191–244.
Arellano, C., Bai, Y., Bocola, L., 2019. Sovereign default risk and firm heterogeneity. *NBER Working Paper* No. 23314.
Arteta, C., Hale, G., 2008. Sovereign debt crises and credit to the private sector. J. Int. Econ. 74 (1), 53–69.
Asonuma, T., 2016. Sovereign defaults, external debt and real exchange rate dynamics. IMF Working Paper 16/37.
Bai, J., Wei, S.-J., 2014. When is there a strong transfer risk from the sovereigns to the corporates? Property rights gaps and CDS spreads. *CEPR Discussion Paper* No. DP9252.
Bedendo, M., Colla, P., 2015. Sovereign and corporate credit risk: evidence from the Eurozone. J. Corp. Finan. 33, 34–52.
Borensztein, E., Cowan, K., Valenzuela, P., 2013. Sovereign ceilings "Lite"? The impact of sovereign ratings on corporate ratings. J. Bank. Financ. 37 (11), 4014–4024.
Broner, F., Martin, A., Ventura, J., 2010. Sovereign risk and secondary markets. Am. Econ. Rev. 100 (4), 1523–1555.
Brutti, F., 2011. Sovereign defaults and liquidity crises. J. Int. Econ. 84 (1), 65–72.
Campbell, J.Y., Hilscher, J., Szilagyi, J., 2008. In search of distress risk. J. Financ. 63 (6), 2899–2939.
Chatterjee, S., Eyigungor, B., 2012. Maturity, indebtedness, and default risk. Am. Econ. Rev. 102 (6), 2674–2699.
Cuadra, G., Sapriza, H., 2008. Sovereign default, interest rates and political uncertainty in emerging markets. J. Int. Econ. 76 (1), 76–88.
Cuadra, G., Sanchez, J.M., Sapriza, H., 2010. Fiscal policy and default risk in emerging markets. Rev. Econ. Dyn. 13 (2), 452–469.
Cui, W., Kaas, L., 2020. Default cycles. J. Monet. Econ. (forthcoming).
Das, U., Papaioannou, M., Trebesch, C., 2010. Sovereign default risk and private sector access to capital in emerging markets. IMF Working Paper 10/10.
de Ferra, S., 2018. Sovereign debt crises, fiscal austerity and corporate default. Stockholm University, Mimeo.
Eaton, J., Gersovitz, M., 1981. Debt with potential repudiation: theoretical and empirical analysis. Rev. Econ. Stud. 48 (2), 289–309.

Engler, P., Große Steffen, C., 2016. Sovereign risk, interbank freezes, and aggregate fluctuations. Eur. Econ. Rev. 87, 34–61.
Fink, F., Scholl, A., 2016. A quantitative model of sovereign debt, bailouts and conditionality. J. Int. Econ. 98 (1), 176–190.
Gennaioli, N., Martin, A., Rossi, S., 2014. Sovereign default, domestic banks, and financial institutions. J. Financ. 69 (2), 819–866.
Gopinath, G., Neiman, B., 2014. Trade adjustment and productivity in large crises. Am. Econ. Rev. 104 (3), 793–831.
Gorneman, N., 2015. Sovereign default, private investment, and economic growth. University of Pennsylvania, Mimeo.
Greenwood, J., Hercowitz, Z., Huffmann, G., 1988. Investment, capacity utilization, and the real business cycle. Am. Econ. Rev. 78 (3), 402–417.
Hatchondo, J.C., Martinez, L., 2009. Long-duration bonds and sovereign defaults. J. Int. Econ. 79 (1), 117–125.
Hatchondo, J.C., Martinez, L., Sapriza, H., 2010. Quantitative properties of sovereign default models: solution methods matter. Rev. Econ. Dyn. 13 (4), 919–933.
Ilzetzki, E., Vegh, C.E., 2008. Procyclical fiscal policy in developing countries: truth or fiction? NBER Working Paper No. 1419
Jankowitsch, R., Nagler, F., Subrahmanyam, M.G., 2014. The determinants of recovery rates in the US corporate bond market. J. Financ. Econ. 114 (1), 155–177.
Jermann, U., Quadrini, V., 2012. Macroeconomic effects of financial shocks. Am. Econ. Rev. 102 (1), 238–271.
Kirsch, F., Rühmkorf, R., 2017. Sovereign borrowing, financial assistance, and debt repudiation. Economic Theory 64 (4), 777–804.
Klein, C., Stellner, C., 2014. Does sovereign risk matter? New evidence from Eurozone corporate bond ratings and zero-volatility spreads. Rev. Financ. Econ. 23 (2), 64–74.
Mendoza, E., Yue, V., 2012. A General equilibrium model of sovereign default and business cycles. Q. J. Econ. 127 (2), 889–946.
Moody's, 2017. Latin American corporate default and recovery rates, 1990 to June 2017, *Technical report*. Moody's Investors Service.
Neumeyer, P.A., Perri, F., 2005. Business cycles in emerging economies: the role of interest rates. J. Monet. Econ. 52 (2), 345–380.
Niemann, S., Pichler, P., 2017. Collateral, liquidity and debt sustainability. Econ. J. 127 (604), 2093–2126.
Pancrazi, R., Seoane, H.D., Vukotic, M., 2017. Sovereign risk, private credit, and stabilization policies. University of Warwick, Mimeo.
Roch, F., Uhlig, H., 2018. The dynamics of sovereign debt crises and bailouts. J. Int. Econ. 114, 1–13.
Sandleris, G., 2014. Sovereign defaults, domestic credit market institutions and credit to the private sector. J. Money, Credit, Bank. 46 (2–3), 321–343.
Scholl, A., 2017. The dynamics of sovereign default risk and political turnover. J. Int. Econ. 108, 37–53.
Sosa-Padilla, C., 2018. Sovereign defaults and banking crises. J. Monet. Econ. 99, 88–105.
Sturzenegger, F., Zettelmeyer, J., 2006. Debt Defaults and Lessons from a Decade of Crises. MIT Press.
Talvi, E., Vegh, C., 2005. Tax Base variability and procyclical fiscal policy in developing countries. J. Dev. Econ. 78 (1), 156–190.
Yue, V.Z., 2010. Sovereign default and debt renegotiation. J. Int. Econ. 80 (2), 176–187.